UNFS

Upper North Farming Systems

2021

RESULTS


# UPPER NORTH FARMING SYSTEMS ANNUAL RESEARCH AND EXTENSION COMPENDIUM

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## A Message from the Chair - 2021

It's been an honour to serve as the Chair of Upper North Farming Systems (UNFS). Throughout my first 12 months in this position, UNFS continues to work hard in our farming community, continually striving for responsive and resilient farming systems. The impact of COVID continues to create uncertainty in our lives but I am proud to say that primary production continues to thrive and UNFS is at the very centre of this.

This year UNFS continued to promote primary production in our region and bring our community together. This was showcased by our Tools, Technology and Transformation event held in July at the Melrose showgrounds. This event had a fantastic line-up of presenters, trade stalls and brought our members together for a great day of networking. The sheep producer's tech group was and continues to be a very well received program. I have received very positive feedback from participants and the quality of the program is a credit to our team member Rachel Trengove. Another highlight was the Precision Ag workshops, a high calibre program delivered by Jess Koch but very much a team effort with contributions from other committee members and collaborators.
Our RD&E projects pipeline continues to be very strong, which the 2022 compendium will validate. I am also very excited about the future projects potentially coming through the pipeline. I would like to thank the Operations Committee for their hard work during the year. Your contribution to the project pipeline is invaluable. Also, a massive shout out to all the hub representatives, there have been some awesome hub events held this year. We are always on the lookout for new hub rep's so please get in touch if you are interested.

Everything UNFS has achieved during the year wouldn't be possible without the contribution of the funding bodies, project partners, sponsors and volunteers. We thank you for your support. I am very grateful for the hard work of the UNFS team (Kristina Mudge, Morgan McCallum, Rachel Trengove, Jade Rose) without them none of this would be possible. A massive thanks to Ruth Sommerville, your leadership and professionalism cannot be overstated. Finally, I would like to personally thank all the strategic board members for their contributions during the year. I've really enjoyed working with each of you as a team.

Best wishes to all our members for the year ahead.

**James Heaslip**
Chairman 2021/2022

# Upper North Farming Systems

# Contact Details 2021/22

## Strategic Board Members

**James Heaslip** - **Chairman and Booleroo/Appila Hub Rep** - Appila
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0429 233 139

**Michael Zwar** - **Vice Chairman**
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**Matt Nottle** - **Finance Officer and Ag Technology Hub Rep** - Booleroo Centre
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**Joe Koch** - **Board Member and Ag Technology Hub Rep** - Booleroo Centre
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**Barry Mudge** - **Board Member** - Baroota
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**Chris Crouch** - **Board Member**– Wandearah
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**David Clarke** - **Board Member** - Booleroo Centre
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**Beth Humphris** - **Board Member and Jamestown/LOTL Hub Rep**
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**Kym Fromm** - **Public Officer** - **Non-Committee Member** - Orroroo
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## Operations Committee Members

### Industry Representatives

**Emma McInerney**
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**Michael Eyers**
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**Ed Scott**
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**Rhiannon Schilling**
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### Ladies on the Land

**Jess Koch**
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**Steph Lunn**
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### Morchard/Orroroo/Pekina/Black Rock

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### Nelshaby Hub

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### Quorn

**Paul Rodgers**
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### Wilmington

**John J Carey**
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### New Farmer Representatives

**Alison Henderson**
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## STAFF

### Executive Officer

Ruth Sommerville
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E: ruth@unfs.com.au
M: 0401 042 223

### Farming Systems Project Coordinator

**Jade Rose**
**Adelaide- Part-time**
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### Administration and Finance Officer

Kristina Mudge
Baroota - Part-time
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### Engagement Co-Ordinator and Project Officer

Morgan McCallum
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### Project Officer

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# THANK YOU TO OUR SPONSORS

## DIAMOND SPONSORS

## GOLD SPONSORS

## SILVER SPONSORS

## BRONZE SPONSORS

# THANK YOU TO OUR FUNDING BODIES AND PROJECT PARTNERS

**National Landcare Program: Smart Farming Partnerships; Department of Agriculture, Water and the Environment: Future Drought Fund; SAGIT; GRDC; Department of Water and Natural Resources; Landscape South Australia Northern and Yorke; MLA; SARDI; SPAA, Birchip Cropping Group, Mallee Sustainable Farming, Agrifutures; Ag Excellence Alliance; Rufous and Co., AIR EP, Ag Consulting Co., AgXtra; Greening Australia; Elders, University of Adelaide; Agbyte; Northern Ag; NR Ag; YP Ag; HART; Pinion Advisory, Nutrien Ag Solutions, Seednet, Ag Communicators and Ag Tech Services.**

Without the support and funding from these organisations and funding programs the Upper North Farming Systems Group would not remain viable.

## UPPER NORTH FARMING SYSTEMS
## 85 989 501 980

## INCOME STATEMENT
## FOR THE YEAR ENDED 30 JUNE 2021

| | Note | 2021 $ | 2020 $ |
|---|---|---|---|
| **INCOME** | | | |
| **Group Income** | | | |
| Interest | | 84.31 | 287.77 |
| Membership | | 5,704.30 | 5,658.83 |
| Project Administration | | 45,905.67 | 3,128.35 |
| Field Days | | 19,053.00 | 18,968.91 |
| Commercial Paddock | | 8,430.38 | 5,535.80 |
| Sponsorship | | 9,409.09 | 9,250.00 |
| Donations | | 500.00 | - |
| | | 89,086.75 | 42,829.66 |
| **OTHER INCOME** | | | |
| **Abnormal Income** | | | |
| ATO Cash Flow Boost | | 10,000.00 | 10,000.00 |
| **Project Income** | | | |
| Barley Grass Management Option | | 23,750.00 | 34,167.00 |
| Vetch on Saline Soils | | 2,000.00 | 3,000.00 |
| Ag Tech Hub | | 595.00 | - |
| Regenerating Goyder's Line | | 10,000.00 | 50,000.00 |
| SARDI Partnership Projects | | 19,381.22 | - |
| Sheep Producer Tech Group | | 25,000.00 | - |
| Soil Pathogen | | 1,000.00 | - |
| Building Soil Knowledge in the UN | | 92,500.00 | - |
| Producer Technology Uptake | | 11,951.00 | - |
| Ladies on the Land Workshop | | - | 2,132.00 |
| Time of Sowing Trial | | - | 1,331.25 |
| Pasture Options Demo | | - | 1,434.00 |
| Micronutients in Upper North | | - | 48,165.00 |
| Pulse Check | | 15,229.00 | 13,814.00 |
| Cover Crop | | 5,000.00 | 37,000.00 |
| Dryland Legumes | | 20,000.00 | 30,000.00 |
| Weather Station Network | | 20,000.00 | 80,000.00 |
| Barley Time of Sowing | | 28,875.00 | 28,875.00 |
| Fodder Crop Trials | | 6,000.00 | 6,000.00 |
| | | 281,281.22 | 335,918.25 |
| | | 291,281.22 | 345,918.25 |
| | | 380,367.97 | 388,747.91 |

The accompanying notes form part of these financial statements.

## UPPER NORTH FARMING SYSTEMS
## 85 989 501 980

## INCOME STATEMENT
## FOR THE YEAR ENDED 30 JUNE 2021

| | Note | 2021 $ | 2020 $ |
|---|---|---|---|
| **EXPENDITURE** | | | |
| **Group Expenses** | | | |
| Administration | | 58,249.90 | 50,167.02 |
| Audit Fees | | 2,150.00 | 2,050.00 |
| Minor Equipment & Maintenance | | - | 218.68 |
| Insurance | | 1,971.60 | 1,264.80 |
| Advertising | | 982.92 | 562.22 |
| Publications | | 2,408.18 | 6,881.02 |
| Field Days | | 20,609.27 | 24,760.25 |
| Commercial Paddock | | 3,720.25 | 12,977.15 |
| Bank Fees | | - | 120.00 |
| Depreciation Weather Station | | 18,262.00 | 7,211.00 |
| Other Project Expense | | 10,058.77 | 2,584.85 |
| Travel | | 3,289.70 | 295.50 |
| WorkCover RTWSA | | 377.05 | 262.80 |
| Total Wage Expense | | 22,070.88 | 379.58 |
| Merchandise | | 3,545.14 | 1,248.64 |
| Depreciation - Plant & Equip | | 1,340.29 | - |
| | | 149,035.95 | 110,983.51 |

The accompanying notes form part of these financial statements.

## UPPER NORTH FARMING SYSTEMS
## 85 989 501 980

## INCOME STATEMENT
## FOR THE YEAR ENDED 30 JUNE 2021

| | Note | 2021 $ | 2020 $ |
|---|---|---|---|
| **Project Costs** | | | |
| Barley Grass Management Options | | 9,076.36 | 13,741.95 |
| Vetch of Saline/Sodic Soils | | 3,402.61 | 1,546.02 |
| Ag Tech Hub | | 127.50 | 467.50 |
| Regenerating Goyder's Line | | 7,431.28 | - |
| SARDI Partnership Projects | | 127.92 | 170.00 |
| Sheep Producer Tech Group | | 12,059.92 | 85.00 |
| Soil Pathogen | | 1,902.41 | - |
| Building Soil Knowledge in the UN | | 10,201.99 | - |
| Septoria Epidemiology | | 87.50 | - |
| Producer Technology Uptake | | 98.80 | - |
| Drought Hub Partnership | | 350.00 | - |
| Ladies on the Land | | - | 3,944.75 |
| Time of Sowing Trial | | - | 29,832.67 |
| Pasture Options Demo | | - | 2,346.25 |
| Micronutrients in Upper North | | 38,109.25 | 8,100.61 |
| Pulse Check | | 36,191.04 | 10,172.38 |
| Cover Crop | | 10,251.87 | 14,823.36 |
| Dryland Legumes | | 11,050.04 | 10,100.51 |
| Weather Station Network | | 1,880.49 | 1,897.50 |
| Barley Time of Sowing | | 15,367.74 | 8,105.25 |
| Fodder Crop Trials | | 6,691.34 | 1,811.61 |
| | | 164,408.06 | 107,145.36 |
| | | 313,444.01 | 218,128.87 |
| Profit before income tax | | 66,923.96 | 170,619.04 |
| **Profit for the year** | | 66,923.96 | 170,619.04 |
| Retained earnings at the beginning of the financial year | | 514,255.76 | 326,635.53 |
| **Retained earnings at the end of the financial year** | | 581,179.72 | 497,254.57 |

The accompanying notes form part of these financial statements.

# UPPER NORTH FARMING SYSTEMS
## 85 989 501 980

## BALANCE SHEET
## AS AT 30 JUNE 2021

| | Note | 2021 $ | 2020 $ |
|---|---|---|---|
| **ASSETS** | | | |
| **CURRENT ASSETS** | | | |
| Cash and cash equivalents | 3 | 524,094.60 | 417,079.75 |
| **TOTAL CURRENT ASSETS** | | 524,094.60 | 417,079.75 |
| **NON-CURRENT ASSETS** | | | |
| Property, plant and equipment | 4 | 73,045.00 | 91,307.00 |
| **TOTAL NON-CURRENT ASSETS** | | 73,045.00 | 91,307.00 |
| **TOTAL ASSETS** | | 597,139.60 | 508,386.75 |
| **LIABILITIES** | | | |
| **CURRENT LIABILITIES** | | | |
| Trade and Other Payables | 5 | 15,959.88 | 11,132.18 |
| **TOTAL CURRENT LIABILITIES** | | 15,959.88 | 11,132.18 |
| **TOTAL LIABILITIES** | | 15,959.88 | 11,132.18 |
| **NET ASSETS** | | 581,179.72 | 497,254.57 |
| **MEMBERS' FUNDS** | | | |
| Retained earnings | 6 | 581,179.72 | 497,254.57 |
| **TOTAL MEMBERS' FUNDS** | | 581,179.72 | 497,254.57 |

The accompanying notes form part of these financial statements.

# NOTES TO THE FINANCIAL STATEMENTS
# FOR THE YEAR ENDED 30 JUNE 2021

| | | 2021 $ | 2020 $ |
|---|---|---|---|
| **3** | **Cash and Cash Equivalents** | | |
| | Freedom Bank Account 92540 | 264,138 | 157,207 |
| | Business Bank Account 93340 | 259,957 | 259,873 |
| | | 524,095 | 417,080 |
| **4** | **Property, Plant and Equipment** | | |
| | Plant & Equipment - at Cost | 1,340 | - |
| | Less Prov'n for Depreciation | (1,340) | (9,443) |
| | | - | (9,443) |
| | Other Plant & Equipment | 100,750 | 100,750 |
| | Less Prov'n for Depreciation | (27,705) | - |
| | | 73,045 | 100,750 |
| | **Total Plant and Equipment** | 73,045 | 91,307 |
| | **Total Property, Plant and Equipment** | 73,045 | 91,307 |
| **5** | **Accounts Payable and Other Payables** | | |
| | **Current** | | |
| | PAYG Withheld | 3,319 | 72 |
| | Superannuation Liability | 1,348 | 47 |
| | GST Account | 11,293 | 11,013 |
| | | 15,960 | 11,132 |
| **6** | **Retained Earnings** | | |
| | Retained earnings at the beginning of the financial year | 497,255 | 326,636 |
| | Audit Adjustment from previous year | 17,001 | |
| | Net profit attributable to the association | 66,924 | 170,619 |
| | Retained earnings at the end of the financial year | 581,180 | 497,255 |

# INDEPENDENT AUDITOR'S REPORT
# TO THE MEMBERS OF UPPER NORTH FARMING SYSTEMS
# 85 989 501 980

**Report on the Audit of the Financial Report**

**Opinion**

I have audited the accompanying financial report, being a special purpose financial report, of Upper North Farming Systems (the association), which comprises the balance sheet as at 30 June 2021, and the income and expenditure statement for the year then ended, and notes to the financial statements including a summary of significant accounting policies and other explanatory information, the statement by members of the committee.

In my opinion, the accompanying financial report of the association for the year ended 30 June 2021 is prepared, in all material respects, in accordance with the Associations Incorporation Act 1985.

**Basis for Opinion**

I conducted my audit in accordance with Australian Auditing Standards. My responsibilities under those standards are further described in the Auditor's Responsibilities for the Audit of the Financial Report section of my report. I am independent of the association in accordance with the auditor independence requirements of the ethical requirements of the Accounting Professional and Ethical Standards Board's APES 110 Code of Ethics for Professional Accountants (the code) that are relevant to my audit of the financial report in Australia. I have also fulfilled my other ethical responsibilities in accordance with the code.

I believe that the audit evidence I have obtained is sufficient and appropriate to provide a basis for our opinion.

**Emphasis of Matter- Basis of Accounting**

The Association had a change in accounting programs at the start of the financial year. The result of this was a number of small changes to the assets & liabilities which had been carried forward for several years. The adjustment is included at Note 6.

**Responsibilities of Management and those Charged with Governance**

Management is responsible for the preparation and fair presentation of the financial report in accordance with the Associations Incorporation Act 1985 and for such internal control as management determines is necessary to enable the preparation of the financial report is free from material misstatement, whether due to fraud or error.

In preparing the financial report, management is responsible for assessing the association's ability to continue as a going concern, disclosing, as applicable, matters related to going concern and using the going concern basis of accounting unless management either intends to liquidate the association or to cease operations, or has no realistic alternative but to do so.

Those charged with governance are responsible for overseeing the association's financial reporting process.

## INDEPENDENT AUDITOR'S REPORT
## TO THE MEMBERS OF UPPER NORTH FARMING SYSTEMS
## 85 989 501 980

**Auditor's Responsibility for the Audit of the Financial Report**

My objectives are to obtain reasonable assurance about whether the financial report as a whole is free from material misstatement, whether due to fraud or error, and to issue an auditor's report that includes our opinion. Reasonable assurance is a high level of assurance, but is not a guarantee that an audit conducted in accordance with the Australian Auditing Standards will always detect a material misstatement when it exists. Misstatements can arise from fraud or error and are considered material if, individually or in the aggregate, they could reasonably be expected to influence the economic decisions of users taken on the basis of this financial report.

**Name of Firm:** Mid North Accounting
Certified Practising Accountant

**Name of Principal:** ____________________
Vonnie Lea CPA

**Address:** 40 Irvine Street Jamestown SA

**Dated this 26th day of April 2022**

# Unaudited - Profit and Loss

## Upper North Farming Systems
## 1 July 2021 to 30 June 2022

| | 30 Jun 22 |
|---|---|
| **Income** | |
| Events | 739 |
| Membership | 7,136 |
| Merchandise | 64 |
| Project Administration | 25,319 |
| Project Income | 224,135 |
| Transfer In | 74,703 |
| **Total Income** | **332,096** |
| **Gross Profit** | **332,096** |
| **Plus Other Income** | |
| Interest Income - Unrestricted | 55 |
| Sponsorship | 15,809 |
| Sundry Income | 2,680 |
| **Total Other Income** | **18,544** |
| **Less Operating Expenses** | |
| Accommodation | 207 |
| Accounting Fees | 2,690 |
| Administration | 35,854 |
| Advertising & Marketing | 1,109 |
| Bank Fees | 30 |
| Board and Governance Expenses | 5,731 |
| Communications | 2,688 |
| Conference fees | 221 |
| Employment Support and Supervison Costs | 10,845 |
| Event Catering | 9,507 |
| Event Expense | 9,753 |
| Financial Management Fees | 1,015 |
| Grant Refund | 31,153 |
| Industry Representation | 1,225 |
| Insurance | 854 |
| Insurance - Public Liability | 2,109 |
| Membership Fees Paid | 45 |
| Merchandise Exp | 193 |
| Office Expenses | 829 |
| Other Project Expenses | 21,727 |
| Postage, Freight & Courier | 708 |
| Presenter | 18,405 |
| Project Development | 4,069 |
| Project Expenses | 66,521 |
| Project Management | 52,810 |
| Publications & Information Resources | 26,007 |
| Repairs & Maintenance | 136 |

# Unaudited Profit and Loss

| | 30 Jun 22 |
|---|---|
| S&W - Computer Data Allowance | 1,625 |
| S&W Superannuation | 7,945 |
| Salaries & Wages - Engagement Coordinator | 34,538 |
| Salaries & Wages - Project Officer | 8,100 |
| Salaries & Wages - Research Coordinator | 19,758 |
| Salary & Wages - Finance Officer | 19,978 |
| Stripe Fees | 13 |
| Transfer Out | 56,020 |
| Travel | 10,764 |
| **Total Operating Expenses** | **465,183** |
| **Net Profit** | **(114,544)** |

# UNAUDITED PROJECT FUNDS POSITION
## Financial Year Ending 30th June 2022

| Project Funds Position: 1 July 2021 - 30 June 2022 | 101 - Group Management | 102 - Hubs | 103 - Field Days & Tours | 104 - Commercial Paddock | 224 - Micronutrients | 226 - Pulse Check | 227 - Cover Crop | 228 - Barley Grass Mgmt Options | 229 - Dryland Legumes | 230 - Vetch on Saline / Sodic Soils | 231 - Weather Station Network | 232 - Barley TOS | 233 - Fodder Crop Trials | 235 - Regen Goyder's Line | 236 - SARDI Partnership Projects |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Income** | | | | | | | | | | | | | | | |
| Events | $0.00 | $739.09 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| Membership | $6,886.09 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| Merchandise | $63.64 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| Project Administration | $25,319.27 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| Project Income | $0.00 | $5,500.00 | $11,906.57 | $10,256.90 | $0.00 | $0.00 | $0.00 | $14,583.00 | $30,000.00 | $0.00 | $0.00 | $29,521.25 | $0.00 | $9,000.00 | $0.00 |
| Transfer In | $58,064.71 | $3,250.00 | $6,836.97 | $51.37 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $1,500.00 | $0.00 | $0.00 | $5,000.00 | $0.00 |
| **Total Income** | **$90,333.71** | **$9,489.09** | **$18,743.54** | **$10,308.27** | **$0.00** | **$0.00** | **$0.00** | **$14,583.00** | **$30,000.00** | **$0.00** | **$1,500.00** | **$29,521.25** | **$0.00** | **$14,000.00** | **$0.00** |
| | | | | | | | | | | | | | | | |
| **Gross Profit** | **$90,333.71** | **$9,489.09** | **$18,743.54** | **$10,308.27** | **$0.00** | **$0.00** | **$0.00** | **$14,583.00** | **$30,000.00** | **$0.00** | **$1,500.00** | **$29,521.25** | **$0.00** | **$14,000.00** | **$0.00** |
| | | | | | | | | | | | | | | | |
| **Plus Other Income** | | | | | | | | | | | | | | | |
| Interest Income - Unrestricted | $54.76 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| Sponsorship | $3,809.09 | $7,000.00 | $5,000.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| Sundry Income | $2,680.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| **Total Other Income** | **$6,543.85** | **$7,000.00** | **$5,000.00** | **$0.00** | **$0.00** | **$0.00** | **$0.00** | **$0.00** | **$0.00** | **$0.00** | **$0.00** | **$0.00** | **$0.00** | **$0.00** | **$0.00** |
| | | | | | | | | | | | | | | | |
| **Less Operating Expenses** | | | | | | | | | | | | | | | |
| Accommodation | $207.45 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| Accounting Fees | $2,690.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| Administration | $10,360.00 | $0.00 | $175.00 | $0.00 | $0.00 | $0.00 | $0.00 | $1,458.30 | $3,000.00 | $0.00 | $0.00 | $3,107.50 | $0.00 | $6,000.00 | $500.00 |
| Advertising & Marketing | $809.28 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| Bank Fees | $30.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| Board and Governance Expenses | $5,730.50 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| Communications | $2,687.73 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| Conference fees | $220.91 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| Employment Support and Supervison Costs | $10,844.89 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| Event Catering | $441.95 | $3,458.36 | $3,165.66 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $4.55 | $0.00 | $0.00 | $0.00 | $0.00 | $4.55 | $0.00 |
| Event Expense | $87.27 | $231.58 | $923.27 | $0.00 | $0.00 | $0.00 | $1,650.00 | $250.00 | $0.00 | $0.00 | $0.00 | $750.00 | $0.00 | $0.00 | $0.00 |
| Financial Management Fees | $1,014.56 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| Grant Refund | $2,680.00 | $0.00 | $0.00 | $0.00 | $28,473.16 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| Industry Representation | $1,225.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| Insurance | $331.77 | $0.00 | $0.00 | $522.32 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| Insurance - Public Liability | $2,109.33 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| Membership fees paid | $45.45 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| Merchandise Exp | $193.46 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| Office Expenses | $829.17 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| Other Project Expenses | $0.00 | $300.00 | $1,066.39 | $2,007.44 | $0.00 | $0.00 | $19.05 | $19.05 | $4,951.75 | $0.00 | $0.00 | $184.06 | $0.00 | $1,781.79 | $0.00 |
| Postage, Freight & Courier | $693.03 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| Presenter | $0.00 | $240.00 | $7,131.12 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $135.00 | $0.00 |
| Project Development | $3,675.00 | $0.00 | $393.75 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| Project Expenses | $0.00 | $175.00 | $262.50 | $2,595.60 | $0.00 | $0.00 | $4,080.00 | $0.00 | $4,250.00 | $0.00 | $750.00 | $20,500.00 | $0.00 | $6,000.00 | $16,500.00 |
| Project Management | $175.00 | $0.00 | $2,800.00 | $0.00 | $175.00 | $0.00 | $5,687.50 | $1,349.16 | $1,014.16 | $0.00 | $0.00 | $5,750.00 | $0.00 | $1,618.75 | $0.00 |
| Publications & Information Resources | $7,352.36 | $87.50 | $0.00 | $0.00 | $0.00 | $0.00 | $1,100.00 | $550.00 | $1,100.00 | $0.00 | $50.00 | $1,650.00 | $0.00 | $0.00 | $0.00 |
| Repairs and Maintenance | $0.00 | $0.00 | $136.36 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| S&W - Computer Data Allowance | $1,625.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| S&W Superannuation | $7,945.18 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| Salaries & Wages - Engagement Coordinator | $12,989.60 | $4,436.40 | $6,743.10 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $2,596.20 | $0.00 |
| Salaries & Wages - Project Officer | $105.00 | $0.00 | $0.00 | $0.00 | $0.00 | $117.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| Salaries & Wages - Research Coordinator | $2,311.92 | $0.00 | $0.00 | $0.00 | $266.76 | $0.00 | $1,956.24 | $2,934.36 | $2,400.84 | $0.00 | $0.00 | $3,307.44 | $0.00 | $0.00 | $266.76 |
| Salary & Wages - Finance Officer | $18,400.50 | $0.00 | $1,478.75 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| Stripe Fees | $13.06 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| Transfer Out | $0.00 | $0.00 | $0.00 | $6,500.00 | $0.00 | $0.00 | $4,814.25 | $42,817.84 | $0.00 | $51.37 | $0.00 | $0.00 | $0.00 | $0.00 | $1,726.06 |
| Travel | $3,960.06 | $26.52 | $2,344.68 | $0.00 | $0.00 | $0.00 | $90.48 | $90.48 | $77.48 | $0.00 | $0.00 | $90.48 | $0.00 | $194.48 | $90.48 |
| **Total Operating Expenses** | **$101,784.43** | **$8,955.36** | **$26,620.58** | **$11,625.36** | **$28,914.92** | **$117.00** | **$19,397.52** | **$49,469.19** | **$16,798.78** | **$51.37** | **$800.00** | **$35,339.48** | **$0.00** | **$18,330.77** | **$19,083.30** |
| | | | | | | | | | | | | | | | |
| **Net Profit** | **-$4,906.87** | **$7,533.73** | **-$2,877.04** | **-$1,317.09** | **-$28,914.92** | **-$117.00** | **-$19,397.52** | **-$34,886.19** | **$13,201.22** | **-$51.37** | **$700.00** | **-$5,818.23** | **$0.00** | **-$4,330.77** | **-$19,083.30** |
| | | | | | | | | | | | | | | | |
| **OPENING BALANCE as at 1/07/2021** | $131,712.32 | $0.00 | $8,027.28 | $21,889.57 | $28,914.92 | $117.00 | $19,397.52 | $34,886.19 | $28,594.45 | $51.37 | $472.01 | $32,277.01 | $2,844.55 | $52,568.72 | $19,083.30 |
| **MOVEMENT** | -$4,906.87 | $7,533.73 | -$2,877.04 | -$1,317.09 | -$28,914.92 | -$117.00 | -$19,397.52 | -$34,886.19 | $13,201.22 | -$51.37 | $700.00 | -$5,818.23 | $0.00 | -$4,330.77 | -$19,083.30 |
| **CLOSING BALANCE as at 30/06/2022** | **$126,805.45** | **$7,533.73** | **$5,150.24** | **$20,572.48** | **$0.00** | **$0.00** | **$0.00** | **$0.00** | **$41,795.67** | **$0.00** | **$1,172.01** | **$26,458.78** | **$2,844.55** | **$48,237.95** | **$0.00** |

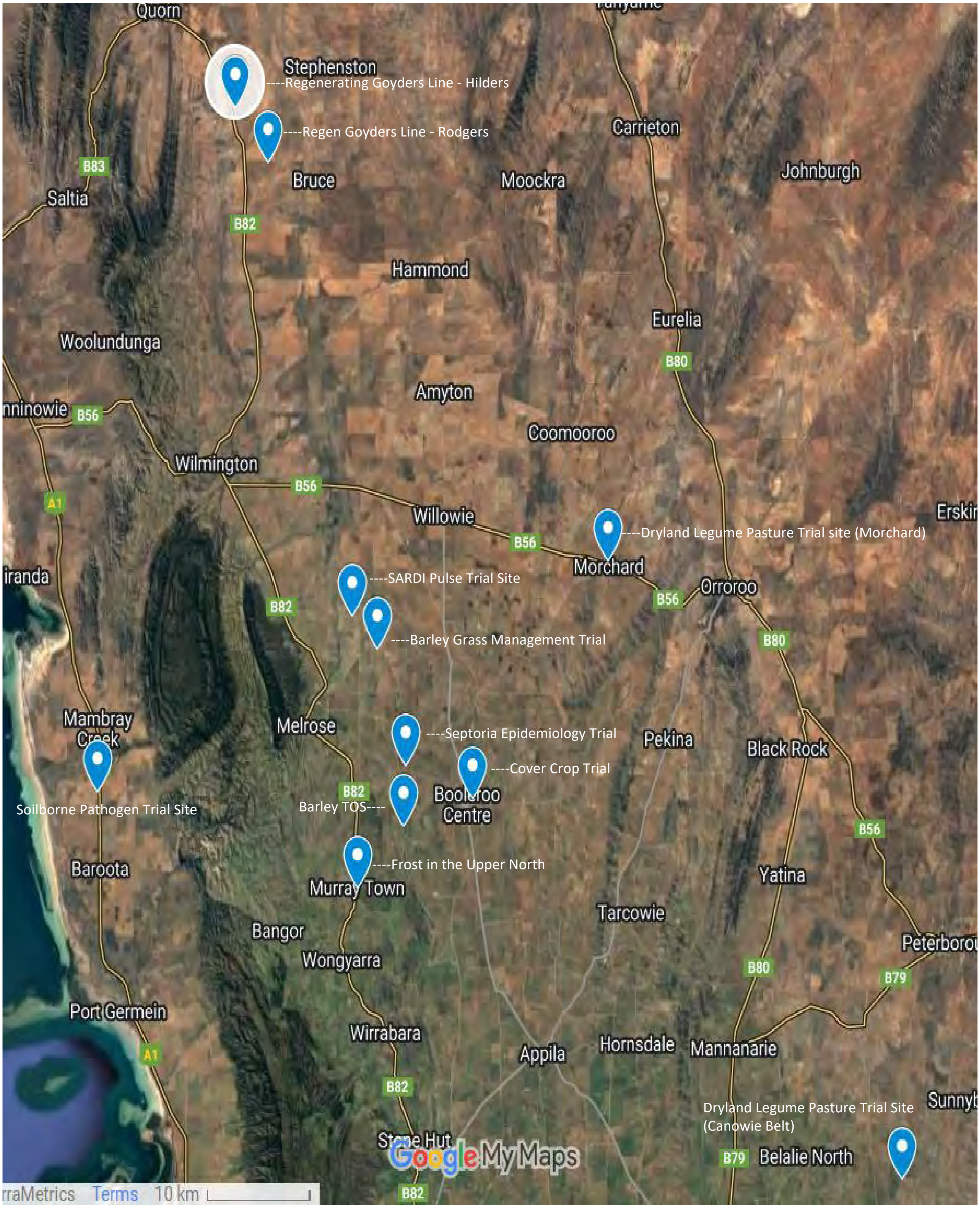
# UNAUDITED PROJECT FUNDS POSITION *continued*
## Financial Year Ending 30th June 2022

| Project Funds Position: 1 July 2021 - 30 June 2022 | 237 - Sheep Producer Tech Group | 238 - Soil Pathogen | 239 - Building soil knowledge in the UN | 240 - Septoria Epidemiology | 241 - Producer Technology Uptake | 242 - Drought Hub Partnership | 243 - Frost in the UN | 244 - Native Plant Guide | 245 - Pulse Extension | 246 - Improved Pasture Mgt Systems | 247 - Lotsa Lambs | 248 - Tools, Tech & Transformation | 249- Canola in the UN | 250- Drought Resilience Mixed Farming Systems | TOTALS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Income** | | | | | | | | | | | | | | | |
| Events | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $739.09 |
| Membership | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $6,886.09 |
| Merchandise | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $63.64 |
| Project Administration | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $25,319.27 |
| Project Income | $0.00 | $14,550.00 | $0.00 | $13,700.00 | $7,967.00 | $0.00 | $20,000.00 | $9,050.00 | $6,000.00 | $10,000.00 | $9,500.00 | $22,600.00 | $0.00 | $0.00 | $224,134.72 |
| Transfer In | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $74,703.05 |
| **Total Income** | **$0.00** | **$14,550.00** | **$0.00** | **$13,700.00** | **$7,967.00** | **$0.00** | **$20,000.00** | **$9,050.00** | **$6,000.00** | **$10,000.00** | **$9,500.00** | **$22,600.00** | **$0.00** | **$0.00** | **$331,845.86** |
| | | | | | | | | | | | | | | | |
| **Gross Profit** | **$0.00** | **$14,550.00** | **$0.00** | **$13,700.00** | **$7,967.00** | **$0.00** | **$20,000.00** | **$9,050.00** | **$6,000.00** | **$10,000.00** | **$9,500.00** | **$22,600.00** | **$0.00** | **$0.00** | **$331,845.86** |
| | | | | | | | | | | | | | | | |
| **Plus Other Income** | | | | | | | | | | | | | | | |
| Interest Income - Unrestricted | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $54.76 |
| Sponsorship | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $15,809.09 |
| Sundry Income | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $2,680.00 |
| **Total Other Income** | **$0.00** | **$0.00** | **$0.00** | **$0.00** | **$0.00** | **$0.00** | **$0.00** | **$0.00** | **$0.00** | **$0.00** | **$0.00** | **$0.00** | **$0.00** | **$0.00** | **$18,543.85** |
| | | | | | | | | | | | | | | | |
| **Less Operating Expenses** | | | | | | | | | | | | | | | |
| Accommodation | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $207.45 |
| Accounting Fees | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $2,690.00 |
| Administration | $0.00 | $1,055.00 | $0.00 | $2,000.00 | $1,848.47 | $0.00 | $2,000.00 | $0.00 | $400.00 | $1,000.00 | $950.00 | $2,000.00 | $0.00 | $0.00 | $35,854.27 |
| Advertising & Marketing | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $300.00 | $0.00 | $0.00 | $1,109.28 |
| Bank Fees | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $30.00 |
| Board and Governance Expenses | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $5,730.50 |
| Communications | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $2,687.73 |
| Conference fees | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $220.91 |
| Employment Support and Supervison Costs | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $10,844.89 |
| Event Catering | $1,508.37 | $4.55 | $4.55 | $4.55 | $330.84 | $0.00 | $4.55 | $0.00 | $9.10 | $0.00 | $0.00 | $560.43 | $4.56 | $0.00 | $9,506.57 |
| Event Expense | $40.00 | $250.00 | $800.00 | $0.00 | $120.00 | $0.00 | $1,500.00 | $0.00 | $1,550.00 | $0.00 | $0.00 | $1,601.02 | $0.00 | $0.00 | $9,753.14 |
| Financial Management Fees | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $1,014.56 |
| Grant Refund | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $31,153.16 |
| Industry Representation | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $1,225.00 |
| Insurance | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $854.09 |
| Insurance - Public Liability | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $2,109.33 |
| Membership fees paid | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $45.45 |
| Merchandise Exp | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $193.46 |
| Office Expenses | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $829.17 |
| Other Project Expenses | $0.00 | $20.20 | $5,583.00 | $5,520.20 | $0.00 | $0.00 | $32.02 | $0.00 | $40.40 | $0.00 | $0.00 | $181.82 | $20.20 | $0.00 | $21,727.37 |
| Postage, Freight & Courier | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $14.50 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $707.53 |
| Presenter | $2,835.09 | $0.00 | $0.00 | $0.00 | $3,437.00 | $0.00 | $785.00 | $0.00 | $0.00 | $0.00 | $27.00 | $3,814.60 | $0.00 | $0.00 | $18,404.81 |
| Project Development | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $4,068.75 |
| Project Expenses | $0.00 | $0.00 | $5,930.00 | $4,322.50 | $307.50 | $0.00 | $848.28 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $66,521.38 |
| Project Management | $1,643.75 | $131.25 | $3,641.67 | $5,718.75 | $9,289.68 | $4,637.50 | $5,677.50 | $0.00 | $218.75 | $918.75 | $787.50 | $1,225.00 | $218.75 | $131.25 | $52,809.67 |
| Publications & Information Resources | $0.00 | $550.00 | $5,847.73 | $550.00 | $1,879.55 | $0.00 | $3,205.00 | $0.00 | $550.00 | $150.00 | $150.00 | $1,235.00 | $0.00 | $0.00 | $26,007.14 |
| Repairs and Maintenance | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $136.36 |
| S&W - Computer Data Allowance | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $1,625.00 |
| S&W Superannuation | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $7,945.18 |
| Salaries & Wages - Engagement Coordinator | $783.50 | $0.00 | $0.00 | $360.00 | $1,264.20 | $622.50 | $1,973.10 | $0.00 | $0.00 | $1,037.40 | $0.00 | $1,732.00 | $0.00 | $0.00 | $34,538.00 |
| Salaries & Wages - Project Officer | $5,616.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $2,262.00 | $0.00 | $0.00 | $0.00 | $8,100.00 |
| Salaries & Wages - Research Coordinator | $0.00 | $2,400.84 | $1,600.56 | $1,244.88 | $0.00 | $0.00 | $622.44 | $0.00 | $444.60 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $19,757.64 |
| Salary & Wages - Finance Officer | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $99.00 | $0.00 | $0.00 | $19,978.25 |
| Stripe Fees | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $13.06 |
| Transfer Out | $110.91 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $56,020.43 |
| Travel | $317.46 | $514.28 | $299.00 | $267.80 | $200.46 | $280.80 | $694.16 | $0.00 | $154.96 | $53.04 | $117.00 | $822.12 | $77.48 | $0.00 | $10,763.70 |
| **Total Operating Expenses** | **$12,855.08** | **$4,926.12** | **$23,706.51** | **$19,988.68** | **$18,677.70** | **$5,540.80** | **$17,356.55** | **$0.00** | **$3,367.81** | **$3,159.19** | **$4,293.50** | **$13,570.99** | **$320.99** | **$131.25** | **$465,183.23** |
| | | | | | | | | | | | | | | | |
| **Net Profit** | **-$12,855.08** | **$9,623.88** | **-$23,706.51** | **-$6,288.68** | **-$10,710.70** | **-$5,540.80** | **$2,643.45** | **$9,050.00** | **$2,632.19** | **$6,840.81** | **$5,206.50** | **$9,029.01** | **-$320.99** | **-$131.25** | **-$114,793.52** |
| | | | | | | | | | | | | | | | |
| **OPENING BALANCE as at 1/07/2021** | $12,855.08 | -$902.41 | $82,298.01 | -$87.50 | $11,852.20 | -$350.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $486,501.59 |
| **MOVEMENT** | -$12,855.08 | $9,623.88 | -$23,706.51 | -$6,288.68 | -$10,710.70 | -$5,540.80 | $2,643.45 | $9,050.00 | $2,632.19 | $6,840.81 | $5,206.50 | $9,029.01 | -$320.99 | -$131.25 | -$114,793.52 |
| **CLOSING BALANCE as at 30/06/2022** | **$0.00** | **$8,721.47** | **$58,591.50** | **-$6,376.18** | **$1,141.50** | **-$5,890.80** | **$2,643.45** | **$9,050.00** | **$2,632.19** | **$6,840.81** | **$5,206.50** | **$9,029.01** | **-$320.99** | **-$131.25** | **$371,708.07** |

## UNFS Projects and Funding

| UNFS Project # | Other Names/ References | Full Name | Funding Source/Contact | UNFS Project Manager | Project Delivery | Project Total (GSTEXCL) | 2020/ 2021 | 2021/2022 | 2022/2023 | Start Date | End Date |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 102 | Hub Activities | Ag Tech, LOTL, Jamestown, Booleroo, Nelshaby, Quorn, Laura/ Glastone, Wilmington, Morchard/Orroroo /Pekina/Black Rock | None Secured | Morgan McCallum | | TBC | | | | ongoing | |
| 103 | Events | Hands on Precision Ag Workshops | GRDC | Morgan McCallum | Pinion/SPAA Colin Hienze | 1000 | 1000 | | | 2021 | 2021 |
| 104 | Commercial Paddock | Fundraising for the delivery of RD&E in the UNFS Region | Northern Ag | Joe Koch | | | 5000 | 5000 | 5000 | ongoing | |
| 224 | Micronutrients in the Upper North | Increasing the knowledge and understanding of micronutrient deficiency in the UN - UNF117 | SAGIT | Jade Rose | Northern Ag - Matt Foulis, YP Ag - Jonno Mudge, Field Systems | 104800 | Carried | | | 1/7/2017 | 30/6/2021 |
| 227 | Cover Crop | Warm and cool season mixed cover cropping for sustainable farming systems in south eastern Australia. | National Landcare Program; Smart Farming Partnerships initiative Rd 1 VIA AG Ex Alliance | Jade Rose | Elders Jamestown - Darren Pech | 47000 | 5000 | | | 1/1/2019 | 7/3/2022 |
| 228 | Barley Grass | Barley Grass Management Options | GRDC/University of Adelaide - Gurjeet Gill/Amanda | Jade Rose | 2019 Matt McCallum 2020 Beth Sleep | 72500 | 23750 | 38333 | | 1/9/2019 | 30/12/2021 |
| 229 | Dryland Legumes | Dryland legume pasture systems project | Rural R&DfP/MSF/Naomi Scholz | Jade Rose | Morchard - Andrew Catford Yr2, Canowie - Beth Sleep Yr 1 | 60000 | 20000 | 20000 | | 2019 | 2022 |
| 231 | Weather Station Network | Upper North Fire Danger Index Alerting Weather Station Network Project | Safecom/NSS | Morgan McCallum | Leeton Wilksch | 95000 | | | | 1/5/2019 | 30/6/2020 |
| 232 | Barley Time of Sowing | Upper North Barley Time of Sowing; Frost / Heat Stress Effects | SAGIT | Jade Rose | Steph Lunn - Agxtra | 88825 | 28875 | 31075 | | 1/4/2019 | 30/8/2022 |
| 235 | Regenerating Goyders Line | Regenerating Goyder's Line. Re-establishing productive pasture in once cropped land | National landcare Program; Smart farming Partnerships iniative round | Ruth Sommerville | Partners - Anne Brown, Native Veg Council, Jack Desbioselles, Succession Ecology, Seeding Natives Inc, Greening Australia | 50000 | 50000 | Carried | | 2020 | 2022 |
| | | | NYLandscape Board | | | 10000 | 10000 | | | 2021 | 2021 |
| 236 | SARDI Partnership Projects, | Site Management Support to SARDI Research Sites in the Upper North | SARDI/Penny Roberts, Sarah Day | Jade Rose | SARDI | -20000 | -20000 | | | 2021 | 2021 |
| 237 | Sheep Tech Group | Red Meat and Wool Growth Program - Producer Technology Group, Upper North Farming Systems | PIRSA/Jodie Reseigh Obrien | Rachel Trengove | UNFS/Nutrien Ag/AC Ag Consulting | 25000 | 25000 | | | 2020 | 2022 |
| 238 | Soil Pathogen Project | Soilborne cereal pathogens national extension project - Workshops | GRDC via FarmLink/Allan Umbers. Also SAGIT via SARDI | Denni Agnew (2020) and | SARDI/ Ag Communicators | 500 | 500 | | | 2020 | 15/7/1905 |
| | | Soilborne cereal pathogens national extension project - Trial Sites | Allan Umbers | Jade Rose (2021) | UNFS Barry and Jonno Mudge | 21550 | 1000 | 4550 | 9000 | 2021 | 2022 |
| 239 | Building Soil Knowledge | Building soil knowledge and capacity to implement change in the farmers of the Upper North Agricultural zone of South Australia. Improving soil structure and function to improve plant health, landscape function and farming system resilience. | National landcare Program; Smart farming Partnerships iniative round/ ID K2LZKXT | Jade Rose | Field Systems and Elders Michael Eyres, Ed Scott, Beth Sleep | 92500 | 25700 | 50400 | 16400 | 1/5/2021 | 2022 |
| 240 | Septoria Epidemiology | Epidemiology of Septoria Tritici Blotch in the low and medium rainfall zones of the Southern region to inform IDM strategies. | GRDC/ Tara Garrard at SARDI | Jade Rose | AgXtra - Steph Lunn | 30900 | 14500 | 14500 | 1900 | 2021 | 2022 |
| 241 | Producer Technology Uptake | Incorporating digital farming for improved productivity in the Upper North of South Australia | Agrifutures | Jess Koch | Breezy Hill PA - Jess Koch | 19918 | 11951 | 7967 | | 31/5/2021 | 31/5/2022 |
| 242 | Drought Hub Partnership | SA Drought Resilience and Innovation Hub | Uni Adelaide | Ruth Sommerville | | TBC | | tba | tba | 2021 | 2024 |
| 243 | Frost in UN | Frost Extension in the Upper North | GRDC / MSF Tanja Morgan | Morgan McCallum | Breezy Hill PA - Jess Koch | 20000 | | 20000 | | 2021 | 2022 |

UPPER NORTH FARMING SYSTEMS 2021 RESEARCH SITES



# EVENT SUMMARY 2021

After another challenging year for running events within UNFS due to covid and state-wide lockdowns, UNFS as a group showed great resilience to still put on 25 successful events throughout the year with a total attendance of 572 across all the events.  Each event bringing some new ideas and concepts across all enterprises. There was a range of events held covering off on topics such as sheet technology, grains research updates, farm business technology and many more. 2021 highlights were the UNFS annual expo, after such a challenging year and a postponed date, it was great to see up to 90 attendees support and engage with this event.

| Date | Event | Location | Participants | Details |
|---|---|---|---|---|
| February | | | | |
| 11 | GRDC Grains Research Crystal Brook update | Crystal Brook | 80 | Involvement in prep for GRDC update in Crystal Brook |
| 17 | Precision Ag workshop | Gladstone | 10 | Guest presenter Adrian Roles stepped through the fundamentals of PA, local farmers Rob Price and Andrew Kitto talked through their own experience with PA. In the afternoon we looked at hands on field exercise and simulation. |
| 18 | Pulse Check Meeting | Napperby | 24 | Penny Roberts, Senior Researcher, SARDI - Warnertown trial results wrap up Sam Holmes, Central Ag Solutions: Growing lentils in a closer rotation and the issues to watch out for. Richard Saunders, Pinion Advisory: Gross Margin Tool for assessing risk & profitability of different rotations |
| 19 | Pulse Check Meeting | Booleroo Centre | 10 | As above. |
| March | | | | |
| 1 | Strategic Planning Day | Laura | 11 | Troy Forrest from Strategy Road leads the Strategic Board, Ops committee and staff members through a workshop to ascertain the strategic plan for the next 5 years 2021 - 2025. |
| 10 | Pulse Check Bus Tour | Adelaide | 25 | Pulse growers from UNFS area and researcher Mick Brougham departing from Port Pire to Adelaide via Adel Uni Roseworthy campus, Dublin Clean Grain facility and networking at the Koolunga Hotel on return trip |
| 19 | Sheep Producers Tech Group – Workshop 2 | Gladstone | 25 | Shearing Sheds & Sheep Yards: Hosted by Andrew Kitto: Daniel Schupp an (Nutrien Ag) facilitated presenters: Michelle Cousins, Cousins Merino Services - EID demonstration and presentation on Mark Noonan (Hornsdale) and Andrew Kitto (Gladstone) |
| 25 | GRDC Better Frost Decisions | Booleroo Centre | 7 | Dane Thomas presented via zoom on frost and risk in a changing climate. He showed raw data that influences modelling and how to interpret weather data. Mick Faulkner talked about Zoning strategies, how Michael Moody talked about how frost can affect profitability and whole farm gross margin. |

| | | | | |
|---|---|---|---|---|
| 31 | Regenerating Goyders Line | Quorn | 19 | Paul Rodgers Property. Speakers - Ben McCullum (SAAL Landscape board- soil seedbank), Mary-Anne Young (PIRSA-Soil erosion), Trevor Gum (Willowie Farmer- native grass seeder), Anne Brown (Native vegetation and Land Management) |
| April | | | | |
| 4 | Ladies on the Land Farm Fire Safety | Jamestown | 23 | Burn off used to teach ladies how to use farm fire units and brief prezzo giving hints / tips for fire safety |
| July | | | | |
| 1 | Sheep Producers Tech Group – Workshop 3 | Wirrabara | 34 | Sheep yard and lead-up race design - Tom Austin, Atlex Stockyards presented on yard design and training working dogs |
| 9 | Sheep Producers Tech Group – Workshop 4 | Booleroo Centre | 13 | Merino Sheep Flock Profiling. Guest presenters Anne Collins and Andrew Michael Presented on merino flock profiling and ram select |
| 20 | Producer Tech Uptake | Napperby | 12 | Jessica Koch presented on using farm data to make decisions and a run through of the different applications available. |
| 22 | Producer Tech Uptake | Zoom | 22 | Jessica Koch presented on using farm data to make decisions and a run through of the different applications available. Held on Zoom due to SA lockdown. |
| August | | | | |
| 8 | Precision Ag workshop | Gladstone | 5 | Jessica Koch presented on using farm data to make decisions and a run through of the different applications available. Guest presenter Adrian Roles stepped through the fundamentals of PA |
| 9 | UNFS Members Expo & AGM | Booleroo Centre | 90 | Presenters: Mark Farrell CSIRO - Profitable Soils; David Cooper, CC Cooper & Co - Profitable & rewarding systems; at Melrose with presenters: Sarah Day and Penny Roberts SARDI - trial site report & novel cropping systems; Jade Rose UNFS & Beth Sleep, Elders - Building soil Knowledge project; Stephanie Schmidt, ACT for Ag; Michael Nash - Reducing Pest Incursions; Marg Evans SARDI - Crown Rot; Sheep Tech Panel. The afternoon session was held on farm trial site at Melrose with presenters: Sarah Day and Penny Roberts SARDI - trial site report & novel cropping systems; Jade Rose UNFS & Beth Sleep, Elders - Building soil Knowledge project; Jess Koch, Breezy Hill PA Systems & Michael Eyres, Field Systems Aust - Frost in the UN project; Mark Farrell CSIRO & Ed Scott, Field Systems Aust - Soil Pit presentation.'2021'! |
| 10 | Producer Tech Uptake | Melrose | 8 | Jessica Koch presented on using farm data to make decisions and a run through of the different applications available. |
| September | | | | |

| | | | | |
|---|---|---|---|---|
| 13 | GRDC Forum & Eastern Spring Crop Walk | Melrose | 10 | Jess Koch presented about the Frost extension site, Steph Lunn presented on some of the findings so far within the trial and did a trial walk through. Lastly, Jade Rose touched on Barley Grass management within the Barley Grass project. |
| 14 | Western Spring Crop Walk & Nelshaby Ag Bureau Sticky Beak Day | Wandearah/ Baroota | 20 | Michael Eyres and Ed Scott from Field Systems walked everyone through two separate soil pits with a large focus of soil nutrition. Sam Trengrove presented on the background of the trials, some trial results and future plans within the phosphorus space in relation to trial work. Penny Roberts and Dylan Bruce presented information about the trial and some findings. |
| October | | | | |
| 6 | Sheep Producers Tech Group – Workshop 5 | Black Rock | 28 | Hosted by Jim & Tom Kuerschner, Black Rock. Presenters: Daniel Schuppan (NutrienAg) - Confinement feeding and Feedlot design, Jane Kellock - Farmer experience adopting technology on farm. |
| 7 | Melrose Hub Event | Melrose | 4 | Penny Roberts from SARDI presented on all things intercropping at the site located at Melrose. |
| 13 | Gladstone/Laura Hub event | Gladstone | 15 | Sticky beak day looking at Sheeted water catchment at Phillip Coombes property at Stone Hutt, GM canola and also Soil fertiliser strips. Brian Hughes from PIRSA also presented on AG B SA Drought Project Team. |
| 18 | Advance Ag Conference | Adelaide | 2 | Conference with a large focus on Agtech, what can be implemented on farm and some new emerging tech. |
| November | | | | |
| 25 | Ladies on the Land - Bubbles & Chats | Bundaleer Forrest | 70 | A Christmas gathering at the new Bundaleer Function Centre 'Maple and Pine' organised to support local women with Guest Speakers: Rebecca Moore, Erin McCarthy, Barb Carr, Britt Cunningham and Jessica Koch. |

# 2021 HUB REPORTS

## Appila Hub Report

### 2021 Hub Rep: James Heaslip

Season 2021 was positive for Appila, receiving approximately average rainfalls and yields that were boosted by strong commodity prices. We held one hub event at the Appila Hall that was attended by a small but enthusiastic group. Following the theme of Ag Tech we had a guest speaker from Phoenix Livestock talk about their latest updates to their farm management software and their new app. We also heard a UNFS project update from Jade Rose and Darren Pech.

Covid restrictions are now easing and I look forward to holding more frequent hub events during the season ahead, so please reach out if you have any suggestions.

## Wilmington Hub Report

### 2021 Hub Rep: John Carey

The 2021 season in the ranges saw some good germination from two rainfall events 15 to 30mls but needed follow up. Off the ranges, it was still very dry  with only 5 to 12 mls; however, a big percentage of seeding was completed successfully.

Due to covid, no events were held in 2021, but 2022 has kicked off with a great hub event. Around 15 people attended the morning session with a cross section of Graziers, Cereal Growers and Land Management Associates in attendance.

First speaker was Michael Eyres who gave a presentation on a broad range of soil research including assessment and management of soil capability and condition for increased performance.

Second cab off the rank was a presentation by Miles Cockington of Podium Livestock. The topic being Flock Profiling, a platform to market and monitor your livestock which is a handy tool for sales and purchases.

There was good feedback from all those present on the day, interaction and discussion was good and was followed by a BBQ lunch.

## Young Farmers Hub Report

### 2021 Hub Rep: Alison Henderson

The Young Farmer's Hub was relaunched at the 2020 UNFS Members Expo.

As the young farmer rep for UNFS I feel that it is a very exciting time to be involved in farming as a young person. Despite every season throwing up its unique challenges, we have more tools, research and resources at our disposal than ever before to make good decisions. UNFS leads the way with coordinating and presenting regionally relevant research and information in both the cropping and sheep sectors.

I would love to see a group of passionate young farmers come together in the UNFS region to learn together from the plethora of trials running under UNFS oversight in our backyard and lead the way in applying the key learnings on our own farms. I also really value peer learning and would love to see the Young Farmer's group meet a couple of times a year to review the season, share ideas and make the most of the combined intellect that we have to help us all become more profitable, sustainable farmers in the Upper North.

Please get in contact with me if you have any ideas for field trips, workshops or any guest speakers that you would like to hear from and let's get the Young Farmers Hub up and running to make the most of and best equip the young talent that we have in our region.

## Quorn Hub Report

### 2021 Hub Rep: Paul Rodgers

The Quorn area had another poor season even though some areas received nearly 200mm in the growing season. It was a poor finish,  with only 13mm in August and 6mm in September. Crops away from the Ranges were not harvested, crops near the Ranges averaged from 0.6tonha to 1.5tonha. Most Grain was downgraded due sprouting after 75mm in November.

Livestock wise, July was a good month for pasture growth with most of the district receiving 60-100mm but with no follow up, it fizzled out in September. Lambing was average to a little below average with unusually high ewe mortality reported.

75-100mm was recorded in November, germinating some summer feed in the grazing country, hopefully converting to some good conception rates in livestock in the Autumn and Winter and getting the boom spray out in arable country.

Regenerating Goyder's line project was put on hold until 2022 due application issues/Covid/lack substantial opening rain, hence no hub events were held regarding the project.

## Gladstone/Laura Hub Report

**2021 Hub Rep: Andrew Kitto**

Our first 2021 Laura Ag Bureau Meeting was on 8th Feb. Due to a fire which started on one of our member's property the drinks and meals were left on the tables, with Guest speaker Alexia Catford from NY Landscapes SA. Not long after, they returned and the 25 discussed topics (besides the fire!) of fox baiting, 20/21 harvest results, our straw run update and organised our focus paddock soil field day.

Later in Feb, we had a sticky beak around Orroroo visiting Dew's Kangaroo shop, then a pub to wash it down, followed by a visit to Soil Management Systems Brenton Byerlee's farm. Then Laura Ag Bureau were invited to a thankyou BBQ at Orroroo Golf club for the straw donations. Here Kate Burke joined via zoom to talk about her book which she dedicated to Matt McCallum. A PA workshop was held in Gladstone on the 17th Feb. More road trains of donated barley straw went to north of Orroroo in March.


Our major event for the year was a soil field day "Beyond Straight lines" Held on March 30th at Idlib Rd Laura. The 160 Ha pd had extensive soil testing and guest speakers talked about how we could best use this information. About 50 attended and was funded by the NY Landscapes Board.

June was AGM/ Pizza tea with Bevan Oster (Yorke and North AG B Rep). Also the last of 1500 donated bales was delivered. August was RBS – Resources exploration. In September we held a voluntary truck inspection day with NHVR.

October we had a sticky beak afternoon looking at sheeted water catchment at Stone Hut, a GM Canola crop at Laura and soil fertility test strips.

The year 2021 was a very mixed bag. It was the driest start till the end of May since 2005. Then June and July were the wettest since 1985. November was the wettest on record with many local gauges over 125mm. About 20 Laura Ag Bureau members received severe hail storms in November that caused losses up to 99%. Barley and legumes were more affected than wheat.

## Black Rock/Orroroo/Morchard/Pekina Hub Report

**2021 Hub Rep: Tom Kuerschner**

I have just started in the role as the Black Rock/Orroroo/Morchard/Pekina Hub Rep, attempting to fill the big shoes left after the retirement of Gilmour Catford. Gilmour has done a great job with UNFS over the years, and we thank him for his efforts.

2021 was quite varied across the district. Some fortunate enough to be reaping above average crops, some below average, and a few who were unable to grow any crops at all due to the dry conditions. It was quite amazing, the difference that could be seen, just by driving 10 or 15 kilometres. Stock feed was a similar story, with many still supplementary feeding at times.

We have started off 2022 with technology based hub events. Our event focused on the options available for farm record keeping programs and apps, showcasing Agriwebb, ProductionWise, and Agworld. Beth Humphris also presented the results of the UNFS barley grass trial.

At time of writing, 2022 seeding is well under way, with dry seeding being the only way to go so far, with no significant rainfall anywhere yet. Hopefully it begins to roll in soon!

Remember to contact your local district hub reps with any suggestions for UNFS research projects or hub event topics.

## Melrose Hub Report

**2021 Hub Rep: Andrew Walter**

The 2021 season had a great deal of variation across our region. A late break to the season with around 10mm late May followed by a similar amount in the second week of June got crops started, with a wet second half of July setting some solid potential. Unfortunately, the follow up soaking rains we needed didn't eventuate, with dribs and drabs throughout the rest of the season enough to keep crops moving but not allowing them to reach full potential. Scattered rains off weak forecasts also had people scratching their heads about the decision to spread or not to spread. This was made even more confusing by the lack of availability of urea, with some in the area using UAN for the first time.

A wet November through a spanner in the works during harvest, with a lot of grain getting downgraded. This also meant the boom spray got pulled out as soon as the header left the paddock.

Just as spraying was completed, another 75-100mm in January got the weeds perked up again, with many people spraying their whole farm for a second time. Hopefully this retained moisture will help set us up for a bumper year to make the most of the incredible grain prices and recoup some of the costs which are going out for the 2022 season.

A hub event was held in conjunction with the SARDI Intercropping trial held on our block North East of Melrose. Penny Roberts and Sarah Day were there and gave some great insights into the research that was being done in the intercropping space, as well as some details on some of the legume trials that were at the site. Attendees also had a look over our Bourgault air seeder which we had used to sow our own 10Ha intercropping trial, with canola and lentils being sown in the same paddock, canola through the mid row banding discs on 24” spacing, with lentils going out through the tynes on 12” spacing.

The UNFS expo also finished up at the same location, with a soil pit being dug and analysed on the day for attendees. This has led to an additional trial being held on the block in 2022, with deep ripping taking place to try and rectify some of the constraints which were found.

As well as this, SARDI are running another pulse and intercropping trial in the paddock next year, great to see this work continuing in the same area to really be able to compare results. A canola variety trial in the region rounds out a good set of trials in this area and will hopefully provide some data to help people make decisions on best varieties to be growing in our region.
Always excited to have trials occurring locally, you can't beat trial data in your own region! As always, feel free to contact me if you wish to visit any of these trial sites at any time.

## Nelshaby Ag Bureau Hub Report

### 2021 Hub Rep: Nathan Crouch

Mixed results were produced in 2021 for Bureau members, as rainfall was not consistent in all areas. Coupled with significant amounts of rain at the beginning of harvest, there were also some downgraded crops. The higher-than-average grain prices certainly helped to boost income, especially with these downgrades.

In March, the Bureau went on a UNFS Pulse Bus tour. After an early start from Port Pirie and some pickups on the way, we were met at the Roseworthy Campus by University of Adelaide Researchers Ben Fleet and Gurjeet Gill who spoke about their research around agronomy and weeds. The group moved on to a tour of plant breeding and research at Australian Grain Technologies (AGT), followed by lunch. After lunch the bus travelled to pulse (soil amelioration) sites as well as looking at lentil hay, led by Mick Brougham. To make our way home we stopped at Dublin Clean Grain to have a tour with Simon and Andrew Koch. A great day was had by all.

Our guest speaker for the June meeting was Andrew Sergeant, who spoke about his Nuffield Scholarship and overseas travels. Travelling across the USA, Canada, Netherlands, Germany, Austria and Australia, Andrew engaged in a series of interviews, farm visits, conferences and presentations to identify the challenges and barriers to adoption and the opportunities open-source software offers the agricultural sector. It was a very interesting presentation which was enjoyed by everyone.

In September we had our Annual Nelshaby Ag Bureau Sticky Beak Day and UNFS Western Spring Crop Walk. The day started boarding a bus at Nurom and travelling to Mambray Creek. There we looked at a soil pathogen (crown rot) demo site. While we were there, we also looked at soil pits at Mambray Creek and Baroota with Michael Eyres and Edward Scott (Field Systems). Looking at the soil texture with hard compactions layers with also some PH issues being brought to attention. After the morning sessions, we travelled back to Crystal Brook to look at some phosphorus trials Sam Trengrove has been managing with a key focus on the 3 defining soil boundaries of phosphate availability, as well as soil PH. To finish off the day we went to Warnertown SARDI Pulse Trial Site, where we had Penny Roberts and Dylan Bruce (SARDI) explained new seed varieties as well as time of sowing. The day was well received with a great attendance and a lot of discussion within the group and guests with a BBQ and drinks for tea.

The Nelshaby Ag Bureau is looking forward to a wet growing season and hope that everyone has a safe and successful year.

## Jamestown Hub Report

### 2021 Hub Rep: Beth Sleep

As with all other areas across the upper north farming region, Jamestown had a late break to begin the 2021 growing season. This meant limited to no knockdown before sowing which placed a lot of pressure on our pre-emergent herbicides, and limited green pick for sheep at the beginning of the season. Once the break of season finally came in early June, soils temps had fallen and emergence was slow. Some areas experienced mice issues and false germinations, but overall the season turned around, with a lot of rain thereafter.

In-crop sprays were in many cases delayed due to paddocks being too wet to drive over and much of my agronomy was done by foot throughout June and July, a problem I will never complain about! The rain continued to fall throughout early Spring until September when it came dry again. Early areas suffered from this the most, with crops running out of moisture to properly fill grain. Rain then came throughout November, just in time for colder areas where crops were still green. This then became a sprouting issue into harvest. To finish the season off there were a few isolated hail events, in some areas reducing crop yields by 100%, due to crops being so ripe at the time of hail. This then led to concerns around mice populations coming into the 2022 growing season. Everyone was eager to get canola off APAS, with prices at extreme highs, a nice Christmas bonus!

Throughout harvest there was a lot of talk around product supply for the 2022 season, in some scenarios growers having to order canola seed, fertiliser and chemical for 2022 before even having any of the 2021 crop off. Hopefully not something that will not repeat this coming harvest.

Due to covid restrictions, staff changes and hub rep changes, no events were held in the 2021 season unfortunately. In the 2022/23 season, the Jamestown hub is looking for a new hub rep to be a part of the team, please reach out to UNFS if you think you would be a great fit.

# Ladies on the Land Hub Report

**2021 Hub Reps: Beth Sleep, Jessica Koch, Steph Lunn**

LoTL had another action packed year throughout 2021. The hub hosted two main events for the year, our Fire Awareness workshop and Bubbles and Chats. The group also remained very active on our social media, with our annual **#buyfromthebush** campaign and other posts working to connect rural women.

For the third time now, our hub did an annual **#buyfromthebush** social media campaign just in time for Christmas shopping. This campaign looked to highlight all our amazing local businesses throughout the months of November and December. Overall, we featured more than 50 local businesses via our Facebook page, using facebook stories to highlight products offered across our region. This included businesses from Hawker, Peterborough, Melrose, Booleroo, Gladstone, Crystal Brook and everywhere in-between!

Our first event for the year, the Fire Awareness workshop, was held at the Jamestown Gun Club on the 18th of April. A controlled paddock burn off took place, allowing attendees to use farm fire fighters to control the fire, gaining practical hands-on experience. The day also included presentations from local CFS members to upskill our local women on fire safety. Presentation topics included what to consider if you're home alone when there is a threat of fire, what channels, apps and websites you can access for more information, when the right time is to leave, or what to do if that is not an option to leave, what to consider packing and an opportunity for open discussion. There was great conversation that fell out of the day and all attendees walked away feeling more confident.

To round out our year the hub held our Bubbles and Chats event on the 25th of November, a beautiful summer's night. The event was held at the newly built Maple and Pine venue in the Bundaleer forest. We were over the moon with just how many ladies attended this event! The night included 5 presentations from local women, Rebecca Moore, Brittany Cunningham, Barb Carr, Erin McCarthy and Jess Koch who talked about their life, inspiring all those in attendance. Catering was done by a local business, The Good Paddock, who supplied grazing boxes and all drinks were provided by Maple and Pine.

We look forward to another exciting year throughout the 2022 season, with more events to be held spanning across our region to help connect, inspire and upskill our rural women!

Fire Awareness Workshop

Bubbles and chats

# Understanding trial results and statistics

Jim Egan
SARDI, Port Lincoln

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

## The average (or mean)

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

## The LSD test

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

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

## Results from replicated trial

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

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

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

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

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

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

## On-farm testing - Prove it on your place!

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

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

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

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

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

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

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

# Some useful conversions

### Area

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

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

1 ha = 2.471 acres

### Mass

1 t (metric tonne) = 1,000 kg

1 imperial tonne = 1,016 kg

1 kg = 2.205 lb

1 lb = 0.454 kg

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

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

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

1 bu (wheat) = 60 lb = 27.2 kg

1 bag = 3 bu = 81.6 kg (wheat)

### Volume

1 L (litre) = 0.22 gallons

1 gallon = 4.55 L

1 L = 1,000 mL (millilitres)

### Speed

1 km/hr = 0.62 miles/hr

10 km/hr = 6.2 miles/hr

15 km/hr = 9.3 miles/hr

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

### Pressure

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

25 psi = 1.7 bar = 172 kPa

### Yield

1 t/ha = 1000 kg/ha

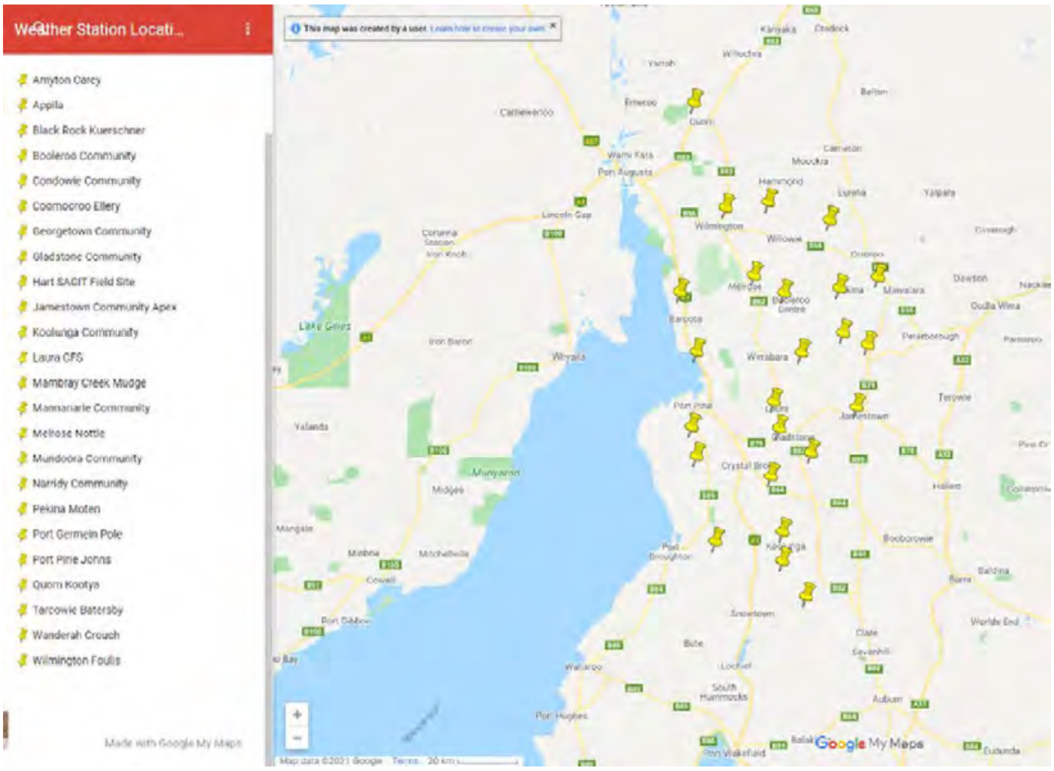
### Yield Approximations

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

# UNFS

# WEATHER STATION NETWORK

UNFS has a network of 22 weather stations that are managed by AgByte and were installed in a grant aimed at improving community access to data for better decision-making during fire danger season. There are additional sites available through the AgByte network that tie into the UNFS sites and together they provide a comprehensive network across the Upper North Region of South Australia.



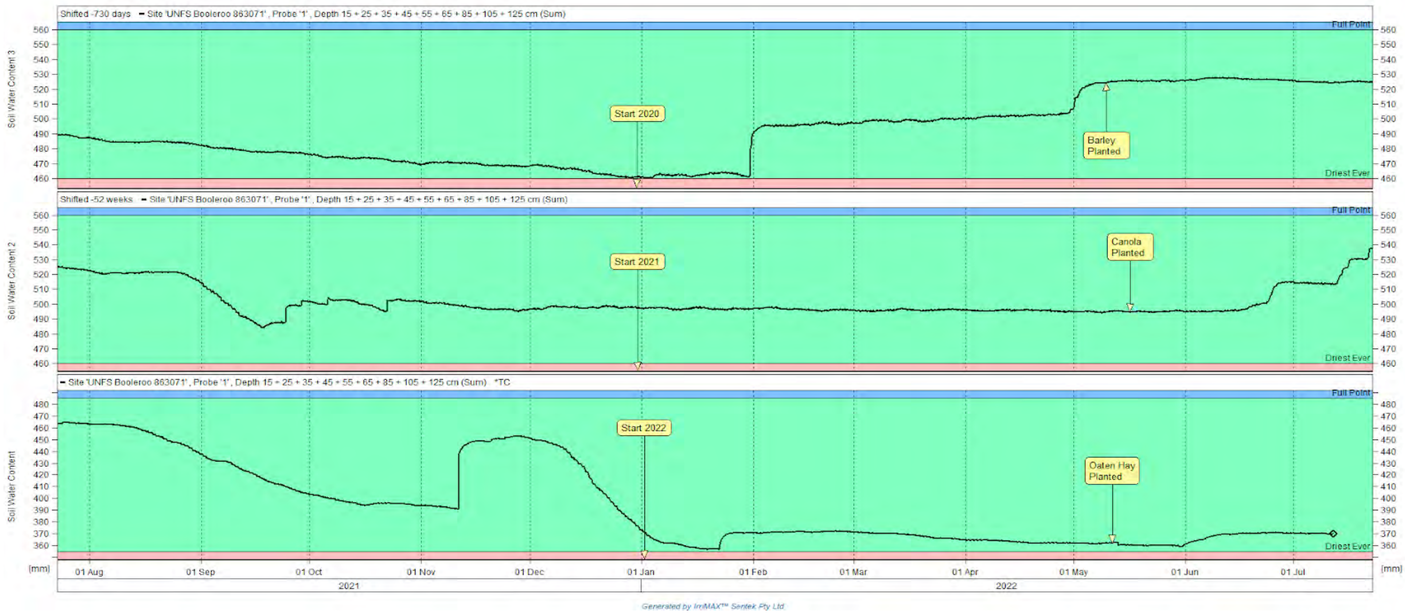

The weather station data can be accessed through the UNFS website, [www.unfs.com.au](http://www.unfs.com.au) under Resources. Full details on interpreting the data can also be found on the website. We continue to receive positive feedback about the sites, particularly around decision making at harvest time with the fire risk.

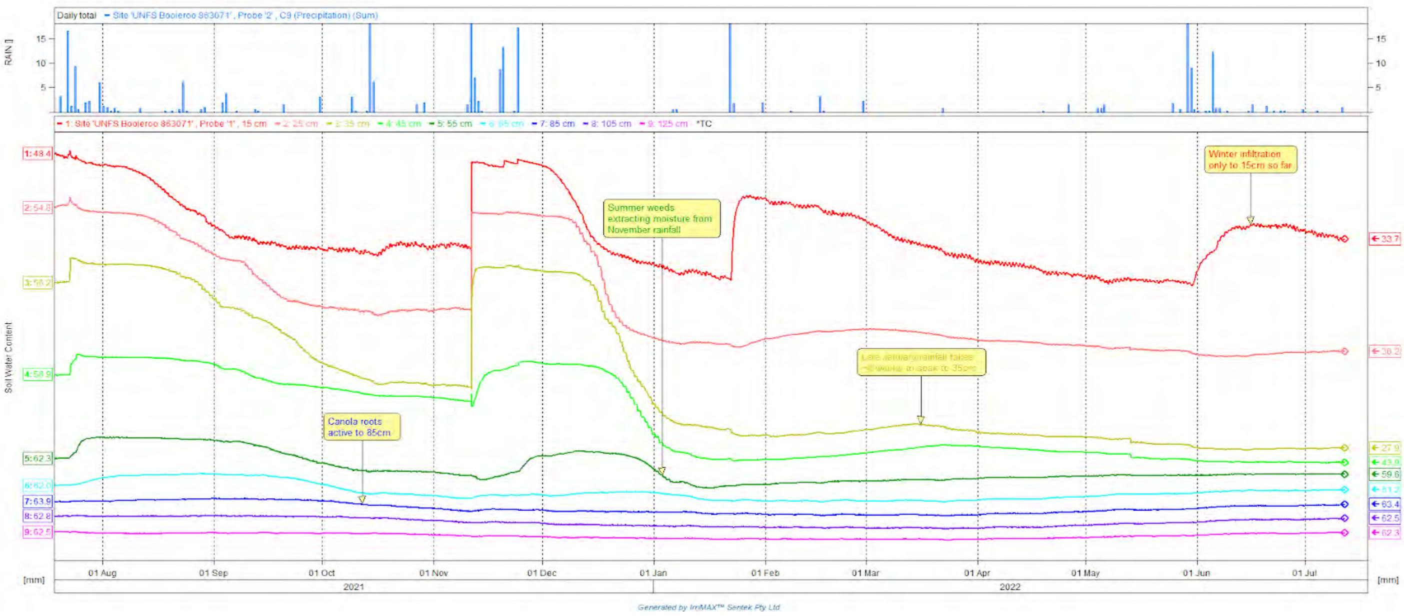
In the 2021 season the highest temperature recorded was at the Johns Pirie South site on 31st December 2022 with 41.1C. Coldest Temperature was only 2 nights ago 10th July with -4.6C at Foulis Wilmington, was 6.9 at Pole Port Germein at the same time. Highest Ave wind speed was 85km/hr for Kyoota Quorn over a windy couple of days on 30thMay/1st June.  Many sites spent the best part of 2 days averaging ~40km/hr.

The soil probe graph at the Booleroo trial site paddock has shown a classic case of what happens when weeds aren't sprayed out after summer rainfall.  The late November rain saw infiltration down to ~55cm but this also caused weeds to germinate.  Their roots powered down the profile as evident by the diurnal fluctuation 'stepping' seen progressively at each sensor depth from early December to early

January. Evapotranspiration during this time saw all of the moisture that came into the profile from the November rain effectively removed and thus not available for this year's crop. Looking at the Summed comparison graph, this 'bulge' from the November rainfall is gone by Mid-January plus some. The roots of the weeds obviously got down deeper than the rainfall had infiltrated.

The Fire Danger Index is going through some changes in the code coming in at the end of August which the CFS/GPSA are communicating, this will be a national *Fire Behaviour Index*, Leighton will report these changes to all member



How to use

# PRECISION AG DATA LAYERS

to accurately and economically soil test

*Jessica Koch (Breezy Hill Precision Ag Services), Beth Sleep (Elders, Jamestown)*

## WHY?

Soil testing can be an expensive and time-consuming process for the grower. Results can appear daunting and complicated to interpret if they're not collected with a specific focus or goal in mind.

It is common for farmers to have several years of yield data collected from their grain harvesters. It is less common for growers to be using these data layers to help determine soil zones in a field. Yield data is valuable when there are several seasons of data, in different crop rotations to compare trends. It is even more valuable when coupled with soil survey data and satellite imagery, as these layers can begin to reveal patterns about soil variability changes within a field and how they relate to final yield. Most fields will have inherent spatial soil variability.

This fact sheet is designed to demonstrate a process to use data layers to soil test strategically, then show how the results can help make variable management decisions.

## SOIL TESTING

Whilst pre-season combined soil surface testing is valuable for determining nutrition input requirements for the upcoming season, deep core soil sampling (0-90cm), using a hydraulic soil corer, can measure more mobile nutrients such as available nitrogen or sulphur and assess subsoil constraints to root growth.

Soil coring at multiple depths down the profile in strategic locations can provide great insight into the soil attributes in each horizon; these influence the conditions the plant encounters at each stage of the growing season.

Data layers give clues about soil variability, which is important as it is a major influence on grain performance (yield and protein).

## WHERE DO I START?

I want to use my data layers to select where to take soil cores

1. Pick a field where the cause of the variability is unknown
2. The degree of variability can be assessed using coefficient of variation (or CV%), or standard deviation/mean expressed as a percentage
    - <= 8% - not very interesting!!
    - >8% <= 16% worth investigating
    - >16% well worth exploring the cause and pursuing the opportunities

### READILY AVAILABLE DATA LAYERS INCLUDE:

- Yield data
- Satellite imagery
- Elevation data
- Soil Survey (EM38/Gamma Radiometrics)
- Soil grid maps (pH, P, K)
- Protein data

3. Compare yield maps with season rainfall (total and the distribution of the rainfall over the growing season) to remove environmental influence on yield. We are searching for factors within our control to change throughout this process

4. Collect and organise the data layers available to you and ensure they're accurate (processed)

## WHAT IS DATA PROCESSING?

Processing precision ag map data involves looking at the raw data points to remove errors to ensure the finished map is a true reflection of what was collected in the field. Most raw data will contain outliers that need to be removed. Other factors like GPS drift can cause 'data delays' and these can also be corrected through processing. The raw data points will then be smoothed and given a colour scale with a representative legend.

5. Look at cereal rotations and compare the patterns over several different seasons. It is best to omit yield maps that have been heavily impacted by environmental factors such as frost or hail.

6. Compare yield maps with in-season imagery
    - Early season maps are good indicators of topsoil variability
    - Late season maps are good indicators of subsoil variability as plant roots venture into the sub soil resource

7. Use 'constant' map layers to compare with the yield and imagery to begin to find correlations – eg Elevation, EM38 or Gamma Radiometric data. Grid soil data may be useful too
    - Don't be concerned if you haven't got many layers to start with yet. The following steps will help to determine appropriate map layers to collect for localised soil type.

8. Develop 'zones' to test. This may require input and consultation from an agronomist

9. Choose a representative core site in each zone. The aim is to develop a deep and comprehensive understanding of the soil conditions within each zone. Record the latitude and longitude at the soil core site

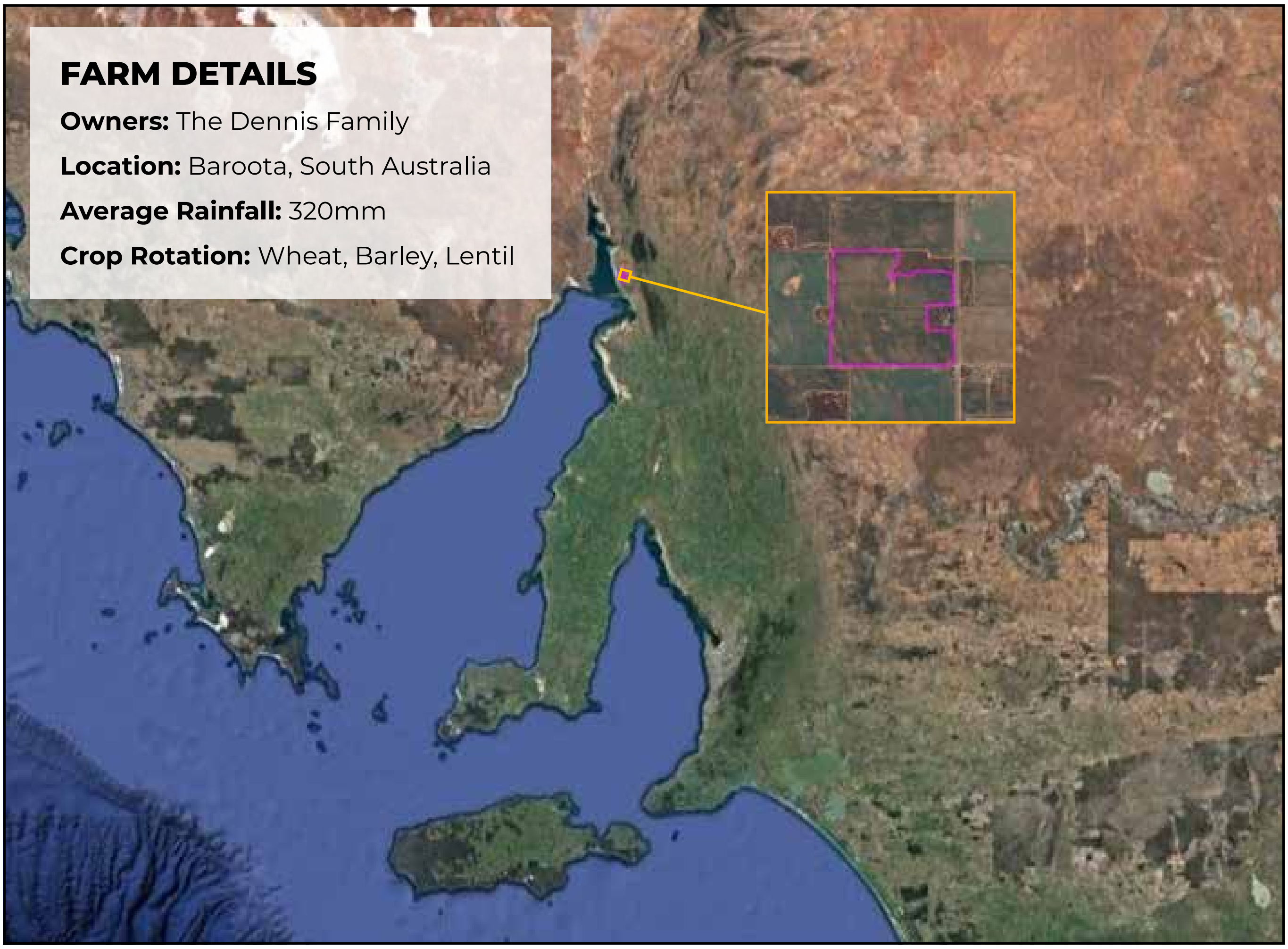
10. When the cores are taken, (usually up to a depth of 90cm), it is best to split the cores by horizons for testing. Take photographs of the cores to help with analysis and track root growth. It is best to take cores throughout spring in a cereal rotation. We are considering factors that do not fluctuate quickly here including soil texture, organic carbon, phosphorous, salt content and pH.

11. Use the results to determine overarching soil type for each zone, consider the soil properties at each location, as each zone may require different agronomic management. Also consider the differences down the profile as the crop may experience different growing conditions throughout the season, which will influence early and late season decisions differently.

12. Using the above soil core results, make an educated decision on which soil survey data will add value to your farming enterprise. These layers will provide special data across the paddock to help create variable rate management maps. This can be grid sampling or zoned aggregated sampling. Again, consult your agronomist for your individual situation.

Case Study

# CYRILL'S PADDOCK




The case study site selected to demonstrate the strategic coring process was at Baroota, in the Upper North Agricultural Zone of South Australia. The Dennis Family had recently taken over management of the field and wanted to gain a better understanding of the soil constituents. The yield maps were showing variable patterns and the Dennis' (landowners) suspected soil variability as the driver.

*Brad, Robbie, and Matt Dennis on their Baroota, South Australia, property (Source: GRDC)*

## Map layers collected and analysed to create temporary zones and select soil coring sites.

*These data layers were processed and presented in PCT AgCloud for the case study site.*

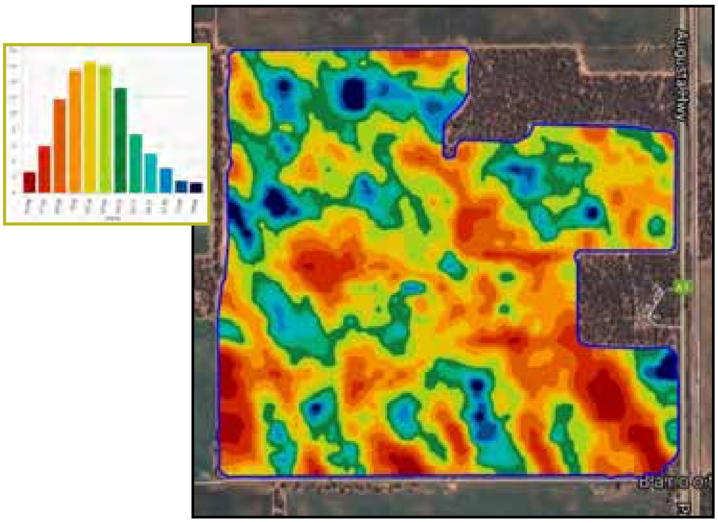


***Figure 1 -*** *EM38 50cm Depth Map surveyed by AgTech Services on 2nd August 2021*

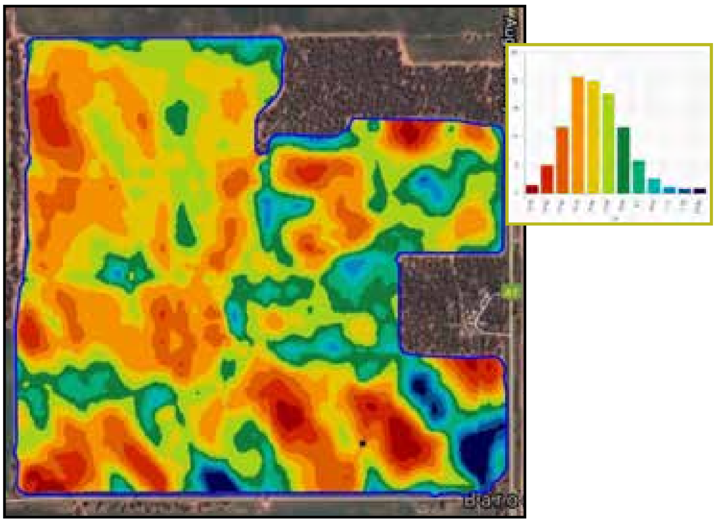


***Figure 2 -*** *Landscape Change Map derived from elevation data. The elevation data was processed using 'as applied data' from the Dennis' seeding system*

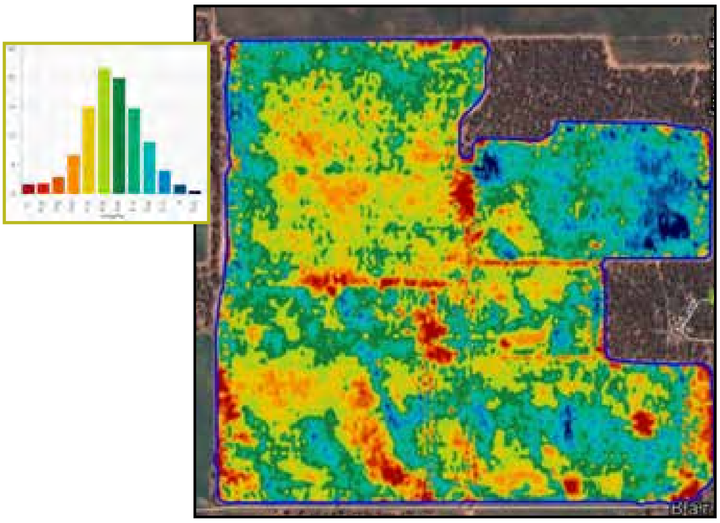


***Figure 3 -*** *2019 Barley Yield Map*

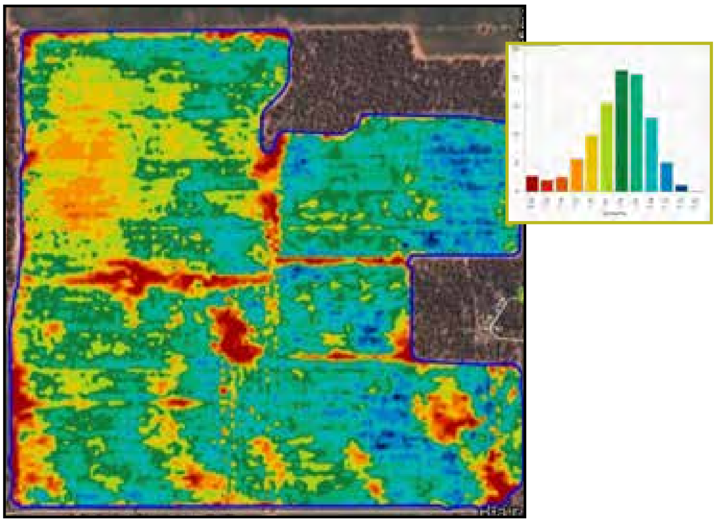


***Figure 4 -*** *2020 Lentil Yield Map*

## Selecting sites to soil test in 'Cyril's' paddock

The 'where to start' guide above was used to work through the process of analysing the maps. An agronomist, precision ag consultant, and the farmers knowledge of the field all fed into the interpretation to eventually settle on the sites to take the cores. The goal is to find the most representative soil types in the field.

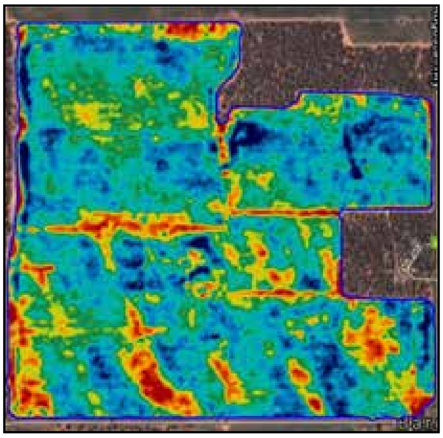
The Dennis family knew there was significant yield variability through their observations at harvest and by viewing their own yield maps. The coefficient of variation in their barley yield map is 13%– worth investigating for variable management. The raw data layers were processed and presented in PCT AgCloud. The seasonal rainfall was then compared with the yield maps and SVI satellite maps. The reason this process is important, is that patterns can be revealed about sub soil constraints and soil water holding capacity when comparing wet vs dry springs and the patterns that may cause in the yield maps. There were two yield maps available for Cyril's, one in a dry season, one in a wetter season and the patterns were quite similar between the two.

All maps clearly showed the old fence lines in this paddock, which have now been removed. These areas consistently showed up as poorer yielding areas, which was attributed to sand drift patterns. Another environmental influence identified in this paddock included the 'shelter belt' running around the north, east corner of the paddock. This vegetation acts to reduce sand drift, consistently boosting yield in this area.  Upon comparing the EM38 and elevation maps, similar patterns were found, suggesting that we are working within a clear 'dune, swale' system. Areas showing higher elevation, showed lighter soil texture. These patterns are also weakly correlated to the yield maps we had available too. Therefore, we chose to base our soil sampling on the EM38 map, with the intuition that soil texture is a strong influence of yield potential at this site. A soil core was placed in each zone of the EM38 map, with landscape positioning when sampling also front of mind.

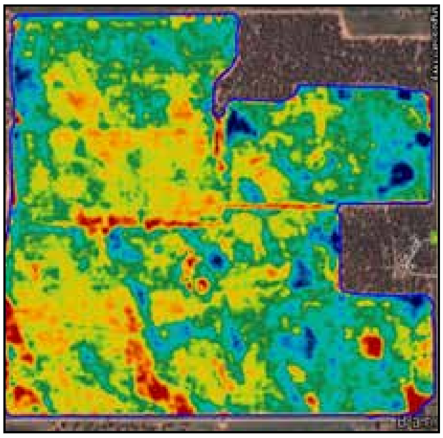
The 'constant' map layers we had available were EM38 and elevation (and derivatives such as landscape change, slope, aspect etc). These maps gave more insight into the soil type makeup of the field,

It was decided that taking 6 cores should give good representation, particularly when broken up by horizon and analysed separately.

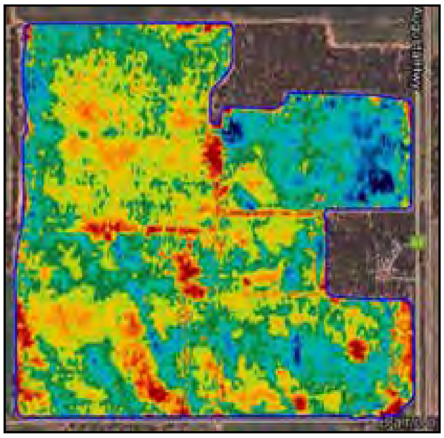

***Figure 2*** *- Annual rainfall by month for Baroota in 2019. This be compared with the NDVI/SVI imagery throughout the season and helps decipher how the crop behaves under different soil moisture situations*



*NDVI June 2019*



*NDVI Sept 2019*



*Barley Yield 2019*

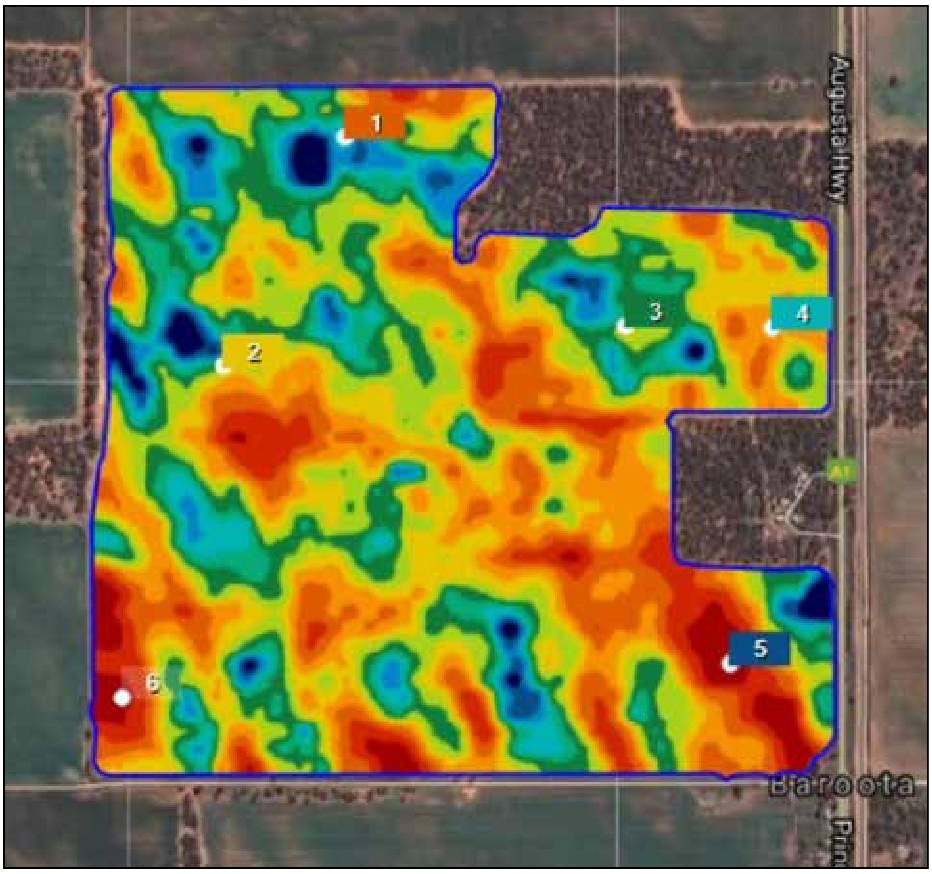
## The EM38 map in focus

EM38 refers to electromagnetic soil mapping. Electrical conductivity is primarily influenced by soil texture, in particular clay content, soil salinity and moisture levels. EM38 data is used to generate a spatial layer that provides information about soil variability within a field. As further analysis was carried out in this field, it became

clear the EM38 would become a 'standout' layer to help describe soil type and would largely help in determine management zones.

## WHY?

The patterns in the landscape change map, the two yield maps we had available, and the imagery throughout the season indicated that soil texture (often indicated in an EM38) was driving variability.




## Interpreting the Soil Test Results

It is important to enlist the assistance of an agronomist and/or soil consultant to analyze the core results. Splitting the cores into topsoil and sub soil horizons is hugely valuable and the information from these results in isolation can lend themselves to different management decisions as the plant root system moves through the soil profile.

*Two soil tests were used for this case study:*

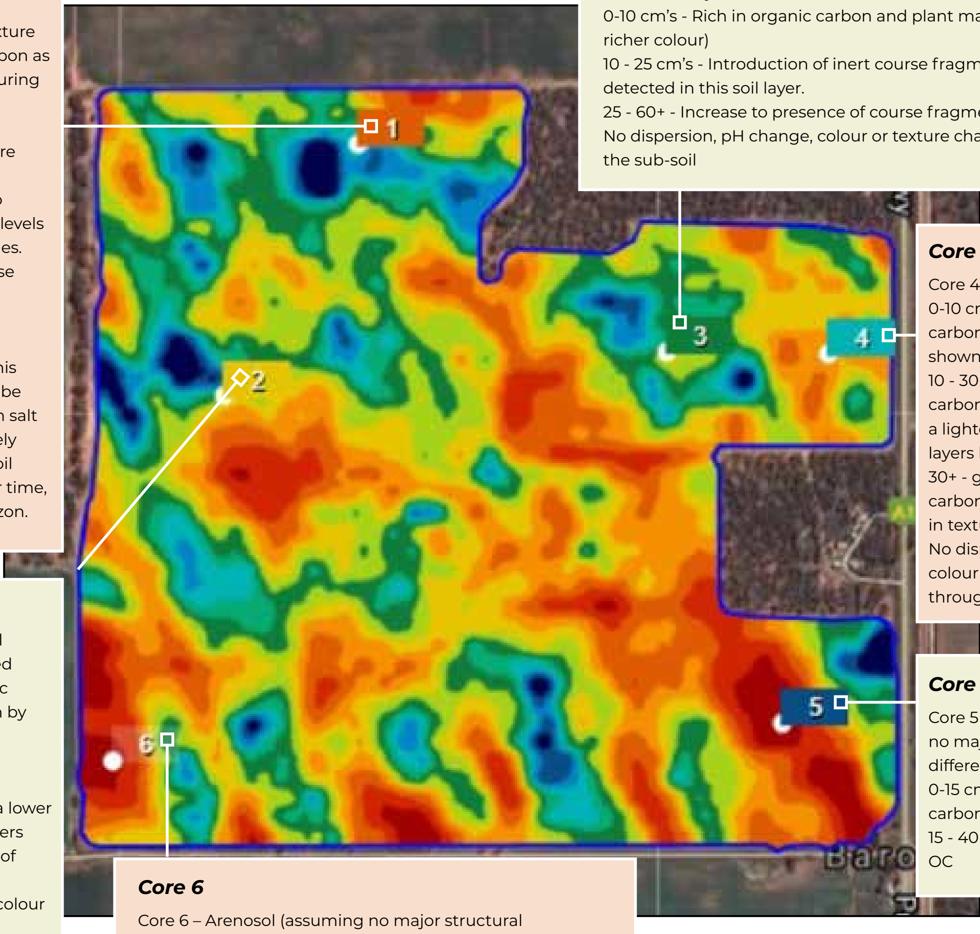
| | | |
|---|---|---|
| **Topsoil** | Comprehensive Analysis | Soil pH, pH CaCl, S-OC-WB.12, Soil P Colwell, Soil PBI, Soil DGTP, S, Ca, Mg, K, Na, Soil Ca:Mg, Soil Ca %, Soil Mg %, Soil K %, Soil Na %, Al, EC, CEC, Soil ECse, B, Soil Clay %, Soil Sand %, Soil Silt % |
| **Subsoil** | Health Check | Soil pH, pH CaCl, Ca, Mg, K, Na, Soil Ca:Mg, Soil Ca %, Soil Mg %, Soil K %, Soil Na %, Al, EC, CEC, Soil ECse, B, Soil Clay %, Soil Sand %, Soil Silt % |

*Why did we choose these tests?*

- Budgeting, keep the cost of the testing affordable, and ensure 'bang for buck'
- Matching information to potential variable management possibilities. There are differing management possibilities between the topsoil and subsoil. For example: DGT P, Colwell P and PBI have relevance to phosphorus management – an element managed in the topsoil. Phosphorus is an immobile element compared to an element like Nitrogen. Therefore, the phosphorus-based tests were taken in topsoil only. Alternatively, salts were measured in the subsoil health check, as they are typically soluble and therefore readily move into the subsoil.

## Physical Properties

Having information about soil attributes in different EM38 sites, at different depths throughout the horizon gives a detailed insight into the overarching soil types. If the regressions between the EM38 value and attributes such as Soil Clay %, Cation Exchange Capacity (CEC) and Sodium (Na) are strong it validates that the EM38 is a good indicator of soil texture change, therefore soil type changes.




***Core 1***

0-15 cm - lighter in soil texture and higher in organic carbon as shown by the darker colouring of this soil fraction.
15-45 cm - There was an increase in both soil texture and pH when moving to this horizon. There was no dispersion indicating low levels of sodium and clay particles.
45-60 cm - a steep increase in pH was observed when moving to this horizon, driven by the presence of carbonate. Additionally, this soil fraction was found to be dispersive, indicating high salt concentrations. This is likely where salts from above soil layers have moved to over time, accumulating in this horizon.

***Core 2***

Core 2 - Likely a calcarosol
0-15 - split due to increased plant material and organic carbon content (as shown by richer colour of the soil)
15-35 - The presence of carbonate comes in from approx. 15 cm's. This is at a lower level of underlying soil layers
35 + - increased presence of carbonate in this fraction
No dispersion, texture or colour change from 15 cm +

***Core 3***

Core 3 - Likely a calcarosol
0-10 cm's - Rich in organic carbon and plant material (as shown by richer colour)
10 - 25 cm's - Introduction of inert course fragment. No carbonate detected in this soil layer.
25 - 60+ - Increase to presence of course fragments (?)
No dispersion, pH change, colour or texture change throughout the sub-soil

***Core 4***

Core 4 - Likely a calcarosol
0-10 cm's - Rich in organic carbon and plant material (as shown by richer colour)
10 - 30 cm's - Less than 20% carbonate in this fraction and a lighter texture compared to layers below
30+ - greater than 20% carbonate and slightly heavier in texture
No dispersion, pH change, colour or texture change throughout the sub-soil

***Core 5***

Core 5 - Arenosol (assuming no major structural differences)
0-15 cm's - higher in organic carbon then underlying layers
15 - 40 cm's - Slightly higher OC

***Core 6***

Core 6 – Arenosol (assuming no major structural differences)
0-15 cm's - higher in OC then underlying layers
15+ - no pH or dispersion change and colour texture same throughout

## Chemical Properties

Below is a summary of findings from each core taken in the project paddock. The summary considers pH, salt content, texture, organic carbon, phosphorous and micro-nutrient deficiencies, and toxicities for each site at dual depths. The chemical driver of this paddock is carbonate (free lime), which influences pH and hence nutrient availability.The main physical constraint of this paddock is soil texture and hence water holding capacity.

| Core 1 | Core 2 | Core 3 | Core 4 | Core 5 | Core 6 |
|---|---|---|---|---|---|
| pH is considered strongly alkaline throughout the whole core, increasing as you move down the profile. This will be a yield limiting constraint for commonly grown crops in this area. When considering EC(1:5), which looks at the salt content of the sample, levels are reasonable. However, when considering EC(se), which takes into consideration soil texture and salt content, concentrations will result in toxicity for legume crops in particular. The main salt present at this site was found to be sodium and magnesium. Therefore, applications of gypsum may be required in this area of the paddock long-term. Phosphorous levels are bordering on low, meaning replacement plus some should be applied in this area. The top soil of this site has a low phosphorous buffering index, meaning the tie up of P at this site is low. Potassium levels are good with sulphur being low. | The pH of this site is strongly alkaline, driven strongly by the presence of carbonate, with a low organic carbon content. The texture of this site ranged from a loam to a clay loam, meaning water holding capacity is reasonable at this site. The alkalinity of this site will likely reduce yield potential. When considering EC(1:5) the salt concentration at this site is not of concern, however when taking into account soil texture (ECse), the sub soil of this site has a salinity issue that will limit legume production. Calcium levels are elevated in the top soil fraction. Throughout the sub soil, magnesium and sodium are elevated, likely causing dispersion issues and driving toxicity issues at depth. Applications of gypsum should be considered at this site. Phosphorous levels are low, with a moderate PBI in this zone. Phosphorous should be built on in this area moving forward. Potassium levels are good and sulphur is low. | pH at this site was found to be strongly alkaline, likely driven by the presence of carbonate (free lime). Organic carbon levels were found to be low, reducing soil structural stability and water holding capacity, which is particularly important for lighter textured soils. EC(1:5) did not show excess salts present at this site, however, when considering EC(se) salt levels will reduce productivity of legume crops due to toxicity. Magnesium and sodium salts are driving this. Phosphorous levels were low at this site, with a low PBI, reducing P tie up. Potassium levels are good with sulphur levels low. | This core was found to be highly alkaline, increasing down the core, with very low organic carbon levels. Soil texture ranged from a loamy sand to a silty loam, making organic carbon important to contribute to the CEC of this site in addition to the overall structure. Colwell P was low at this site, with a moderate to low PBI, long-term P should be built at this site. Sulphur was also found to be low, likely due to leaching as a result of lightly texture soils. EC(1:5) was considered low, with EC(se) showing a possible yield limiting constraint. Calcium was high in this soil, with magnesium, potassium and sodium within reasonable levels. Gypsum may be required here to correct toxicity issues. | The pH of this site was found to be extremely high (alkaline), again increasing as you move down the profile. This site has a very low organic carbon content. The texture throughout was sand, meaning this site will have a very low water holding capacity and nutrients will readily leach from the plant root zone. Therefore, increased organic carbon will lift yield at this site significantly. Phosphorous levels are bordering on low, with a low PBI. Sulphur is also low, likely due to leaching. Salt levels at this site are not of concern, with a very low likelihood of this site experiencing dispersion due to very low clay content.<br><br>This site should be tested for hydrophobic characteristics. When coring this site, the corer hit a hard layer at approx. 40 cm's. This will reduce rooting depth and therefore water and nutrient availability to the crop. | This site was found to be strongly alkaline, driven by the presence of carbonate which increased with depth. The site had a low organic carbon content, with the texture of this site a sand throughout. Therefore, moisture holding capacity is low and nutrients are easily leached beyond the plant root zone. Phosphorous levels are low at this site, with a low PBI. Sulphur is also low, likely due to high water infiltration taking S beyond the plant root zone. Salt levels at this site are low, with very low likelihood of ever needing gypsum at this site due to high levels of water infiltration due to texture. |

***Notes:***

*Structure not assessed (cannot do so when using cores) which could be a potential yield limitation of this paddock.
No comment on N as sampling did not suit this type of analysis.

## Correlation between EM38 and CEC

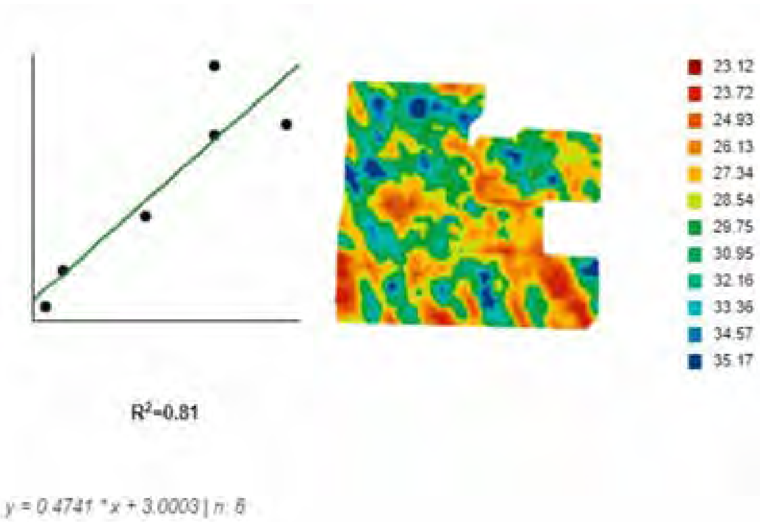



***Figure 7 -*** *The 0-60cm CEC soil results at each core site plotted against EM38. The 0.81 regression indicates that the EM38 map is picking up soil type changes*

To be confident that the EM38 Map is a strong indicator of representative soil types, a regression was drawn between Soil CEC (Cation Exchange Capacity) and the EM38 map in the PCT AgCloud Analytics tool. Soil CEC is a good indicator of soil texture in this field due to the fact there are low organic carbon levels (so CEC is more linked to increasing clay). Regressions between soil test attributes and soil sensor layers such as EM38 can tell a powerful story. In this case, the strong correlation between soil CEC and the EM38 map gave us confidence to use the EM38 map as a base layer for a soil amelioration prescription map for biosolids application. The aim of this application was to increase yield potential on lighter textures areas of the paddock, by increasing water and nutrient holding capacity.

The bell curve to the right helps to explain the main yield driving factors of this paddock. As EM38 increases (and hence clay content), so does the yield response to a point. This can be directly attributed to an increase in plant available water and nutrients. However, beyond a tipping point, other limitations come into play. In this scenario, this is nutrient toxicity and salinity levels. In the heavier textured soils leaching of salts and nutrients is reduced and hence held in the plant root zone creating toxicity issues.

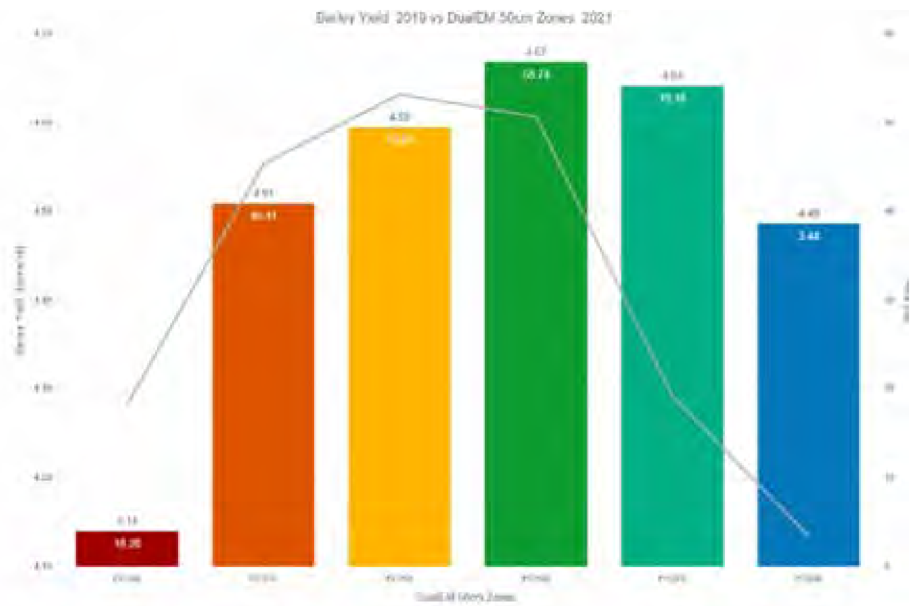
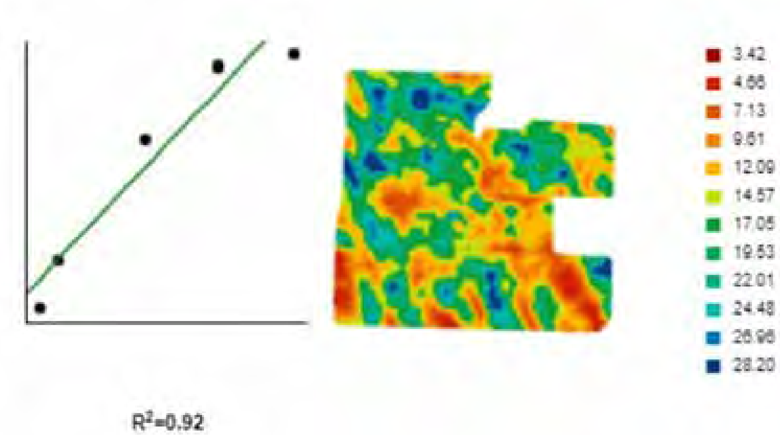


***Figure 8 -*** *A graph with the Dual EM38 50cm zones vs the yield within that zone in t/ha*




Looking at the figure above, the EM38 map is a very strong indicator of soil texture, therefore likely, available water content for the crop. The EM38 map layer would make a quality base layer for calculating target yields in different areas of the paddock and their associated input decisions, and of course taking soil tests, as has been done in this case study.

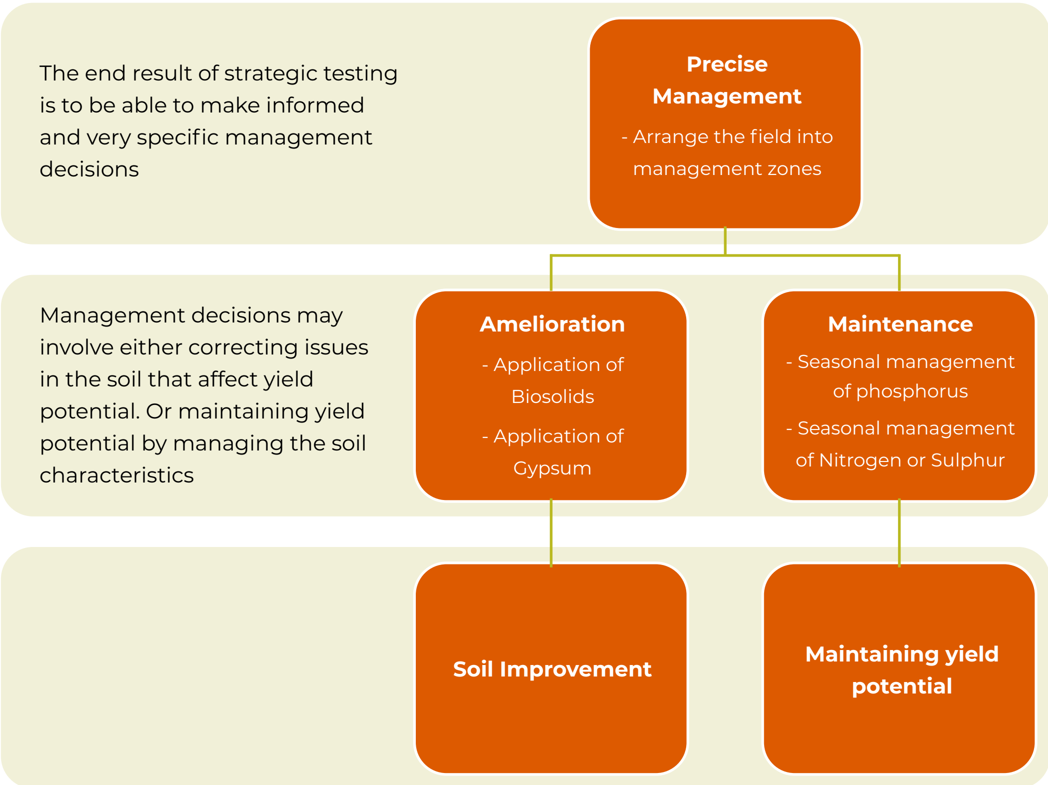
***Figure 9*** *- Soil Clay % from 0-60cm at all 6 sites plotted against EM38, a strong regression, once again indicating that the EM38 map is a good indicator of soil texture*

## What Management Decisions can be drawn from soil testing by zones in this field?

The overarching purpose of strategically coring in different soil zones is to match inputs to the *productive capacity* of the soil. It is useful to think about variable management in two different management practices – Amelioration and Maintenance.

Fertilisers like nitrogen and sulphur can be tailored in season to capitalise on plant available water and seasonal requirements but can also be applied variably to match the yield potential of different soil types. These have been characterised in the table below as *maintenance* precision ag inputs.

*Amelioration* refers to long term improvement of the soil chemical and physical structure. In this case study at Baroota, the amelioration recommendation is prioritised around chemical inputs rather than physical amelioration like ripping.




Based on the soil results and the interpretation of the soil and yield maps, this paddock is a good candidate for variable rate maintenance and ameliorant applications. In consultation with soil consultants and agronomist the following was recommended: 'see below'

## AMELIORATION

### Variable Rate Biosolids

Biosolids is an organic rich amendment which increases organic carbon content of the soil resource, therefore increasing water holding capacity of the soil. The upper limit of the biosolids rate must be considered carefully as the product can have high levels of heavy metals which can accumulate within the soil. Additionally, the low rate will also be carefully considered, ensuring that there is enough product to achieve a uniform spread pattern.


***Figure 10*** *- The biosolids variable rate prescription map, with higher rates on the lighter soil textures (confirmed by EM38 map)*

## AMELIORATION

### Variable Rate Gypsum Application

Gypsum is recommended in a variable rate application for this field to release sodium from the CEC, allowing it to leach beyond the plant root zone. This will ultimately prevent dispersion and compaction. When sodium is on the cation exchange site (CEC) of a clay / OC particle, upon wetting the sodium molecules will repel one another, pushing apart soil particles and causing dispersion. Upon drying, this leaves the soil resource 'structureless' increasing the required 'force' of plant roots to explore the profile and making it difficult to access water and nutrients.

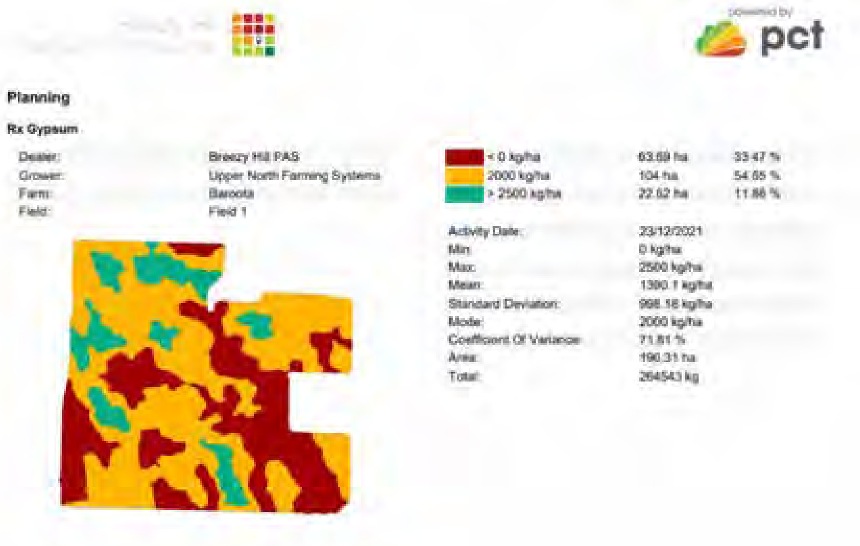



***Figure 11*** *- Gypsum variable rate map, using EM38 map as the base layer to make the zones. Gypsum would be applied at a higher rate on the heavier, clay soil types*

| Sodicity Rating | Non | Slightly | Moderately | Highly |
|---|---|---|---|---|
| ESP rating % | 6 | 6-10 | 10-15 | >15 |
| Rating and Action | No action | Apply 2.5t/ha | Apply 3.75t/ha | Apply 5t/ha |

***Ref: IPL Soil Manual***

## Cost of operation – comparing Variable Rate with blanket rate

Area of field: 190ha

Assumption of product sourced from closest supplier to Baroota, working on figures from the grower

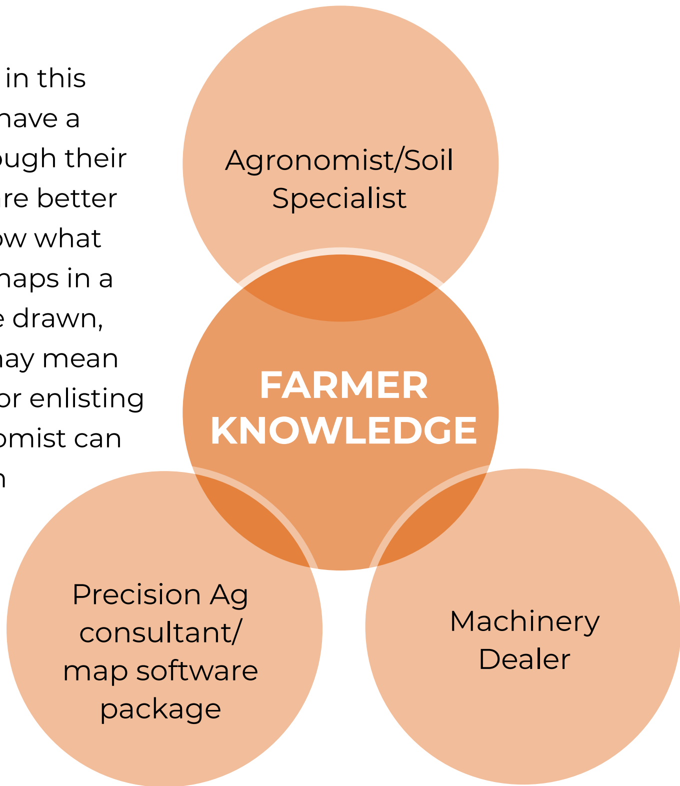
| Biosolids | Area Spread | Tonnes required for operation | Cost/tonne (product and freight) | Total Cost of product required | Spreading costs per hectare | Total cost Spreading | Total cost of operation |
|---|---|---|---|---|---|---|---|
| Blanket Rate | 190ha | 950 | $23.50 | $22,325 | $12 | 190 x 12 = $2280 | ***$24,605*** |
| Variable Rate | 167ha | 915 | $23.50 | $21,503 | $12 | 167 x 12 = $2004 | ***$23,507*** |

| Gypsum | Area Spread | Tonnes required for operation | Cost/tonne (product and freight) | Total Cost of product required | Spreading costs per hectare | Total cost Spreading | Total cost of operation |
|---|---|---|---|---|---|---|---|
| Blanket Rate | 190ha | 380 | $48 | $18,240 | $12 | 190 x 12 = $2280 | ***$20,520*** |
| Variable Rate | 127ha | 265 | $48 | $12,720 | $12 | 127 x 12 = $1524 | ***$14,244*** |

***Ref: Agworld 14/01/2021***

## SUMMARY

The value of involving a network of professionals in this process cannot be understated. The grower will have a great understanding of the paddock history through their management, and the areas of their fields that are better yielding will generally be known regardless of how what maps they have available. However, having the maps in a format that is organised allows correlations to be drawn, and makes the maps simpler to interpret. This may mean paying for a more specialised software package or enlisting the help of a precision ag consultant. The agronomist can assist with interpreting map layers and advise on where to take the soil cores. A machinery dealer can assist with enabling easy flow of data into and out of hardware equipment in the machine. Each of these parties are integral in moving forward with precision ag in the business.




The goal in this process is to make a more informed decision. Crop management involves making many decisions throughout the growing season. Year on year, the grower will make many passes over the field, most of the time at a blanket rate. A blanket rate pass is a decision in itself. By knowing the spatial variability throughout the field, and the soil attributes in the major soil types, this can be considered in every pass of product, whether in an *amelioration or maintenance* application to better match the *yield potential* of the soil zone.

Beth Sleep, Agronomist said 'with some layers the grower already had in hand (yield data and NDVI imagery), we were able to add an EM38 map and 6 cores to gain a deeper insight into the soil properties of this field. The grower now has the confidence in managing this paddock variably, with scientific backing behind them. There are significant savings to be made in the gypsum and biosolids spreads alone, and the opportunities for other inputs like phosphorus can be explored'.

### *Things to consider*

- Use map layers to determine patterns
- Take cores in strategic zones, to help determine the overarching soil type zones and their characteristics
- Consider the soil attributes in each horizon
- Once overarching soil types have been determined, use the information to manage inputs accordingly
- Pick the low hanging fruit first - eg. soil ameliorants to correct soil issues if applicable
- Soil information can assist in upfront fertiliser decisions at seeding time and when making nitrogen management decisions throughout the season

### *Acknowledgements*

*This fact sheet is part of the 'Producer Technology Uptake Program', funded by Agrifutures, an initiative of the Upper North Farming Systems.*

*The data and analysis was compiled and written by Jessica Koch, Breezy Hill Precision Ag Services in conjunction with Bethany Sleep, Elders Jamestown.*

*A special acknowledgement to the growers – the Dennis Family for providing the paddock for analysis, and to Michael Zwar, AgTech Services for the soil coring and soil survey data.*

How to use

# PRECISION AG MAP LAYERS

## to think about frost differently

*Jessica Koch (Breezy Hill Precision Ag Services)*

Frosts strike across southern and eastern agricultural regions nearly every season, with most damage caused in early spring during flowering. Frost is one of the biggest environmental and ultimately financial, issues grain growers are faced with, given there are no genetic strategies to mitigate the effects of frost, and very few cost-effective options for insurance.

Actual occurrence of frost is determined by location and landscape factors as well as climate. The rate of cooling and final temperature of the plant canopy is determined in part by the balance between thermal radiation emitted to space and radiation absorbed from the soil. Local topography is also important, as cold air tends to run down slopes and drainage lines and will pool in flats and basins. Barriers such as tree or fence lines can impede flow and allow cold air to accumulate higher in the landscape. The severity of the frost and hence the extent of the subsequent damage is therefore variable across the landscape (Biddulph, 2016).

### What is a frost?

**Frost** - Radiation frost consists of cold, chilling and freezing damage. Canopy air temperatures ≤0°C

**Freezing Temperature** – Canopy air temperatures ≤0°C at which freezing of plant tissue may occur, screen (at 1.2m) temperatures ≤2°C.

There is evidence that cold and chilling temperatures that don't drop to the freezing range cause damage to the plant:

**Chilling Temperature** – Canopy air temperatures less than 5°C and greater than 0°C

**Cold Temperature** – Canopy air temperatures less than 8°C and greater than 5°C. From this temperature and below pollen viability is reduced (Thakur et al, 2010; Cakrabarti et al., 2011)

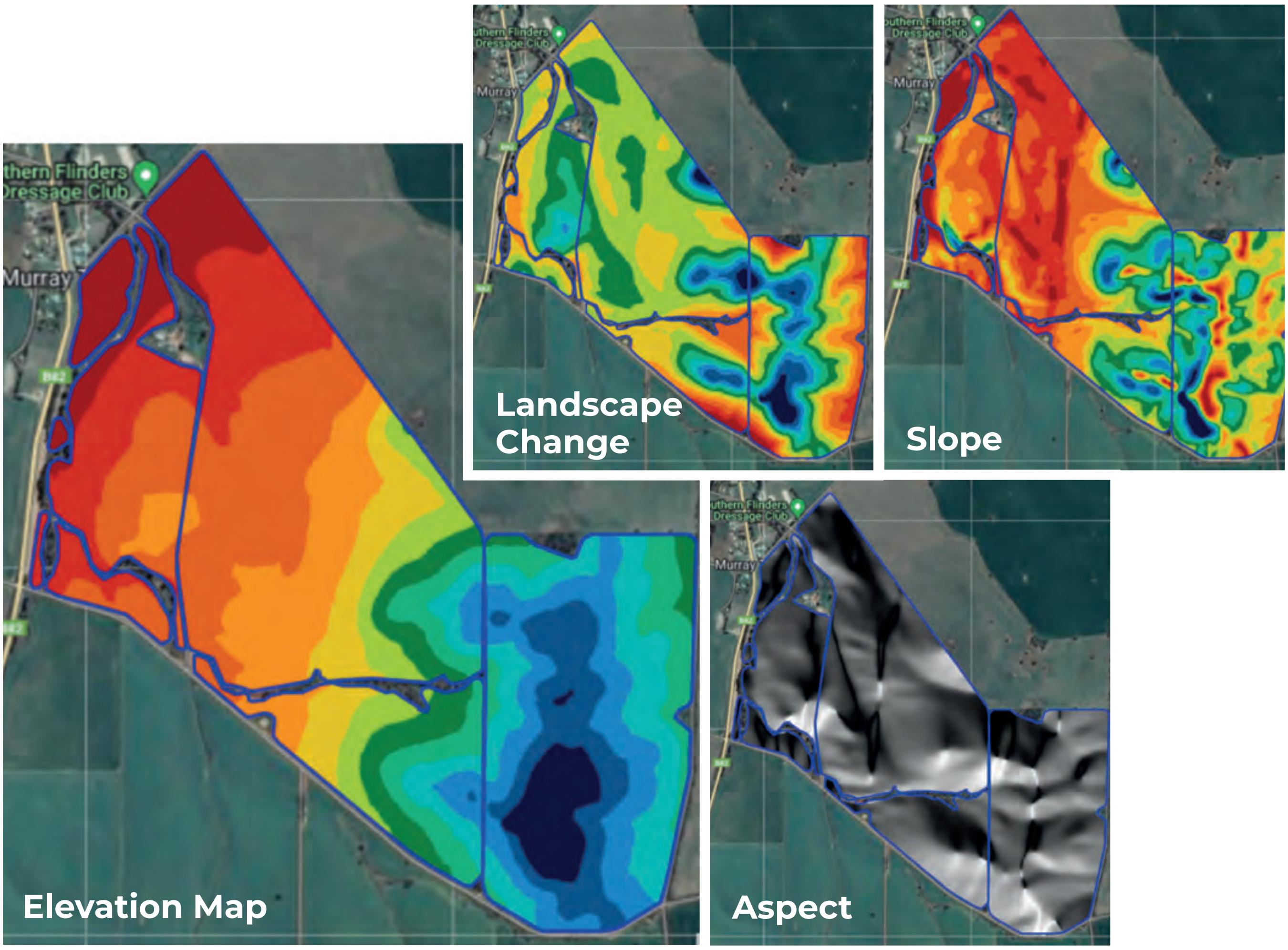
### Which Precision Ag Layers could we use to make frost management decisions?

There are a variety of precision ag map layers collected and available to the modern grain grower. The wide range of practical uses for map layers is not always realised when making variable crop management decisions. Elevation data for example, is collected and embedded in documentation data from agricultural machinery when recording seeding, spraying or spreading operations. This data is particularly useful when it is recorded using RTK GPS signal, as is it is extremely accurate – 2cm in fact. Elevation data can be processed into a map layer which can then be compared with other layers, such as yield data to look for correlations, such as frost impact on yield.

## There are other map layers that can be processed as a 'derivative' of elevation data, including aspect, slope, and landscape change.

Let's look at the landscape change map in more detail:

- An ***elevation map*** provides absolute height differences across a field – expressed as a metre above sea level value. Red indicates a lower value, blue indicating a higher value.
- A ***landscape change*** map can give more intricate detail about localised height difference. To explain in basic terms – you could be standing on top of a hill, but still be standing in a localised, minor hollow! The landscape change map picks up this detail, whereas the elevation map does not. Hence the landscape map could provide great value and insight into movement (shedding and pooling) of water and cold air movement. It is expressed as a positive or negative value, once again represented by red as low, and blue as high.




## Why investigate these maps further?

- To understand the extent and daily range of temperature variances in differing areas of a field and how much impact minor topographical changes in a field can impact on yield
- To understand how common precision ag layers such as elevation, landscape change and yield data can help farmers plan for, scout for and respond to frost damage using variable or zoned management.

# THE DEMONSTRATION SITE


## FARM DETAILS

**FARM DETAILS**

**Owners:** Orrock Farming (leased property)

**Location:** Murraytown, SA

**Field Details:** 195ha

**Average Rainfall:** 425-450mm

**Crop Rotation:** Beans, Canola, Wheat, Wheat, Barley

The purpose of this demonstration was to 'ground truth' a landscape change map as an indicator of the temperature changes (and resulting frost) at different points in the field, and to see how this related to yield variability.

Having a data layer indicating the spatial effects of frost may be very useful when crop scouting or making management decisions before or after a frost event occurs. The process needed to be simple and affordable so that farmers could collect the data and place sensors on their own properties to monitor frost following our process.

Elevation data is commonly recorded by farmers 'in cab' software using precision ag mapping technology, so the data simply had to be downloaded and processed into a map; an inexpensive process.

The demonstration site located at Murraytown in the Southern Flinders Ranges is cropped by Orrock Farming. It is situated in a productive, grain growing region of the Southern Flinders with an average rainfall of 425-450mm.

*'There are so many factors about farming I cannot change'* said Todd Orrock *'and frost, at this stage, is one of those factors. Collecting quality precision ag data is something that we try to do well, and I am confident that as the years go on, we are learning more about what these maps are telling us. The yield maps, compared with the topographical maps such as the landscape layer help us make quick and calculated decisions about managing frost based on the commodity prices and spring weather conditions each season'.*

# A History of Frost Events and Extensive Damage

'Woolfords' paddock is 195ha of highly undulating loamy clay with calcareous outcrops on rises, with 50m elevation gain from the low-lying frost prone areas, up to the ridges that rarely encounter a frost event. The field has a significant paddock history of frost, confirmed by yield maps, satellite imagery and crop scouting post frost event. The paddock was sown to Spartacus Barley on the 12th of May 2021 into dry soil.

The low-lying areas of the field are affected by frost in September and October to some extent in 80% of seasons, as described by Todd Orrock.

Orrock Farming do not run any livestock, so grazing frosted crops is not an option. Their equipment is not geared for a broad scale hay operation, so the decision to cut for hay needs to be precise, considered, and a last resort option. The business is therefore very interested in tracking and monitoring frost accurately, to plan for and to enable viable management decisions to be made late in the growing season.

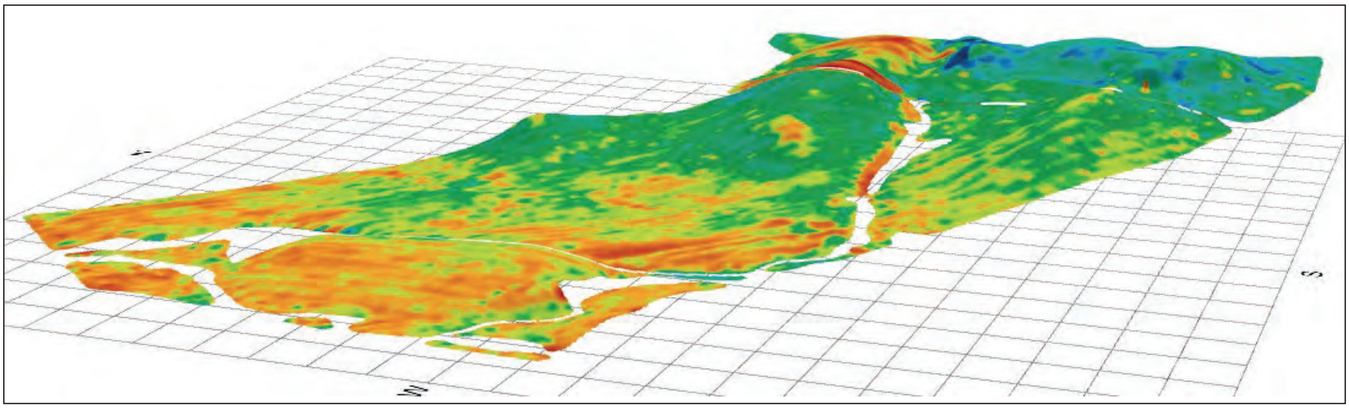


***Figure 1** - Yield affected by frost in 2016 (shown in orange). The higher elevation on the top of the ridge (RHS) side is largely unaffected by frost.*

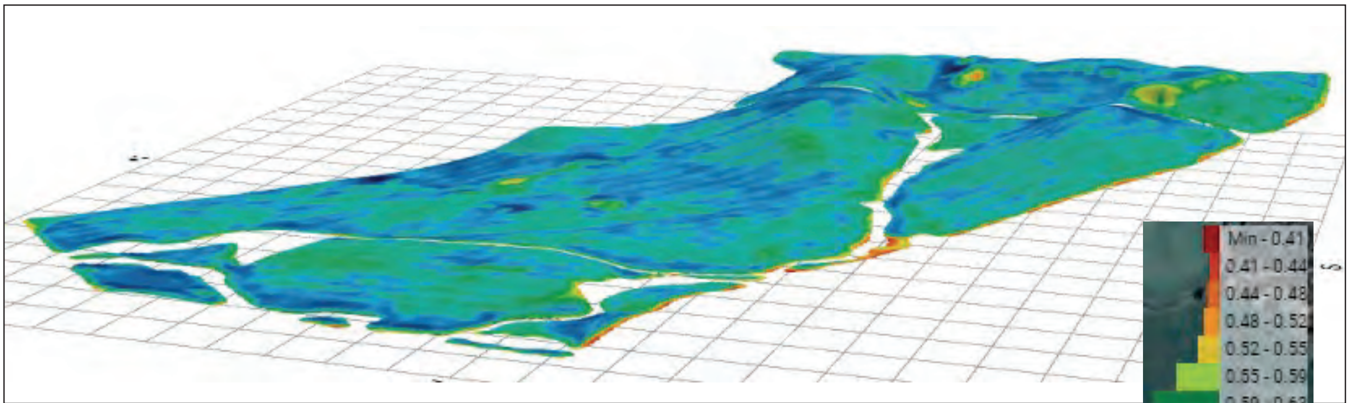



***Figure 2** - SVI Satellite image from September 2016, before the frost event. The biomass in the field is relatively even and tracking towards an even and solid barley yield. SVI (Satamap Vegetation Index, or 'NDVI') image from the 2nd Sept 2016 – The variation (CV%) in biomass is 13%. The Barley Yield variation (CV%) at the end of the season was 24%, due to the impact of late season frost*

The above figures show the severity and variability of an extreme, late season frost event in Woolfords paddock in 2016. Figure 2 shows that the barley biomass was tracking relatively evenly after solid winter and spring rainfall. After a severe frost event on October the 26th, the crop was left with a massive yield penalty. Figure 1, a yield map, shows the yield penalty with losses up to 2.87 t/ha.

## What we did...

To look at the variability of frost impact in the different landscape zones, ten iButton temperature sensors were placed in strategic locations throughout the field. By viewing the landscape change map as a background layer in the PCT AgCloud software program, the sensor sites were selected. Some were placed in 'negative' zones (red), meaning a localised depression, some were placed in a 'positive' value zone, a localised rise or ridge. Some were placed in neutral areas, where the terrain is relatively even and flat. The aim was to have sensors in varying degrees of landscape change to test the accuracy of the map as an indicator of cold air movement, hence frost risk.

The sensors are designed for outdoor use and were set to log every 20 minutes and the data needed to be downloaded every 30 days. The sensors were mounted at 1.1m height, an industry standard. When downloaded, the data was available in raw form as a CSV spreadsheet and a temperature line graph.

With predicted frost impact zones established, and temperature data across these zones being recorded, the impact of frost on the crop was noted by visual assessments by the grower and the agronomist, and at each sensor download event by the project manager. Photographs of the crop at each site were taken by the project manager, and the end of the trial, grain and plant samples were collected for further assessment.

***Figure 3*** *- The iButton Sensors placed through-out the field and a description of the terrain at each site in the table.*

Yield mapping with the Intelliview mapping system on the New Holland CR9.90 harvester gave a paddock scale indication of the frost damage across the field.

| | |
|---|---|
| **1** | Low lying, localised depression |
| **2** | Low lying, along a creek |
| **3** | Mid Slope, flat neutral landscape |
| **4** | Side of mild slope |
| **5** | Mid slope, slight hollow |
| **6** | In centre of a mild depression |
| **7** | Top of ridge |
| **8** | Top of ridge |
| **9** | Side of steep slope, gully |
| **10** | Side of steep slope |


***Figure 4*** *- The iButton Sensor sites. These were selected in PCT AgCloud using the Landscape Change map as a background layer then exported as KMZ geo-referenced points to scout to the locations and install the sensors in the field.*

# The Results

## *The variation in frost affect across the field...*

The paddock was harvested on the 10th December 2021 and averaged 3.8t/ha barley yield. The yield map (processed) captured values from 2.02t/ha through to 6.63t/ha. The Coefficient of Variation is 17% - indicating significant variability and a suitable candidate for variable or zoned management. Looking at the placement of the sensors on top of the yield map, sensors #1, #2, #3 and #4 (in low lying zones) appear to have low yield values at 2.5t/ha, compared to the average of 3.8t/ha. Given the assessments throughout the season and the fact these are rich and fertile soil types, preliminary assumptions are that these low-lying sensors have captured low temperatures and lower yield values due to frost. Low yields at sensors #7 and #8 can be explained by shallow and eroded soil types, this is typical for this area of the field. Sensor #9's location has yielded well as expected (area, although low lying, tends to drain cool air well and the historical yield maps rarely show damage at this site). Sensor #10 was affected by crop chemical damage, so this low yielding result can be ignored as far as frost is concerned.

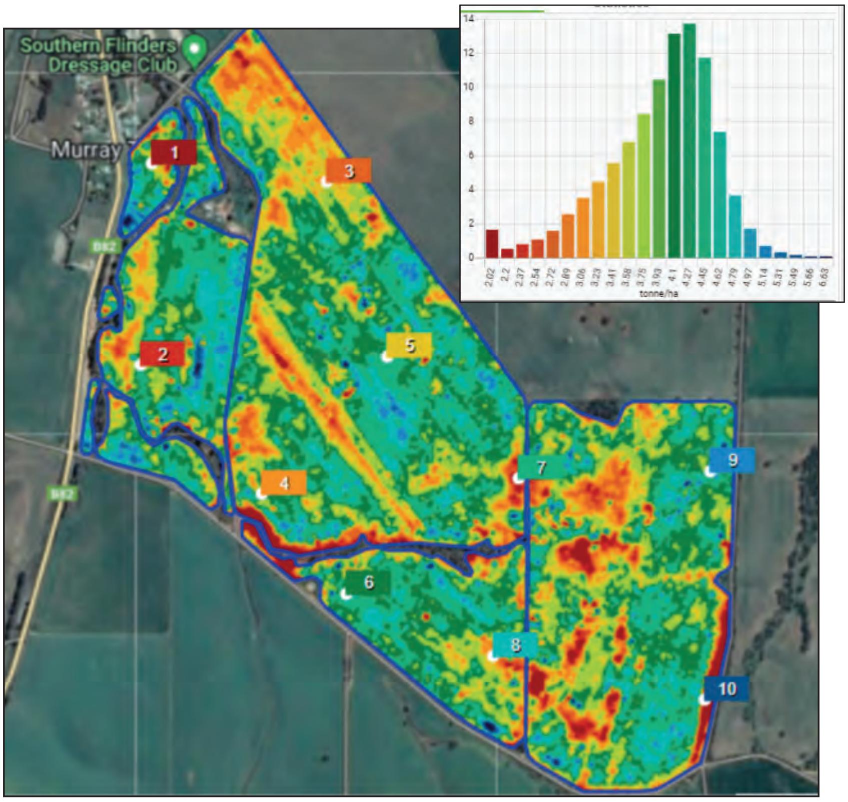



***Figure 5 -*** *The 2021 Barley yield map with the sensor sites placed over the top. The low yielding areas on the eastern side of the field where the '#7' Sensor and '#8' Sensor are located can be explained by soil type – this is a shallow limestone ridge. On the west side of the field there is evidence of a yield penalty (due to frost) where #1 and #2 sensors are located.*


***Figure 6 -*** *A comparison of each Landscape change zone x 2021 Barley Yield. There is a direct correlation - the more positive the value (blue zone) on the landscape change map, the higher the yield. There are a couple of outliers. The orange column circled may be attributed to low lying areas of the field which are not affected by frost. We can assume that these zones drain cool air effectively. The small blue zone circled is just (3ha) and is simply an elevated zone that yielded poorly. This is the peak of the limestone ridge, a well elevated, but eroded soil zone that is known to yield poorly.*

## ‘#1’ Sensor – Localized depression
### (Negative or RED/ORANGE Zone)

The ‘#1 sensor’, located in a low lying, frost prone area of the field. This site had signs of significant crop damage to the barley heads after the October frost event upon visual assessment.

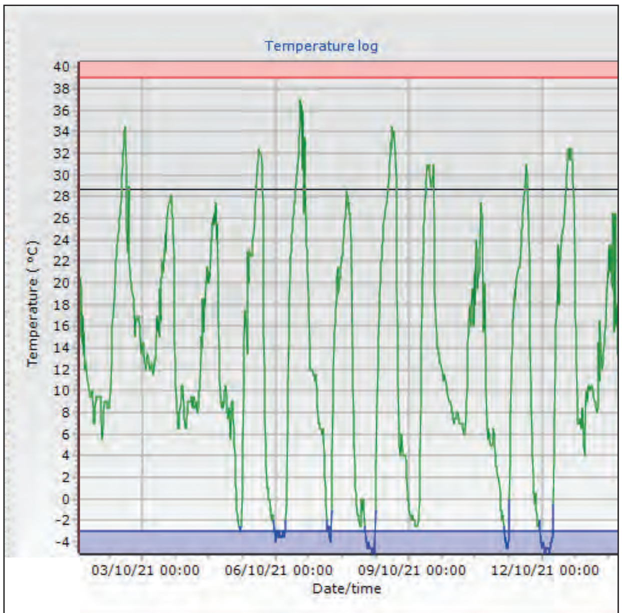
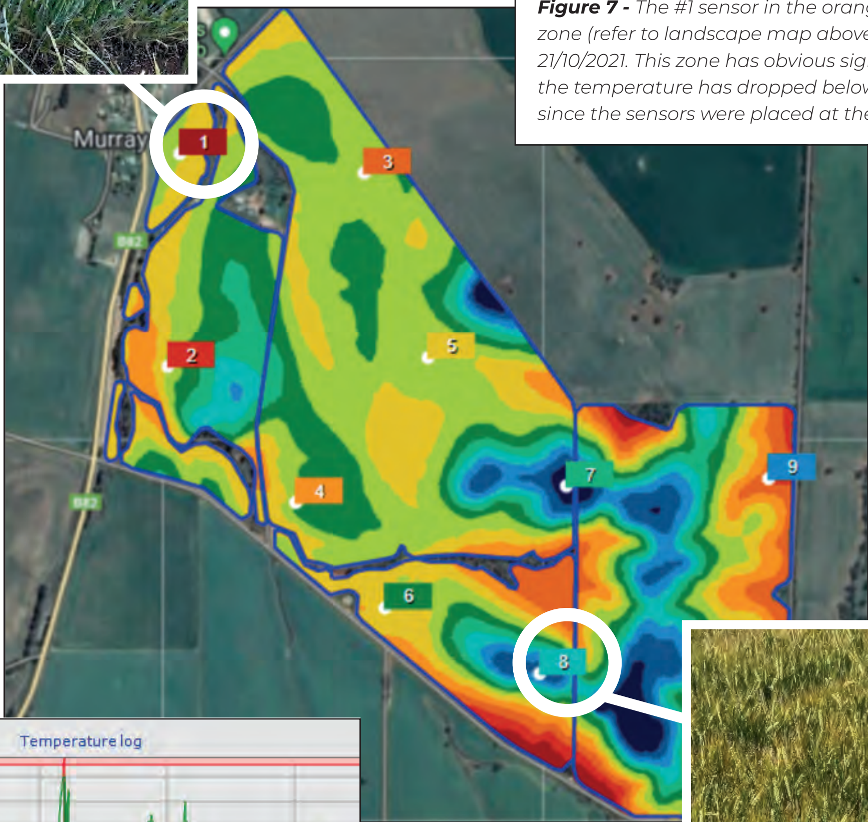



*__Figure 7 -__ The #1 sensor in the orange landscape change zone (refer to landscape map above) from 24/9/2021 to 21/10/2021. This zone has obvious signs of frost damage, and the temperature has dropped below zero on several evenings since the sensors were placed at the site in July.*



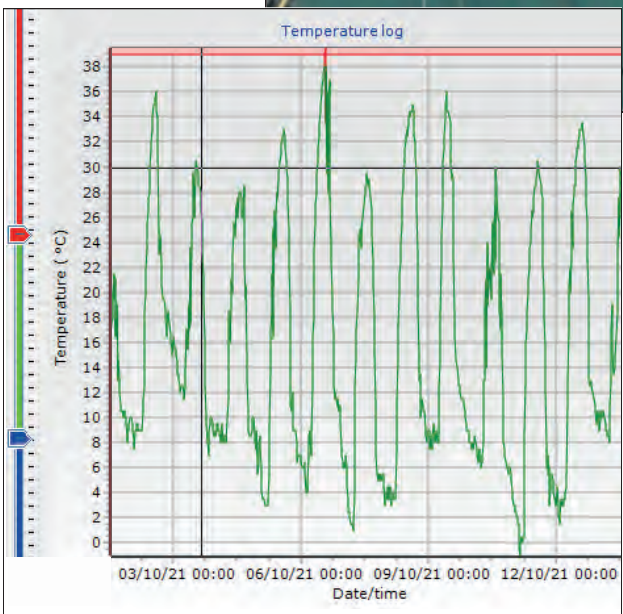




*__Figure 8 -__ #8 sensor in the blue zone (refer to landscape change map above) from 24/9/2021 to 21/10/2021. This zone has no visible signs of frost and the low temperatures have been far less extreme*

## ‘#8’ Sensor – Top of Ridge
### (Positive or BLUE Zone)

‘#8’, located on a limestone rise, highly elevated area (blue zone on Landscape Change Map). This site had no signs of frost damage upon inspection. This sensor recorded just a handful of incidences where the temperature dipped to zero. The ridge is a low-risk frost zone due to it’s location, where cold air is very unlikely to pool.

# Frost Frequency and Severity

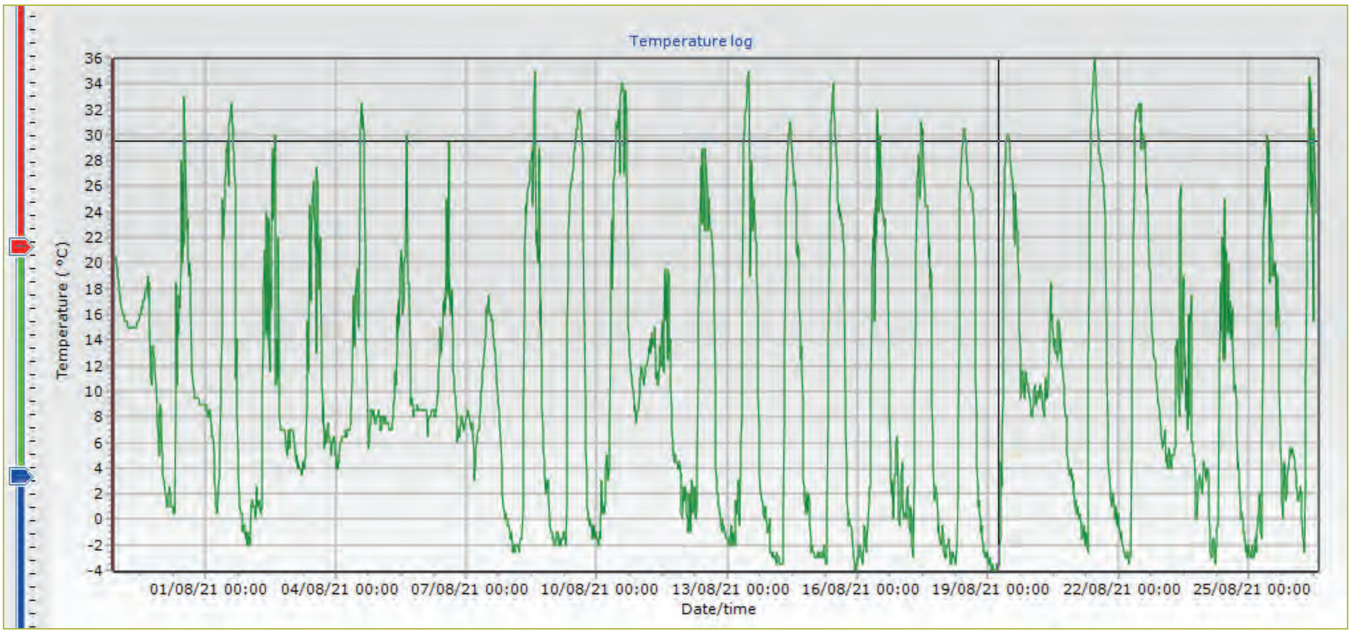
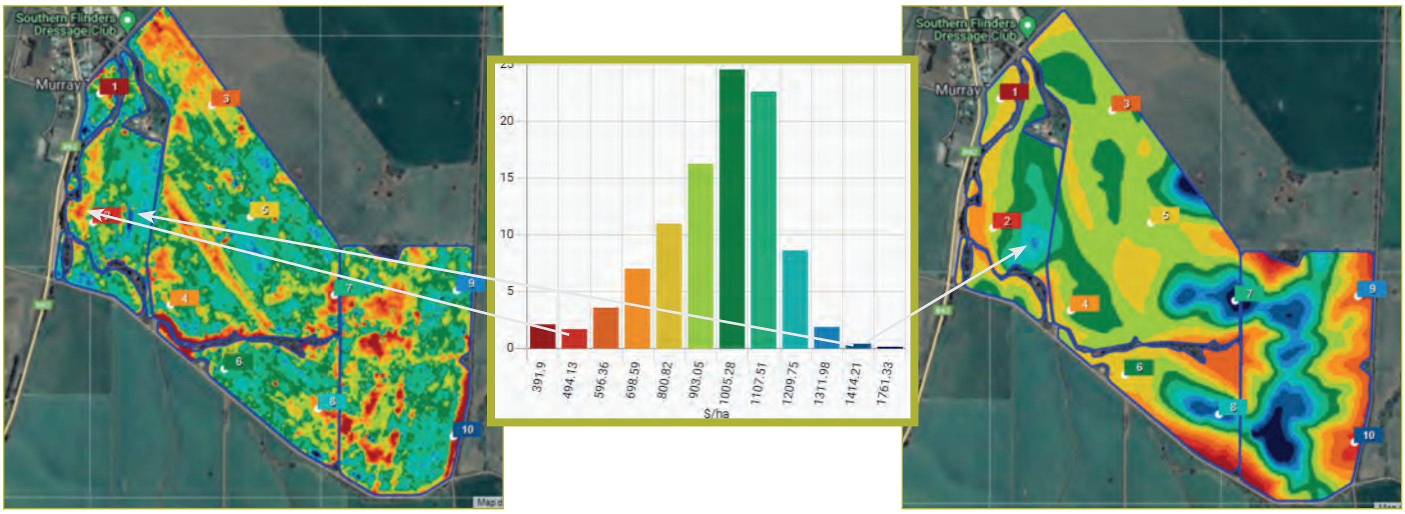



***Figure 9 -*** *An example of the typical frost frequency in July, August and September for the low-lying sensors. The red line is at 0°C. In this graph, the sensor recorded 17 frost events in a 30-day period.*

The sheer quantity of frost events was a shock to the grower and a surprise when analysing the results. The temperature dipped below zero degrees up to 17 times in the months of August, September and October whilst the iButton sensors were present in the field at sensors #1, #2 and #4. A testament to the resilience of our cereal crops!




In terms of economics, the profit map above suggests that last year the option of carrying the crop through to harvest, and not cutting for hay was a profitable (and the simplest option). The field averaged a profit of $903/ha. There were zones where this peaked to $1761/ha and some zones, as indicated on the graph above, that were frost effected/or poor soil types resulting in these areas dipping to $391/ha profit, but even still, they were profitable. This is important to note, as when a profitability maps have been generated for Orrock Farming in previous seasons, frost affected zones in yield maps can incur losses of up to -$300/ha.

## WHY WAS HARVESTING THE BEST OPTION IN 2021?

- High grain prices and low hay prices
- Ease of coordination to simply harvest rather than call in hay contractors
- Even though frost damage was evident throughout the season, it was not severe or widespread enough to warrant a variable management operation, unlike past seasons

Now that we have established that the Landscape Change map is useful layer for predetermining the frost risk in Woolfords paddock, the plan will be to simplify it into management zones, which Orrock Farming could be used to 'snap into action' if frost strikes in future seasons.

## 'HOW TO' - Steps to establish management and monitoring zones for frost on your own farm

If you are interested in using precision ag data to monitor frost and create management zone maps for your own fields, these maps could be a template for management practices such as:

- Selecting frost tolerant varieties to grow in the frost prone zones
- Rolling high risk zones in preparation for hay cutting
- Having the zones ready for frost assessment, making the crop scouting process quicker
- Grazing or partially grazing zones of frost affected crops
- Refencing the most prone zones to manage them entirely differently year in, year out, eg fencing off separately as a new field

## What steps should I take to collect the information I need about my own fields?

Collect 'as applied' data from the seeder, or other slow and consistent moving paddock vehicle using RTK GPS. This data needs to be processed to obtain the Landscape Change map layer. This may involve the assistance of a Precision Ag Consultant.

Compare the Landscape Change layer with layers such as yield maps and imagery from seasons with known frost events to look for correlations.

Use the Lanscape Change Map to strategically select sites for frost sensors. It is best to select positive and negative extremities (red and blue zones). If using multiple sensors, place the majority of the sensors in the historically frost prone areas.

Download and compare the data from the frost sensors, paying particular attention to suspected frost incidence, and how these locations performed in the yield map.

If appropriate, split the field up into frost management zones based on the risk severity. These zones can be used for a variety of management decisions throughout the season.

## Creating my frost management zones

If you have a field with enough frost risk variability to warrant splitting the field into management zones, there are number of ways to do this. It may involve the assistance of a precision ag consultant to help with the map creation.

The Landscape Change map, for example could be simplified down into three simple zones based on their susceptibility to frost. Here is what we created for 'Woolfords' paddock. We split the map zones at the -5m, -1m and +4m intervals which produced a reasonable and representative looking zone map. A few small depressions were moved from the red zone to the yellow zone, (area circled below). Despite the fact this is a low-lying area, it doesn't ever seem to cop a yield penalty so must drain cool air well.


### A landscape change frost management zone map

| | |
|---|---|
| | High Frost Risk |
| | Moderate to Low Frost Risk |
| | Low to Very Low Frost Risk |

***Figure 10 -*** *The Landscape Change map was compared with yield maps from several seasons to and then simplified into three management zones in PCT AgCloud.*

# Conclusion

For some growers, that are logistically set up for hay operation, the decision to cut a frost affected crop can be simple. However, on many occasions like for Orrock Farming, who are very much geared towards a grain harvest operation, hay or grazing is not the simple answer. The most powerful tools that growers can have in their PA toolbox - are spatial map layers to explain the yield limiting factors in their fields. Information gathered from their own farms, doing 'your own science', is the best way to understand the factors driving productive capacity in different areas of the field. Precision data such as the the Landscape Change layer, coupled with information gathered from the iButton sensors goes a long way to spatially capturing the most frost prone zones and their area, so when frost does strike, scouting and decisions can be quickly made, with the ultimate goal of salvaging profit.

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### *Acknowledgements*

This fact sheet is part of the 'Producer Technology Uptake Project' funded by Agrifutures, and the 'Frost Extension Project' funded by GRDC, an initiative of the Upper North Farming Systems.

The data and analysis were compiled and written by Jessica Koch of Breezy Hill Precision Ag Services with review from the Upper North Farming Systems committee and staff.

A special acknowledgement to the growers - Todd, Brooke and Mitchell from 'Orrock Farming' for providing the site, being generous with the use of their data, as assisting with access for paddock analysis.

# Barley Time Of Sowing

***Author:*** Steph Lunn

***Funded By:*** South Australian Grains Industry Trust

***Project Title:*** Barley Time Of Sowing in the UN and Yield Loss from Heat and Frost Stress

***Project Duration:*** 2019-2022

***Project Delivery Organisations:*** Upper North Farming Systems, AgXtra, SARDI

**Key Points:**

- Planet numerically recorded the highest yields of all the varieties and across all times of sowing.
- TOS 1 and 2 recorded statistically higher yields compared to TOS3 across all varieties except for Planet which equalled the lowest yielding varieties in TOS1 and 2.
- Later sowing had a negative impact on yield and grain quality across all varieties.

**Background**

The Barley Time of Sowing trial was conducted at Fullerville, 7km West of Booleroo Centre. The site was in the same paddock and located south of the 2020 site and sown into a Faba bean stubble. The initial aims of this trial included:

- Evaluate how heat stress at the end of the season affects grain fill.
- Capture how frost stress during flowering affects grain development.
- Identify phenotype differences within barley varieties that may enable farmers in the Upper North to manage their seeding window and variety choices to minimise risk/maximise yield across their barley crop.

**Methodology**

This trial was sown with four replicates in a complete randomised block design (RCBD). The plots were 12m long x 2.5m wide and sown with the UNFS plot seeder.

There were three times of sowing (TOS):

TOS1 - 14$^{th}$ April

TOS2 - 16$^{th}$ May

TOS3 - 22$^{nd}$ June

The varieties of barley sown were:

V1 - Planet

V2 - Leabrook

V3 - Maximus CL

V4 - Laparouse (formally tested as WI4592)

V5 - Spartacus

The buffer plots were sown to Fathom.

Due to the very dry start to the season, the whole site was watered on the 6th May to allow TOS1 to germinate and give a more realistic representation of an earlier sowing timing given the main season rainfall did not come until June. The equivalent of 7mm of rain was applied across the whole site so that each plot was treated the equivalently. **A big thank you to Todd Orrock, Matt Nottle and Joe Koch for providing the spray bar and water truck**

All the barley varieties were sown at a rate of 70kg/ha with an upfront fertiliser application of:

- 70kg DAP (N: 9kg/ha, P: 10kg/ha)
- 30kg Urea (N: 9.2kg/ha).

A pre-emergent was applied at TOS1 consisting of1.25L overwatch and 800ml Gramoxone. The soil type of the paddock was a neutral loam.

Throughout the growing season, growth stages of the plots were observed and recorded using the Zadocks scale. Biomass cuts were taken at milk development and green weights recorded. The samples were then dried in an oven for 48 hours at 60 degrees and dry matter weights measured. The trial was harvested, and grain yields taken. All data was analysed using ARM software.

*Table 1. Fullerville Weather Station data 2021, supplied by AgByte*

| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rainfall Total (mm) | 7.0 | 4.5 | 20.8 | 1.3 | 11.0 | 70.8 | 89.0 | 16.0 | 14.3 | 44.3 | 96.8 | 0.3 | **375.8** |
| Min Temp (°C) | 7.1 | 8.2 | 7.2 | 5.9 | 1.6 | 3.5 | 2.0 | 1.2 | 1.9 | 2.2 | 5.6 | 6.5 | **1.2** |
| Max Temp (°C) | 41.0 | 38.6 | 34.1 | 32.8 | 26.7 | 20.9 | 19.8 | 24.2 | 28.6 | 33.9 | 32.7 | 38.4 | **38.4** |
| Av. Temp (°C) | 22.9 | 19.8 | 20.2 | 17.0 | 12.4 | 9.9 | 8.9 | 9.9 | 12.7 | 14.5 | 16.9 | 21.4 | **15.5** |
| Min RH (%) | 6.8 | 14.3 | 11.8 | 9.0 | 18.0 | 27.8 | 35.5 | 20.5 | 11.7 | 10.5 | 10.6 | 12.3 | **6.8** |
| Max RH (%) | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 98.3 | **100** |
| Av. RH (%) | 49.1 | 49.4 | 55.8 | 55.0 | 64.3 | 83.3 | 80.6 | 75.3 | 62.4 | 59.5 | 63.2 | 47.7 | **62.1** |

Weather station data from a near-by Fullerville site (Table 1) suggests that there were no extreme daily temperatures. In total, days that recorded temperatures below 2°C was 13; with 9 of these days in August and 1 day in September. During the growing season, six days in late October and November recorded above 30°C. Frost events were not significant or during flowering times, therefore no noteworthy observations were made or had any impact on yield regardless of Time of Sowing.

Rainfall for the year was slightly below the long-term average for Booleroo Centre (390.7mm; BOM Data). It was a very dry start to the season with a late break. Good winter rains occurred which helped increase biomass, however; there was a below average start to spring which put crops under stress. Late spring rains helped finish off the season.

**Results and Discussion**

*Table 2. Zadock Growth Stages by Variety and Time of Sowing throughout the year*

| | | Growth Stages 2021 | | | | |
|---|---|---|---|---|---|---|
| | | 12th July | 3rd Aug | 31st Aug | 14th Oct | 3rd Nov |
| | | BBCH | BBCH | BBCH | BBCH | BBCH |
| TOS1 | | | | | | |
| 1 | Planet | 24 | 30 | 41 | 75 | 92 |
| 2 | Lebrook | 21 | 31 | 41 | 76 | 92 |
| 3 | Maximus | 23 | 31 | 45 | 77 | 92 |
| 4 | Laparouse | 22 | 30 | 37 | 75 | 92 |
| 5 | Spartacus | 23 | 30 | 49 | 76 | 92 |
| TOS2 | | | | | | |
| 6 | Planet | 22 | 30 | 32 | 71 | 92 |
| 7 | Lebrook | 22 | 30 | 39 | 72 | 92 |
| 8 | Maximus | 22 | 30 | 37 | 73 | 92 |
| 9 | Laparouse | 22 | 30 | 37 | 71 | 92 |
| 10 | Spartacus | 22 | 25 | 41 | 73 | 92 |
| TOS3 | | | | | | |
| 11 | Planet | 11 | 21 | 25 | 55 | 83 |
| 12 | Lebrook | 11 | 22 | 27 | 55 | 83 |
| 13 | Maximus | 11 | 22 | 26 | 54 | 87 |
| 14 | Laparouse | 11 | 22 | 24 | 54 | 83 |
| 15 | Spartacus | 11 | 22 | 23 | 55 | 85 |

A very dry start to the season and no summer rain to germinate weeds meant no summer knockdown was applied to the paddock. A pre-emergent was used but sprayed across the whole site at TOS1 only and was applied in dry conditions. Whilst it did a reasonably good job on TOS1 and 2, there was very little control by the time TOS3 was sown. This meant considerable amounts of barley grass as competition, rep 4 being most affected.

Because TOS1 had to be watered, there was less than two weeks between TOS1 and TOS2 germinating. They remained consistent throughout the season and developed as expected. TOS3 fell far behind in growth (Table 2) and then a late start that went straight into cold weather meant there was very slow establishment and early growth. Less than average spring rain held it back further meaning the plants did not flower until far too late, in mid-October. This resulted in a yield penalty across all varieties.

*Table 3. Summary Table of Means of Yields and Biomass Data*

| | | Fresh weight | | Dry weight | | Grain yield | |
|---|---|---|---|---|---|---|---|
| | | WEIGHT (g) | | WEIGHT (g) | | YIELD (t/ha) | |
| | | 1 PLOT | | 1 PLOT | | 1 ha | |
| TOS1 | | | | | | | |
| 1 | Planet | 1461.8 | ab | 483.5 | - | 5.21 | ab |
| 2 | Lebrook | 1476.5 | ab | 513.8 | - | 4.58 | bcd |
| 3 | Maximus | 1338.8 | bc | 439.5 | - | 4.28 | cde |
| 4 | Laparouse | 1508.8 | ab | 469.8 | - | 4.73 | bcd |
| 5 | Spartacus | 1517.5 | ab | 508.3 | - | 4.4 | b-e |
| TOS2 | | | | | | | |
| 6 | Planet | 1360.3 | abc | 440.8 | - | 5.87 | a |
| 7 | Lebrook | 1615 | a | 505.8 | - | 5.09 | abc |
| 8 | Maximus | 1321 | bc | 410.5 | - | 4.02 | def |
| 9 | Laparouse | 1420 | ab | 412 | - | 4.83 | bcd |
| 10 | Spartacus | 1448.5 | ab | 445.3 | - | 4.41 | b-e |
| TOS3 | | | | | | | |
| 11 | Planet | 1132.8 | cd | 533.3 | - | 3.57 | ef |
| 12 | Lebrook | 999.3 | de | 481.3 | - | 2.41 | g |
| 13 | Maximus | 970.5 | de | 450.3 | - | 2.53 | g |
| 14 | Laparouse | 822.5 | e | 401.5 | - | 3.09 | fg |
| 15 | Spartacus | 873 | de | 426.3 | - | 3.31 | fg |
| | | | | | | | |
| LSD P=.05 | | 274.52 | | 103.63 | | 0.921 | |
| Standard Deviation | | 192.38 | | 72.62 | | 0.645 | |
| CV | | 14.98 | | 15.74 | | 15.39 | |

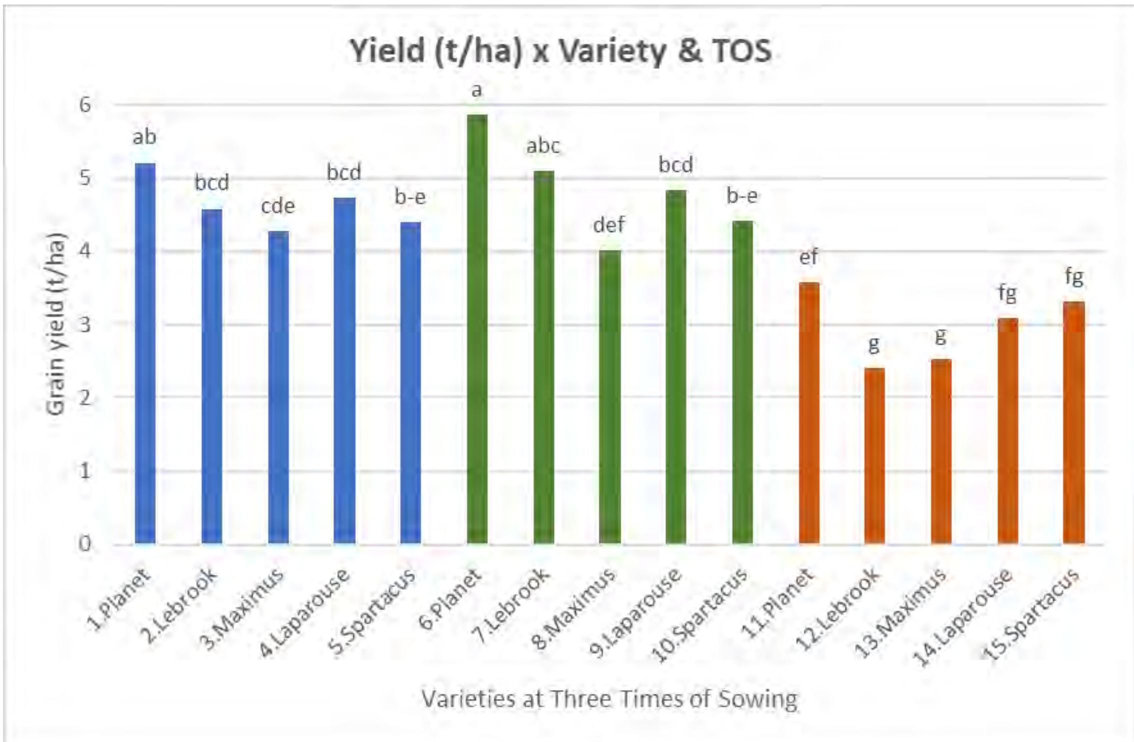


*Figure 1. Grain Yield by Variety at Three Times of Sowing*

Overall, TOS 1 and 2 achieved the highest yields with all varieties being statistically equivalent in each time of sowing (Figure 1). Planet numerically out-performed all varieties across all times of sowing and produced the greatest grain yield at TOS2 across the while trial.

Apart from Planet, all varieties in TOS3 had yields that were statistically lower than TOS1&2.
We can assume this correlates to the late time of sowing and the seasonal conditions stated above, but also the lack of chemistry left in the soil to combat germinating weeds, creating greater competition. Two plots from replication four were removed as outliers where the weeds were problematic and their poor yields skewed otherwise sound data.

Leabrook in TOS2 had the highest numerical fresh weight across all varieties and times of sowing (Table 3). Apart from Planet, all varieties in TOS3 had significantly lower fresh weights than TOS2 and 3. In the dry weights however, there was no significant differences across all the varieties and times of sowing. Planet in TOS3 produced the highest dry weight numerically.

*Table 4. Summary Table of Grain Quality Data*

| | | Test Weight | | Protein | | Retention | | Cracked Grain | |
|---|---|---|---|---|---|---|---|---|---|
| | | Kg/Hectolitre | | % | | % | | % | |
| TOS1 | | | | | | | | | |
| 1 | Planet | 69.4 | cd | 10.9 | d | 93.83 | - | 2 | - |
| 2 | Lebrook | 69.5 | cd | 12 | bcd | 94.49 | - | 1 | - |
| 3 | Maximus | 71.3 | ab | 11.9 | bcd | 93.25 | - | 1 | - |
| 4 | Laparouse | 70.8 | abc | 11.7 | bcd | 93.64 | - | 2 | - |
| 5 | Spartacus | 71.2 | ab | 12.7 | abc | 89.44 | - | 2 | - |
| TOS2 | | | | | | | | | |
| 6 | Planet | 68.9 | d | 11.4 | cd | 91.68 | - | 1 | - |
| 7 | Lebrook | 70.6 | abc | 12 | bcd | 95.53 | - | 1 | - |
| 8 | Maximus | 71.4 | ab | 11.5 | cd | 85.81 | - | 1 | - |
| 9 | Laparouse | 72 | a | 11.6 | bcd | 89.94 | - | 2 | - |
| 10 | Spartacus | 71.3 | ab | 11.9 | bcd | 90.53 | - | 2 | - |
| TOS3 | | | | | | | | | |
| 11 | Planet | 69.5 | cd | 13.1 | ab | 91.61 | - | 1 | - |
| 12 | Lebrook | 68.7 | d | 12.5 | abc | 95.06 | - | 1 | - |
| 13 | Maximus | 69.5 | cd | 13.7 | a | 88.03 | - | 1 | - |
| 14 | Laparouse | 69.5 | cd | 13.8 | a | 92.4 | - | 1 | - |
| 15 | Spartacus | 69.8 | bcd | 13.9 | a | 91.82 | - | 1 | - |
| | | | | | | | | | |
| LSD P=.05 | | 1.63 | | 9.973 | | 1.4 | | 1.62 | |
| Standard Deviation | | 1.14 | | 6.989 | | 1 | | 1.13 | |
| CV | | 1.62 | | 85.25 | | 75.24 | | 9.21 | |

TOS3 had numerically lower test weights and significantly higher protein than TOS1 and 2 which was expected. Little spring rain poor grain fill meant smaller grain size. Laparouse at TOS2 recorded the highest test weight overall. The was no significant differences recorded in Retention and minimal cracked grain across all varieties and times of sowing.

In conclusion, Planet at TOS 1 and 2 recorded the highest grain yields at all three times of sowing. Delaying sowing caused a significant decrease in yield. 2021 recorded very few extreme weather events and therefore had minimal effect on yield.

***Acknowledgements***

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- This research was possible due to the investment from the South Australian Grains Industry Trust (SAGIT).
- Thank you to seed suppliers AGT, Intergrain and Seednet for providing seed for this trial.
- Thank you to SARDI Clare team for harvesting the trial.
- Thank you AgXtra for site assessments and management.

# Barley Time of Sowing
# Summary and Collated Results 2019-2021

***Author:*** Steph Lunn, AgXtra, Jade Rose, UNFS
***Funded By:*** South Australian Grains Industry Trust, Project #: UNF232
***Project Title:*** Effects of time of sowing and effects from frost and heat stress for barley
***Project Duration:*** 2019-2022
***Project Delivery Organisations:*** Upper North Farming Systems, YPAG, AgXtra, SARDI

**Key Points:**

- In 2019, Maximus CL, Spartacus CL and Fathom sown in TOS1 yielded the highest. TOS1 also had the best overall biomass results due to the extreme dry finish.
- In 2020, all yields were statistically equivalent across the TOS due to the mild seasonal conditions at the site.
- In 2021, Planet numerically yielded the highest across all times of sowing at 5.21t/ha at TOS1, 5.87 t/ha at TOS2 and 3.57 t/ha at TOS3. Later sowing had a negative impact on yield and grain quality across all varieties.
- Earlier time of sowings produced the highest yields across three years.

**Background**

The Barley Time of Sowing trial was conducted for three years approximately 7km out of Booleroo Centre.


*Photo: Trial Locations in the 2019, 2020 and 2021 seasons. Trials were rotated in the paddock each year.*

The aims of this trial included:

- Evaluate how heat stress at the end of the season affects grain fill,
- Capture how frost stress during flowering affects grain development,
- Identify phenotype differences within barley varieties that may enable farmers in the Upper North to manage their seeding window and variety choices to minimise risk/maximise yield across their barley crop.

**Methodology**

Each year, the trial was sown with 4 replicates in a complete randomised block design. The plots were 12m long x 2.5m wide and sown with the UNFS plot seeder. A summary of the varieties and agronomics of each year are as below (Table 1.) The buffers were sown to Spartacus in the first year and Fathom in years 2 and 3.

*Table 1. Summary of BTOS trial varieties and agronomics for the 3-year project.*

| Year | Varieties | Sowing Date | Watered | Fertiliser | Pre-emergent |
|---|---|---|---|---|---|
| | | | | | |
| 2021 | Planet | TOS1 - 14th April | 7mm - 6th May | 70kg DAP | 800ml Gramoxone |
| | Leabrook | TOS2 - 16th May | Whole site | 30kg Urea | 1.25L Overwtach |
| | Maximus CL | TOS3 - 22nd June | | | |
| | Laparouse (WI4592) | | | | |
| | Spartacus | | | | |
| | | | | | |
| 2020 | Planet | TOS1 - 14th April | | 60kg DAP | 1.5L Weedmaster Argo |
| | Leabrook | TOS2 - 9th May | | 20kg Urea | 2.5L Boxer Gold |
| | Maximus CL | TOS3 - 27th may | | | 25g Paradigm |
| | WI4592 | | | | |
| | Spartacus | | | | |
| | | | | | |
| 2019 | Spartacus | TOS1: 13th April | 10mm | 50kg DAP | 2.5ml Gramoxine |
| | Fathom | TOS2: 14th May | TOS1 only | 20kg Urea | 2.5L Boxer Gold |
| | Maximus CL | TOS3: 31st May | | | |
| | Banks | | | | |
| | Urambie | | | | |

During the season frost assessments and biomass cuts were performed and assessed. The trial was harvested, and grain yields analysed via ARM software. Site visits were made throughout the year where growth stages and flowering timings for each variety in each time of sowing were recorded.

Frost assessments were only taken during the 2019 when the site was affected. Visual frost assessments were taken as a percentage % of head damage due to frost, based on the amount of frost damage that occurred on the barley head. Based on the amount of head damage in 25% increments. This was then scored on the overall plot as a percentage of heads affected. Biomass cuts were taken as 4 x 50cm rows from the middle of each plot on all three years. The fresh weights were taken, and the samples were dried in a drying oven and weighed for Dry Matter weights.

**Variety Summary**

**Maximus CL (Intergrain)**
Maximus CL (previously IGB1705T) is a high yielding, early to mid-flowering, potential malt, imidazolinone (IMI) tolerant barley. Similar to Spartacus CL, Maximus CL has an erect plant type, strong lodging tolerance and a low-medium head loss risk. The variety also has very good physical grain qualities, including excellent grain retention (grain plumpness) (higher than Spartacus CL) and good hectolitre weight. The variety has a short coleoptile and it is recommended that sowing depth be considered carefully when planting this variety

**Spartacus CL (Intergrain)**
Spartacus CL is a malting accredited imidazolinone-tolerant barley with a similar plant type and flowering behaviour to Hindmarsh and La Trobe. It is a high yielding, quick maturing variety with relatively low head loss risk and generally has good lodging resistance.

**Planet (Seed Force)**
RGT Planet is a high yielding spring barley well suited to Australian conditions. Its strong agronomic package combined with its yield potential makes it a good economic option. It is a high yielding variety *with* earlier planting opportunity, low protein therefore high hot water extract suited to malting and mid-season type adaptable to early or late season finishes.

**Banks (Intergrain)**
Banks is a mid-late maturing barley that is feed quality. Banks has been developed by Intergrain and targeted for the medium to high-rainfall environments. Its long-term yield performance has been four to seven per cent above Commander in most SA districts.

**Leabrook (Seednet)**
Leabrook is an accredited malting variety with high grain yield. It has a medium-tall plant height, with mid-early maturity. It has improved grain size over Compass and slightly lower screenings. It is resistant for CCN, MR/MS as a provisional rating for Powdery Mildew, S/VS for Scald and Leaf Rust, MS for SFNB and MR/MS for NFNB.

**Laperouse (Seednet)**
Laperouse, formally WI4592 was released as a ‘feed’ type but is currently being evaluated for malting and brewing. It has a medium spring maturity with potential for early sowing, competitive growth habit with medium plant height.

*Please refer to the GRDC crop sowing guide, South Australia for further relevant yearly information.*

**Weather summary**

2019 and 2021 experienced later than expected breaks and therefore had to be watered to initiate an earlier germination than the second time of sowing. 2019 and 2021 also recorded lower than average rainfall for the year, particularly within the growing season. 2019 recorded the most extreme temperatures, therefore frost observations were recorded.

**2019**

*Table 2. Weather Station data – 2019 – Booleroo Weather Station by Agbyte*

| 2019 Booleroo Weather Station Data | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AVG (°C) | 29.7 | 26.2 | 23.3 | 18.2 | 11.7 | 8.1 | 8.9 | 8.3 | 13.5 | 19 | 20.2 | 27.6 | 17.8 |
| MIN (°C) | 7.9 | 6.5 | 5.4 | 1.2 | 0.5 | -3.8 | -2.2 | -3.5 | -2.5 | -0.5 | 0.6 | 4 | -3.8 |
| MAX (°C) | 59.3 | 55.6 | 52.3 | 43.3 | 31.3 | 25.2 | 22.5 | 24.6 | 33.9 | 43.8 | 48.7 | 59.4 | 59.4 |
| SUM (mm) | 5.8 | 6.8 | 3.8 | 4.8 | 31.8 | 44.5 | 12 | 20.5 | 10.5 | 0.8 | 9 | 8.5 | 158.5 |
| AVG (% RH) | 38.2 | 43.4 | 49.1 | 50.1 | 69.7 | 72.9 | 76.4 | - | - | - | - | - | 56.8 |
| MIN (% RH) | 7.7 | 12.7 | 13.7 | 11.3 | 28.3 | 33.2 | 24.9 | - | - | - | - | - | 7.7 |
| MAX (% RH) | 94 | 90.5 | 96.9 | 95.7 | 98.6 | 99.2 | 99.3 | - | - | - | - | - | 99.3 |

The weather station data for 2019 (Table 2) shows the minimum and maximum temperatures that occurred throughout that year. June through to October recorded temperatures below 0 ºC (Table 3) which had the potential to cause severe damage to head development and flowering.

*Table 3. Frost Event Summary 2019*

| | Days Below 0ºC | Coldest Minimum ºC - Date | |
|---|---|---|---|
| June | 11 | -3.8 | 24th June |
| July | 7 | -2.1 | 31st July |
| August | 17 | -3.5 | 5th August |
| October | 6 | -2.5 | 10th October |
| November | 1 | -0.5 | 9th November |

Frost assessments were taken on October 9th to record damage to plant heads that would affect crop yield. Maximum temperatures throughout the growing season did not reach extreme levels (>35 ºC) with the hottest being recorded on 15th September at 33.9ºC. September did record 11 days over 30 ºC. This, as well as July, August, September, and October all receiving lower than average rainfall, had an impact on plant head development and plant health. The total annual rainfall was 186.1mm in 2019 compared to the long term annual average rainfall for Booleroo at 390.7mm (BOM Data).

**2020**

*Table 4. Booleroo Centre weather station data 2020, supplied by AgByte.*

| Booleroo Weather Station Data 2020 | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AVG (°C) | 25.6 | 23.7 | 21.1 | 16.1 | 10.6 | 8.8 | 8.2 | 9 | 13.5 | 14.8 | 21.6 | 20.8 | **16.1** |
| MIN (°C) | 6.7 | 7.4 | 5.1 | 5.6 | 0.6 | -1.9 | -1.5 | 0 | -0.1 | 1 | 2.3 | 3.7 | **-1.9** |
| MAX (°C) | 55 | 51.8 | 45.9 | 32.2 | 23.9 | 21.9 | 21.9 | 24.1 | 29.7 | 33.9 | 44.3 | 41.6 | **55** |
| SUM (mm) | 26.3 | 62.3 | 4.5 | 57.8 | 30.5 | 14.3 | 14 | 34.3 | 70 | 79.3 | 1.5 | 25.3 | **420** |
| AVG (% RH) | - | 56.1 | 49 | 63.5 | 69.4 | 72.2 | 75.7 | 72.9 | 61.9 | 64.4 | 46.4 | 50.2 | **62.2** |
| MIN (% RH) | - | 16.8 | 13.3 | 15.9 | 29.5 | 33.6 | 30.3 | 19.7 | 15.3 | 19.5 | 9.6 | 9.3 | **9.3** |
| MAX (% RH) | - | 97.9 | 94.8 | 97.3 | 97.3 | 98 | 98.6 | 98 | 97.6 | 98.6 | 98.4 | 96.1 | **98.6** |

The Booleroo Centre weather station data (Table 4) showed that the daily temperatures for 2020 were not as extreme as experienced in 2019. Frost events were not significant or at the time of flowering, therefore; there were no significant frost observations to be made during the growing season. This means frost would have had little to no impact on yield regardless of Time of Sowing.

Heat events were also minimal (Table 5), and majority occurred in November when the crop was mature. This is compared to 2019 when September recorded 11 days over 30C and had more significant effect on flowering periods.

*Table 5. Frost and Heat Event Summary.*

| Days below 0C | | Days above 30C |
|---|---|---|
| 5 | June | 0 |
| 6 | July | 0 |
| 1 | August | 0 |
| 1 | September | 0 |
| 0 | October | 5 |
| 0 | November | 22 |

Good rainfall was recorded throughout the whole growing season of the trial. Growing Season Rainfall totalled to 300mm and Total Annual Rainfall totalled 420mm. This is above the long term annual average rainfall for Booleroo which is 390.7mm (BOM data).

**2021**

*Table 6. Fullerville Weather Station data 2021, supplied by AgByte*

| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rainfall Total (mm) | 7.0 | 4.5 | 20.8 | 1.3 | 11.0 | 70.8 | 89.0 | 16.0 | 14.3 | 44.3 | 96.8 | 0.3 | **375.8** |
| Min Temp (°C) | 7.1 | 8.2 | 7.2 | 5.9 | 1.6 | 3.5 | 2.0 | 1.2 | 1.9 | 2.2 | 5.6 | 6.5 | **1.2** |
| Max Temp (°C) | 41.0 | 38.6 | 34.1 | 32.8 | 26.7 | 20.9 | 19.8 | 24.2 | 28.6 | 33.9 | 32.7 | 38.4 | **38.4** |
| Av. Temp (°C) | 22.9 | 19.8 | 20.2 | 17.0 | 12.4 | 9.9 | 8.9 | 9.9 | 12.7 | 14.5 | 16.9 | 21.4 | **15.5** |
| Min RH (%) | 6.8 | 14.3 | 11.8 | 9.0 | 18.0 | 27.8 | 35.5 | 20.5 | 11.7 | 10.5 | 10.6 | 12.3 | **6.8** |
| Max RH (%) | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 98.3 | **100** |
| Av. RH (%) | 49.1 | 49.4 | 55.8 | 55.0 | 64.3 | 83.3 | 80.6 | 75.3 | 62.4 | 59.5 | 63.2 | 47.7 | **62.1** |

Weather station data from a near-by Fullerville site (Table 6) suggests that there were no extreme daily temperatures. In total, days that recorded temperatures below 2°C was 13; with 9 of these days in August and 1 day in September. Days during the growing season that recorded above 30°C was six and these were in late October and November. Frost events were not significant or during flowering times, therefore no noteworthy observations were made or had any impact on yield regardless of Time of Sowing.

Total rainfall for the year was 375.8mm which is slightly below the long-term average for Booleroo Centre (390.7mm; BOM Data). It was a very dry start to the season with a late break. Good winter rains which helped increase biomass but then a below average start to spring putting crops under stress. Late spring rains did occur in October.

**Results and Discussion**

**Frost (2019 only)**

Frost visual scores were taken on the 9th of October (Table 7). The percentage of heads across the plot with frost damage were recorded based on the severity of the damage of the head (Tipping – just the tip of the head, ¼ - quarter of the head, half – half of the head, ¾ - 3 quarters of the head damaged).

*Table 7. Frost visual scores (Oct. 9th). Variety 1- Spartacus CL, V2- Fathom, V3- Maximus CL, V4- Banks, V5- Urambie*

| TOS1 | Tipping | One quarter | Half | Three quarter |
|---|---|---|---|---|
| V4 | 10 | 40 | 50 | 0 |
| V3 | 50 | 15 | 0 | 0 |
| V2 | 10 | 0 | 0 | 0 |
| V1 | 50 | 30 | 0 | 0 |
| V5 | 70 | 20 | 0 | 0 |
| | | | | |
| **TOS2** | **Tipping** | **One quarter** | **Half** | **Three quarter** |
| V4 | 0 | 90 | 0 | 0 |
| V3 | 80 | 0 | 15 | 0 |
| V2 | 0 | 40 | 30 | 20 |
| V1 | 50 | 0 | 30 | 0 |
| V5 | 0 | 30 | 0 | 0 |
| | | | | |
| **TOS3** | **Tipping** | **One quarter** | **Half** | **Three quarter** |
| V4 | 85 | 0 | 0 | 0 |
| V3 | 90 | 0 | 0 | 0 |
| V2 | 10 | 0 | 0 | 0 |
| V1 | 10 | 40 | 45 | 0 |
| V5 | 40 | 30 | 10 | 0 |

Whilst a higher percentage of heads with frost damage was noticed in TOS3, the most severe frost damage was noticed in TOS2 with greater amount of the plant head damaged.

At TOS2, Spartacus, Fathom and Maximus all suffered half head loss throughout the plot but also recorded similar growth stages throughout the year at this time of sowing (Figure1).

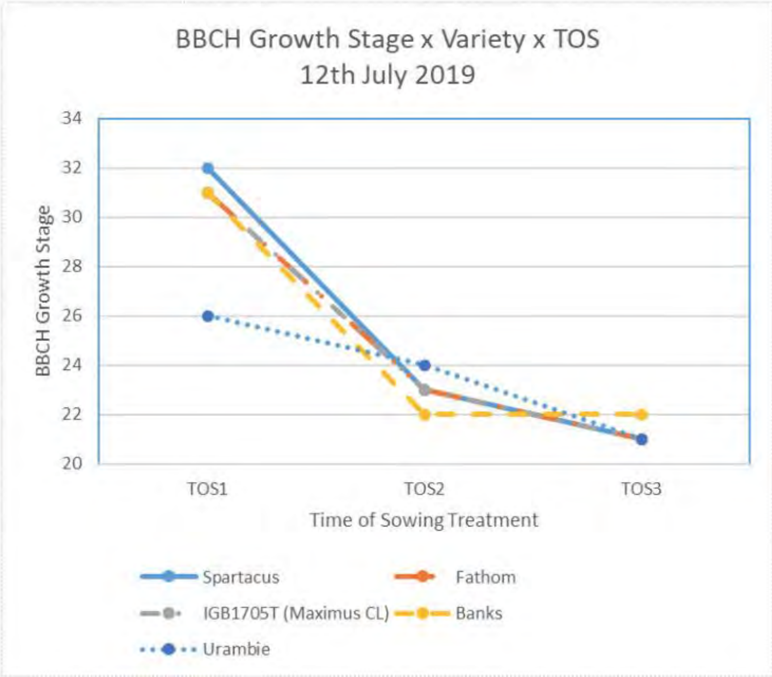



*Figure 1. Growth stage by Time of sowing by variety on 12th July 2019*

**Growth and Flowering**

2019

Flowering was spread out across the three time of sowing treatments. Flowering occurred as follows for TOS1 - Spartacus and Maximus flowering on 20th August; by 26th August all varieties were flowering apart from Urambie. Urambie flowered on 11th September. For TOS2 all varieties but Urambie flowered on 11th September. TOS3 flowering was not recorded but was approximately the end of September for all varieties.

2020

Given the year and consistent rainfall, all the varieties developed and matured as expected based on their time of sowing. Up until the 10th of August, growth stages within their times of sowing were consistent. On the 10th of August however, Spartacus and Maximus CL in TOS1 were further developed than the other varieties which then meant earlier flowering. In TOS3 on the 10th of August, Leabrook was further ahead in maturity. This did not correlate to earlier flowering, with Spartacus and Maximus CL still flowering before all other varieties for TOS3.

2021

Because TOS1 had to be watered, there was less than two weeks between TOS1 and TOS2 germinating. They remained consistent throughout the season and developed as expected. TOS3 fell far behind in growth due to a late start that went straight into cold weather, therefore, was very slow to establish or have early growth. Less than average spring rain held it back further meaning the plants did not flower until far too late, in mid-October. This resulted in a significant yield penalty for TOS3 across all varieties.

**Biomass and yield**

**2019**

Due to a change in varieties for the 2020 and 2021 seasons, 2019 has been kept separate in this report.

*Table 8. Means, Grain Yield and Biomass of the Barley TOS trial in 2019.*

| No. | Name | Biomass T/Ha | | Yield T/Ha | |
|---|---|---|---|---|---|
| 1 | Early Spartacus CL | 7.01 | a | 2.57 | ab |
| 2 | Early 'Fathom | 6.39 | a | 2.56 | abc |
| 3 | Early Maximus CL - IGB1705T | 6.27 | a | 2.65 | a |
| 4 | Early Banks | 5.83 | ab | 2.18 | d |
| 5 | Early Urambie | 4.48 | c | 1.4 | f |
| 6 | Mid Spartacus CL | 4.5 | c | 2.19 | cd |
| 7 | Mid Fathom | 4.69 | bc | 2.23 | bcd |
| 8 | Mid Maximus CL - IGB1705T | 4.68 | bc | 2.05 | de |
| 9 | Mid Banks | 4.59 | bc | 1.71 | ef |
| 10 | Mid Urambie | 3.22 | de | 1.01 | g |
| 11 | Late Spartacus CL | 3.96 | cd | 1.69 | ef |
| 12 | Late Fathom | 3.6 | cde | 1.66 | f |
| 13 | Late Maximus CL - IGB1705T | 3.74 | cd | 1.68 | f |
| 14 | Late Banks | 3.19 | de | 1.35 | fg |
| 15 | Late Urambie | 2.38 | e | 0.58 | h |
| | Means followed by same letter or symbol do not significantly differ (P=.05, LSD). | | | | |

In 2019, all varieties showed declining yield and biomass production with delayed time of sowing (Table 8), however; these responses were not equal due to the phenology of each variety. The decline in yield and biomass as a result of delayed sowing time is likely due to a number of factors including soil temperature during establishment, impacts of frosts and the combined interactions of growth stages, biomass and severe moisture and heat stress at the end of the season.

The first time of sowing resulted in the largest biomass production and yield in all varieties, with Maximus CL, Spartacus CL and Fathom yielding significantly higher than all other treatments. Grain yield in all but two varieties showed a statistically significant decline as time of sowing was delayed in 2019. Time of sowing one resulted in the largest biomass production across all varieties, except Banks being statistically greater than TOS2. TOS3 showed reduced yield and biomass. This is not all due to frost and heat stress but also day length, radiation and reduced physiological development of the plant due to cooler soil conditions.

**2020**

*Table 9. Summary Table of Means of Grain Yield and Biomass data of Barley TOS trial 2020.*

| | | | |
|---|---|---|---|
| Crop Name | Spring barley | Spring barley | Spring barley |
| Crop Variety | Various | Various | Various |
| Description | Biomass - fresh | Biomass - dry | Yield |
| Assessment Date | 15-Sep-20 | 15-Sep-20 | 30-Nov-20 |
| Part Assessed | WEIFRE C | WEIDRY C | PLOT C |
| Assessment Type | WEFRRE | WEDRRE | YIELD |
| Assessment Unit | g | g | T-MET |
| Reporting Basis | 1.0 PLOT | 1.0 PLOT | 1 PLOT |
| Crop Stage Majority/Min/Max | 49 77 71 | 49 77 71 | 99 - - |
| Plant-Eval Interval | 111 DP-1 | 111 DP-1 | 187 DP-1 |
| ARM Action Codes | | | TY1 |
| Trt No. Treatment Name | 19 | 20 | 22 |
| 1 TOS 1 - 14 April 2020 Barley cv. Planet | 572.7ab | 261.3b | 1.74- |
| 2 TOS 1 - 14 April 2020 Barley cv. Lebrook | 591.7a | 288.3a | 1.70- |
| 3 TOS 1 - 14 April 2020 Barley cv. Maximus | 436.3cde | 227.3c | 1.66- |
| 4 TOS 1 - 14 April 2020 Barley cv. WI4592 | 481.3a-e | 229.0c | 1.79- |
| 5 TOS 1 - 14 April 2020 Barley cv. Spartacus | 512.3a-d | 247.7bc | 1.76- |
| 6 TOS 2 - 09 May 2020 Barley cv. Planet | 478.7b-e | 196.7d | 1.78- |
| 7 TOS 2 - 09 May 2020 Barley cv. Lebrook | 543.7abc | 225.7c | 2.14- |
| 8 TOS 2 - 09 May 2020 Barley cv. Maximus | 447.7cde | 195.7d | 1.59- |
| 9 TOS 2 - 09 May 2020 Barley cv. WI4592 | 426.7de | 181.7de | 1.85- |
| 10 TOS 2 - 09 May 2020 Barley cv. Spartacus | 419.3de | 184.7de | 2.04- |
| 11 TOS 3 - 27 May 2020 Barley cv. Planet | 418.3de | 128.0g | 1.77- |
| 12 TOS 3 - 27 May 2020 Barley cv. Lebrook | 420.7de | 161.7ef | 1.63- |
| 13 TOS 3 - 27 May 2020 Barley cv. Maximus | 475.7b-e | 172.0def | 1.82- |
| 14 TOS 3 - 27 May 2020 Barley cv. WI4592 | 421.0de | 155.7f | 2.04- |
| 15 TOS 3 - 27 May 2020 Barley cv. Spartacus | 397.3e | 155.7f | 1.61- |
| LSD P=.05 | 112.37 | 25.24 | 0.483 |
| Standard Deviation | 67.18 | 15.09 | 0.289 |
| CV | 14.31 | 7.52 | 16.1 |
| Grand Mean | 469.56 | 200.73 | 1.795 |
| Bartlett's X2 | 17.718 | 27.269 | 11.606 |
| P(Bartlett's X2) | 0.22 | 0.018* | 0.638 |
| Rank X2 | | | |
| P(Rank X2) | | | |
| Skewness | 0.2175 | 0.3814 | -0.2292 |
| Kurtosis | -0.6385 | -0.5507 | -1.2299 |
| Analyzed as | RCB | RCB | RCB |
| Replicate F | 2.747 | 7.770 | 4.797 |
| Replicate Prob(F) | 0.0814 | 0.0021 | 0.0162 |
| Treatment F | 2.452 | 26.393 | 0.967 |
| Treatment Prob(F) | 0.0210 | 0.0001 | 0.5075 |

Leabrook at TOS1 had the numerically highest biomass of all treatments (Table 9). This was statistically equivalent to all other varieties in TOS1 except Maximus which had lower mean biomass. Leabrook in TOS2 was also statistically equivalent. In TOS3, Maximus had significantly higher biomass fresh weights than the other varieties.

Dry matter weights showed Leabrook at TOS1 was significantly higher than all other varieties across the three times of sowing (Table 9). Leabrook also had a significantly higher biomass than the other varieties in TOS2 only. In TOS3 only, Maximus was numerically higher in biomass dry weight and statistically equivalent only to Leabrook.

There were no significant differences in grain yield across all treatments (Table 9). Numerically, Leabrook in TOS2 recorded the highest average yield.

**2021**

*Table 10. Summary Table of Means of Grain Yields and Biomass Data of Barley TOS trial in 2021.*

| | | Fresh weight | | Dry weight | | Grain yield | |
|---|---|---|---|---|---|---|---|
| | | WEIGHT (g) | | WEIGHT (g) | | YIELD (t/ha) | |
| | | 1 PLOT | | 1 PLOT | | 1 ha | |
| TOS1 | | | | | | | |
| 1 | Planet | 1461.8 | ab | 483.5 | - | 5.21 | ab |
| 2 | Leabrook | 1476.5 | ab | 513.8 | - | 4.58 | bcd |
| 3 | Maximus | 1338.8 | bc | 439.5 | - | 4.28 | cde |
| 4 | Laparouse | 1508.8 | ab | 469.8 | - | 4.73 | bcd |
| 5 | Spartacus | 1517.5 | ab | 508.3 | - | 4.4 | b-e |
| TOS2 | | | | | | | |
| 6 | Planet | 1360.3 | abc | 440.8 | - | 5.87 | a |
| 7 | Leabrook | 1615 | a | 505.8 | - | 5.09 | abc |
| 8 | Maximus | 1321 | bc | 410.5 | - | 4.02 | def |
| 9 | Laparouse | 1420 | ab | 412 | - | 4.83 | bcd |
| 10 | Spartacus | 1448.5 | ab | 445.3 | - | 4.41 | b-e |
| TOS3 | | | | | | | |
| 11 | Planet | 1132.8 | cd | 533.3 | - | 3.57 | ef |
| 12 | Leabrook | 999.3 | de | 481.3 | - | 2.41 | g |
| 13 | Maximus | 970.5 | de | 450.3 | - | 2.53 | g |
| 14 | Laparouse | 822.5 | e | 401.5 | - | 3.09 | fg |
| 15 | Spartacus | 873 | de | 426.3 | - | 3.31 | fg |
| LSD P=.05 | | 274.52 | | 103.63 | | 0.921 | |
| Standard Deviation | | 192.38 | | 72.62 | | 0.645 | |
| CV | | 14.98 | | 15.74 | | 15.39 | |

In 2021, TOS 1 and 2 achieved the highest grain yields with all varieties being statistically equivalent in each time of sowing (Table 10). Planet numerically outperformed all varieties across all times of sowing and produced the greatest grain yield at TOS2 across the whole trial.

Apart from Planet, all varieties in TOS3 had yields that were statistically lower than TOS1 and 2. Factors affecting this can include, the late time of sowing and the seasonal conditions stated above, but also the lack of chemistry left in the soil to combat germinating weeds, creating greater competition. Two plots from replication four were removed as outliers where the weeds were problematic, and their poor yields skewed otherwise sound data.

Leabrook in TOS2 had the highest numerical fresh weight across all varieties and times of sowing (Table 10). Apart from Planet, all varieties in TOS3 had significantly lower fresh weights than TOS2 and 3. In the dry weights, there were no significant differences across all the varieties and times of sowing. Planet in TOS3 produced the highest dry weight numerically.

**Conclusions**

Barley is a versatile and slightly more frost- tolerant (1°C) option to wheat, allowing it to be planted earlier in the season. Other trials have also shown it is also a better option for late planting compared to wheat, typically if feed grain prices are suitable (GRDC, 2016). Early (Early April - Mid May) planting has various benefits such as producing higher yields, lower protein levels and larger grain size, often meaning it is likely to achieved malt quality. Early grazing is also a suitable option as it often produces a good grain crop when grazed before stem elongation (GS31). This project highlighted that if the sowing window for each variety/phenotype is matched and a mix of varieties are sown to provide some variation in the flowering window, the timeliness of sowing has a significant benefit to the production capacity of the barley crop in both yield and biomass for feed. Late (Mid May onwards) plantings often lead to maturing in hot dry weather, which reduces yield, grain size and malting quality. TOS3 in all three years had reduced grain yield between 0.5-1 t/ha for most varieties. Across all three years of this project, earlier time of sowings produced the highest grain yields, however; seasonal conditions each year were very diverse, therefore decision making from this project should be treated with caution.

**Acknowledgements**

- This research was possible due to the investment from the South Australian Grains Industry Trust (SAGIT).
- A special thank you to Todd and Brook Orrock and the Orrock family for providing this wonderful site, the trial sowing, management, and support provided.
- Thank you to seed suppliers AGT, Intergrain and Seednet for providing seed for this trial.
- Thank you to SARDI Clare team for harvesting the trial.
- Thank you AgXtra for site assessments and management.

**References**

GRDC Barley Grow Notes (2016), https://grdc.com.au/resources-and-publications/grownotes/crop-agronomy/northernbarleygrownotes/grdc-grownotes-barley-northern.pdf (Accessed 24/9/22).

Appendix.

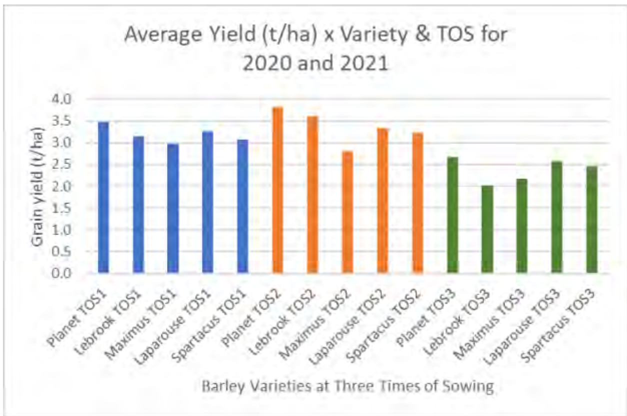



*Figure 2: Grain Yield by Variety at Three Times of Sowing*

*Table 10. Combined average yields for 2021 and 2022*

| | Variety and TOS | Average yield of 2020 and 2021 t/ha |
|---|---|---|
| 1 | Planet TOS2 | 3.825 |
| 2 | Leabrook TOS2 | 3.615 |
| 3 | Planet TOS1 | 3.475 |
| 4 | Laparouse TOS2 | 3.34 |
| 5 | Laparouse TOS1 | 3.26 |
| 6 | Spartacus TOS2 | 3.225 |
| 7 | Leabrook TOS1 | 3.14 |
| 8 | Spartacus TOS1 | 3.08 |
| 9 | Maximus TOS1 | 2.97 |
| 10 | Maximus TOS2 | 2.805 |
| 11 | Planet TOS3 | 2.67 |
| 12 | Laparouse TOS3 | 2.565 |
| 13 | Spartacus TOS3 | 2.46 |
| 14 | Maximus TOS3 | 2.175 |
| 15 | Leabrook TOS3 | 2.02 |

# Barley Grass Management Options

***Author(s):*** Matt McCallum, Beth Sleep

***Funded By:*** Grains Research & Development Corporation

***Project Code:*** GRDC Project 9176981

***Project Title:*** Demonstrating and validating the implications of integrated weed management strategies to control barley grass in the low rainfall zone farming systems

***Project Duration:*** 2019 - 2022

***Project Delivery Organisations:*** UNFS on behalf of The University of Adelaide. Site management by Matt and Ross McCallum and Elders Jamestown

**Key Points:**

- The trial was established in 2019, a low rainfall year (80 mm growing season rainfall). This had a direct negative impact on the performance of treatments, leading to reduced difference between treatments and ability to draw conclusions from this trial.
- Barley grass throughout this region was identified as 100% resistant to Quizalofop (group 1/A) and Clethodim (Group 1/A). There was no resistance detected for Glyphosate, Paraquat or Intervix.
- Sowing after opening rains, to allow for a good knockdown, was found to significantly reduce barley grass pressure in the cereal phase when compared to dry sowing. This tactic will only be suited to particular seasons, depending on timing and quantity of opening rains, in addition to the overall sowing program.
- A double knock throughout late spring (before barley grass seed set and after medic seed set) in the 2020 pasture phase was found to have good control on the barley grass population, after an above average rainfall throughout the spring. Again, this tactic will only be suited to systems where a self-regenerating pasture phase/vetch pasture is utilised.
- In 2021, final counts showed extremely good barley grass control following the double knock the year prior, with limited to no yield penalty to the wheat crop identified. Ongoing control will be required to ensure no population blow outs moving forward, with appropriate herbicide mode of action rotation in combination with the use of other cultural controls.

**Background**

This project occurred following observations of uncontrolled barley grass populations across the region, resulting in negative crop competition and issues associated with grass seeds in livestock. The trial was established in 2019, in the Melrose region. It was suspected, but not confirmed, that this was a result of herbicide resistance to commonly used chemistries used for control in legume phases (typically Group A's/1's).

Options are often limited in the cereal phase unless growing an Imi tolerant variety, however there are carry-over issues to following rotations. This project aimed to investigate management options to help control barley grass populations using nonchemical management strategies.

The project investigated the impact (and interaction) of two locally relevant cropping tactics on barley grass levels:

1. Impact of dry seeding cereals vs seeding after germination rain and knockdown application
2. Effect of cutting a crop for hay vs taking it through to grain.

*The treatments were applied on the two levels of initial infestation- high and low.

**Methodology**

The trials lifespan was three years. The first year implemented the different management styles (table 1) followed by year two in which a self-regenerating pasture phase was spray topped in spring and the third year sown to a cash crop (barley). Treatments were randomised and replicated, with treatments repeated in a high and low barley grass infestation area. Barley grass populations were counted each year firstly after opening rains, then again at the end of the season, considering barley grass head densities as a measure of success for each treatment. The project also completed a region wide survey of barley grass resistance status (appendix 1).

*Table 1. A table outlining the different treatments utilised as part of this three-year trial*

| Year | T1 | T2 | T3 | T4 |
|---|---|---|---|---|
| 2019 | Spartacus barley, dry sown, harvested as grain | Spartacus barley, dry sown, cut for hay | Spartacus barley, sown after break, harvested for grain | Spartacus barley, sown after break, cut for hay |
| 2020 | Natural regen pasture, spring topping double knock | | | |
| 2021 | Barley cash crop | | | |

Herbicides applied:

a. 2019 - Pre-emergent Trifluralin 1.5 L/ha, Avadex 2 L/ha. Post break sown - Glyphosate 540 knock-down at 1.2 L/ha
b. 2020 - Double knock throughout spring - Glyphosate 450 @ 360 ml/ha followed by paraquat at 800 ml/ha
c. 2021 - Pre-emergent Trifluralin 1.5 L/ha, Avadex 2 L/ha

**Results and Discussion**

The implementation of different treatments in 2019 had a positive impact on the barley grass population in that year and the season following. Reduced barley grass pressure occurred (figure 1,2) consistently in plots sown after the break of season. This can be directly attributed to plots sown after the break achieving a better knockdown on barley grass populations, which germinated before sowing under this management style. This will only be effective in barley grass populations which are not resistant to glyphosate. Where there is resistance, other knockdown herbicides, such as paraquat, could be used as a substitute. The best outcome from this trial was a double knock approach where a systemic herbicide, i.e. glyphosate, is applied first followed by a contact herbicide, such as paraquat, to pick up the survivors and reduce seed set of resistant populations for future years.

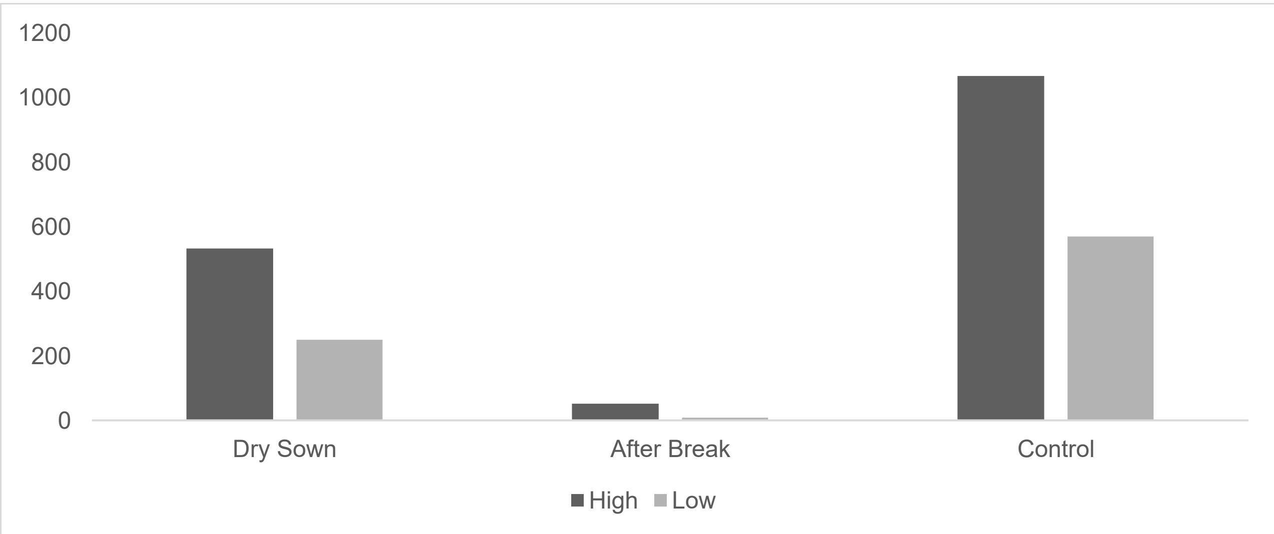



*Figure 1. Barley grass counts taken on the 12th of June 2019 across the two different times of sowing and in the high and low barley grass areas*

Another management style investigated was using a hay cut to physically remove weed seeds from the paddock. There was no significant difference when comparing the grain harvest versus hay cut treatments. The lack of results found between these treatments can be strongly attributed to the limited biomass production throughout 2019, due to well below average growing season rainfall. This made it difficult to remove weed seeds from the plots in the form of hay. Therefore, results grained here are inconclusive, with hopes that Upper North Growing Systems can complete further work in this area to gain more useful results moving forward.

The last management style investigated was the use of break crops to control grass weeds. The second year (2020) of this trial was a self-regenerating medic pasture phase. Plant counts were taken prior to the double knock, with panicle counts completed four weeks after the chemical application (figure 2). The double knockdown was able to significantly reduce barley grass pressure, with reduced plants consistently across the trial site in the following season (figure 3). In field observations at time of taking final counts noted that there were limited to no barley grass seeds present on the soils surface in 2021. Therefore, it is reasonable to conclude that plant counts are representative of the total barley grass population remaining at this site. In comparison, there were high numbers of medic plants and seeds, indicating that the chemical application throughout spring had little impact on legume populations, due to timing of chemical application. This management would only work on crops that are not taken through to harvest, as the timing of chemical application is important to control barley grass.

Group A chemistries were not utilised throughout the pasture phase of this trial, due to known resistance. However, this is another management option to help reduce grass pressure earlier in the season, followed then by a non-selective herbicide at the end of season to clean up any surviving plants and capture any that germinate after the initial chemical application.

Barley grass populations were found to be patchy across the whole site at the time of counts in 2021, with increases in barley grass presence correlating strongly with reductions to crop biomass. The patchy nature of barley grass population is likely a result of single resistant plants going on to set seed, all of which remained in close proximity to the original plant. This has then presented extra crop competition, reducing crop biomass due to reduced accessibility to resources such as moisture and nutrients.

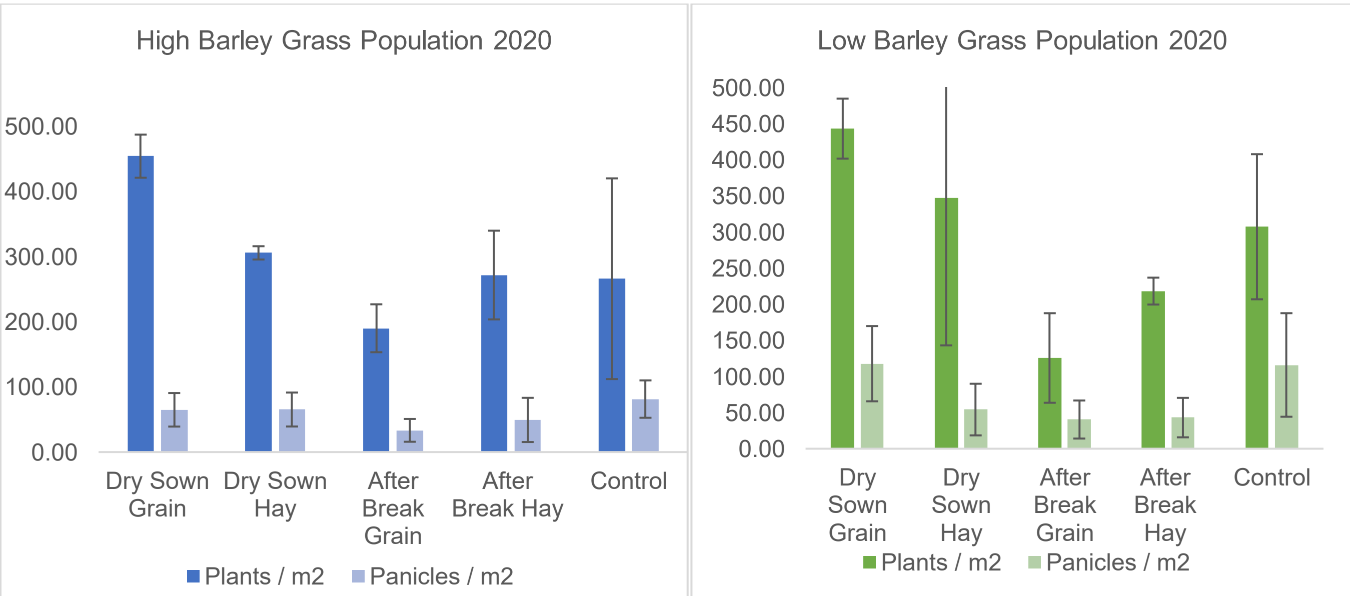



*Figure 2 (a,b). Counts taken in the pasture phase of this project, considering the high (a) and low (b) barley grass populations. First counts were taken on the 29th of May 2020, counting barley grass plants / $m^2$. Second counts were taken on the 11th of September, approximately 4 weeks after chemical application, counting panicles / $m^2$.*

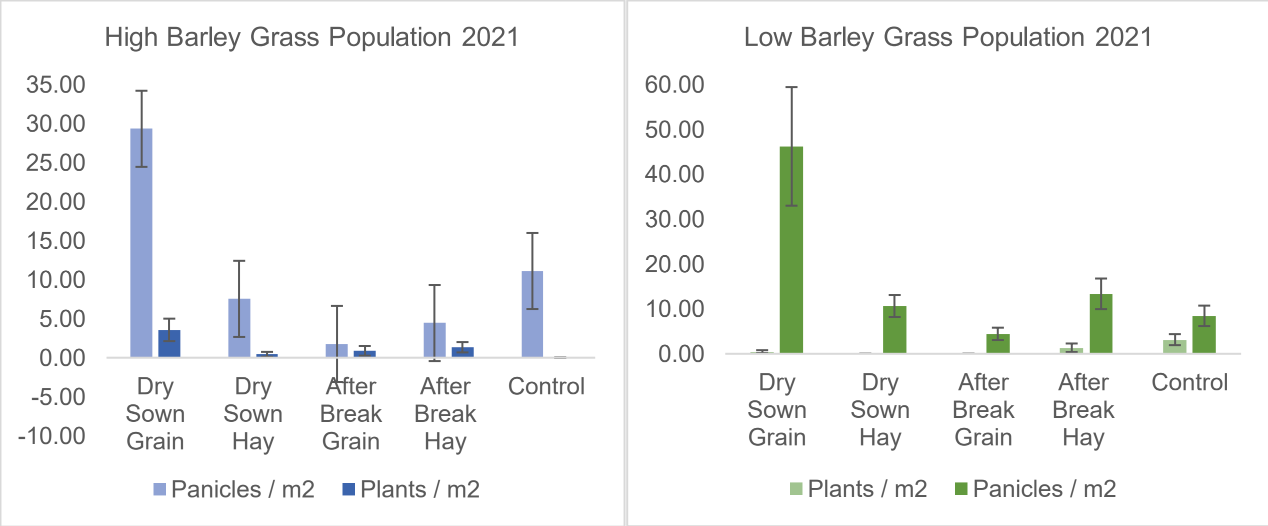



*Figure 3 (a,b). Counts taken in the last cereal phase of this project, considering the high (a) and low (b) barley grass populations. First counts were taken on the 21st of June 2021, counting barley grass plants / m$^2$. Second counts were taken on the 17th of September, counting panicles / m$^2$.*

**Conclusions**

Findings from this project highlighted the importance of using a combination of management practises to control weed populations, both chemical and cultural. Although the initial establishment of this trial was heavily impacted by poor growing conditions in the 2019 growing season, it was still found that late sowing, to allow for a weed germination and therefore knockdown, is highly effective at reducing weed competition in problem paddocks. This management style demonstrated an increase to grain yield in the same season, due to reduced competition. Additionally, the use of a double knock in the pasture phase of a rotation is highly effective at controlling barley grass populations, economically, without impacting the legume pasture if completed at the correct timing. Whilst there is no evidence grained from this trial, it is also hypothesised that completing a hay cut to physically remove weed seeds is also a management practise suited to our localised systems. This will however reduce the marketability of the end hay product and needs to be considered prior to cutting for hay. UNFS group intend to continue trial work to gain data to support this moving forward. This project identified a growing problem around the resistance of group A’s when controlling barley grass populations. In response, UNFS identified three management practises to help reduce the negative impacts barley grass has in our growing systems.

***Acknowledgements***

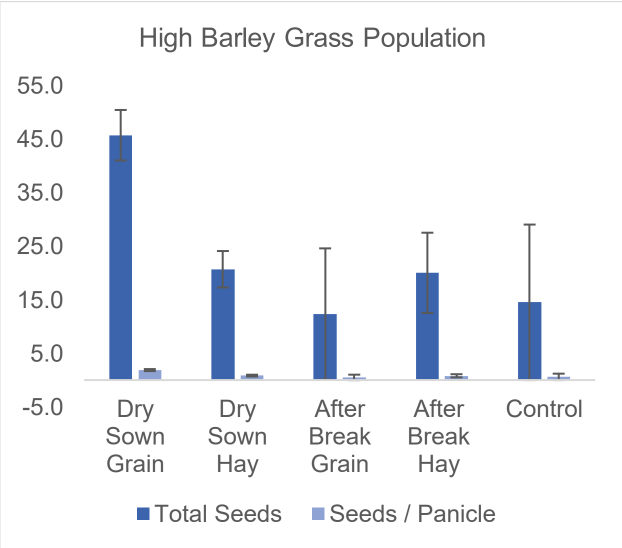
- A special thank you to Matt and Ross McCallum for the trial site and management of the site
- Thank you to the GRDC for funding this project and to the University of Adelaide and Dr Gurjeet Gill for partnering with UNFS to deliver the project in the region

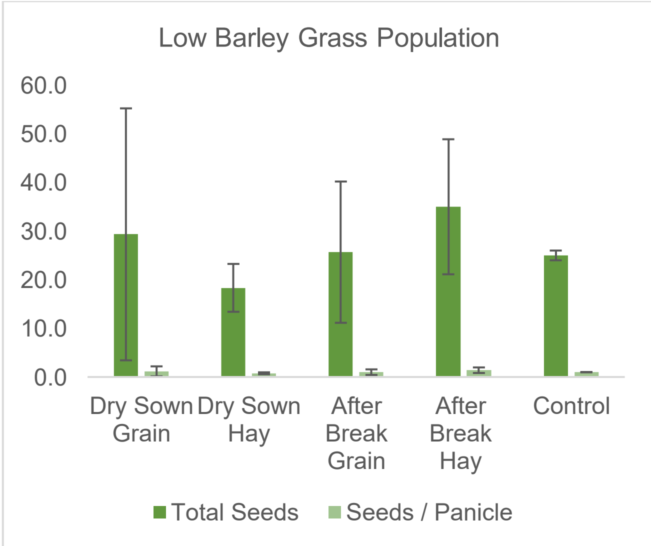
*This report has been compiled in memory of Matt McCallum – who undertook the trial and all operations and measurements for the first year. Sadly, the passing of Matt in December 2019 has had a vast impact on his family and the community.*

**Appendix 1**

- Resistance to quizalofop (group A/1) was confirmed in 4 or the 10 sample in the first run. Three samples with higher levels of resistance were retested and confirmed to be resistant with the remaining sample found to have a developing level of resistance.
- Resistance to clethodim (group A/1) found the same three samples were found to be highly resistant in the first run, one of these had a developing level of resistance. The highly resistant samples were still uncontrolled even at the higher rate of 500 ml/ha.
- One of the FOP resistant samples was killed using butoxydim, with the other two FOP resistant samples showing levels of resistance at the higher rates of butorxydim. As seen with other samples, byuroxydim can control many clethodim resistant populations.
- All samples submitted were controlled with intervix, glyphosate and paraquat.

**Appendix 2**




*Barley grass seed counts collected on the 11$^{th}$ of September with 10 barley heads collected from each plot for assessment. No statistically significant difference between plots was identified.*

# Frost Prevention - Blue Sky Research in the Upper North

## The Effect of Firestik 4 on Barley Grain Yield – Murraytown, Upper North, SA

## 2021

*"Observance of the abiotic stress mitigation potential of foliar applied, "food grade" Quorum Sensing Inhibition (QSI) phenolics for potential influence on modulation of ice nucleating bacteria (INB) and plant stress resilience in dryland broadacre cropping systems"*

Breezy Hill Precision Ag Services

UNFS Upper North Farming Systems

FIELD SYSTEMS Strategic Soil Management

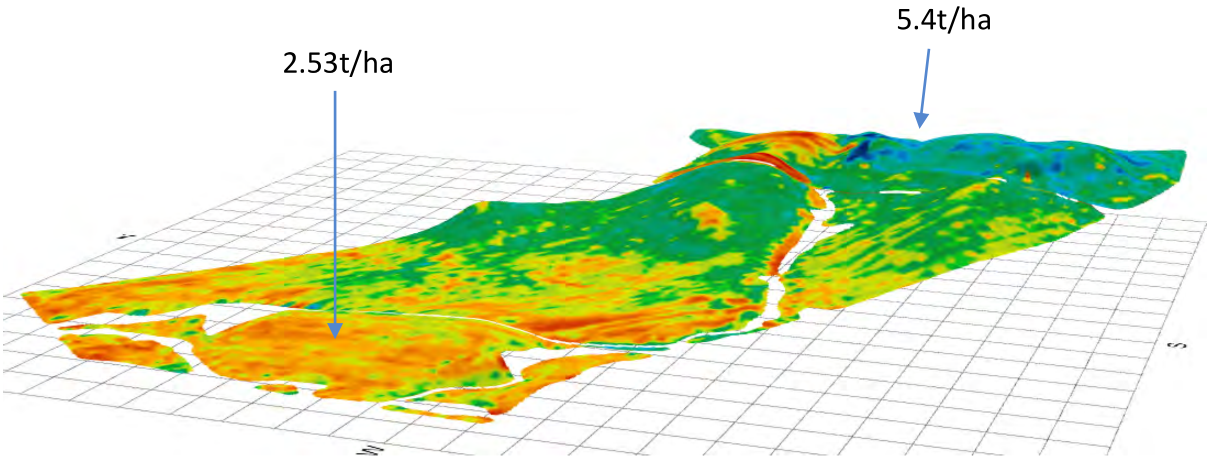
Located in the Upper North of South Australia, 'Woolfords' paddock is 195 Ha. It is undulating with 50m elevation gain from the low-lying heavily frost prone areas to the higher limestone ridges that rarely encounter a yield limiting frost event. The site is situated in a productive grain growing region at Murraytown with an average annual rainfall of 425-450mm. The field has a significant paddock history of frost, confirmed by yield maps and satellite imagery and crop scouting records (from inspection after suspected frost events). The low-lying areas of the field are affected by late season frost in September or October in 80% of seasons (as described by the grower).

**The Background**

Several years of yield data, combined with satellite imagery and elevation data has built a clear picture of where, and how dramatically the frost occurs in the field. Following is a 2016 example:

The following 3D images demonstrate the effect of late season frost on Barley yield in 2016. The bottom image is an SVI Satamap layer from late September 2016. It indicates relatively even biomass, with a CV of 13% - with the entire yield showing great yield potential due to above average winter and spring rainfall. The crop encountered a severe frost on the 26th October 2016.

Unfortunately the yield map from harvest showed a CV of 26%, with the low lying areas significantly effected by the season frost. There was a yield loss of more that 2.5T/ha in the frost affected zone.



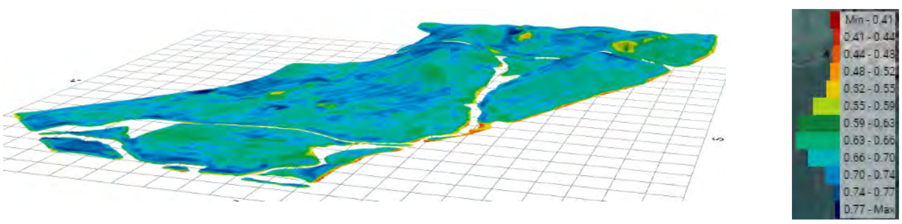




Figure 1 : Elevation Map

The 'Woolfords' paddock, along with several other fields in the valley at Murraytown are affected by frost in most seasons. Yield data, along with other precision ag data layers collected over many seasons, has shown consistent spatial patterns. It appears logical to utilise these spatial layers, to be more selective, when looking for frost effect and pre-emptive options for managing frost.

**The Process:**

We sprayed a 4 ingredient food grade product called Firestik 4 on 7/10/2021 – (a smoke derived "food grade" polyphenol solution currently used for other soil and crop applications in agriculture) on this barley crop at Murraytown. The sprayer is 36m wide. The product was applied at an average rate of 2L/ha with 100L of water on the historically (low elevation) frost affected areas of the field. As-applied product application data was recorded by the boom spray and provided an accurate record of exactly where the product was sprayed. The boom spray and the harvester are on 2cm repeatable RTK signal, which provides a lot of confidence in the placement of the product. The AB line for the harvester is the same as the boom spray on a controlled traffic system, meaning the 'sprayed vs unsprayed' sections can be easily compared by selecting these passes in the yield data.

On the 12th October the crop encountered a severe frost event with temperatures dropping to -7C overnight.

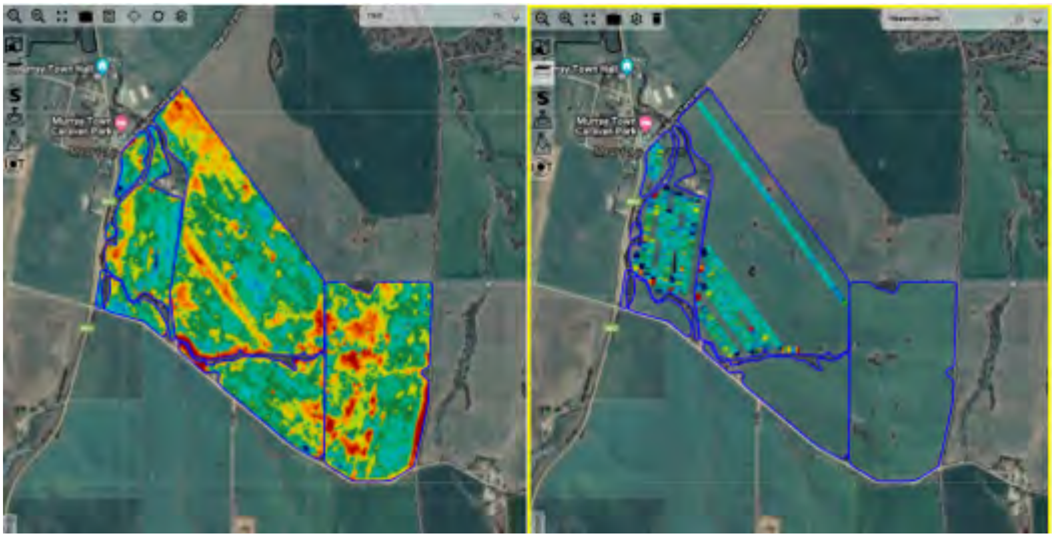


*Figure 2 - Processed, interpolated 2021 yield map on the left, as-applied Firestik 4 application data on the right*

*Figure 3 – Photo taken 14th October 2021 at 7.08pm . Visible and noticeable "frost effect" difference from foreground (unsprayed) to background (treated at 2L per Ha). Lowest elevation site in trial paddock.*

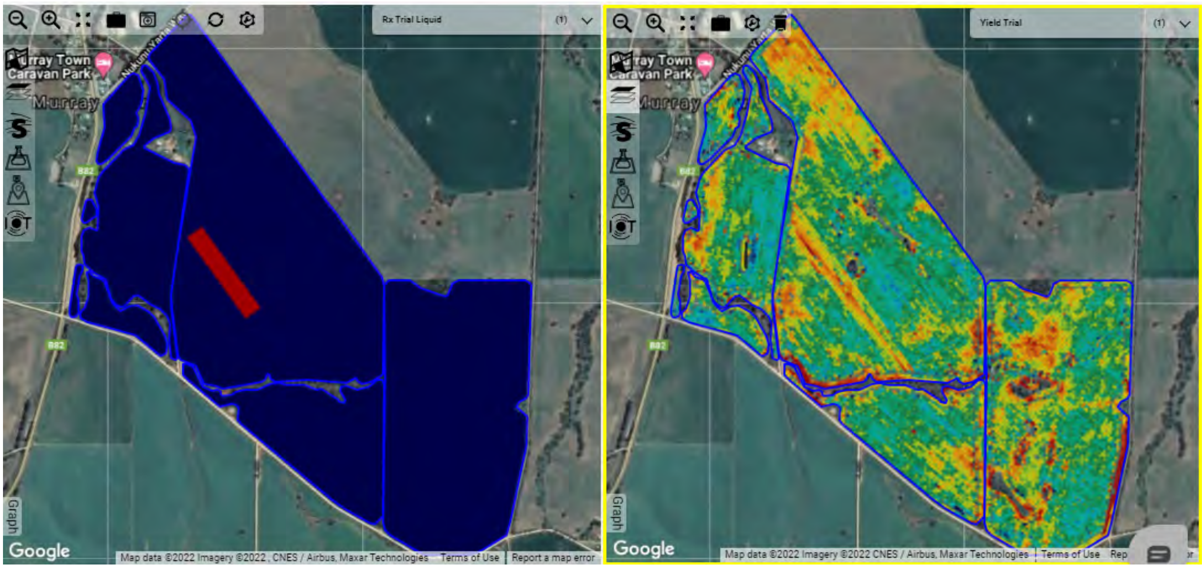


*Figure 4 - The Strip Trial Analyser in PCT AgCloud, allowed 6 passes of yield data to be compared against one another, 3 sprayed with firestik, 3 unsprayed. Example of trial strip length provided in map on left - above.*

Usually, yield maps are interpolated, or smoothed, for ease of viewing and practical purposes, such as creating prescriptions. However, in this scenario, individual passes by the harvester were considered in isolation to assess the trials, to ensure there was no ‘throw’ of data from one pass to the next from smoothing. There are three harvester(12m)passes to every pass by the sprayer (36m).

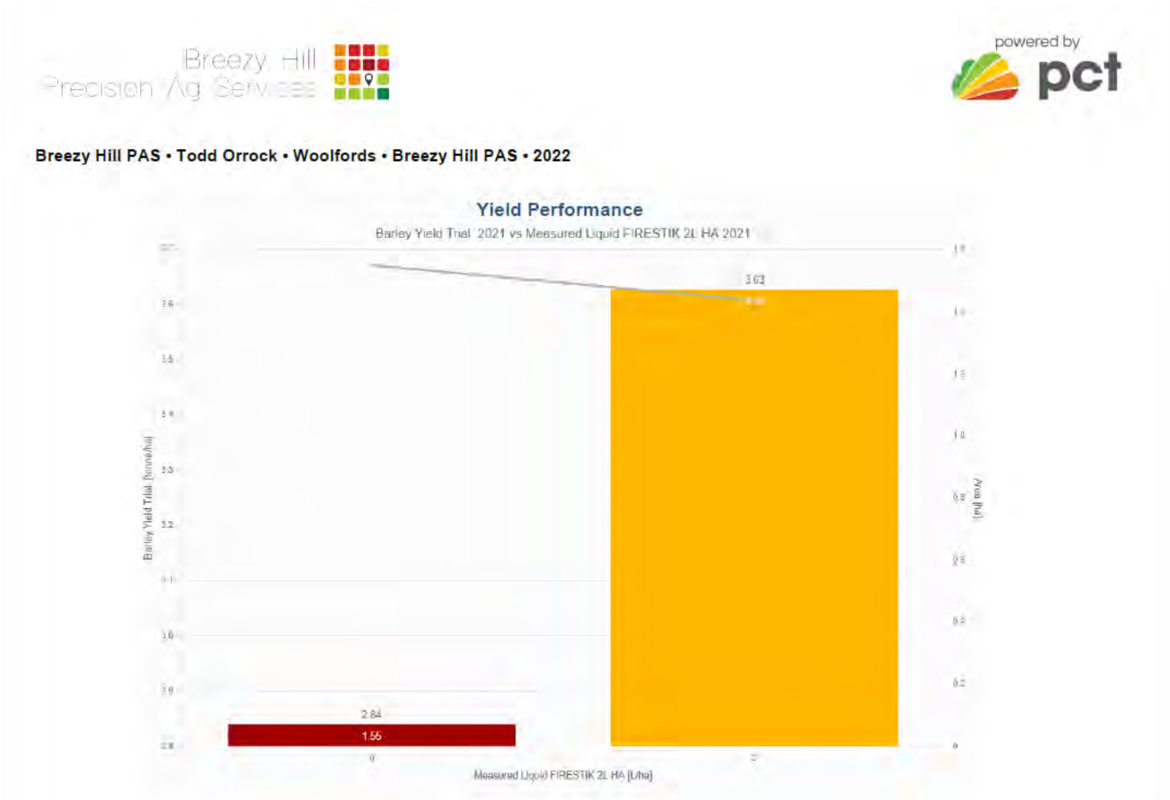


*Figure 5 - Strip Trial analysis. The left column indicates that the three passes left unsprayed had an average yield of 2.84T/ha. The three passes sprayed with 2L/ha of Firestik had an average yield of 3.63T/ha*

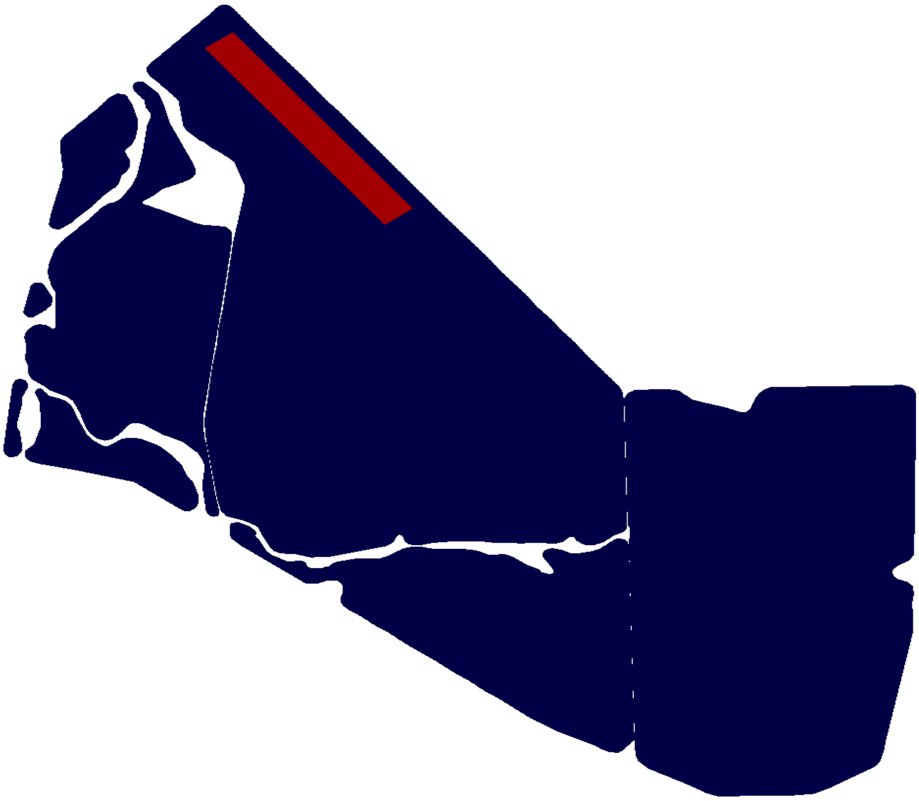


Figure 6 : Comparative site (same paddock) at high elevation as comparison

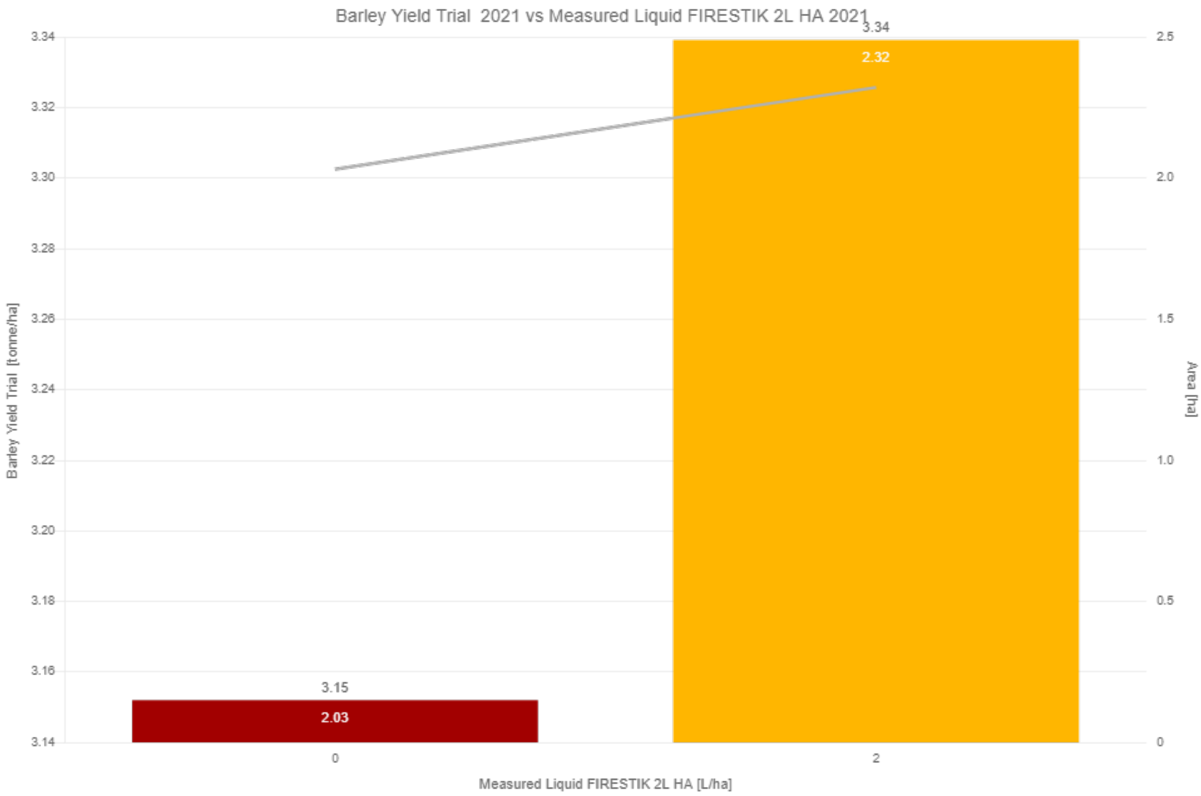



Figure 7 : Comparative site (same paddock) at high elevation - yield differential

The preliminary results indicated that there was a yield advantage when comparing areas sprayed and unsprayed with Firestik 4. There was a visual response when crop scouting and taking samples throughout the growing season, shown below.

The grain and plant samples are yet to be formally analysed, and more assessment needs to be carried out before any substantial conclusions can be drawn. This report is a review upon early data investigation and is only for discussion in relation to the potential of applied agents in broadacre cropping systems that can regulate and control ice nucleating bacteria, act as an antioxidant for management of abiotic stress (heat and cold extremes) and potentially aid plant supercooling responses at later stages of crop maturity.

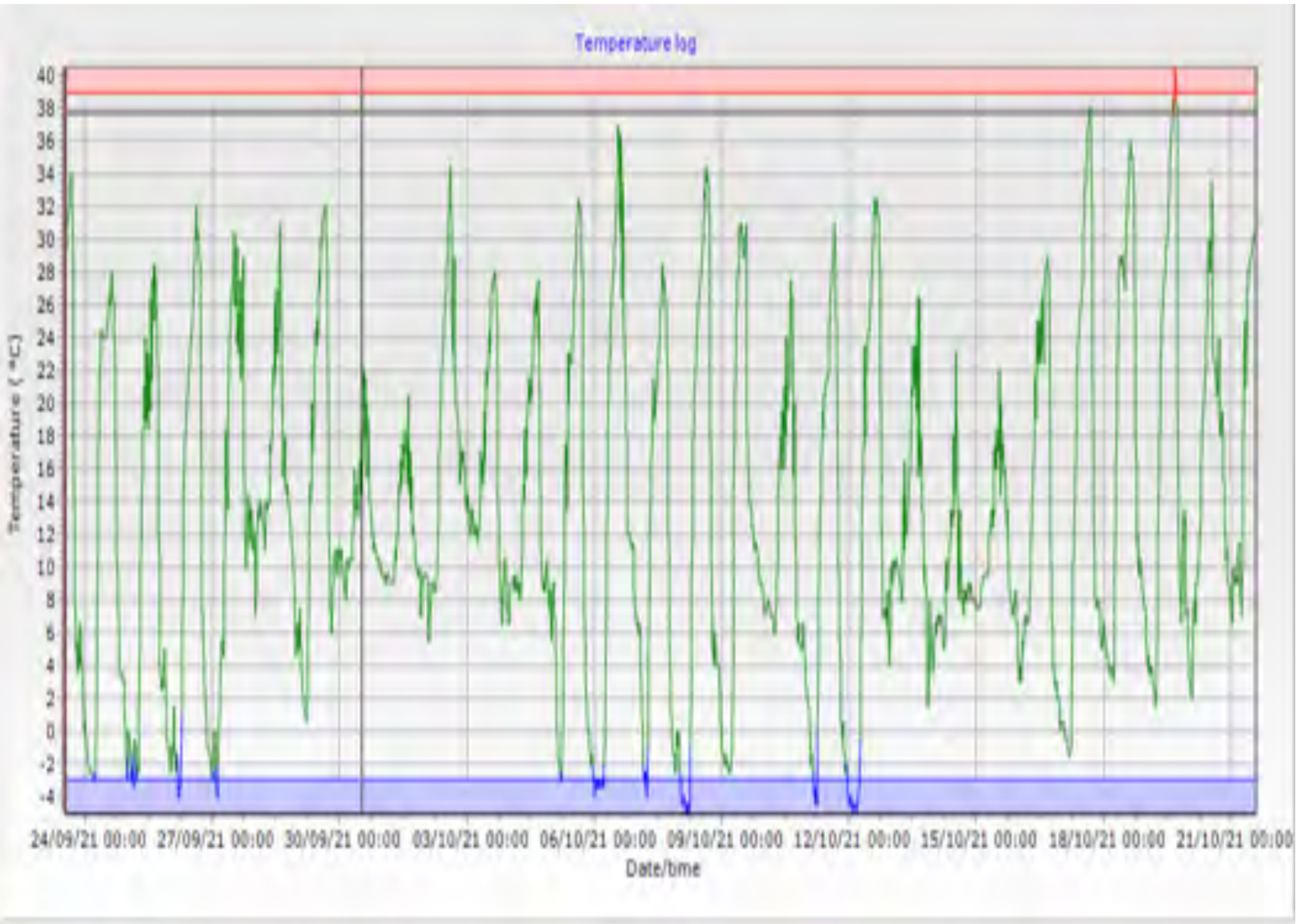



Figure 8 - Temperature Log from frost sensors at “Woolfords” trial site

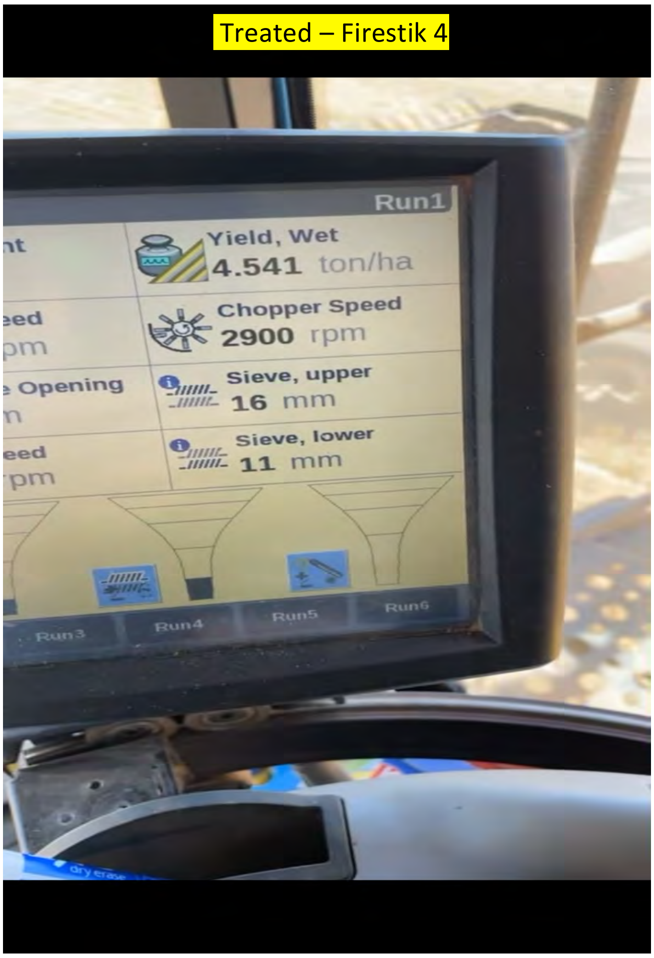






Figure 9 - Photos above are from the trial paddock when harvested by landowner. Photos are stills taken from video footage of visual change in paddock where application rate crossed in to Nil Treatment zone. Soil type, soil history, management, climate variation, aspect and elevation also play a role in determination of frost susceptibility and resilience. These factors all need to be taken in to consideration with any further investigation. As highlighted previously, this information is only a preliminary study of the potential of in crop regulation of bacterial INA (Ice Nucleation Activity) in cropping systems.

*Figure 10 - Unsprayed*

*Figure 11 – 1 pass to the south – sprayed with Firestik 4*

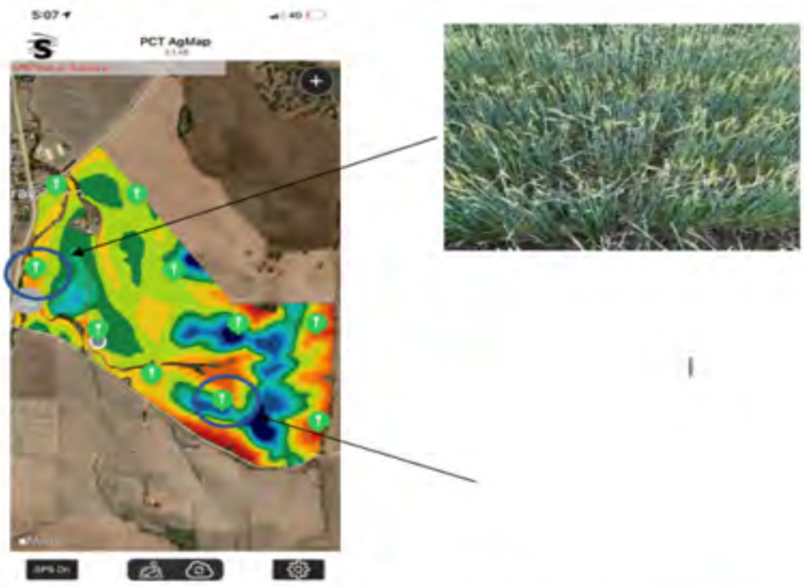



Figure 12 – A 'landscape change' map showing depressions, contours and ridges in 'Woolfords' paddock. The frost sensor locations are shown by the green pins. Photos of the crop in each location were taken on October 21st

# Addressing our sub-soil yield limitations by digging up the answers of localized soil constraints

A farmer friendly guide to subsoil management across the Upper North

Author: Beth Sleep, Elders Jamestown
Co-Authors: Jade Rose, UNFS & Ed Scott, Field Systems

*This literature review has been compiled as part of the National Landcare Program: Smart Farms Small Grants Round 4 project 'Building soil knowledge and capacity to implement change in the farmers of the Upper North Agricultural zone of South Australia. Improving soil structure and function to improve plant health, landscape function and farming system resilience'*

# CONTENTS



UNFS
Upper North Farming Systems


*This literature review has been compiled as part of the National Landcare Program: Smart Farms Small Grants Round 4 project 'Building soil knowledge and capacity to implement change in the farmers of the Upper North Agricultural zone of South Australia. Improving soil structure and function to improve plant health, landscape function and farming system resilience'*

# INTRODUCTION

This review aims to analyse available literature regarding sub-soil constraints relevant to South Australia's Upper North growing region and farming systems. These constraints were identified through a region wide survey directed at growers and agronomists in collaboration with localized soil science knowledge. It is written as part of a project funded by Smart Farms Small Grants Round 4 and will summarize some of the questions around yield limiting sub-soil constraints leading to loss of soil structure, function and management. This literature review will provide Upper North (UN of SA) farmers tools to help identify potential constraints paired with local examples of practical and cost effective soil remediation activities & best practice soil management.

01. An overview of the project and our localized soil type.

02. A review of results gained from a region wide survey. This was taken with the aim of baselining current knowledge, uptake of soil amelioration techniques and knowledge gaps that this project work aims to address.

03. The review will then break down sub-soil constraints experienced across our growing region into a series of fact sheets, summarizing what the constraint is, how to identify such constraints and discussion around common amelioration techniques.

# SOILS IN THE UPPER NORTH

This project aims to close the knowledge and language gap between farmers of the Upper North and the soil science community. Consequently, we aim to help growers identify and match yield limiting soil constraints with best practise soil amelioration techniques to ultimately achieve sustainable soil management. There are varying soil types spanning across our region, ranging from sand over sodic clay soils to hard setting red clays with limestone parent material. Soil types can change abruptly with topography and landscape, meaning farmers need an understanding of numerous soil types and how they change across our growing farm sizes. This can increase complexity of soil management, with site specific management (SSM) of soils both between and within paddocks being a good option to help match management and inputs with soil type. This project aims to consider management of both cropping and pasture soils in line with our dominant mixed-farming systems utilised across the region.

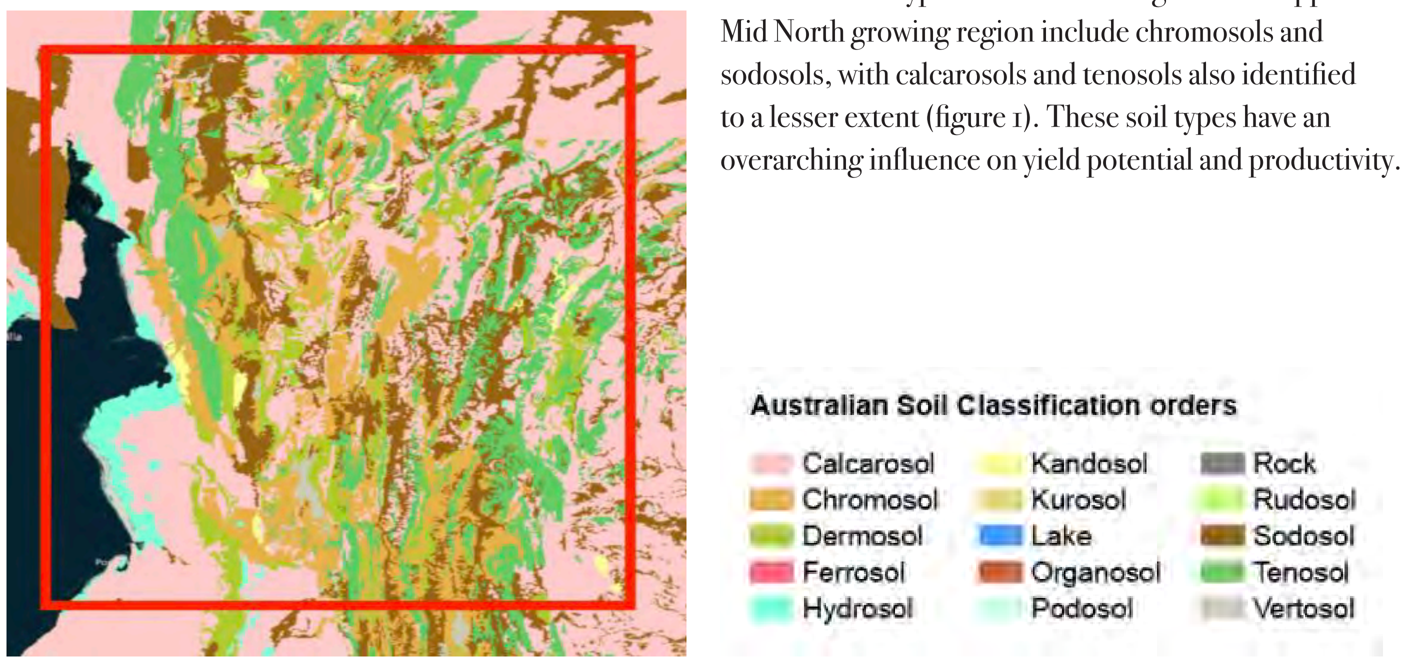



*Figure 1: A map of South Australia's Upper North region, showing the areas of different soil orders (CSIRO SoilMap 2018).*

Under long term farmer management, a shift in localised soil properties has been observed. This includes changes to pH, organic carbon (OC), electrical conductivity (EC) and nutrition. Historically described as an alkaline landscape, the district is now known to have all pH combinations, with a trend toward acidification in some soil types. Organic carbon has also fluxed throughout management history, now typically stabilised or trending upward, resulting in the slow improvement of soil structure. Some management practises accelerate this positive change which will be investigated throughout this project. Lastly, sodicity and salinity is also a dynamic factor in the landscape with areas experiencing dryland salinity, dependant on growing region and rainfall. These factors and the influence each has on crop and biomass yield will be discussed in this paper and explored throughout the lifespan of this project, assessing the viability of common and novel soil amelioration techniques available to Upper North growers.

Dominant soil types identified throughout the Upper Mid North growing region include chromosols and sodosols, with calcarosols and tenosols also identified to a lesser extent (figure 1). These soil types have an overarching influence on yield potential and productivity.

## Chromosols:

Brown and red Chromosols, such as those found in the Upper North, are typically found in well-drained areas with annual rainfall between 350 and 600 mm. Chromosols tend to have moderate chemical fertility and water-holding capacity, giving them moderate agricultural potential. Chromosols can be susceptible to soil acidification and structural degradation. The defining characteristic of a chromosol is a texture contrast soil that is not acidic or sodic in the B horizon and are rich in iron giving a red or dark brown colour

## Calcarosols:

Characterised by their calcium carbonate content, typically concentrated to the sub-soil layers. Carbonate is a type of free-lime, originating from parent material in-situ or aeolian (wind) deposition which has accumulated in the profile. Carbonate influences the ability of plants to access a range of macro and micro-nutrients. Calcarosols are found in either imperfectly drained sites where annual rainfall is up to 400 mm, or in well-drained sites where annual rainfall is between 250 and 500 mm. Calcarosols typically have low to moderate agricultural

## Sodosols:

This order is characterised by a highly sodic sub-soil but is not highly acidic (pH >5.5). Sodosols are only found in poorly drained sites, either due to low rainfall or compaction layers leading to reduced infiltration. They generally have very low agricultural potential due to their high sodicity, poor structure, high erosion risk, low permeability and low to moderate chemical fertility. Sodosols can also have problems with salinity. Sodosols are classified when the B horizon has an exchangeable sodium percentage greater than 6%. Sodosols are often

## Tenosols:

Typically, tenosols are very sandy and without clear horizons, defined as a weakly developed profile. Tenosols generally also have little structure, with high sand concentration. Typically, tenosols have lower agricultural potential due to their low chemical fertility and poor water holding capacity as a result of the high sand content. However, in marginal rainfall years, they can produce productive crops and pastures due to lower water retention which increases plant available water in low moisture environments. These soil types can

# SUBSOIL CONSTRAINTS OF THE UPPER NORTH REGION

The subsoil is defined as the underlying layers of soil beneath the topsoil that often contain less organic matter and more characteristics of the soil's parent material. This is typically less weathered in comparison to the topsoils and is generally below 300 mm from the soils surface. However, the depth can vary depending on soil formation and erosional processes. Subsoil constraints are often the elephant in the room when it comes to improving land management. Soil management is often focussed on the topsoil as this layer has greatest impact on crop and pasture establishment however in marginal rainfall environments access to subsoils and its associated moisture is a critical piece in the land management strategy. Not only do subsoil constraints such as sodicity, salinity, acidity, alkalinity, and compaction have negative impacts on crop production, but also have on going environmental impacts that influence at a landscape level. Subsoils are a major driver for overall landscape productivity, with majority of the resources required by plants concentrated to the 300-900 mm fraction of soil. Additionally, when subsoils are compromised, topsoils are of greater risk of degradation with decreased capacity to grow biomass, leading to reduced ground cover. This increases risk of erosion which can lead to the loss of the most fertile fraction of a soil profile. In soils that are less hostile, effects can sometimes go under the radar, but still significantly reduce yield potential.

## The main sub-soil limitations in the Upper North growing region, as identified by a grower and agronomist survey, are listed below.

Each of these constraints will be explored in detail, in the form of a fact sheet, discussing associated production limitations and how to best identify and ameliorate the relevant constraint.

**Soil pH imbalances**
- Acidity (low pH)
- Alkalinity (high pH)
- Macro and micro-nutrient deficiency including, but not limited to, nitrogen (N), phosphorus (P), potassium (K), sulphur (S) and calcium (Ca), zinc (Zn), copper (Cu), magnesium (Mg), manganese (Mn), molybdenum (Mo) and iron (Fe)
- Nutrient toxicity including, but not limited to, boron (B) and aluminium (Al)

**Soil sodicity (high in sodium) and salinity (high in salts)**

**Compaction**
- Low organic carbon and its impact on soil structure and structural stability
- Reduced porosity leading to lesser plant available water (PAW)

**Non-wetting soil**

**Historically eroded soils leaving exposed sub-soil, commonly either gravel based or chemically imbalanced**

**Soil stratification**
- A large difference in soil physical or chemical characteristics between top and sub-soil layers





## From the above constraints, seven case studies have been formed to help identify the best practice management for each. This is summarized below.

**Table 1. Summary table for case studies that will be completed as part of this project.**

| | Case Study Title | Treatment one | Treatment two |
|---|---|---|---|
| Case Study 1(a) | Increasing organic carbon content of soils | Controlled cell grazing with mixed annuals | Set stocking with monoculture annual pasture |
| Case Study 1(b) | | Cover cropping | Continuous cropping |
| Case Study 1(c) | | Green / brown manuring | |
| Case Study 1(d) | | Organic rich amendment spreading | Outside of treatment zone |
| Case Study 2(a) | Improving soil structure and structural stability | Controlled traffic and use of tap rooted species to create bio pores | 'Before' measurements taken at same site, 5 years ago |
| Case Study 2(b) | | Disc, stripper front and controlled traffic system | Historical soil tests to look for upward trends in organic carbon |
| Case Study 3 & 4 | Amending subsoil constraints (acidity, sodicity and compaction layers) | Ripping / spading combined with chicken manure applications | Outside of treatment area |
| | | Deep ripping with gypsum, lime and organic rich amendment at varying rates | |
| Case Study 5 | Use of precision agriculture mapping to identify and ameliorate subsoil constraints | A fact sheet developed outlining how to use PA technology to complete site-specific amelioration | |

# SOIL PH

## What is soil pH?

pH is the measurement of hydrogen ions within the soil solution and can have a large impact on the availability of nutrients to plants (figure 2). The scale begins at zero, moving up to fourteen, with a value of seven being considered neural. Anything below seven is acidic and anything above, alkaline. Ideally, productive agricultural soils should be between a pH of six to eight and ideally six and a half, as this is where nutrients are most available to plants. Soils outside this range will show nutritional deficiencies and toxicities (figure 1). pH is on a logarithmic scale, meaning moving one pH unit has a tenfold change to the amount of acidity or alkalinity.

## How are pH imbalances identified?

Typically, pH is measured in a laboratory using either a calcium chloride ($CaCl_2$) or water ($H_2O$) extraction. Typically, pH measured with $CaCl_2$ is used as this best represents what roots would experience more closely when compared to the water extraction method. pH needs to be considered through the profile and across the landscape as it can change quickly, altering management decisions. pH mapping is a great tool, available in our region, to identify such changes. Alternatively, zoned aggregate sampling and stratified layer sampling are further options.

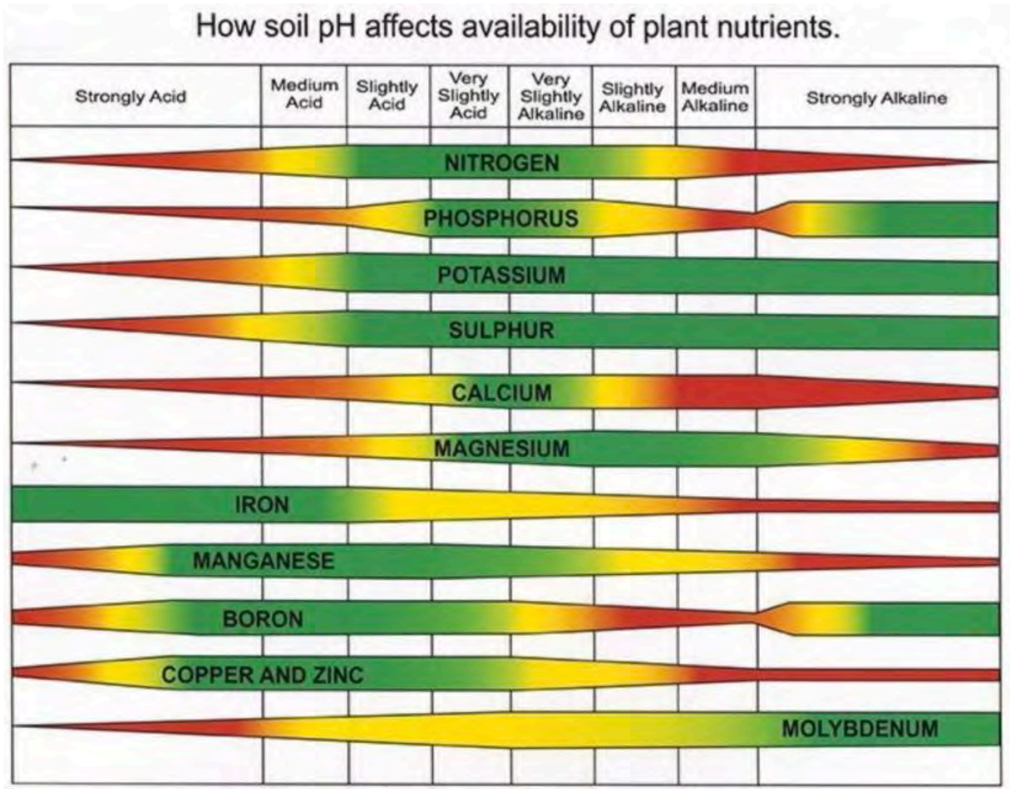



*Figure 2. pH scale showing the availability of nutrients required for plant growth (AgroBest, 2017).*

## Current amelioration techniques / management

**Soil Acidity:**

For acidic soil resources, the addition of either calcium carbonate, (lime), or magnesium carbonate (dolomite) can help correct topsoil acidity. pH corrections become more complex moving into subsoil layers as lime applications can take time to move through the profile due to low solubility and is dependent on degree of soil incorporation and rainfall. Lime rates are calculated on the desired change to pH, soil texture and quality of the lime resource. When considering quality of lime, two factors; particle size and neutralizing value, are considered. Finer sources are better when attempting to ameliorate a subsoil constraint as they have greater solubility and capacity to move through the profile. Modern land use practices are naturally acidifying our soil resources and therefore maintenance lime is now becoming necessary across more areas. This is as a result of fertiliser use, export of nutrients in the form of harvest products, incorporation of legumes into our cropping rotation (which excrete acid from roots in an attempt to increase phosphorous availability) and natural leaching of cations down the soil profile with water movement. Maintenance applications of a neutralizing product is therefore becoming increasingly important. Some growers turn to lower quality lime and dolomite sources, as these typically are lower in solubility and hence are 'slow release'. Alternatively, novel research is considering the application of bio-solids to help maintain pH, with the added benefits of micronutrients and organic carbon to the soil at the same time.

Due to our mosaic of soil types, pH within paddocks often move from acid to alkaline conditions abruptly. This can be attributed largely to the presence of carbonate out-crops/limestone parent material, typically seen in rising ground. Therefore, whole paddock aggregated sampling paired with blanket lime applications are not well suited to our area. By surveying pH change across paddocks and targeting lime application to the acid areas of the paddock, growers are better able to avoid further increasing the pH of alkaline areas in paddocks. This leaves more lime / dolomite to target acid areas of the paddock enabling the speed at which these areas are raised to a pH of 6.5 ($CaCl_2$).
The decision between lime and dolomite is based mainly on the requirement of magnesium within the soil resource. Dolomite is generally more expensive compared to lime and so if magnesium is not required, lime is typically preferred.

**Soil Alkalinity:**

Soil alkalinity cannot be as cost effectively managed with a soil amendment compared to acidic soils, but is typically managed using strategic land management decisions. In alkaline soils, plant accessibility to nutrients is significantly reduced (figure 2). This is particularly true for phosphorous, iron, copper, zinc, manganese, and nitrogen. Therefore, increased phosphorous rates resulting from the tie up of phosphorus may be required, depending on parent material of the soil. Additionally, the foliar application of nutrients in-season may address annual nutrient deficiencies. This essentially by-passes the soil to prevent tie up and loss of nutrients through entering the plant from above ground biomass. Areas of high alkalinity will also have a negative impact on herbicide efficiency, crop safety and break-down of certain applied agrochemicals which should also be considered.
Typically, alkalinity in our area is caused by carbonate or free lime within the soil resource, as mentioned above. Many of these soils are in medium to low rainfall areas, further inhibiting the use of increased fertilizers to address the increased tie up of P.

**Table 2. Neutralizing resources available to growers throughout the Upper North growing region, as identified by project work completed by Brian Hughes and Andrew Harding**

| Source | Product |
|---|---|
| Tantanoola | Dolomite |
| Coffin Bay | Lime Sand |

| Source | Product |
|---|---|
| GEM Telfords | Limestone |
| Rapid Bay | Lime Sand |
| Southern Quarries (Sellicks Beach) | Limestone |
| Henschke (Naracoorte) | Limestone |
| Penrice Quarries (Penrice) | Limestone |

# SOIL SODICITY AND SALINITY

## What is Soil Sodicity and Salinity?

Soil salinity considers the salt content of the soil; with soils high in salts severely limiting plant growth due to the reduced ability of plants to access water (osmotic potential) and nutrients (ionic potential). A vast majority of Australian cropping land is at risk of salinity due to rainfall containing small concentrations of salt, parent material introducing salts and the rising of saline water tables as a result of increased deep drainage as a result from reduced deep-rooted perennials used in our growing systems (Price 2006). In-season rainfall will have an impact on the severity of symptoms. In drier years salts are less diluted due to limited moisture within the soil profile. This makes symptoms much worse in drier years. Alternatively, wet years help salts to leach beyond the plant root zone and have a higher dilution effect, lessening symptoms. A good analogy to help explain this is a glass of cordial. In dry years, the glass has less water to help dilute the cordial and so it is stronger. However, in a wetter year, there is more water resulting in a higher dilution of the cordial.

Sodicity refers to the excessive content of sodium (Na) relative to the other cations (calcium, magnesium, potassium) on the soil exchange sites and in soil solution. Whereas salinity refers to the presence of salts (both cation (positively charged) and an anion (negatively charged)), commonly sodium chloride (NaCl), within the soil solution. A soil is classified as sodic when the exchangeable sodium percentage is greater than 6%. Soil sodicity can occur solely or in conjunction with salinity. Soil sodicity results in poorly structured soils with slow infiltration rates and poor plant available water capacity.

*Figure 3. image showing the impacts of dispersion, caused by sodicity, which limits plant establishment due to the formation of a hardpan within the top layers of soli (Tullberg et al 2007).*





## How are soil sodicity & salinities identified?

Growers can identify sodicity via a simple in-field dispersion test, where aggregates of soil are placed in a plate with water. If the soil disperses, turning the water milky, then it is reasonable to conclude the soil is sodic. However, in order to quantify the exact level of sodicity, growers are required to send soil samples away for analysis. A comprehensive soil analysis will report the exchangeable sodium percentage (ESP). This measurement will consider the sodium content in relation to the texture (cation exchange capacity) of the soil. When the ESP is greater than 6% the soil is classified as sodic.

Typically, the salts in a saline soil are introduced from the water table rising due to dryland salinity. Salts can be measured using a laboratory test, giving a reading of electrical conductivity (EC) and concentration of individual salts. Often two readings are reported, EC1:5 extract and ECe. ECe is a calculated EC that accounts for the soil texture making the EC reading easier to interpret when comparing soils of varying texture. Each of these have associated thresholds, matched with farming systems and species. Thresholds are different dependent on crop type. Barley, canola and rye grass are considered highly tolerant to salinity and sodicity compared to wheat, lucerne and peas which are moderately tolerant, and clover or medic considered low in tolerance.

*Figure 4. Example of simple dispersion test, with the sample to the left extremely dispersed and the sample to the right only moderately dispersed (Beth Sleep, 2021).*

## Current Amelioration techniques /management changes

**Sodicity**

Sodium can easily become bound to the cation exchange sites (CEC) of a soil, meaning ions are held in the plant root zone. If sodium is bound, then the application of gypsum (calcium sulfate), which replaces the sodium on the CEC of the soil with calcium, will allow the sodium salts to leach beyond the plant root zone. In some scenarios, where subsoil layers are sodic, then deep ripping in combination with deep placement of gypsum maybe required to help leach salts.

**Table 3. Gypsum products available to the Upper North growing region, as identified by the agronomist survey completed as part of this project.**

| Gypsum sources nearby; |
|---|
| Penrice |
| Morgan (subject to licensing) |
| Blyth |

**Salinity**

Salinity cannot be easily managed with a soil amendment, but rather managed with altered land care. Salts can be removed from the plant root zone via careful leaching, while water tables can be managed by increased water use efficiency (WUE) and the adoption of deep-rooted plant species into the system. In drier years, salts do not leach as much, meaning saline symptoms will be more prevalent. Crop type should be considered in these years, matching tolerance to salinity levels. Infiltration of the soil plays a big part in the leaching of salts, with compacted soils being linked to reduced water movement down the profile. Improving soil cover and reducing bare soil exposure will reduce the movement of saline water toward the soils surface from underlying layers.

# ERODED SOILS

## What are eroded soils?

Localised soils can exhibit areas of erosion, commonly concentrated to hill tops, where bare gravel rises, containing little to no topsoil (figure 6). Topsoil is typically eroded as a result of both previous land management and local hilly terrain. Repeated cultivation of these soils throughout early cropping years can cause soils were left exposed and depleted of structure. The topsoil in these areas moved to lower lying areas of the paddock, meaning depressions are generally more fertile with a thicker, productive topsoil and hill tops are shallower and often with exposed sub-soil at the surface. These are now typically found as our alkaline hill tops where free lime /carbonate has been exposed, typically lower in productivity.

Alternatively, modern day erosion is typically associated with vetch pastures or legume stubbles, where livestock are left to graze paddocks over summer. The legume residue is often not thick enough to provide adequate cover to hold together soil structure and reduce wind velocity over summer, in combination with livestock moving across the paddock.

## Current Amelioration Techniques /Management Changes

Due to significant soil loss, eroded hill tops generally require longer term amelioration strategies. These areas are essentially functioning with a pseudo-topsoil comprising of the exposed subsoil material, which takes decades to function as a more typical topsoil. The addition of organic amendments to these areas can help to accelerate the process of building structure, function and promoting biological activity. These hilltops are often alkaline in nature, resulting in nutrient availability and agrochemical safety should be considered, as mentioned in the pH section of this review.

Legume based pastures such as vetch, are often utilized as a cereal root-disease break crop. Therefore, growers are often hesitant to add a cereal or brassica species to the diversify the mix due to complexity in weed and pasture management. Where this is an option, the addition of another species can help to hold the soil resource together over summer. However, where this is not an option, rotational grazing may be a better fit. This increases the ability to control how the paddock is being grazed and can help to maintain reasonable levels of ground cover over the summer period.

*Figure 5. A soil core collected on an eroded hill top, highlighting the missing fertile top soil layer reducing in delayed and patchy crop emergence which limits yield potential.*
*Photo source, Beth Sleep*





# COMPACTION

## What is compaction?

Soil compaction is defined as an increase in soil bulk density. Soil compaction is a physical constraint that induces a variety of issues such as reduced water and nutrient holding capacity, reduction of porosity which impacts water and root movement and suppresses microbial activity. One major factor contributing to a lack of soil structure is a deficiency in soil organic matter which acts as a glue, holding together primary particles to form the primary structure of a soil. Sandy soils are more prone to soil compaction; however, compaction is observed right across our growing region. Compaction is also associated with various other negative implications such as soil erosion or the occurrence of dispersion and can be linked with sodicity.

## How is compaction identified?

Soil compaction is defined as an increase in soil bulk density. Soil compaction is a physical constraint that induces a variety of issues such as reduced water and nutrient holding capacity, reduction of porosity which impacts water and root movement and suppresses microbial activity. One major factor contributing to a lack of soil structure is a deficiency in soil organic matter which acts as a glue, holding together primary particles to form the primary structure of a soil. Sandy soils are more prone to soil compaction; however, compaction is observed right across our growing region. Compaction is also associated with various other negative implications such as soil erosion or the occurrence of dispersion and can be linked with sodicity.

## Current Amelioration Techniques/Management Changes

There are various methods growers can employ to reduce the effects of compaction. Among these include increasing organic carbon levels within the soil. This may include reduced soil disturbance associated with seeding practices, the use of stripper fronts or increased stubble retention. The reduced disturbance of soil with seeding operations reduces the loss of carbon into the atmosphere with the introduction of oxygen into the top-soil layers. Alternatively, stubble retention or the use of stripper fronts acts to increase the amount of carbon cycling, sequestrating carbon into the soil resource. Other more novel methods used to increase carbon content of a soil include spreading carbon rich products such as bio-solids and animal manures or growing green/brown manure crops. The continual incorporation of organic matter acts to hold aggregates together, forming a primary level of structure within the soil. Some soil types will require physical intervention such as ripping or delving to alleviate the soil compaction, then best management practice for soil cover and reduced disturbance are employed post strategic physical soil intervention.

Tap rooted species, such as canola, can be used to create ‘bio-pores’ within a compacted soil. These species can exert a greater pressure, in contrast to cereals, to push through compaction layers, leaving channels for following crops to then utilize and build on. This can expose soil layers that were previously inaccessible to plants, increasing plant access to moisture and nutrients.

In addition to the above, the use of controlled traffic farming can help to concentrate compaction within paddocks, with traffic being identified as a primary cause of compaction.

The trafficability of a soil resource should be considered before driving over a paddock. Increased water content, the soil becomes more susceptible to compaction. With the boom spray being the most common implement driving over soils throughout winter, when soils are at the highest moisture content, it may be a viable option to follow controlled traffic for the boom spray, as a minimum. This takes away the pressure of changing axle widths on all machinery, if you have not already do so. Likewise, moisture content should be considered before deep ripping a paddock.

Ripping when the soil resource is too wet can result in ‘smearing’, creating vertical compaction columns where ripping was attempted.

# NON-WETTING SOILS

## What are non-wetting soils?

A soil is considered non-wetting if it does not absorb water but actively repels (beading) water after its application to dry soil. Hydrophobic or water repellence is commonly associated with sandy textured soils. Hydrophobicity occurs when waxes from organic matter coats sand particles, significantly decreasing the ability of the soil profile to infiltrate water. This leads to irregular infiltration and reduced plant growth due to limited water availability (figure 3). With this comes increased likelihood of erosion due to limited ground cover and land becoming unproductive, with sand being highly susceptible to water erosion due to poor structure.

## How are non-wetting soils identified?

Unlike many other soil constraints, non-wetting soils are easily identified without sending away any samples for laboratory analysis. If water droplets bead after being applied to the soil surface, that soil is considered non-wetting. Non-wetting sands can be easily identified indirectly using in-season NDVI maps, showing a difference in biomass and establishment, with poorer areas potentially non-wetting.

*Figure 6. Non-wetting sand soil profile, using blue dye to illustrate the irregular infiltration of water down the profile (The Observer 2018).*

**Table 4 . A summary of symptoms that can be used to assess the severity of water repellence (Agriculture and food WA, 2018).**

| Severity of water repellence | Typical visual symptoms | Water droplet penetration time (seconds) |
|---|---|---|
| Mild | Estabishment impacts in dry seasons only and with early dry sowing. Small lengths crop row missing, typically less than 50cm of row. Water entry generally good but small dry patches can be found after small rainfall events. | 10-60s |
| Moderate | Establishment impacts in many seasons but less pronounced or non-existent in seasons with a wet break and consistent follow-up rains. Water ponds on surface after rain for up to 5 minutes.<br><br>Moderate lengths crop row missins, up to 100cm row. | 60-240s |
| Severe | Establishment impacts in all season, very poot establishment in most seasons, large gaps in crop rows, with gaps up to 100cm or more of row common. Water ponds on the surface after rain for up to 10 minutes or more. Large patches of poor crop establishment and growth. | >240s |
| Very severe | Establishment very poor in all season, sparse crop establishment. Large patches of missing crop and poor emergence, very sparse crop. Water pond on the surface after rain for more than 10 minutes. | >240s |

## Current Amelioration techniques /management changes

Unlike many other soil constraints, non-wetting soils are easily identified without sending away any samples for laboratory analysis. If water droplets bead after being applied to the soil surface, that soil is considered non-wetting. Non-wetting sands can be easily identified indirectly using in-season NDVI maps, showing a difference in biomass and establishment, with poorer areas potentially non-wetting.

In texture contrast soils where there is a suitable source of clay in the sub-soil, this can be delved or spaded, depending on the depth of the source, to bring clay to the surface horizons. The clay source should first be tested for pH, chemical composition, salinity, and mineralogy to ensure it is suitable. The addition of unsuitable clay could lead to further constraints such as soil alkalinity or high free lime content. A technology enabling producers to identify areas where clay is present in the sub-soil is electromagnetic soil mapping (EM-38 survey). This can produce maps directing the grower to exact areas of paddocks were spading and delving are a viable option, avoiding shallow rock or areas lacking clay.

If there is an absence of clay down the profile, then clay needs to be brought in from another source and spread. Typically, this is a less economical option in contrast to delving or spading. Alternatively, manures or bio-wastes can be applied to the soils to add organic matter, contributing to soil structure. These can be sourced from animal feedlots, chicken farms or from waste treatment plants. A major consideration when spreading manures or bio-wastes is heavy metal contaminants. These can accumulate with the repeated use of these produces. Additionally, caution must be taken when apply such amendments, as they can contribute to hydrophobicity.

A cost effective annual option is the application of surfactants/ wetting agents, applied at sowing each year. These products are a temporary solution and therefore need to be re-applied each season.

# SOIL CHEMICAL STRATIFICATION

*Figure 7. Soil taken from an open profile with PH indicator dye applied to each sample. This shows how pH changes down the profile, with an 'acid throttle' shown at this particular site Photo source, Michael Eyres.*

## What are Soil Chemical Stratification?

Stratified soils are characterized by soils which abruptly change either chemical or physical properties when moving from the topsoil into the subsoil. This can change the way in which water moves through the profile and can also 'shock' the root system of plants, resulting in the lateral growth of roots after hitting these layers. If this is occurring, all resources beyond these layers are no longer accessible to the plant and hence resulting in a limitation to yield. This is becoming more frequently observed as a result of the concentration of inputs to the upper layers of the soil resource and is observed more commonly in lower rainfall regions due to reduced water infiltration to help move resources throughout the soil profile.

An example of a change in soil chemistry, commonly observed in our area, is a change in soil pH. For example, the topsoil may be alkaline, resulting from the application of lime to the soil surface. However, when moving down the profile, it may become acidic as a result of limited downward movement of lime to these soil layers (figure 7).

Alternatively, a similar phenomenon can be observed with clay layers. Over time in some soil profiles, clay leaches down the profile and concentrates in a narrow band somewhere throughout the subsoil, resulting in a sudden change to soil texture. This layer is often a zone of accumulation which slowly 'collect' salts and other elements within the soil over time, resulting in a hostile layer that roots struggle to move past, rendering the lower soil layers inaccessible even if they are not hostile This layer is often a zone of accumulation which slowly 'collect' salts and other elements within the soil over time, resulting in a hostile layer that roots struggle to move past, rendering the lower soil layers inaccessible even if they are not hostile vThis layer is often a zone of accumulation which slowly 'collect' salts and other elements within the soil over time, resulting in a hostile layer that roots struggle to move past, rendering the lower soil layers inaccessible even if they are not hostile (figure 8).

## How are stratifications identified?

A soil pit or core can help to identify these layers. Tracking root growth throughout spring is also another way of identifying a hostile layer.

Field pH assessment utilizing a kit, such as Manutec pH kit, to identify where pH changes occur in the field. The identification of free lime in a profile can be readily identified with a solution of dilute hydrochloric acid (1 part HCl:10 parts water), when applied to the soil any layer with free lime present will effervesce. Both tools are available from a typical hardware store.

## Current Amelioration Techniques / Management Changes

Novel approaches are currently being researched, as this is a newly identified limitation in agricultural production. Many of these include strategic tillage operations such as deep ripping and mixing of the soil resource or deep placement of soil amendments. Alternatively, soil biology can become important, helping to 'mix' the soil resource, making the profile more uniform. Promoting biodiversity throughout the soil resource is achieved with increased organic carbon, the energy source utilized by soil biology. Alternatively, the use of liquid amendments may help to increase the movement throughout the profile. This will however likely come at an inflated economic cost to the grower.

*Figure 8. An open soil pit, showing a duplex type face. The top fraction of soil shows good porosity with texture increasing abruptly at approx. 50 cm's. This may inhibit root growth past this point.*

# CONCLUSION

Soil resources are integral to any farming system, acting as the medium for plant growth, nutrient and water holding and biological cycling. Soil resources must be managed thoughtfully, ensuring soil constraints which limit productivity are remediated. As discussed in this paper, there is an array of agricultural innovations and technologies that growers can employ which manage these constraints and correct underlying issues. These are summarized in the table shown on the right.

These management techniques will be considered in the form of case-studies by this project to help identify the most economical options available to Upper North growers. As part of these case studies, different long-term management techniques will be identified throughout our growing region and necessary soil characteristics will be measured.

## Managing acidity, alkalinity, sodicity and salinity



**Table 5. adapted from CRC and Land Management 2006.**

| Surface Soil Constraint | Sub-Soil Constraint | Management |
|---|---|---|
| Acidic | Acidic | Add lime |
| | Alkaline & Sodic | Add lime first then;<br>Add gypsum<br>(consider deep-ripping to incorporate gypsum) |
| | Saline | Add lime<br>Maintain or add surface cover (additions of straw are beneficial to reduce surface evaporation)<br>Plant deep rooted perennial such as lucerne<br>Look at water table and lower if needed |
| Neutral | Acidic | Add lime<br>(consider deep-ripping to incorporate lime) |
| | Sodic | Add gypsum<br>(consider deep-ripping to incorporate gypsum) |
| | Saline | Maintain or add surface cover (additions of straw are beneficial to reduce surface evaporation)<br>Plant deep rooted perennial such as lucerne<br>Look at water table and lower if needed |
| Alkaline | Sodic | Grow tolerant crop<br>Add gypsum<br>(consider deep-ripping to incorporate gypsum) |
| | Acidic | Deep rip and apply lime only to sub-soil |
| Sodic | Sodic | Add gypsum<br>(consider deep-ripping to incorporate gypsum) |
| | Saline | Add gypsum<br>Maintain or add surface cover (additions of straw are beneficial to reduce surface evaporation)<br>Plant deep rooted perennial such as lucerne<br>Look at water table and lower in needed |
| Saline | Any other mixture of constraints | Correct salinity before adding any other amendment<br>Maintain or add surface cover (additions of straw are beneficial to reduce surface evaporation)<br>Plant salt tolerant plants to start building cover |
| Sodic & Saline | Sodic & Saline | Control salinity<br>Control strip of gypsum |
| Non-wetting | Compaction | Incorporate clay or organic carbon<br>Utilise wetting agents at sowing |
| | Acidic | Incorporate clay or organic amendment then;<br>Add lime and consider deep ripping or delving<br>Utilise wetting agents at sowing |
| | Sodic | Incorporate clay or organic amendment then;<br>Utilise wetting agents at sowing<br>Add gypsum and consider deep ripping or delving |

# GLOSSARY

- Acidity/ acidic: A pH below 7
- Alkalinity / alkaline: A pH above 7
- Sodicity / sodic: Excess sodium within the soil resource
- Salinity / saline: Excess salts (this could be sodium, chloride etc.) within the soil resource
- Clay: A primary particle smaller than 2 microns in size
- Loam/silt: A primary particle between 0.05 and 0.002 mm in size
- Sand: A primary particle between 2.00 and 0.05 mm in size
- Gravel: A fragment that is greater than 2 mm in size
- Carbonate: A fragment of undissolved lime, with a pH generally ranging from 7 up to 8.5.
- Aggregate: Primary particles (clay, silt or sand) bound together to form structure
- Soil Amendment: A substance added to the soil resource to improve its physical or chemical characteristics, such as lime or gypsum
- Cation Exchange Capacity: The negative change of the soil, gained from clay and organic matter particles, allowing the soil to hold cations within the soil resource
- Organic Matter: The by-product from the breakdown of plant and animal material
- Plant available Water: Water which is available to the plant root within that particular soil fraction
- Soil Structure: This refers to the way in which primary particles are arranged within the soil resource. Generally, the more pore space between particle, the better structure is.
- Structural Stability: The ability of a particular soil to hold onto structure under various conditions such as trafficking
- Compaction: The mechanical compression of soils from machinery or animals moving over a soil resource – a loss of soil structure
- Leaching: The movement of nutrients, salts or amendments down the soil profile with the movement of water
- Micronutrient: Nutrients that plants require in small amounts including boron, chloride, copper, iron, manganese, molybdenum and zinc.
- Macronutrient: Nutrients that plants require in large amounts including nitrogen, Sulphur, phosphorous and potassium
- Buffering capacity: The ability of a soil to buffer against change, for example a change in pH
- Soil texture: The combination of primary particles (clay, silt and sand), giving an other all soil texture
- Subsoil: The underlying layers of soil beneath the top-soil that often contain less organic matter and more characteristics of the soil's parent material. This is typically less aged in comparison to the top-soils and is generally below 300 mm from the soils surface.

## Other useful resources

- Australian Soil Fertility Manual – G. Price
- UNFS Penetrometer – available to loan by Upper North growers
- Previous projects conducted by UNFS grower group;
    - Micro-nutrients in the Upper North (2017-2021)
    - Maintaining profitable farming systems with retained stubbles in upper north SA (2013-2018)
    - Application of controlled traffic farming in the lower rainfall zone (2014-2019)
    - Vetch on saline and sodic soils
    - Warm and cool season mixed cover cropping trial for sustainable farming systems in SE Australia (2019-2022)

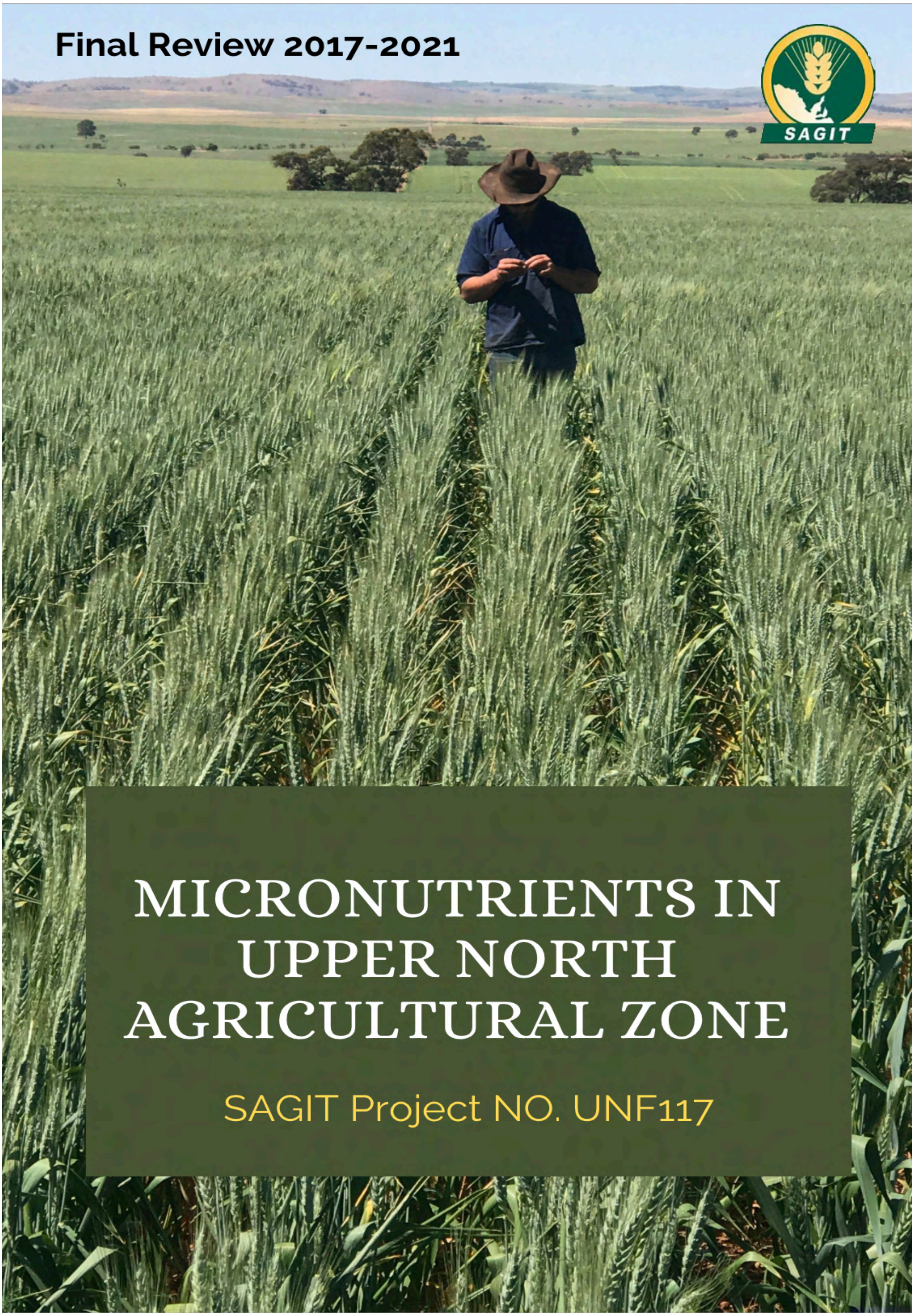


# COMMON SOIL TESTING STRATERGIES

**Table 6. Soil sampling strategies than can be used to gain soil data.**

| Sampling Strategies | Definition |
|---|---|
| Top soil testing | A 0-10 cm core |
| Deep soil coring | A deep core, typically to 90 cm's, split into horizons or 0-10, 10-30, 30-90 cm increments |
| Transect aggregated soil sampling | A series of cores taken in a transect across a paddock, mixed to get the average of a paddock |
| Random aggregated soil sampling | A series a cores taken in random locations across a paddock, mixed together to gain an average of the paddock |
| Zoned aggregated soil sampling | A series of cores taken in a particular zone of the paddock (as determined using special maps), mixed together to gain an average of the area. |
| Grid mapping | Cores taken in a grid pattern (typically 100 m x100m), sampled individually and then used to generate a special map of the paddock |
| Soil sensing using swath widths | On-the-go technology which takes readings in swath lengths that can then be extrapolated into a map afterwards. Eg. Em38 or yield monitors |

*Figure 9. A soil sampling set up, used for soil survey work (photo source, Michael Zwar).*



Final Review 2017-2021

SAGIT

# MICRONUTRIENTS IN UPPER NORTH AGRICULTURAL ZONE

SAGIT Project NO. UNF117

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|---|---|
| **Project Code & Title** | **Project Code: UNF117**<br><br>**Project Title: Increasing the knowledge and understanding of micronutrient deficiency in the Upper North Agricultural Zone** |
| **Commencement** | 1st of July 2017 |
| **Finish date** | 30th of June 2021 |
| **Project Participants** | Upper North Farming Systems |
| **The Problem** | The Upper North Agricultural Region of SA is often characterised by low and unreliable precipitation, later than optimal opening rains, significant persistent wind, cold winters, soil performance variability, hot dry spring finishes and significant frost events. The problem for farmers in the Upper North has been access to critical locally derived nutrient management information to allow confident use and application of micronutrients in their cropping systems. These critical micronutrients need to be cost effective and show a return on investment despite the large variance in seasonal growing conditions. Identifying the critical thresholds, timing of application and volume and type of application for micronutrient use is necessary to refine the management and cost strategies for low rainfall dryland cropping farmers in South Australia. |
| **The Research** | Determination of critical crop and soil micronutrient management information and field application timing for improved crop performance across major soil types in any given cropping season in the Upper North. |
| | |
| **Caption** | Micronutrient Management Strategy in Upper North Agricultural Zone |
| | |
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# Introduction

The SAGIT funded Micronutrient Project undertaken by UNFS from July in 2017 until end of June in 2021 was of paramount importance to farmers and land managers in the Upper North Agricultural Region. Despite three very dry and yield limiting seasons from 2017 – 2020, the objectives of the project were thoroughly researched, validated and carried out by UNFS, although the expectations and anticipated results were not entirely favourable due largely to seasonal constraints (low rainfall , abiotic heat stress and high frost susceptibility). The trial information, data collation, data processing and subsequent annual summaries were completed professionally and annual trial reviews have consistently been made available as reference material to all farmers throughout the Upper North and throughout all growing regions of South Australia. The primary objective of the Project was to ascertain and understand the relationship of selected trace element use (type and volume) on the general profitability and field performance of dryland farming systems of the Upper North.

The objective of the original literature review was to analyse literature pertaining to micronutrient use in South Australia's Upper North region. As an integral part of the project funded by the South Australian Grains Industry Trust, the original review explored the scope and breadth of the potential role of micronutrients as appropriate inputs for commercial farming operations in the Upper North.

This information within the review was used to encourage and drive discussions with researchers and agronomists within the region of the Upper North to determine the existing boundary conditions of micronutrient use in the region (both current and historical). Extremely good evidence of former use, evidence of effect and potential viable role of micronutrient use was well represented in the review. The SAGIT funded project for the Upper North was an important step forward for increasing commercial viability of growers in relation to nutrient evaluation and use

It was recognised that historically there had been been limited research into micronutrients use and application in the Upper North and farmers have had to previously largely rely on external data sources for information to suit their own specific cropping systems. The SAGIT funded Micronutrient trial work has been extremely valuable to highlight the importance of nutrients in their own right, but also deficiency, inefficiency of nutrient supply and indeed sufficiency (high values of one nutrient suppressing uptake of other nutrients).

Many and varied factors were reviewed in relation to relative importance and acted on within the project guidelines and timelines. Soil variability, land management strategies, climate considerations, form and availability of nutrient, volume of nutrient uptake, timing of application and cost effectiveness within Upper North farming systems were all considered appropriately.

Inherent soil properties are significant determinants of seasonal micronutrient availability in the Upper North and all modern farming practice implications can also be important. There is considerable evidence also that conservation tillage and consistent use of certain groups of herbicides can reinforce, exaggerate and enable certain micronutrient deficiencies. Seasonal climate variation certainly creates the performance boundaries of differing soil types in the Upper North.

Micronutrient deficiencies can be corrected, but as Norton, Laycock and Walker (2012) caution against just treating them as the next limiting factor once macronutrient needs have ideally been met. As they note, quite often moisture is limiting, and if farmers are going to invest in micronutrients, it is crucial that the situation is diagnosed and treated correctly. Otherwise, steps taken to improve micronutrient status may end up either not working or else not being cost effective

In reference to the UNFS Micronutrient Project findings, zinc, molybdenum and copper are considered the micronutrients of most interest in the Upper North. Deficiencies are primarily caused by inherent soil values, soil condition and characteristics, and changing farming practices could also have a defining influence. There is strong evidence in the literature that soil and plant tissue testing are, in combination, the most reliable methods for detecting micronutrient status. There are still many gaps in the knowledge surrounding the exact extent of micronutrient deficiencies and inefficiencies in the Upper North region, and there is a genuine need to further identify in more "normal" seasons whether it is ultimately cost effective to utilise and promote their specific use.

## Background

Soil evaluation and general soil type assessment from a taxonomy perspective (Chromosol, Tenosol, Sodosol, Calcarosol) and wet chemistry (laboratory) perspective were well considered and included in initial review. Effects of management practice change over time, herbicide use and effect, and crop cultivar physiological capacity were included for their effect on micronutrient availability and subsequent potential effect. Measurement techniques including soil analysis, plant tissue sampling and grain analysis were all reviewed on individual merit, and it was concluded that no one testing method was more accurate or valuable than any others. Testing to be considered needed to engage with all suggested methods to allow greater accuracy in interpretation.

With discussion that evolved in the literature review it was agreed to ameliorate suspected micronutrient deficiencies in the SAGIT Micronutrient crop trials with post emergent crop foliar application only. The functional role of micronutrients for plant growth, rhizosphere exchange, microbial growth and ultimately yield is essentially to provide small amounts of trace elements to assist with essential soil and plant functions. The essential micronutrients for biological growth are iron, manganese, zinc, copper, boron, molybdenum, cobalt, chlorine and nickel. Soil type, in particular, along with farming practices, cropping rotation, seasonal conditions, and fertiliser and herbicide applications are all factors that influence the availability of micronutrients for crop growth. Depending on the combination of these factors, some micronutrients will be more available in the soil than others and will potentially impact crop yield when present at deficient or toxic levels.

The UNFS literature review identified copper and zinc to be the two micronutrients most likely to be deficient in soils of the Upper North region. Soils in the Upper North are generally classed as chromosols and sodosol soil types, with smaller areas of calcarosol and sandier tenosol soils. Copper and zinc deficiencies are most common in alkaline, sandy soils and both become less available for plant uptake in drying soil conditions. Both nutrients are immobile in the soil, with potential deficiencies being exacerbated with reduced tillage practices. Wheat and barley are most likely to be impacted from copper deficiency, with symptoms being similar to frost and heat stress around flowering (anthesis). Zinc deficiency will show up more in cold conditions early on in the season, with symptoms in cereals looking like stunted growth with opaque yellow stripes on leaves turning often into necrotic lesions. Both copper and zinc deficiencies can be exacerbated through the use of Group B herbicides (i.e. sulfonyl ureas). Molybdenum is also a micronutrient that growers in the Upper North region have shown interest in. In the past there has been limited work undertaken specifically in the Upper North region to illustrate increased yield potential, and hence the economic value of investing in micronutrient inputs. Whilst soils in the region aren't known to be deficient in any particular micronutrients, growers in the region have been interested in understanding the plant response to additional micronutrient nutrition and understanding what soil types may be responsive in varying seasonal conditions. Naturally there won't be an economic response to micronutrient application each season, with other significant factors such as moisture stress, certain biotic stresses, and the effects of heat and frost underpinning crop productivity in the Upper North region.

## Research Aims

The UNFS Micronutrient Project pursued four distinct functional aims:

- The identification of soil types in the upper North that are responsive to micronutrient application.
- The demonstration of different methods of application of micronutrients.
- An increase in the knowledge of farmers in the Upper North in relation to micronutrients and their roles in plant development and yield potential.
- An increase in Upper North farmers' understanding of soil types and their inherent and seasonally dynamic potential for micronutrient tie-up or deficiencies.

The core objectives of the UNFS Micronutrient project were to:

- Demonstrate for Upper North a post emergent micronutrient strategy predetermined by available legacy data sets to determine micronutrient type, form, volume, and application timing
- Determine most cost-effective micronutrient strategies for use in Upper North based on mid-season plant tissue uptake and end of season yield and grain quality parameters.
- Identify the optimal micronutrient use strategy for cropping systems managed within the typical annual seasonal constraints experienced in the Upper North.
- Identify management guidelines for micronutrient application and use based on soil condition and type and plant assessment for the primary cropping cultivars / varieties grown in the Upper North.

# In the Field

The three trial seasons, (2017 was Literature Review only) ,2018, 2019 and 2020, exposed the annual cropping trials to a wide variety of growing conditions – significantly below average rainfall for 2018, very dry conditions in 2019 and more of what would be termed typical growing season conditions in 2020, that unfortunately however included low stored soil moisture to depth for the duration of the growing season.

In each successive year of the Micronutrient Project different trial sites were selected to represent the different soil management zones.

There are four primary farmed soil groups in the UNFS cropping zone that were deemed as most broadly typical of the areas landscapes. UNFS incorporated all four neutral to alkaline soil types in relation to trial site consideration, position in the landscape and annual trial placement. The four soil types defined were as follows:

Chromosols (soils with a strong texture contrast between surface and subsurface horizons and with subsoil horizons that are not sodic and have an alkaline reaction trend),

Calcarosols, which are gradational textured soils with an abundance of carbonate ('free lime') in the profile,

Sodosols, soils with a strong texture contrast between surface and subsurface horizons and with subsoil horizons that are invariably quite sodic.

Tenosol, the 2020 trial site also included a deeper sandy Aeolian (wind-blown) profile near Port Germain with weak soil profile development.

The 2017 Micronutrient literature review, by process of academic deduction and considered field experience, highlighted that copper and zinc were the key micronutrients most likely to be deficient in Upper North soil management systems with some regions potentially also being low on manganese and boron (Both manganese and boron in some soil horizons of the Upper North region may be considered at toxic levels so this was factored in). Molybdenum was also considered with interest as a key micronutrient due to its known influence on nodulation and performance in pulse crops, which are critical cultivars in UNFS cropping rotations. This rationale determined the micronutrient species considered and used in the trial project.

Measurements taken through each growing season included sowing date, soil, plant tissue and field assessment, growth factors, yield (if harvested) and subsequent grain quality parameters.  Rainfall and growing season climate variance was also monitored throughout the trials.

**2018:** The 2018 trial involved the foliar application of two micronutrients (zinc and copper) at two wheat (cereal) trial sites (Carey and McCallum), and two micronutrients (zinc and molybdenum) at one lentil (legume) trial site (Koch). These micronutrients were applied as a range of selected commercially available products, to compare both the performance and the field response of selected foliar micronutrient treatments on crop yield and plant nutrition.

There was no significant difference in grain yield between the micronutrient treatments at each of the three selected trial sites. Both the wheat, and the one lentil trial site (Koch) were under significant moisture stress for most of the 2018 growing season. There was no significant difference between each of the micronutrient treatments for zinc or copper levels in the wheat tissue samples at the McCallum trial site. This indicates that none of the micronutrient treatments or products had an effect on wheat nutrition at this particular site in 2018.

Plant tissue samples were also taken on 3/7/18 on the wheat at the McCallum site, prior to any foliar micronutrient applications. The samples were taken of the youngest emerged leaf blade (YEB) at the early to late tillering growth stage. Results showed sufficient levels of zinc at 32mg/kg, sufficient levels of copper at 9.9mg/kg, and sufficient levels of phosphorus (0.33%) and nitrogen (5.2%). This suggests that the plants were not experiencing any micronutrient deficiencies or were phosphorus or nitrogen deficient prior to the foliar applications in late July. This is an important point in relation to establishing general soil available nutrient fertility estimates.

Whilst there was no difference in zinc levels between treatments, it is noted that all of the wheat tissue samples were showing up marginal levels on zinc. The topsoil (0-10cm) tests at the Carey trial site also showed up a defined zinc deficiency. This supports the basis of this trial indicating zinc has shown up to be a micronutrient likely to be deficient in this district. Copper levels in the plant tissue tests also didn't show up any difference between the treatments or products, and was actually present at an adequate level in the wheat tissue samples.

The soil tests taken on the Koch property trial site indicate adequate zinc levels in the topsoil. As zinc is relatively immobile in the soil, and becomes less available in cold, dry conditions, it is anticipated that poor uptake could be a potential reason behind the deficient tissue sample results. This is an important factor in understanding nutrient uptake potential. Simply because it is in the soil test or has been applied does not necessarily mean that the element is available to the crop.

The 2018 season was a Decile 1 rainfall year in the Upper North region, with both wheat and lentil yields in the district being well below average due to moisture stress and severe frost damage. With water being the most prevalent limiting factor for yield in both wheat and lentils, it is not unexpected that there was no response to the micronutrient treatments shown in the yield data.

**2019:** The 2019 trials involved the same treatments as 2018, however there were two wheat trial sites (Booleroo and Mambray Creek) and one pulse trial site (Booleroo). Results from both wheat micronutrient trials showed no significant results in yield or plant tissue tests. There was no significant response to any applied treatment at these sites. This included formulation type, rate of product and timing of the copper chelate application. Unfortunately, 2019 was an extremely dry season with terminal spring conditions significantly reducing all crop yields. This is the second trial to have netted similar results in consecutive seasons in this region, both being exposed to terminal spring conditions (2018 and 2019). The pulse trial site at Booleroo showed a trend in increased molybdenum levels in plant tissue tests. Unfortunately, the trial site was unable to be harvested due to persistent and terminal drought conditions. Further trial work therefore for 2020 was suggested to include the use of molybdenum with the same treatments. Molybdenum is seen as important in the plant for nitrogen pathways and could assist with increased nitrogen use efficiency. During an average season, it was then expected to show increased results with a greater plant biomass and more rapid plant growth requiring a greater amount of micronutrients.

**2020:** The 2020 trials involved the foliar application of two micronutrients (zinc and copper) at two wheat trial sites (Booleroo and Mambray Creek) and two micronutrients (zinc and molybdenum) at two lentil sites (Booleroo and Mambray Creek). These micronutrients were applied as various products at different rates and timings. Results from the 2020 cereal micronutrient trial at Booleroo Centre indicated no significant response in yield to any of the treatments applied at this site. The trial also showed no effect from treatments copper, zinc or molybdenum in the plant tissue tests. The trial did show a trend where molybdenum levels increased in the plant tissue test when molybdenum was applied. Again, crop growth in the Upper North region was limited by low moisture throughout the growing season. Results from the 2020 cereal micronutrient trial at Booleroo Centre indicated no significant response in yield to any of the treatments applied at this site. The trial also showed no effect from treatments copper, zinc or molybdenum in the plant tissue tests. The trial did show a trend where molybdenum levels increased in the plant tissue test when molybdenum was applied Again, crop growth in the Upper North region was limited by low moisture throughout the growing season.

Results from the 2020 cereal micronutrient trial at Mambray Creek showed a rate response in yield with higher rate or dual applications of zinc, resulting in higher yields. Application of molybdenum resulted in the highest yield (4.24 t/ha) this was also apparent in the tissue test results which showed this treatment had the highest level of molybdenum present across the trial site.

Results from the 2020 pulse micronutrient trial at Booleroo indicated there were clear trends in increased zinc and molybdenum levels assessed across the treatments. All other nutrients analysed in the tissue samples did not show any relevant responses to treatments. Lentil grain tests showed statistically significant increase in molybdenum as a result of a foliar treatment of molybdenum chelate. Other nutrient and grain quality data and grain yield collected from the trial site did not show any significant differences between the treatments.

Results from the 2020 pulse micronutrient trial at Mambray Creek indicated no differences in lentil grain yield from applied micronutrients for all treatments. Nodule counts show variation across treatments, however, there is no difference between molybdenum treatments, which suggests there was no response in nodulation by the time the assessments were taken in this trial. The protein results analysed from grain samples show no trends for molybdenum or zinc applications to protein content. The tissue test results suggest that there is a definite response of nitrogen uptake by the plant following a molybdenum application as well as the increased level of molybdenum itself in these treatments. These results also show an apparent response to various other nutrients when Zinc was applied including Iron, Aluminium and Cobalt.

UNFS Micronutrient Trials Summary (2017 – 2021)

The SAGIT trials that were undertaken from 2018 through until 2020 were all run with absolute precision and the professionalism of the farmers, the researchers and the agronomists charged with the task to complete the research work was of the highest standard. The seasons were not kind, but all trials were set up each season to offer the crops the best chance of providing suitable information once harvested.

Under the UNFS umbrella of researched guidelines, organisational capacity, and support of all involved, the trials were all sown, surveyed, sampled, and harvested with precision. Credit to the well organised people that undertook the valuable work is certainly due, and absolutely appreciated by everyone involved in the UNFS Group and the farming community in South Australia. SAGIT support throughout the entirety of the project has been very much respected, valued and appreciated.

There were 3 marginal seasons over the 3-year trial period. The expectations of micronutrient insight from the results in relation to suitable product type and product rate were not forthcoming and it seems a feasible option to close out a lack of positive micronutrient results to a general lack of in season rainfall. However, It would be remiss in this summary to apportion blame to seasonal conditions only and not consider further insights from the data that may not necessarily be obvious.

There are many supply and demand factors related to nutrient uptake in soils and plants. Considering that plants take up individual nutrients from soil solution by either mass flow (eg Calcium), diffusion (eg Potassium) or root interception (eg Phosphate) and each soil horizon can be a completely different pool of available nutrients of differing pH, conductivity, soil temperature and moisture it leaves growing plants with so many environmental variables to manage that it is often hard to comprehend. These factors do need to be considered when setting up nutrient trials in the future and considered in relation to any findings from this trial work. To understand the critical supply and demand factors around nutrient uptake is of critical importance.

There are three critical pathways of nutrient management dynamics. These factors will change with changing soil, climate, cultivar and management systems.

1. Deficiency – Micronutrient values too low for plants to access (i.e. Copper)
2. Inefficiency – One nutrient may suppress uptake of another (i.e., Nitrogen and Zinc)
3. Sufficiency – High inherent soil values of a nutrient so not necessary (i.e., Potassium)

Micronutrient requirements from a farm management viewpoint are also dependant on growers seasonal yield targets (local and general) and always in direct consideration of water limited yield potential. Target numbers are sometimes a shot in the dark and do not truly reflect a pool of micronutrient availability and guaranteed uptake in any given season.

What was learned and has been considered from UNFS Micronutrient Project 2017-2021

The priority nutrition focus of the UNFS Micronutrient trials were foliar Zinc, Molybdenum and Copper on cereals and Molybdenum for the lentils. In 2020 Iron, Potassium and Manganese were also used. As potential micronutrients that could offer a response this was considered a feasible plan to potentially engineer yield differential in any given season (rain permitting obviously). The following are observations and items of discussion.

1. Moisture stress on crop growth was substantial and as a result the yield response from any micronutrient applications was severely limited. Trials were unfortunately only just significant enough to warrant harvesting in first two years. Decile 1 cropping seasons are depleting. Severe frost is a nail in the coffin with desiccated crops. The last year of trials in 2020 was marginally better as a season.
2. There were significantly different zinc and molybdenum tissue uptake results in lentils but no change in crop performance visually or in terms of yield in the first two trial years. Zinc oxide applied at a double rate (twice in growing season) was effective (500kg/Ha above control) in 2020 trials of Sceptre wheat at Mambray Creek as were the single application treatments of Iron Amino chelate and Potassium Amino in the same cultivar. Potassium and Iron were only considered in final year of trials but have proved their worth based on the data. This warrants further investigation and calls for more work to be done in relating macronutrient use to micronutrient performance.
3. When water is limiting plant growth, then any potential response to micronutrient application was negligible at all trial sites in any given year. A smaller crop in a dry season may require less micronutrients as enzyme catalysts and may well have enough supply from the inherent soil pool. Biomass demands are lower and thus a response is possibly not seen because any additional application of micronutrients may not be necessary physiologically for the plant itself. Utilise Leibigs Law of the Minimum at all times. Farmers need to be ready at all times to adjust to suit seasonal micronutrient requirements based on prior evidence. Biomass is a big factor in uptake and demand of plants. What other nutrients might be limiting?
4. An economic response to foliar micronutrient application can only be achieved when the additional return on yield is greater than the cost of buying and applying product. This could not happen in 2018 and 2019 due to seasonally dry conditions. In the 2020 trials based on the data then a commercial benefit from Zinc, Iron, Potassium and Molybdenum was indeed possible. The nodule counts of the split Molybdenum application in the pulse trial were 46% higher than control. For following years crop this would be a considerable result from a prior legumes performance.
5. Foliar micronutrient applications may need to be factored in earlier in the season due to potential for low soil moisture later in growing season. To engineer a physiological response earlier may offer more potential opportunity for plant response. The tissue uptake of nitrogen and potassium in lentils at the 2020 Mambray Creek site were substantially above the control. Once again the twin application (split) was the most significant result (12% higher). In a higher rainfall season this increase could well have proved more valuable in terms of yield.
6. Need to consider seed applied micronutrient use as an adjunct to a foliar programme to keep micronutrients in a more available pool for crop to utilise for entire growing season. Also need to consider other nutrients such as boron.
7. Need to base soil analysis (in particular the soil values in the individual horizon layers) at the centre of trial planning so that all factors in relation to plant uptake are understood. This is important and critical to determine metrics of micronutrient uptake throughout any growing season. 0–10-centimetre soil focus is not adequate for dryland soil management. Soil analysis must engage to potential rooting depth.
8. Copper, Zinc and Manganese levels were generally low in the surface soil samples taken mid-season at trial sites. A response from application of micronutrients would be expected but with further analysis it shows low available phosphorous (Colwell P of between 12 – 29 mg/kg in 2018) which could be a reason for lessened effect from micronutrient applications (an imposed deficiency) as plants in dry soils with low starting values are even more deficient in P as root interception would be limited.
9. Soil pH values are moderately high at trial sites in 2018 (7.8-8.0 in Calcium Chloride). The soil effect of higher pH may have restricted nutrient availability prior to foliar applications of micronutrients so plant performance may have been compromised. At higher pH, mineral solubility is decreased in the soil and lower soil temperatures can possibly exaggerate this effect. Needs to be considered.
10. High surface chloride levels in one of the alkaline soil trial sites (McCallum) may exaggerate phosphorous adsorption in soil and the crop may have been lacking enough P for its metabolism to be able to utilise any applied micronutrients, Zinc can be antagonistic to P in a plant or soil so it may be why zinc application may not have been an effective treatment despite low rainfall effect on crop growth?
11. Strategies are needed for improving micronutrient levels – possibly building background soil levels with bulk soil applications, then strategic application of foliars in better seasons? More tissue testing needs to be done throughout each season to predetermine micronutrient drawdown, use and final effect.
12. Timing of applications is critical – some trials applied at GS14 – timing wise was a good time to get zinc into plant however for a foliar strategy the leaf area may be too small to permit adequate uptake of nutrient, and a large proportion ends up being surface soil applied where availability will be very poor for some time. Is it better to in future validate seed coatings or in furrow fertiliser options rather than using earlier foliars – target at least 50% soil coverage, or increase application rate relative to the limited leaf area? Remarkably Copper Oxide 100ml treatment GS14 was the only positive result in 2019?

What was learned and has been considered from deep soil analysis from samples taken in 2021 of the 4 main trial sites used for the duration of the UNFS Project. Summary

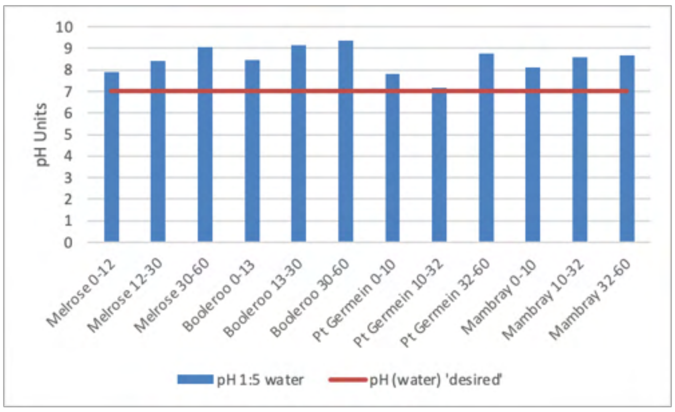
Soil samples were taken to depth in 2021 at all 4 of the 2020 trial sites to determine the effect of deeper soil analysis for micronutrient management based on soil condition, characteristics, and demarcation points for indication of horizon change. This soil testing was done to also ensure that all trial results captured historically at these sights had been interpreted and evaluated in terms of soil to plant performance relationships. This is critical in understanding why the trial results for use of selected micronutrients needs to be far better understood. The 3 years of prior micronutrient trial data had largely shown minimal plant performance change in terms of yield or other measured potentially commercial variables (nodule count, seed testing, tissue analysis). Drought stress, moisture stress, cold stress and possible nutrient stress have all played a role in this outcome. The data sets were graphed to highlight the different nutrient levels in the different soil types and their horizons. See below the variation captured. All 4 soil types are displayed on each graph for better representation. Soil data to depth must be captured prior to any trial work being undertaken as the background soil values offer the most insight in to potential benefits of timed and appropriate micronutrient use.

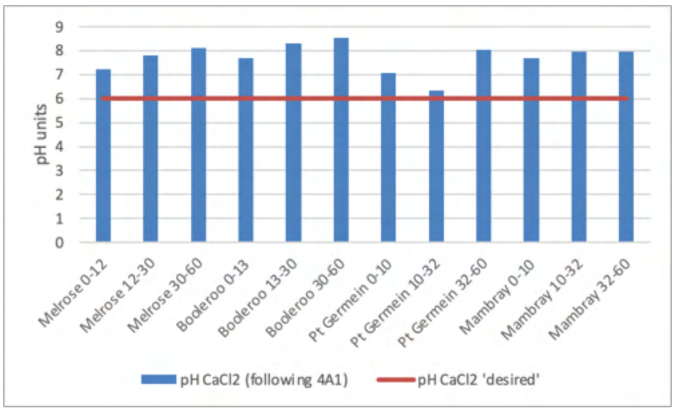
A Milwaukee electric hammer drill and Field Core intact coring tubes were used to extract the intact samples for review and analysis. The first samples were taken at Walters at Melrose, the Carey site at Booleroo, the Mudges sandy soil at Port Germain and finally the sodic subsoil site at Mambray Creek.

**SOIL DATA 2020 Trial Sites.**

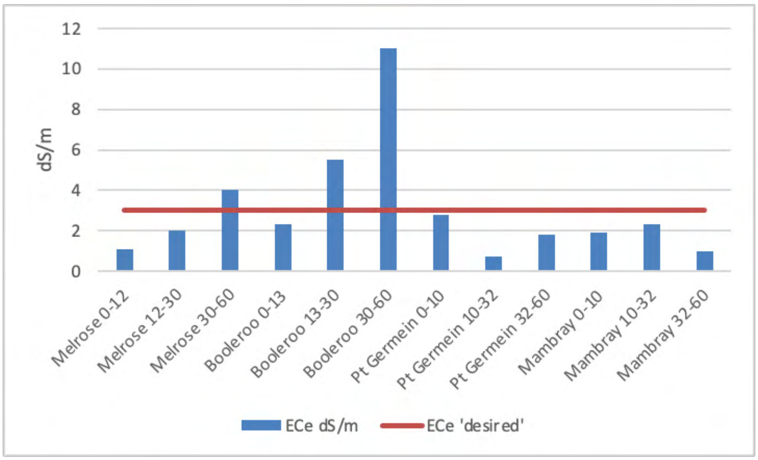
|  |  |  |  |
|---|---|---|---|
| 1, Melrose (Calcarosol) | 2. Booleroo Centre (Sodosol) | 3. Pt Germein (Tenosol) | 4. Mambray Creek (Chromosol) |

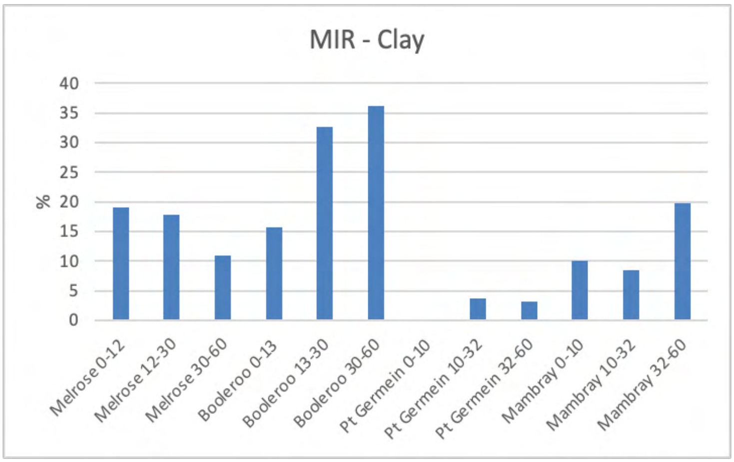
pH



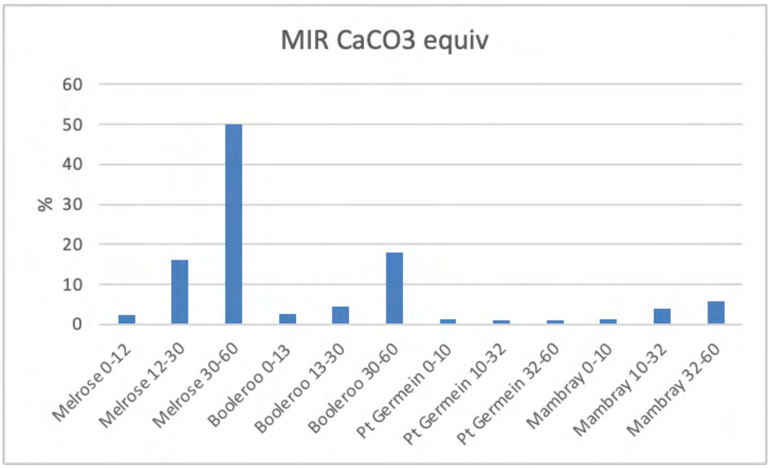

The pH levels of the sites were predominantly alkaline, with th sandy textured soil at Port Germein being the exception with the upper profile being slightly acidic.



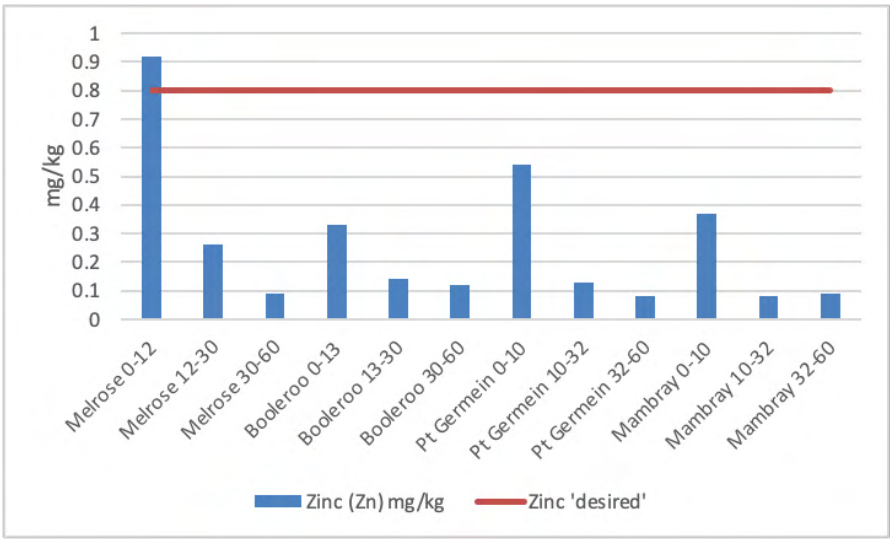

ECe: The salt content of the soil was elevated at the Melrose site and was high at the Booleroo site below 13cm. This was shallower than expected

Clay content: Clay content was greatest at the Booleroo site, clay percentage increased with depth, followed by Melrose site which had decreasing clay content with depth but a large increase in calcium carbonate percentage.

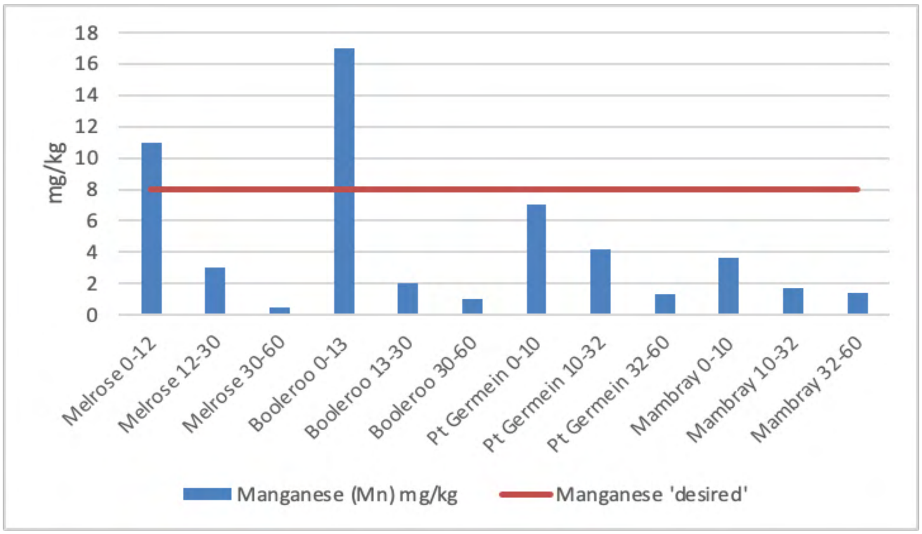


Micronutrient Results – showing variation in soil type and soil layer

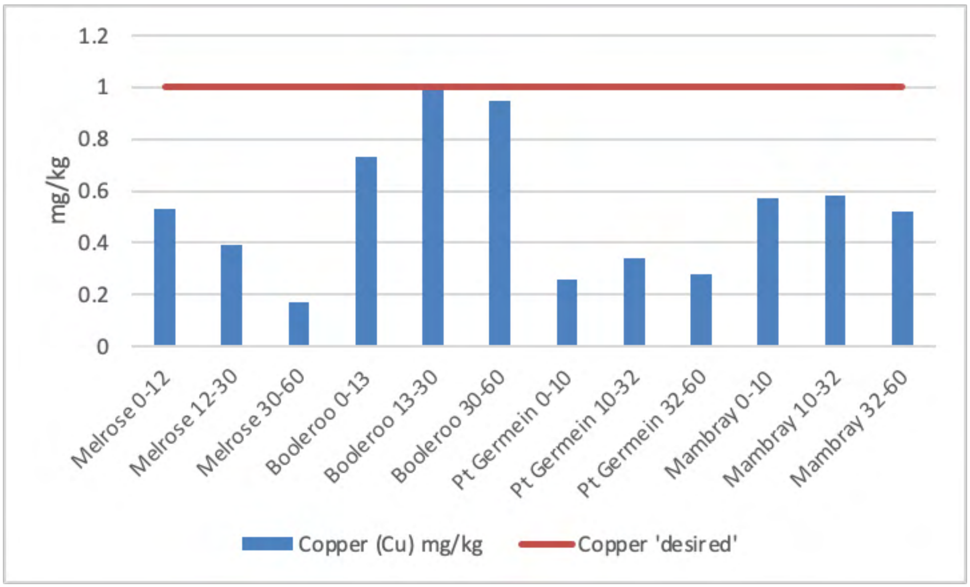
Melrose site highlights the increase in carbonate to depth in the calcareous soil profile – high free lime content will have significant impact on micronutrient availability. Highlighting importance of getting early micronutrient availability in the topsoil and then addressing with foliar applications if relying on subsoil – Why limited results in the trials in marginal year? (supply/ demand discussion – soils can provide adequate supply for sub 2t?? yields)




The zinc levels all generally trended towards higher levels in the topsoil and decreased with depth. However the baseline numbers are still very low compared to the 'target level' except for the topsoil at the Melrose site

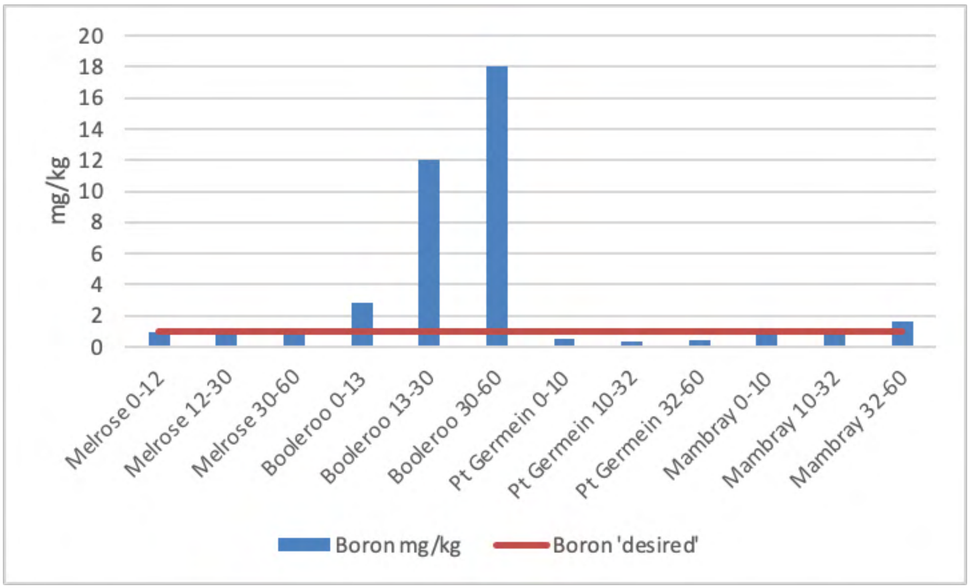



Manganese levels trended highest availability in the topsoil and decreased with depth. The Melrose and Booleroo sites both had adequate manganese in the topsoil however the Port Germein and Mambray site were both comparatively low.




Copper levels marginal to low in all profiles – Booleroo had greatest levels to depth.

Melrose was the calcareous site so copper uptake minimal.




Booleroo site had excess Boron and Pt Germein sandy soil had the lowest levels – may respond to boron in similar vein to 2020 successful Molybdenum trial results ?

## Communication of Results to Farmers and Industry

2021 is the final year of the SAGIT agreement for the UNFS Project “Increasing the knowledge and understanding of micronutrient deficiency in the UN”, and the project is now finalised and completed. A summary of the project trial results will be published in the 2021 UNFS research compendium

In order to communicate project findings to UNFS members and the greater South Australian farming community there have been more limited opportunities in the last 20 months. Due to the restrictions and meeting limitations of COVID 19, our annual Members Expo for 2020 was cancelled. Smaller field trial walks were held in its place for relevant field trials. Due to the lack of defined results or visual differences from these trials during the 2020 season due to seasonal rainfall constraints, no event was held at a trial site in 2020. Final trial results from 2020 were analysed and collated in April and are available for review. The results from these trials will be published in the 2021 UNFS Annual Compendium. Further support has been provided by UNFS to extend the results, guidelines and message delivery to growers for cost effective micronutrient use in the UNFS. This will be achieved with grower information days, micronutrient management data sheets, UNFS zoom discussion forums and as selected webinar topics when suitable dates are organised for grower contribution and attendance.

A series of individual UNFS Hub meetings to discuss the Project results and more specific information on micronutrients and their relevance in the Upper North was organised for July and August 2021, including soil scientists and agronomist as key speakers. Due to Covid restrictions this was delayed. This September and October is now conducive to Covid safe provision of micronutrient information, and this will be done at 2 separate UNFS field days at Nelshaby and Booleroo in Spring of 2021. A 2021 final report summary for SAGIT summarizing the last three years of trial results is to be included in the 2021 UNFS Annual Research Compendium. A summary of follow up grower questions and future work in this area of micronutrient use has been commenced by UNFS.

## Value for Growers

These extensive nutrient trials have clarified the strengths and vulnerabilities of dryland nutrient management in a more marginal cropping climate in the Upper North. The results have proven that rainfall is critical, soil moisture is paramount to nutrient availability and uptake and that soils may possibly have enough micronutrient capacity in low rainfall years but in more productive higher rainfall conditions then micronutrient use will be of greater importance for yield and crop risk management. UNFS growers have realised that more focus on nutrient interactions and multiple use pathways (more comprehension of multiple nutrient effects) is necessary and will need to be adjusted to suit given seasonal conditions. One very valuable outcome from the trial work is the absolute importance of the inclusion of molybdenum in all legume management programmes. This opportunity alone, based on now available evidence will be significant for legume profitability for all Upper North growers from henceforth.

Links

- Website: www.unfs.com.au
- 2017 Project Literature Review
- 2018 Trial Results – Published UNFS Research Compendium
- 2019 Trial Results– Published UNFS Research Compendium
- 2020 Trial Results– Published UNFS Research Compendium
- Facebook: https://www.facebook.com/UpperNorthFarmingSystems
- Twitter: https://twitter.com/UnfsNorth

## Summary

**Micronutrient Management - Next Steps for Upper North Farmers**

Due to the very nature of past paddock rotations, climate variance, management boundaries and commercial limitations it can sometimes be very hard for farmers to make good commercial decisions on micronutrient use. This can add fuel to some conflicting local opinions, evidence, experience and understanding getting discounted by consensus and a status quo on micronutrient use (or lack of in most cases) being maintained. Micronutrients play a valuable role in management of biotic and abiotic stresses in dryland broadacre cropping systems. The use of micronutrients can contribute to yield and crop performance from a grain volume increase perspective and also from a risk mitigation standpoint with frost, disease, heat stress, cold stress and indeed drought.

In the soil types of the Upper North the micronutrient values found in the soils individual layers have by and large occurred naturally, derived from the parent materials and soil forming processes and are actually individual soil minerals themselves. These prior soil forming processes have mostly determined the current micronutrient content of soils in the Upper North and also their availability across a range of different soil conditions, especially pH and EC. As minerals break down during these soil formation processes the micronutrients are eventually released in a form that is deemed plant available. The sources of plant available micronutrients in these soils are either as metals adsorbed on to soil colloids (very small soil particles) or are in the form of dissolved salts in the soil solution. Some micronutrient values from outsourced material will have been added by those farmers over time who have used micronutrients historically as part of their paddock nutrient planning. The addition of applied micronutrients in growing season and at critical points of crop maturity has serious merit if considered as part of a much broader farm management system. All nutrients reinforce each other, there is no silver bullet product as such, and all factors in crop performance need to be considered when micronutrient decisions are to be made.

**Farmers need to ensure poor crop growth is not the result of other important management issues.**

These other issues can be macronutrient deficiency (NPS), drought, salinity (EC), sodicity, disease pressure, insect problem, herbicide injury or some other key physiological problem. Your issues may not be to do with inadequate supply of micronutrients to your crops necessarily. To be comfortable making such decisions farmers need to consult fellow growers, their agronomists, and the interactive agricultural research community as often as possible to determine argument supporting factors for micronutrient use. Examine affected crops for specific micronutrient deficiency symptoms. Micronutrient deficiency symptoms are usually well known and can sometimes, with an experienced and trained eye and visual assessment at the right growth stage, be more effective than acting on plant tissue analysis alone. Some micronutrients have characteristic deficiency symptoms. However, symptoms can be sometimes confused with other nutrient deficiencies. Do your homework. Visual symptoms are very useful indicators when used with other diagnostic tools.

**Farmers need to understand their soils and how they behave with a greater degree of intensity.**

Physical and chemical characteristics of soil affect the availability and uptake of micronutrients. Individual soil layers can be markedly different in the same general soil type and each individual soil horizon can act entirely differently in relation to micronutrient uptake and availability pools throughout a growing season. This fact must be considered in all seasons as depending on climate, cultivar, management and definitely change of soil type, all nutrient availability factors will vary from season to season (and reason). If you don't dig holes, then you won't kick goals. Simple as that. Some soils with low micronutrient levels at the surface (0-15 cm) do not respond to fertilization because they have higher levels of the nutrient in the subsoil layers. This interplay is very important to understand and is closely related to seasonal crop requirements

**Use precision agricultural management techniques and systems where possible**.

Not all areas of your farm will require micronutrient applications to the degree that other areas will. This is where use of an entry level precision agricultural management platform becomes so powerful. General micronutrient decisions need to be made to be proactive rather than reactive for farmers to be able to act effectively on decisions in any growing season. This can be done by understanding variable rate metrics, testing soils to appropriate depth and understanding horizonal and soil zonal differentiation matched to cultivar, yield data and biomass imagery. There are many examples of where varying soil conditions, climatic factors and cultivars can change nutrient availability and subsequent expected effect. For example, as soil pH increases the availability of micronutrients decreases, with the exception of molybdenum. Soils low in surface horizon organic matter (less than 1.2 – 1.4 per cent) usually have lower micronutrient availability. Soils with higher amounts of clay (fine textured Chromosols) are less likely to be low in plant available micronutrients. Sandy soils (course textured Tenosols) are more likely to be low in micronutrients. These basic factors are generally well known and can be acted on with greater confidence.

**Organic matter is very important**.

Organic matter is actually an important secondary source of some vital micronutrients, active soil microbial exchange and improved moisture holding capacity for drying soils. Most micronutrients are held tightly in complex organic compounds within the structure of organic matter and may not be readily available to plants. Organic matter levels are generally quite low in Upper North soil types but organic matter can still be a very important source of micronutrients when they are slowly released into a plant available form as soil and plant residues denature and decompose (break down). Do all you can to maintain and potentially build soil carbon stock values in your soils. Carbon helps mostly from a plant production perspective more so than a potential source of offset revenue (at this stage)

**Understand paddock history and utilize legacy data from your farm**. **No knowledge is ever wasted**.

Find out what kind of micronutrient deficiencies have been identified before in particular crop cultivars or soil types in your area over time. Past experience of other farmers and advisors in your area can be very valuable and a useful tool to ground truth information with. This information may be very valuable not just for understanding the individual micronutrient use but also timing of potential application, form of nutrient, mixing and compatibility issues and expected commercial outcomes. As soil pH increases the availability of micronutrients decreases, with the exception of molybdenum. Soils low in organic matter (less than 1.2 – 1.4 per cent) may have lower micronutrient availability. Soils with higher amounts of clay (fine texture) are less likely to be low in plant available micronutrients. Sandy soils (course texture) are more likely to be low in micronutrients.

**Soil temperature and moisture (obviously) are important factors in relation to micronutrient availability, especially in the Upper North**.

Soil temperature and soil moisture will differ from a seasonal and daily perspective. The Upper North can be cold, be wet and can more often than not, be dry. Many and varied changes can and will take place in surface soils based on soil temperature and available moisture. These processes regulate and mediate the soil physical, chemical and biological processes in our farmed soils. Moisture probes attached to weather stations can be extremely valuable tools when understood and used wisely. Soil temperature changes can either accelerate or slow down the rate of organic matter decomposition and subsequent mineralization. Soil temperature has a large influence on soil water volume, its conductivity and subsequent availability to growing plants. Soil temperature is a major factor governing processes that happen in cropped soils which are indeed vital for plant growth. Soil temperature and moisture changes in soil can affect crop micronutrient demand, especially by restricting supply to growing roots. Drought conditions and seasonally dry environmental effects on crops can certainly be a precursor to lower availability of necessary micronutrients. Drought conditions can create conditions not suitable for micronutrient availability because of reduced nutrient mobility of specifically the diffusion limited micronutrients nutrients such as Copper, Boron and Zinc.

**Farmers need to have organized field scale trials on their own farms under their own management system**.

Collect as much background information as possible on a couple of areas on your farm in different soil types to start understanding the relationship of micronutrient use to increased farm profit. If all indications point to a micronutrient deficiency, apply the micronutrient to a specific, clearly marked out affected area of land to observe results in subsequent cropping seasons. Take soil samples to depth which must include micronutrient values. Soil tests aid in determining whether a particular nutrient is responsible for poor production and provides the basis for deciding the type and amount of fertilizer needed to correct a specific nutrient or multiple nutrient shortage. Send aggregated plant tissue samples from defined areas for complete analysis that includes testing for micronutrient levels. As soils continue to be cropped, micronutrient deficiencies may become more common as available levels of some elements are depleted so this process of on farm trialling is very important. Visual observations and yields from the treated and untreated areas should be taken to determine if a measurable response occurred.

# Acknowledgements

Upper North Farming Systems would like to thank SAGIT for their support and guidance in relation to this micronutrient project.

Upper North Farming Systems would also like to thank all of the agronomists, farmers and staff who contributed substantially to this project over the last four years. Sadly one of the  people instrumental in early delivery of the field work and research, Matt McCallum, was taken from us in a tragic car accident. This entire project is dedicated to his memory.


# Increasing production on sandy soils in low and medium rainfall areas of the Southern Region Warnertown 2021

***Author(s):*** Sam Trengove

***Funded By:*** GRDC

***Project Title: GRDC Sandy Soils IMPACT trials -*** Increasing production on sandy soils in low and medium rainfall areas of the Southern Region

***Project Delivery Organisations:*** *Trengove Consulting*

**Key points:**

- Deep ripping and deep ripping with inclusion plates improved crop growth during the growing season as measured by the GreenSeeker NDVI, while treatments including spading and Plozza plough reduced crop growth during the growing season.
- No significant yield differences were measured in 2021 wheat.
- Deep ripping and deep ripping with inclusion plates produced high cumulative grain yield (9.65-9.9t/ha) over three seasons, increased cumulative partial gross margin by $298-$358/ha and generated return on investment of over 350%.
- All treatments have reduced penetrometer resistance, with the treatment effects detectable over two years after implementation. Treatments including deep ripping have had a greater impact to greater depth than the shallow rip treatment.

**Background**

**Location –** Warnertown, -33.2832, 138.0872

**Constraints -** Low organic carbon, low Cation Exchange Capacity, Mild water repellence, compaction

**Treatments –**

| | |
|---|---|
| 1 | District practice (Control) |
| 2 | Shallow ripping to 30cm (Rip30) |
| 3 | Deep ripping to 50cm (Rip50) |
| 4 | Deep ripping to 50cm with inclusion plates (Rip50 + IP) |
| 5 | Deep rip to 50cm + Plozza plough to 30cm (Rip + Plozza) |
| 6 | Deep rip to 50cm + Spading to 30cm (Rip + Spade) |

**Key dates –**

| Operation | Date |
|---|---|
| Amelioration | 11 April 2019 |
| Seeding | 23 May 2021 |
| Harvest | 1 December 2021 |

## Methodology

**Variety:** 80 kg/ha Scepter Wheat

**Fertiliser:** 60 kg/ha MAP + 60kg/ha Urea

The trial was a randomised complete block design with 6 treatments and 3 replicates. The trial was located on a sand hill near Warnertown. The ripping treatments were implemented using a Yeomans plough ripper with three tines per plot on 450mm spacing. The Plozza plough was a converted John Shearer one-way plough and was built by the trial co-operator Brendon Johns and cut approximately 3.8m. Two adjacent passes of the Plozza were made for each Plozza treatment and the actual plot was located in the second pass. The spader was a Farmax 1.8m machine. Due to dry conditions in April 2019, prior to implementing the Plozza and spading treatments these plots were ripped with the Yeomans plough to 50cm to enable the treatments to reach their targeted working depth. Both the spade and plough treatments were implemented at 5 km/h. The trial was arranged so that the treatments ran up and over the sand hill parallel to the grower's operations. Plot dimensions were 50m * 1.5m sown on 2.1m centres and was 1 bay deep and 31 rows long with buffers left for the grower's controlled traffic lines and allowing 3 additional buffers around each Plozza treatment to allow for the first cut of the one-way plough.

## Results

*Wheat performance in 2021*

*Table 1. Pre sowing deep soil N and S, in crop measurement of GreenSeeker NDVI and grain yield data.*

| Treatment | Deep N (kg/ha) | Deep S (kg/ha) | NDVI 26th July | | NDVI 6th Sept | | Grain yield (t/ha) |
|---|---|---|---|---|---|---|---|
| Control | 86 | 69 | 0.48 | ab | 0.73 | bc | 4.30 |
| Shallow Rip | | | 0.42 | bc | 0.73 | b | 4.59 |
| Deep Rip | 109 | 87 | 0.54 | a | 0.78 | a | 4.82 |
| Deep Rip + Inclusion | 122 | 82 | 0.54 | a | 0.78 | a | 4.76 |
| Rip + Plozza | | | 0.30 | d | 0.69 | d | 4.13 |
| Rip + Spade | 110 | 83 | 0.34 | cd | 0.71 | cd | 4.81 |
| Pr(>F) | | | 0.003 | | <0.001 | | 0.16 |

Higher levels of deep soil N and S were recorded for the deep rip, deep rip plus inclusion and rip plus spade treatments compared with the untreated control (Table 1). All treatments were applied with chicken litter at 5t/ha at trial inception in 2019. One hypothesis is that the incorporation from these treatments has improved mineralisation of chicken litter, contributing to the higher N and S levels. An additional hypothesis is that incorporation of chicken litter has reduced losses of N through loss of volatile ammonia.

Treatments that included some form of soil mixing through either spading or Plozza had lower NDVI at both assessment dates (Table 1). This has been a common occurrence for the Plozza treatment each year over the three trial seasons. However, in season NDVI for the spade treatment has been comparable with other better treatments in 2019 and 2020. The explanation for lower NDVI in this treatment in 2021 is not clear. The deep rip and deep rip plus inclusion plate treatments had the highest NDVI at both assessment dates. These treatments have consistently been in the top bracket of treatments for NDVI response in each season. Grain yield differences were not significant. The average site yield was 4.57t/ha.

*Partial Gross Margin (PGM)*

Ripping with inclusion plates and ripping followed by spading produced the highest cumulative yields of 9.9t/ha over three seasons, followed by deep ripping to 50cm with 9.65t/ha, compared with 8.5t/ha for the untreated control (Figure 1). Cumulative PGM increased in response to improved yields over the untreated control, by $298/ha for deep ripping, $319/ha for deep ripping followed by spading and $358/ha for deep ripping with inclusion plates. However, due to the higher cost base for the spaded treatment the return on investment is lower at 128%, compared with over 350% for both deep rip and deep rip with inclusion plates. These two treatments had also covered costs in the first year, whereas the spaded treatment did not cover costs until the second crop year, again due to the higher cost base.

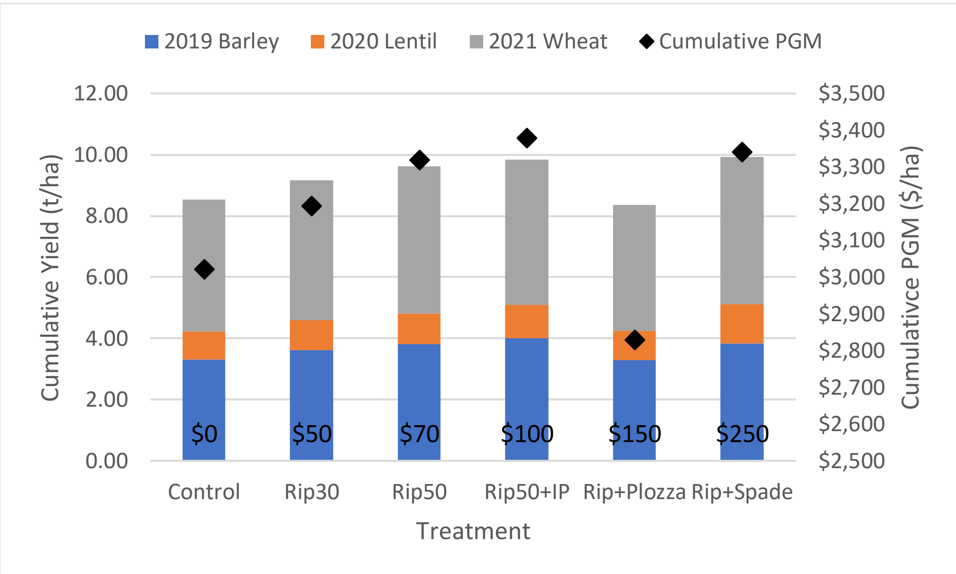



*Figure 1. Cumulative grain yield and partial gross margin analysis for seasons 2019, 2020 and 2021 for the Warnertown trial. Price assumptions include barley BAR1 (2019) $270/t, lentil NIP1 (2020) $680/t, wheat GP1 (2021) $350/t. Estimated treatment costs are shown on each bar.*

*Penetrometer Resistance*

Penetrometer resistance was measured in winter 2021, more than two years after treatments were implemented. Resistance in the untreated exceeded 2500 kPa between 175 and 350mm (Figure 2), indicating that compaction is likely a constraint at this site. All treatments reduced penetrometer resistance, with the depth of treatment intervention evident in the penetrometer resistance profiles. Shallow rip had the smallest impact, due to its shallower working depth. All other treatments included deep ripping to 50cm as part of the treatment. Deep ripping to 50cm had an impact on penetrometer resistance nearly to the full working depth. The use of inclusion plates, spading and Plozza plough appear to have generated more loosening at the shallower depths where they operate, compared with deep ripping alone. However, the inverse appears to occur at deeper depths, where the straight deep rip treatment has lower penetrometer resistance compared to when deep ripping was used in combination with inclusion plates, spading or the Plozza plough. The long-lasting impact of treatments on penetrometer resistance would suggest that treatment effects will continue to be observed in future seasons.

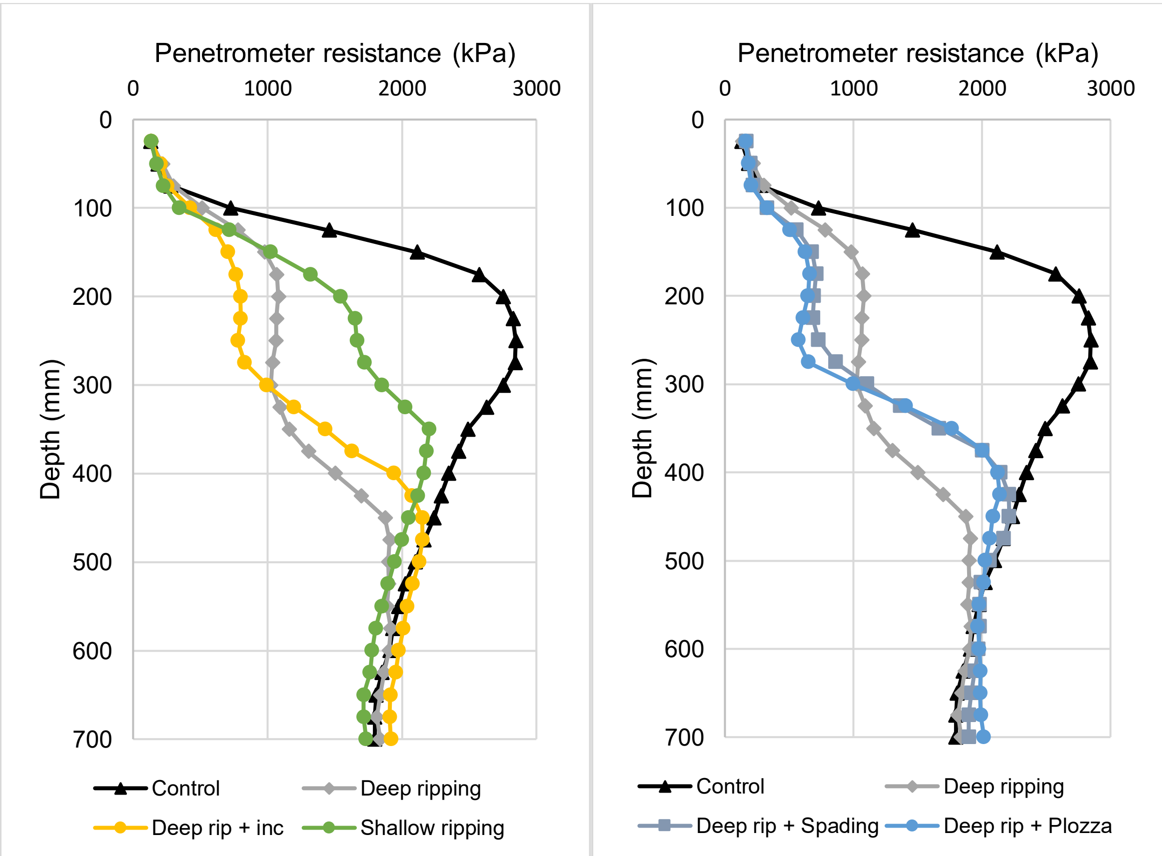



*Figure 2. Penetrometer resistance measured using a cone penetrometer in Winter 2021.*

**Acknowledgements**

Funding for this trial is gratefully acknowledged from GRDC project CSP00203 ‘Increasing production on sandy soils in low and medium rainfall areas of the Southern Region’. Brendon and Denise Johns are thanked for hosting the trial on their property and assistance with applications of pesticides and fertiliser throughout the season.

# Sheep Technology Project
# Annual Report

***Author(s):*** Rachel Trengove, Project Officer, UNFS

***Funded By:*** SA Red Meat and Wool Growth Program

***Project Title:*** Producer Technology Group

***Project Duration:*** July 2020 - May 2022 (completed)

***Project Delivery Organisations:*** PIRSA, UNFS

**Background**

Upper North Farming Systems (UNFS) was successful in acquiring funding to run a Producer Technology Group through the SA Red Meat and Wool Growth Program which is an initiative of the Government of South Australia, supported by Meat & Livestock Australia, SA Sheep and Cattle Industry Funds and SheepConnect SA.

The group met four times over an 18-month period, with the format, content and delivery of the group's activities tailored to suit group members' knowledge and skills. The timing of the program was ideal with sheep prices high, labour prices also high and many producers keen to explore how to improve productivity and profitability through precision livestock technologies. The opportunity was provided to come together to learn from experts, share experiences and support sheep producers in implementing and applying technology in their enterprises.

The UNFS Sheep Technology Group program started in July 2020 and was organised by UNFS Project Officer Rachel Trengove. A core group of ten assisted in designing a delivery plan of four workshops with four themes. The plan for the group was then circulated to all UNFS members and attracted about 30 members committed to the group during the program. A summary of extension activities is listed in Table 1.

**Key Outcomes**

The greatest achievement for our group was the engagement and commitment of our group members which was shown in attendance of workshops and willingness to share knowledge and experiences at those workshops. There was a high level of interest generated in use of precision livestock technologies and we have seen uptake of new technology and systems by the group members throughout the duration of the program.

Feedback suggested that group members really valued the opportunity through funding to come together locally with like-minded people and learn from each other and experts in the industry.

We had multiple farmer “case studies” at workshops which was a local sheep producer sharing their experiences with the group on adoption of technologies on their farm. They provided a presentation, shared costs, farm data, benefits and challenges and there was very good discussion generated from these presentations.

Daniel Schuppan, Animal Production Specialist with Nutrien Ag Solutions was engaged as a facilitator which provided consistency across workshops. His knowledge and insight into the livestock industry was well regarded by group members.

**Other achievements**

Actual/measured implementation of precision livestock technologies in the group (from group member feedback and final survey data):

- 14 farmers conducted DNA profiling on their flocks and several other members planning on doing so in 2022
- 15 producers booked one on one sessions for sheep yard re-design in order to incorporate sheep handling technologies as a result of workshop 3
- Adoption of electronic identification (EID) technology
- Better use of data already collected from EID’s for record keeping and decision making
- Better understanding of Australian Standard Breeding Values (ASBV’s) and RamSelect App
- Several group members are considering use of software such as AgriWebb in their enterprises
- Confinement feeding designs considered for several producers
- At our UNFS Expo, a “Farmer Panel” of group members was facilitated to reflect on their experiences as a member of UNFS Producer Technology Group to promote the program to other UNFS members and the wider community

*Table 1. Summary of the activities undertaken during the project*

| Activity | Date & Location | Workshop Objective | Activity Description |
|---|---|---|---|
| Workshop 1: Paddock to plate - how technology can be used in assessing and achieving sheep meat quality | 29th September 2021<br><br>Blacksmith's Chatter, Orroroo | To provide information on livestock technologies with a focus on meat quality to assist producers in adopting technology in their enterprises and utilise the information in decision making | **Daniel Schuppan, Nutrien Ag Solutions, Animal Production Specialist:** Technologies and how to make a profit from sheep<br><br>**Drs Benjamin Holman and Stephanie Fowler, Meat Scientists, NSW Department of Primary Industries:** Lamb meat quality - factors affecting meat quality and development of measurement technologies<br><br>**Elke Hocking, Elke Hocking Consulting:** Genetics and ram selection for meat quality, use of ASBVs, utilising sheep carcass feedback, livestock technology systems for labour efficiency<br><br>**Dayna Grey, Thomas Foods International:** Maintaining meat quality through the meat supply chain to better satisfy consumer demand, auditing and quality assurance programs in the future, Meat Standards Australia (MSA) |
| Workshop 2: EID and its application | 19th March 2021<br><br>Andrew Kitto's shearing shed and sheep yards – Gladstone | To provide information and demonstrations of EID technology and how it can be implemented and utilised in sheep enterprises | **Michelle Cousins, Cousins Merino Services**<br><br>Data management including:<br>· Identification of livestock and session vs lifetime data<br>· Understanding bucket files and useful excel functions<br>· Software options for managing data<br>· Uploading and downloading data<br>· Using data to make informed decisions on farm.<br><br>**Andrew Kitto and Mark Noonan (Hornsdale):** farmer's perspective on the use of EID's in their sheep enterprise and share their experience collecting data on body weights & wool traits<br><br>**Dan Roe, Neogen SheepDNA:** genomic flock profiling<br><br>**Joe Scammell, Spence Dix & Co:** demonstration of an auto drafter and EID scanner (Trutest)<br><br>**Anne Collins (AC Consulting):** Producer Demonstration Site discussion and brainstorming ideas in our region<br><br>Facilitated by **Daniel Schuppan, Nutrien Ag Solutions** |
| Workshop 3: Sheep Yard and Lead-up Race design | 30th June 2021<br><br>Lachie Smart's property, Wirabara | To provide a hands on demonstration by presenter on how to improve sheep yard design and incorporate technology into yard design for efficiency and productivity outcomes. | **Tom Austin, Stockyard Designer, Atlex Stockyards**<br><br>· Animal behaviour<br>· Labour efficiency<br>· Low stress stock handling skills<br>· Creating an effective lead up to your handler |

| | | | |
|---|---|---|---|
| | | | · Why is the on-property design so critical to designing the best yards?<br>· Breeding dogs and how to select the best pup from a litter<br>· Loading ramps<br>· Not all upgrades have to cost a lot<br>· Where to spend the money to give you the best bang for your buck |
| Extra Workshop: Merino Flock Profiling | 9th July 2021<br><br>Booleroo Centre Sports Centre | Small group of those interested in flock profiling as a result of the knowledge and confidence gained in workshop 2 | **Presented by Andrew Michael, Leahcim Poll Merino & White Suffolk Stud & Anne Collins, AC Ag Consulting**<br><br>• Understanding Australian Sheep Breeding Values (ASBVs) and Indexes<br>• Why use ASBVs when buying rams<br>• Defining a breeding objective<br>• Merino Flock Profiling—understanding test results & how to use the information<br>• RamSelect app |
| Workshop 4: Confinement feeding | 6th October 2021<br><br>Kuerschner's Property, Orroroo | Presentations by industry consultants and tour of host farm feedlot design to increase knowledge and skills in confinement feeding and technology adoption. | **Daniel Schuppan, Nutrien Ag Solutions**<br>- Confinement designs<br>- Feed budgeting<br>- Feed out systems—troughs, self feeders, autofeeders, total mix rations<br><br>**Jane Kellock, Kellock Farming** shared her experiences with using technology in their sheep enterprise including; EID's and AgriWebb<br><br>**Project wrap-up and ideas and plans for future MLA livestock programs** |
| Farmer Panel | 9th September 2021<br><br>UNFS Annual Expo Booleroo Centre | For Sheep Technology Group members to share experiences in adoption of technology in their enterprises | **Joe Koch, Andrew Kitto, Andrew Henderson, Jim Kuerschner** |

# Improving pulse performance through early sowing opportunities in low to medium rainfall environments

***Author(s):*** Dylan Bruce, Sarah Day, Penny Roberts

***Funded By:*** UNFS

***Project Duration:*** 2021

***Project Delivery Organisations:*** South Australian Research and Development Institute (SARDI), UNFS

**Key Points:**

- Grain yield increases up to 0.35 t/ha and 0.64 t/ha were achieved through early sowing lentil and faba bean, respectively.
- Mid flowering faba bean varieties, such as PBA Samira, exhibited greater yield stability across different times of sowing, compared to early flowering varieties, including PBA Marne and Farah.
- Mid-maturing wheat varieties had negative yield responses when sown early.

**Background**

Pulses in Australia currently account for approximately 8% of total winter cropping area sown, equating to 2.94 million tonnes of production (ABARES, 2021). Conventionally, the sowing of most pulse crops is delayed to reduce the risks of disease pressure, to avoid reproductive growth stages occurring during periods of cold and frosty conditions, to minimise excessive growth leading to premature lodging, shading and smothering, and to minimise crop injury from herbicide carryover. However, delaying sowing often results in shorter plants with lower bottom pod height resulting in harvesting difficulties, reduced biomass production, less flowering nodes, fewer pods, and flowering and grain fill occurring in periods of heat and moisture stress, ultimately resulting in lower yields. In recent years, targeted breeding for varietal improvements in agronomic performance specific to rainfall environment, coupled with increases in disease resistance and reduced susceptibility to lodging has led to earlier sowing times in some regions, particularly low to medium rainfall environments (Walela et al., 2016). These improvements have allowed growers to adapt to changes in rainfall pattern, weather extremes and increasing farm size. Unlike cereal crops, where flowering and reproductive growth occurs within a narrow window, pulses are indeterminate in their growth pattern, meaning that vegetative and reproductive growth occur concurrently. Flowering and podding often occur over an extended period, where developing flowers and pods are subjected to a broader range of climatic conditions than those experienced by a cereal crop. Negative conditions, such as frost occurrence during this time can result in flower abortion, however, this can be compensated for by the continuation and later development of flowers and pods. It is this indeterminacy and adaptability in the growth habits of pulse species that has potential for exploitation to overcome environmental constraints, to extend the growing season and maximise yield potential, compared to conventional sowing times in lower rainfall environments.

**Methodology**

A field experiment was undertaken at Warnertown (Mid North) in 2021, to investigate the opportunistic early sowing of pulses, compared to a cereal wheat crop. The location represents the low to medium rainfall environments, where previous research has shown the greatest potential for early sowing. The aim of this experiment was to extend the growing season and boost the grain yield potential of pulse crops in the region, by sowing them earlier than district practice. The first time of sowing (ToS) was completed on the 30th of March, followed by the second the 11th of May. Supplementary irrigation equivalent to 20mm of rainfall was applied via in-furrow drippers on the 31st of March post-first ToS and 1st of April pre-second ToS, to simulate a singular rainfall event that would trigger sufficient germination and establishment. Five varieties of faba bean, and three varieties each of lentil and wheat were selected based on known differences in phenological characteristics of flowering time and crop maturity. Four faba bean breeding lines were also selected to investigate their phenological characteristics which were unknown (Table 1). The experiment was sown in a split plot design, with crop type and time of sowing randomly assigned to the main plot and variety randomly assigned to the sub plot to ensure each crop received appropriate agronomic management. To reduce the likelihood of shattering, the first ToS lentils were harvested on the 19th of October, followed by the first ToS faba beans on the 26th of October and the rest of the trial on the 5th of November. Data was analysed in Genstat 21st edition using a split plot ANOVA model.

*Table 1. Phenological characteristics of lentil, faba bean and wheat varieties sown at Warnertown, 2021.*

| Crop | Variety | Flowering Time | Maturity Time |
|---|---|---|---|
| Lentil | GIA Leader | Mid-late | Mid-late |
| | PBA Jumbo2 | Mid | Mid |
| | PBA Highland XT | Early | Early-mid |
| Faba Bean | PBA Amberley | Mid | Mid |
| | PBA Samira | Mid | Early-mid |
| | PBA Bendoc | Mid | Early-mid |
| | Farah | Early-mid | Early-mid |
| | PBA Marne | Early | Early-mid |
| | AF03029 | Unknown | Unknown |
| | AF14062 | Unknown | Unknown |
| | AF15278 | Unknown | Unknown |
| | AF15283 | Unknown | Unknown |
| | | **Maturity Classification** | |
| Wheat | Nighthawk | Very slow | |
| | Trojan | Mid-slow | |
| | Scepter | Mid | |

## Results and Discussion

Seasonal rainfall at Warnertown in 2021 was below average, with growing season rainfall (GSR [Apr-Oct]) of 225 mm and annual rainfall of 274 mm, compared to a long-term average GSR of 264 mm and annual rainfall of 375 mm. A meagre 3 mm of rainfall was received during April following the first ToS, with a follow-up rainfall event exceeding 10 mm not received until the 24th of May. Air temperatures immediately following the first ToS also exceeded 30°C over seven consecutive days, increasing the level of evaporation post-irrigation. Rapid and sufficient germination and establishment was achieved post-first ToS, but with insufficient follow-up rainfall, all crop types exhibited moisture stress, with cereals more affected than pulses. The presence of mice early in the season also affected establishment percentage of the early ToS, primarily in the wheat. Rainfall events steadily increased during the winter months of June (48 mm) and July (63 mm). Flowering of the first ToS faba bean and lentil coincided with head emergence in the wheat, while all crop types in the second ToS remained vegetative (Figure 1). Rainfall during the following months of August (19 mm) and September (21 mm) were equal to half the long-term average at this location. By this period the first ToS faba beans were in their final stages of pod development, while the second ToS faba beans were in the beginning stages of pod development. Lentils from the first ToS were also towards the final stages of pod development, while the second ToS were progressing through the final stages of flowering and entering the pod development stage. Meanwhile, the wheat varieties from the first ToS were well into their grain fill stages, with the second ToS progressing through the flowering phase. Only on two occasions did temperatures fall below 0°C during the season, when -1°C temperatures were recorded on the 27th of August and 21st of September.

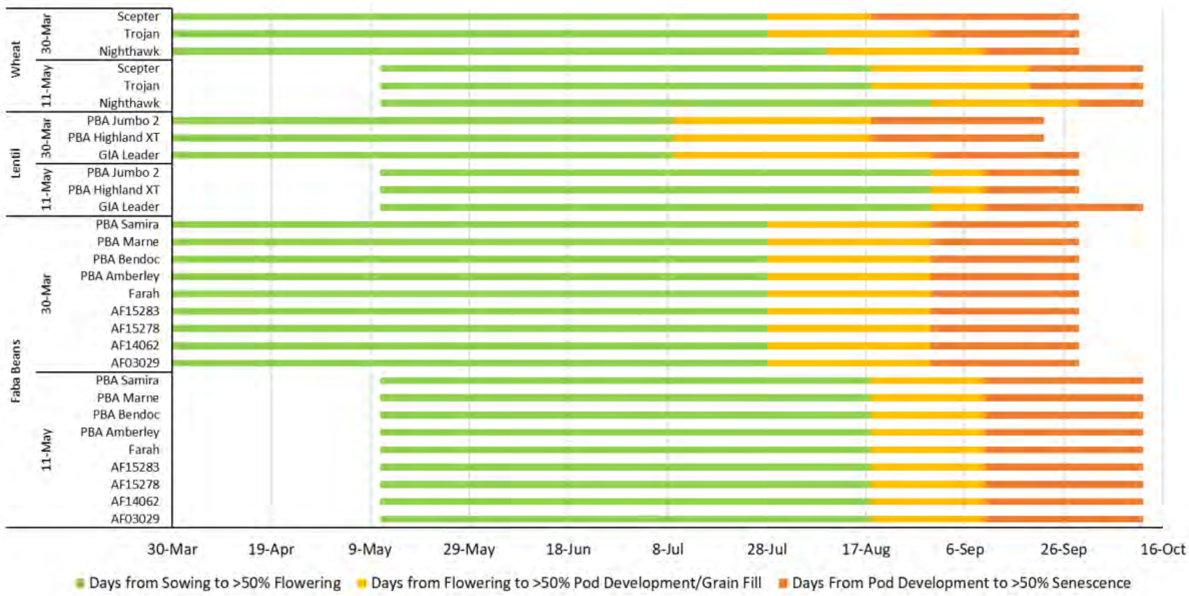



*Figure 1. Observed phenological characteristics of faba bean, lentil and wheat varieties sown at different times at Warnertown, 2021. Note: phenological assessments presented in this figure were taken at one-to-two-week intervals. The data provides only an approximate guide to differentiate between crop types and their phenological progression when sown at different times.*

Grain yield results indicated that both pulse species benefitted from early sowing, with increases ranging from 0.06 to 0.64 t/ha in the faba beans and 0.1 to 0.35 t/ha in the lentils at Warnertown (Figure 2). Whereas, early sowing negatively impacted the grain yield of the two quicker maturing wheat varieties, Scepter and Trojan, recording a 1.24 and 0.71 t/ha reduction in grain yield, respectively.

Faba bean varieties PBA Marne, PBA Amberley and PBA Bendoc performed the best amongst the faba beans when sown early, yielding around 2.5 t/ha. Lentil varieties GIA Leader and PBA Highland XT yielded close to 2 t/ha when sown early, while Scepter and Trojan wheat varieties performed best when sown later, yielding the same at 3.2 t/ha. The grain yield response to ToS between varieties differed slightly in all crop types, as quicker flowering varieties such as PBA Marne and Farah showed greater differences in yield between ToS, compared to the later flowering varieties PBA Amberley and PBA Samira that exhibited greater yield stability across ToS. The response in grain yield stability of varieties like PBA Samira to early sowing was also observed in 2020 at Warnertown, during a contrasting season that saw an additional 215 mm of annual rainfall at the site compared to 2021 (Day et al., 2020). The response amongst lentil was mixed, with GIA Leader and PBA Highland XT, mid-late and early-mid maturing varieties, respectively, exhibiting increased yield from early ToS, however, a larger yield gap between ToS.

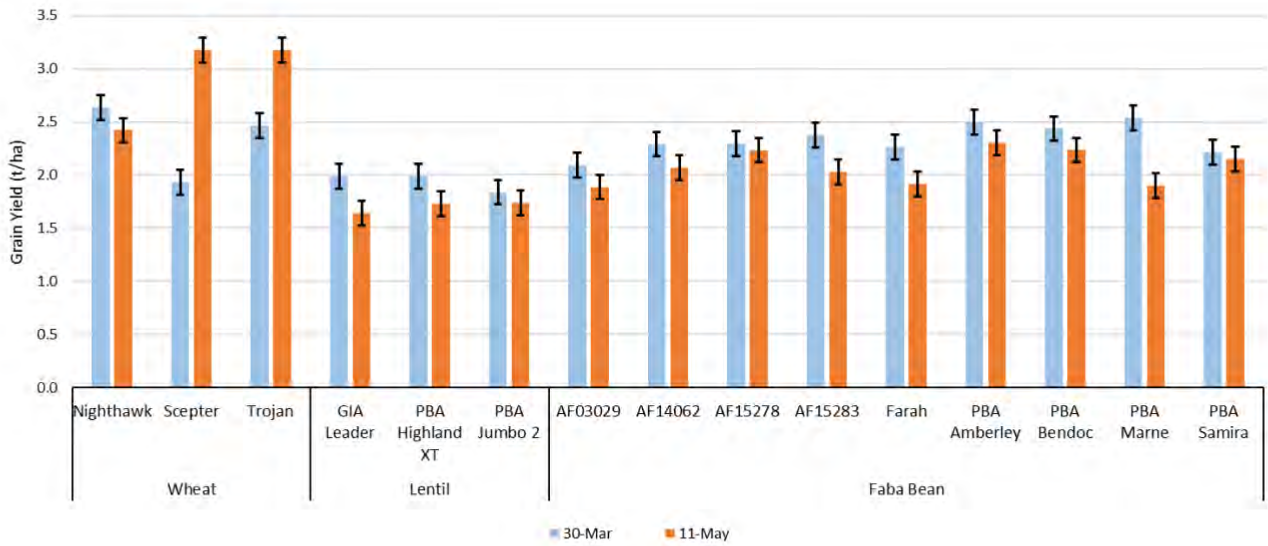



*Figure 2. Grain yield (t/ha) response of wheat, lentil and faba bean to different times of sowing at Warnertown, 2021. Error bars represent standard error (P<0.05).*

When utilising the opportunistic early sowing of pulses as a strategy to improve production in low to medium rainfall environments, other agronomic considerations need to be taken. Disease management requires particular attention when sowing early in average to wet seasons. It is well known that disease pressure and intensity is favoured by early sowing, which generally produces excessive early growth. Management options to combat this include maintaining sound crop rotations and farming practices, such as using varieties with the best-known disease resistance, choosing more erect varieties, and using disease free seed. In certain environments where the incidence of frost can severely affect pulse flowers and pods, flowering should ideally occur after the frost period has finished. High risk areas should be avoided, such as low-lying paddocks, while a range of varieties with differing maturities should be used to spread the risk. Early sowing can also limit opportunities for effective weed control by restricting the pre-sowing window for an effective herbicide knockdown.

In these circumstances paddocks with low weed burdens should be chosen, along with selecting varieties with improved herbicide tolerance traits, as pulses are generally poor competitors with weeds.

Previous research has established the negative impact of delayed sowing on grain yield and crop performance of pulse crops (McMurray et al., 2009). However, the implications of pushing the limits of early sowing times, when sufficient moisture is available, is yet to be established. This research would provide an indication of when management decisions, such as time of sowing, can deliver an increased return to growers, while taking into consideration other variables within a production system, such as weed, pest and disease control, and the logistics of effective farming practices.

***Acknowledgements***

The research undertaken was made possible by the significant contribution of UNFS and growers through both trial cooperation and the support of UNFS and SARDI, and the authors would like to thank them for their continued support. The continued assistance in trial management from the SARDI Agronomy group at Clare is gratefully acknowledged and appreciated.

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# Exploring salt tolerance and alternative seed types in lentil

***Author(s):*** Sarah Day, Penny Roberts

***Funded By:*** GRDC (UOA2105-013RTX, Melrose trials only)

***Project Title:*** Development and extension to close the economic yield gap and maximise faming systems benefits from grain legume production in South Australia

***Project Duration:*** *2021-2025*

***Project Delivery Organisations:*** *University of Adelaide*

**Key Points:**

- Alternative seed types to the commonly grown red lentil have potential for successful production in longer growing seasons and higher rainfall zones, due to their later maturity.
- Lentil varieties with improved tolerance to salinity and boron toxicity are available for areas where these soil constraints are identified.

## Background

Lentil production has significantly increased over the last decade in the Upper North region of South Australia. While growers report great success with lentil production, lentil is highly sensitive to herbicide residues, climate extremes and soil constraints, such as boron toxicity and salinity. Some varieties offer improved tolerance to soil salinity and boron toxicity and may have improved production in constrained soil types. Evaluation of lentil varieties often occurs in uniform, ideal paddock conditions, and evaluation on constrained soil types is limited.

Red, or 'small', lentil is the most widely grown lentil type in Australia. However, there are alternative options, such as green, or 'large' lentil. Green lentils have a green to brown seed coat and a yellow kernel and are used whole for cooking. Green lentil currently represents <1% of Australian lentils, with most seed sold into markets in the Middle East. Other niche varieties have been developed for restaurants or specialist uses and are currently grown in small quantities, including Spanish brown, French green and black seeded types. Wide evaluation of these varieties, in particular the niche types, is limited.

## Methodology

*Salt tolerant lentil variety trial*

Seven varieties of lentil with improved tolerance to salinity were compared to popular lentil variety PBA Hurricane XT at Melrose in 2021, to assess production potential in a low rainfall environment where constraints to lentil production have been identified. The trial was a randomised complete block design with three replicates. Plots were sown on May 26th with an experiment plot seeder with 23 cm row spacings.

Plots were harvested on November 22nd after crop desiccation, and grain yield was calculated. Grain quality, including grain weight (grams per 100 seeds), protein (%) and screenings (percentage of grain smaller than 2 mm) were assessed using harvest grain samples. Protein content was measured using a NIR (near-infrared) grain analyser. Data was analysed in Genstat 21st Edition using an ANOVA model.

*Alternative type lentil trial*

Twelve lentil varieties, with a range of niche types and seed sizes, were sown in a randomised complete block design in three replicates, to assess yield potential of the alternative varieties, at Warnertown 2021. Plots were sown on May 11th with an experiment plot seeder with 23 cm row spacings. Plots were harvested on November 5th after crop desiccation and grain yield was calculated. Grain weight (grams per 100 seeds) was assessed using harvest grain samples. Data was analysed in Genstat 21st Edition using an ANOVA model.

A small demonstration trial where alternative seed types were compared to PBA Kelpie XT and PBA Highland XT was sown at Melrose, 2021. Plots were sown on May 26th with an experiment plot seeder with 23 cm row spacings. Plots were harvested on November 22nd after the crop was desiccated, and grain yield was calculated. Grain weight (grams per 100 seeds) was assessed using grain samples harvested from the trial. Data was analysed in Genstat 21st Edition using an ANOVA model.

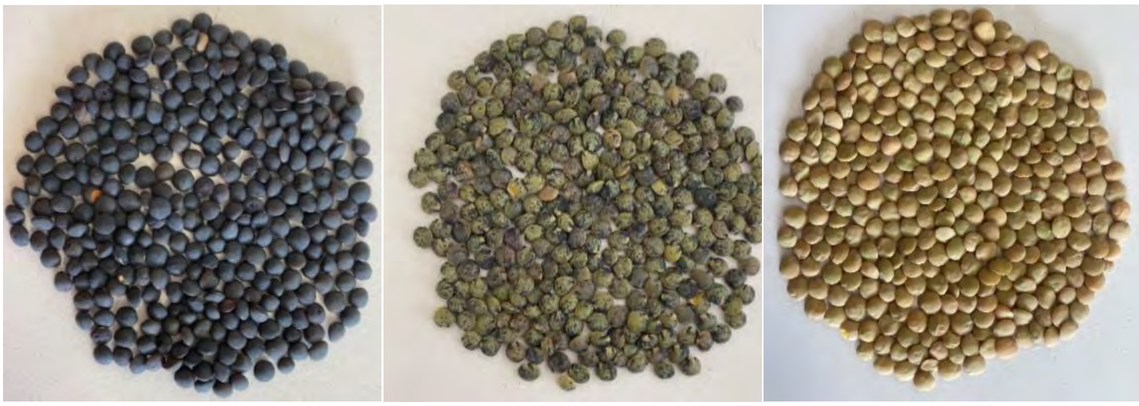


*Figure 1: Examples of niche lentil varieties (L-R) Hack, a small black seed type, 04-116L07HS3001, a mottled seed type, and SP1333, a large green seed type*

**Results**

*Salt tolerant lentil variety trial*

Average grain yield of salt tolerant lentil varieties was 1.13 t/ha at Melrose, 2021. However, no differences between varieties were observed (P>0.05). Differences between varieties were observed for grain quality measurements (Table 1). Grain weight reflects seed size from harvested grain. PBA Bolt (4.9 g) and 12H1305L-15HS3002 (5.0 g) had the largest seed size. GIA2101L (3.8 g) had the smallest seed size, with PBA Hurricane XT (4.0 g) second smallest. Percentage of screenings less than 2 mm differed between varieties. However, all varieties had screenings less than 4% and therefore all samples fall under then maximum limit for the highest visual grade lentil market category. Protein content within lentil varieties differed, with a range of 21-23%.

Current whole or split grain lentil markets do not assess protein content of grain, as markets are based on visual quality standards. However, increasing demand for plant-based protein, and development of pulse protein fractionation and manufacturing locally, may see the expansion of market opportunities for growers to sell lentil grain based on protein content, particularly where visual quality classifications cannot be met.

*Table 1. Grain weight (g per 100 seeds), protein content (%) and screenings (% of grain less than 2 mm), of salt tolerant lentil grain harvested from Melrose, 2021. Different letters in the same column indicate a significant difference between varieties.*

| Variety | Grain weight (g/100seeds) | | Protein (%) | | Screenings (%) | |
|---|---|---|---|---|---|---|
| 08200L-11HHI3019-13SA-15BO01 | 4.612 | b | 23 | ab | 1.37 | bcd |
| 12H1305L-15HS3002 | 5.009 | a | 22.37 | abc | 1.51 | ab |
| 14H152L-15HSHI2001 | 4.562 | b | 20.87 | e | 1.10 | bcd |
| GIA2002L-I | 4.344 | c | 21.23 | de | 0.79 | d |
| GIA2101L | 3.82 | e | 23.27 | a | 1.30 | bcd |
| PBA Bolt | 4.914 | a | 22.1 | bcd | 1.95 | a |
| PBA Hallmark XT | 4.637 | b | 21.8 | cde | 1.37 | abc |
| PBA Hurricane XT | 3.989 | d | 22.7 | abc | 0.85 | cd |
| *LSD (P<0.05)* | | | | | | |

*Alternative type lentil trial*

Green lentil types SP1333 and PBA Greenfield, along with niche types CIPAL0714, 14H044L-4-17H4004, 07H242L-11H4016, were the highest yielding lentil varieties at Warnertown, 2021 (Table 2). These alternative types were lower yielding than red lentil varieties, with an average grain yield of 1.7 t/ha, sown as part of an early sowing trial at the same site (Bruce et al 2022). Older black seed coat colour lentil varieties, Hack and Indianhead, were the lowest yielding alternative type lentils, alongside CIPAL0719, 16H632L-17HS3007, 08H209L-11H4004, and 04-116L07HS3001. Many of the alternative types have a medium to small seed size, with the larger seed sizes seen in green lentil types. The three large green lentil varieties had different grain weights, with SP1333 the largest seed type (7.1 g) followed by Boomer (6.7 g) and PBA Greenfield (5.9 g). Small black lentil type, Indianhead, had the smallest seed size (2.5 g).

The two commercial red lentil varieties, PBA Kelpie XT (0.96 t/ha) and PBA Highland XT (1.01 t/ha), were higher yielding than alternative lentil types at Melrose, 2021 (Table 3). There were no differences in grain yield between the green, black and mottled seed varieties sown in this environment (0.73-0.79 t/ha). Differences in grain weight, as a reflection of seed size, were observed, with PBA Kelpie XT (5.9 g) and green type 13H020L-3-15AHM3004 (5.8 g) as the largest seed types. 10H408L-3-11BO3002-13BO003 (3.8 g) had the smallest seed size, smaller than PBA Highland XT (4.3 g).

*Table 2. Grain yield (t/ha) and grain weight (grams per 100 seeds) of alternative lentil types sown at Warnertown, 2021. Different letters in the same column indicate a significant difference between varieties.*

| Variety | Seed coat colour | Cotyledon colour | Grain Yield (t/ha) | | Grain weight (g/100 seeds) | | Seed size |
|---|---|---|---|---|---|---|---|
| 04-116L07HS3001 | mottled | yellow | 0.86 | cd | 3.46 | fg | small |
| 07H242L-11H4016 | pale | red | 1.33 | ab | 3.66 | f | small |
| 08H209L-11H4004 | pale | red | 0.95 | cd | 3.51 | f | small |
| 14H044L-4-17H4004 | mottled | red | 1.30 | ab | 3.11 | h | small |
| 16H632L-17HS3007 | grey | red | 0.98 | cd | 3.93 | e | small |
| Boomer | green | yellow | 1.17 | bc | 6.70 | b | large |
| CIPAL0714 | mottled | yellow | 1.32 | ab | 4.33 | d | medium |
| CIPAL0719 | black | red | 0.88 | cd | 3.16 | h | medium |
| Hack | black | red | 0.68 | de | 3.25 | gh | small |
| Indianhead | black | yellow | 0.46 | e | 2.54 | i | small |
| PBA Greenfield | green | yellow | 1.52 | a | 5.94 | c | large |
| SP1333 | green | yellow | 1.51 | a | 7.10 | a | large |
| *LSD (P<0.05)* | | | *0.32* | | *0.22* | | |

*Table 3. Grain yield (t/ha) and grain weight (grams per 100 seeds) of alternative lentil types sown at Melrose, 2021. Different letters in the same column indicate a significant difference between varieties.*

| Variety | Seed coat colour | Cotyledon colour | Grain Yield (t/ha) | | Grain weight (g/100 seeds) | | Seed size |
|---|---|---|---|---|---|---|---|
| PBA Highland XT | Grey | Red | 1.01 | a | 4.33 | c | Small |
| PBA Kelpie XT | Grey | Red | 0.96 | a | 5.86 | a | Large |
| 15H173L-2-17HS4003 | Mottled | Red | 0.79 | b | 4.82 | b | Medium |
| 13H020L-3-15AHM3004 | Green | Yellow | 0.78 | b | 5.83 | a | Large |
| 10H408L-3-11BO3002-13BO003 | Black | Red | 0.73 | b | 3.77 | d | Small |
| *LSD (P<0.05)* | | | *0.12* | | *0.17* | | |

**Conclusion**

Lentil production can be successful in low rainfall environments with the correct variety selection and management. Lentil varieties are available with improved tolerance to soil salinity and boron toxicity, and these options may be more productive in constrained soil types.

Red lentil is the common lentil type grown in South Australia, however, there are alternative and niche types available that are grown for specific end-uses or markets.  Growers are advised to secure markets before deciding to grow these lentil types. The alternative types, particularly green lentil, are later maturing than red lentil varieties and are more suited to longer growing seasons or higher rainfall zones. Longer growing seasons will enable varieties with later maturity times to develop seed to its full potential. Evaluation of green and niche lentil types in low rainfall environments under early sowing opportunities is yet to be explored.

## References

Bruce D. 2022. Improving pulse performance through early sowing opportunities in low to medium rainfall environments. Upper North Farming Systems Summary 2021.

***Acknowledgements***

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC (UOA2105-013RTX), and the authors would like to thank them for their continued support. The continued assistance in trial management from SARDI Agronomy groups at Clare is gratefully acknowledged and appreciated.

# Dryland Legume Pasture Systems Morchard trial site 2019-21

***Author:*** Andrew Catford (Northern Ag)

***Funded By:*** Upper North Farming Systems

***Project Title:*** Dryland Legume Pasture Demo

***Project Duration:*** 2019-2021

***Project Delivery Organisations:*** Upper North Farming Systems & Northern Ag Booleroo Centre

**Key Points:**

- Vetch was the best for bulk feed in the first year of the rotation
- Medics were the best species at regenerating following a cereal
- Serradella and Biserrula didn't perform well in the demonstration

**Background**

Since around the late 1930s in the Upper North region of South Australia, many farmers have adopted lay farming. This is the rotation of cereals with pasture legumes. This requires growers to juggle the constant compromise of managing pastures for livestock around cropping cereals and legumes for grain purposes. It has shown to be very profitable as both sides of the rotation can be advantageous to the other. The benefits of a pasture legume as a break crop include increased soil fertility, soil structure, forage production and herbicide options for weed control.

With all this in mind choosing the right type and variety of pasture legume that suits the growers' climate, conditions, rotation, and soil type can be very difficult when also considering the vast range of legume pastures on offer. The overall outcome of this demonstration is to gain greater understanding of which pasture legume options are best suited to the environment of the Upper North. This demonstration was run over three seasons (2019, 2020 and 2021) and looked at several different factors which influence how a pasture legume can fit into the modern farming rotation in the area.

**Methodology**

The demonstration was set up on the Morchard Progress Committee block directly north of the tennis courts. Ten treatments varying in cultivar, species and sowing rates were replicated twice using plots of 2 meters by 20 meters. These cultivars included Sultan-SU (barrel medic), Toreador (disc medic), Scimitar (burr medic), PM250 (burr medic), Margurita (serradella), Volga (vetch), Biserrula, Sardi (rose clover) and Bartolo (bladder clover). These cultivars were selected due to their excellent fit in other similar environments, or their characteristics which potentially looked like an excellent fit.

*Table 1. Trial Layout with Cultivar, Species and Sowing rate*

| West | | | |
|---|---|---|---|
| **Row** | **Cultivar** | **Species** | **Rate kg/ha** |
| 1 | Sultan- SU | Barrel Medic | 10 |
| 2 | Sultan- SU | Barrel Medic | 2.5 |
| 3 | Toredaor | Disc Medic | 7.5 |
| 4 | Scimitar | Burr Medic | 7.5 |
| 5 | PM250 | Strand Medic | 7.5 |
| 6 | Margurita | Serredella | 7.5 |
| 7 | Volga | Vetch | 40 |
| 8 | Volga | Vetch | 10 |
| | Sultan- SU | Barrel Medic | 10 |
| 9 | Biserrula | Biserrula | 5 |
| 10 | Sardi Rose | Rose Clover | 3.75 |
| | Bartolo | Bladder Clover | 3.75 |
| 11 | Control | | |
| 12 | Sultan- SU | Barrel Medic | 10 |
| 13 | Sultan- SU | Barrel Medic | 2.5 |
| 14 | Toredaor | Disc Medic | 7.5 |
| 15 | Scimitar | Burr Medic | 7.5 |
| 16 | PM250 | Strand Medic | 7.5 |
| 17 | Margurita | Serredella | 7.5 |
| 18 | Volga | Vetch | 40 |
| 19 | Volga | Vetch | 10 |
| | Sultan- SU | Barrel Medic | 10 |
| 20 | Biserrula | Biserrula | 5 |
| 21 | Sardi Rose | Rose | 3.75 |
| | Bartolo | Bladder | 3.75 |

The cultivars were assessed over three seasons to demonstrate a common rotation between pasture legumes and cereals. Year one (2019, pasture establishment phase) assessments included establishment counts, biomass cuts (originally planned at three growth stages but due to the poor season was reduced cut to one at peak biomass), nodule counts, N-Fixation, and nutrition tests. Year two (2020, cereal phase) looked at cereal NDVI, mid-season weed assessment, cereal yield and protein. Year three (regenerative phase) counted the number of regenerated species per cultivar.

## Results and Discussion

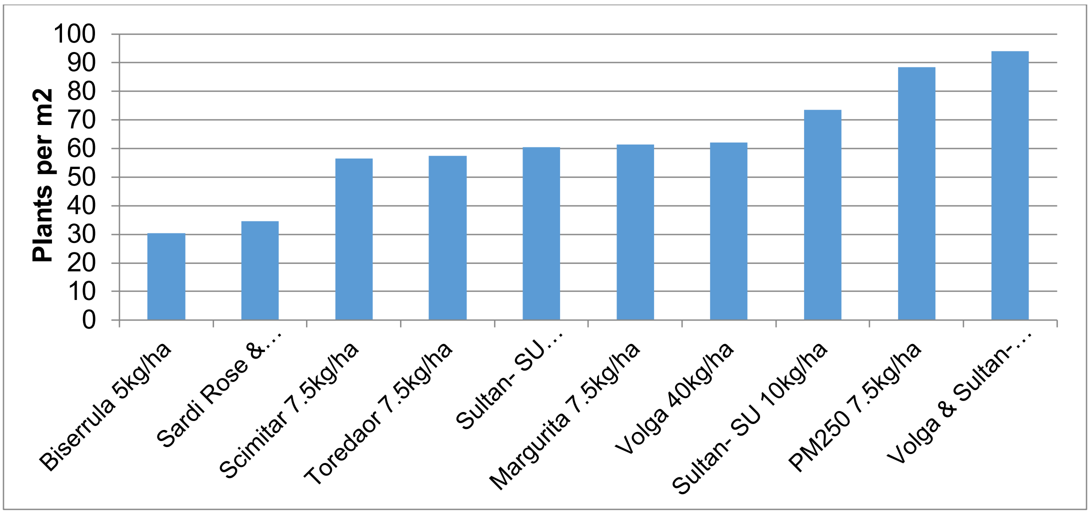



*Figure 1. Establishment plants counts per m$^2$ against each treatment in year one (2019)*

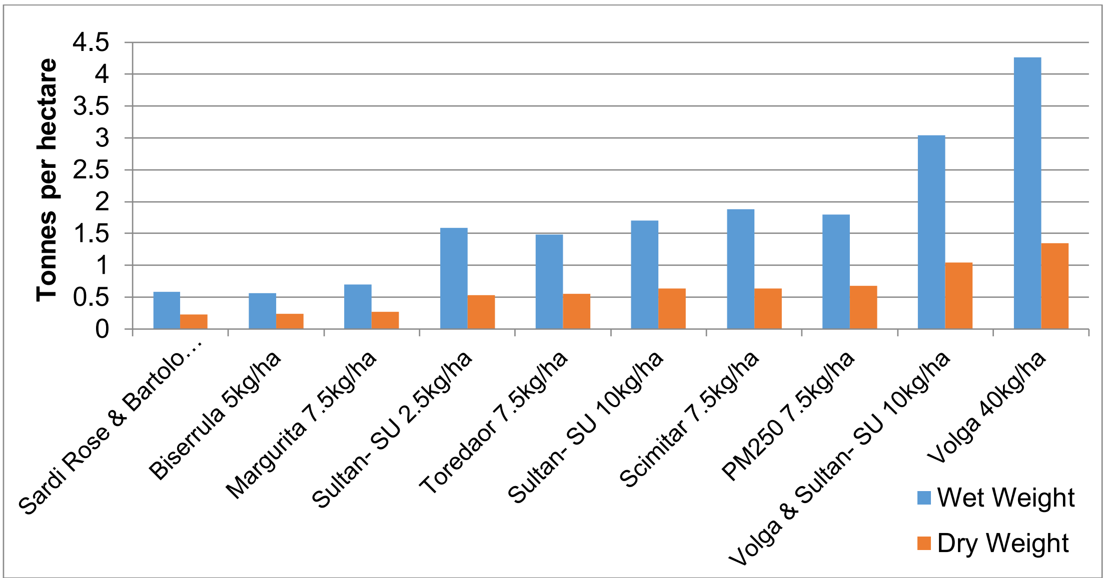



*Figure 2. Biomass cuts (wet and dry weight, t/ha) against each treatment in year one (2019)*

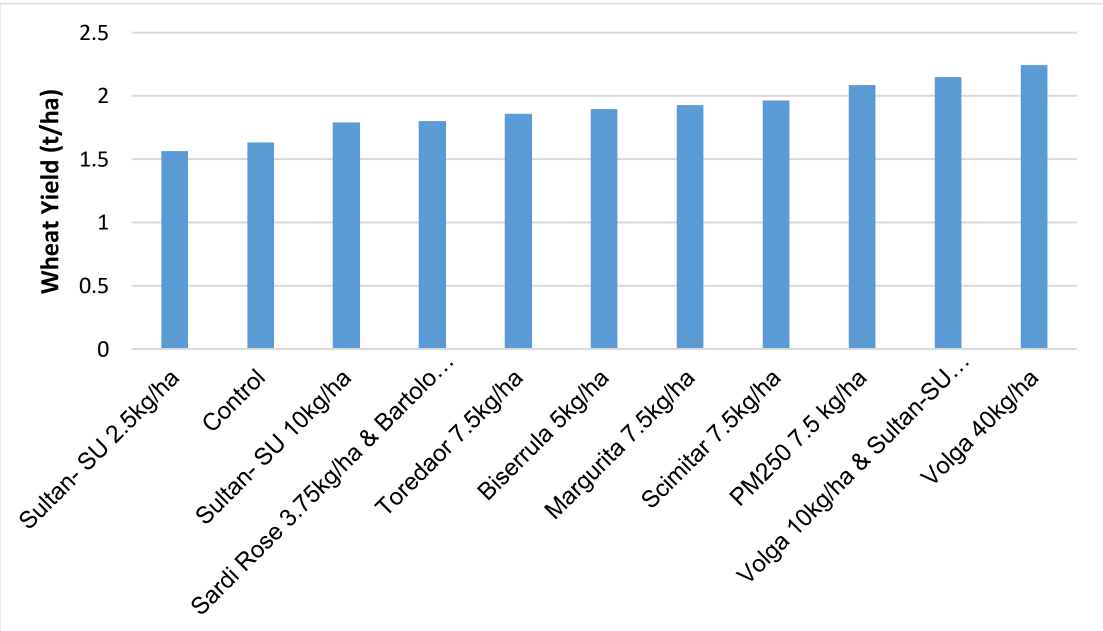



*Figure 3. Cereal yield (t/ha) against each treatment in year two (2020)*

*Table 2. Average percentage of pasture species to regenerate in the 3rd season after sowing per treatment*

| Average of both Reps | Sowing rate | Sultan Medic | Vol Wheat | IH Mustard | Wireweed | Toreador Medic | Scimitar Medic | PM250 | Native Medic | Ryegrass | Biserrula | Sardi Rose Clover | Bladder Clover | Vetch | Serradella |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sultan- SU | 10 | 60% | 23% | 10% | 3% | 0% | 0% | 0% | 5% | 0% | 0% | 0% | 0% | 0% | 0% |
| Sultan- SU | 2.5 | 58% | 33% | 8% | 3% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Toreador | 7.5 | 0% | 20% | 5% | 0% | 75% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Scimitar | 7.5 | 0% | 45% | 10% | 0% | 0% | 45% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| PM250 | 7.5 | 0% | 40% | 13% | 0% | 0% | 0% | 48% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Margurita | 7.5 | 0% | 55% | 28% | 0% | 0% | 0% | 0% | 10% | 0% | 0% | 0% | 0% | 0% | 8% |
| Volga | 40 | 0% | 60% | 13% | 0% | 0% | 0% | 0% | 23% | 3% | 0% | 0% | 0% | 3% | 0% |
| Volga | 10 | 55% | 28% | 8% | 0% | 0% | 0% | 0% | 8% | 3% | 0% | 0% | 0% | 0% | 0% |
| Sultan- SU | 10 | | | | | | | | | | | | | | |
| Biserrula | 5 | 0% | 48% | 33% | 3% | 0% | 0% | 0% | 8% | 0% | 10% | 0% | 0% | 0% | 0% |
| Sardi Rose | 3.75 | 0% | 40% | 20% | 3% | 0% | 0% | 0% | 0% | 0% | 0% | 5% | 33% | 0% | 0% |
| Bartolo | 3.75 | | | | | | | | | | | | | | |
| Control | | 0% | 30% | 35% | 0% | 0% | 0% | 0% | 20% | 15% | 0% | 0% | 0% | 0% | 0% |

**Discussion**

The demonstration yielded no statistically significant results between treatments. However, a number of trends can be observed from the data.

Sowing rate of each treatment was the key factor in affecting first year establishment plant counts **(figure 1),** with most pasture cultivars and species showing no strong effects. The one exception was PM250 which demonstrated much higher establishment counts compared to the other medic varieties at the same sowing rate. Unsurprisingly any treatment that had vetch outperformed all other treatments for biomass cuts **(figure 2)** (both wet and dry counts). PM250 was the standout medic cultivar, however; not statistically different. Serradella, biserula and the clovers all underperformed compared to the medics and vetch.

Wheat yields per treatment **(figure 3)** in year two of the demo showed no statistically different results, however; they followed similar trends to biomass cuts with vetch producing the highest subsequent yields and PM250 being the best performing medic species for subsequent wheat yield. It should be noted soil testing for moisture and nutrients and NDVI testing of the wheat crop showed no evidence of cause-and-effect relationship between increase biomass of the treatment and an increase yield of the following wheat crop. It is more likely but also unproven that the soil types and natural variation of the plots had a greater effect on both biomass cuts in the first year and wheat yield in the second year rather than biomass being the cause of increased wheat yield. Increase randomised replication of plots in future demonstrations and trials would help overcome this issue.

Regeneration data **(table 1)** showed that as a rule, the medics outperformed all other cultivars. Clovers were ranked second. Vetch showed to be very poor at regenerating under the demonstration's conditions.

Overall, the demonstration has helped reaffirm current beliefs about each treatments pros and cons. If a grower is looking for more bulk in their feed from their pasture and are willing to sow every year, then vetch is the clear standout. If a grower wants to save on the sowing cost and go for a pasture that is better at regenerating, then a medic would be their best option. When comparing medic species in this trial, PM250 looks to be the standout in both establishment counts and biomass cuts. Biserula and Serradella didn't appear to suit the demonstrations conditions.

***Acknowledgements***

- **Morchard Progress Committee for hosting the demonstration site**
- **Todd Orrock for sowing the demonstration**
- **Gilmour Catford for maintain the site for visitors**
- **Ross Ballard for expert input into the running of the demonstration**
- **For more data collected from the demonstration please contact Northern Ag Booleroo**

# Identifying suitable legume species for dryland, marginal rainfall farming land Canowie Belt

***Author(s):*** Bethany Sleep, Ross Ballard

***Funded By:*** SARDI

***Project Title:*** Southern Pulse Extension Project #226

***Project Duration:*** 2020 - 2022

***Project Delivery Organisations:*** UNFS, Elders Jamestown

**Key Points:**

- Year two of the three-year trial
- Site was sown to wheat, with self-regenerating legumes sprayed out in season
- No significant differences in yield between treatments (appendix A)
- Site will go back to a pasture phase in the coming season (2022)

**Background**

This study aimed to investigate the suitability of various legume species in a dryland, marginal rainfall environment, where typical break crops such as faba beans, field peas or canola are not economically viable or suited to the system. The project will highlight the ability of various pasture legumes to regenerate from a seed bank, following a rotation of a cereal cash crop. This attempts to achieve the well-known benefits of a break crop, such as nitrogen fixation, herbicide mode of action rotation and cereal disease break in addition to complementing livestock grazing requirements. Species were assessed for feed quality and timing of feed on offer throughout the season, ensuring species are suited to our modern mixed farming systems across the Upper North, where focus has shifted toward continuous cropping. Therefore, viability of established perennial pastures no longer fits the system.
The site ran across three growing seasons with several different factors assessed throughout the trial predominantly including how a pasture legume is able to fit into the modern rotation of farming in the Low Rainfall Zone (LRZ) regions of South Australia.

**Methodology**

This trial was located in the Canowie Belt region, approximately 20 km's North-East of Jamestown and 10 km's South of Yongala. Long term annual rainfall is ~350 mm with soil and atmospheric temperatures typically declining quickly at the beginning of the season due to frost events. This presents a challenge for early growth, resulting in a feed gap at the beginning of the season which a self-regenerating pasture may be able to address.

The trial was originally sown to legumes on the 5th of May 2020 with 40 kg/ha starting fertilizer (MAP), after species were inoculated using a slurry coating. Pasture cultivar and species, seeding depth and rates are shown in table 3. The trial utilised a randomised trial design, with three replications. Plots ran North, South with the trial site located on a slight incline. Soil type across the trail is a red, brown earth with clay content increasing down the profile. No major soil constraints were identified in the initial soil sampling (Appendix B). The site pH increases as you move up the slope, meaning the third replication has alkaline conditions, whilst replication one is closer to neutral.

The trial ran over three years (2020 – 2022), with each phase highlighted in table 4. In year one establishment counts, peak biomass, nodulation, feed quality and N fixation are evaluated. Year two assessments include weed pressure, NDVI, grain protein and cereal yield, with year three considering pasture regeneration and DSE for grazing.

*Table 3. Cultivar and species used in this trial, which employed a randomised trial design across 3 replications, using plots of 1.75 m by 15 m. Sowing rate and depth used in the trial is also shown below.*

| Cultivar | Species | Sowing Rate (kg/ha) | Sowing Depth (cm) |
|---|---|---|---|
| *Casbah | Biserrula | 5 | 1 |
| PM250 | Strand Medic | 7.5 | 1 |
| *Scimitar | Burr Medic | 10 | 1 |
| SARDI Rose | Rose Clover | 7.5 | 1 |
| SARDI Rose + Bartolp | Rose Clover<br>Bladder Clover | 3.7<br>3.7 | 1 |
| Margarita | Serradella | 7.5 | 1 |
| Saltan | Barrel Medic | 7.5 | 1 |
| Studencia | Vetch | 40 | 2 |
| *Volga + Saltan | Vetch<br>Barrel Medic | 15<br>7.5 | 2 |
| *Volga | Vetch | 40 | 2 |
| Lanza | Tedera | 10 | 2 |
| *Mawson | Sub Clover | 10 | 1 |

***** Identifies cultivars where we used old seed. Germination tests were undertaken, with the Casbah (Biserrula) seed being identified as not viable seed and therefore is disregarded in this trial.

*Table 4. Trial timeline, beginning in 2020 and concluding in 2023.*

| | |
|---|---|
| **Year 1** | Pasture legumes sown and let to set seed |
| **Year 2** | Wheat sown and pasture legumes sprayed out |
| **Year 3** | Re-generation of pasture legumes |

## Results and Discussion

Opening rains came late at the beginning of the 2021 growing season, with no significant rainfall events until the third week of June at the site (appendix C). Therefore, the wheat was not sown until the 3rd of June, with establishment much later that month. As a result, there was a poor knockdown at the site and sowing depth was not optimum.

A broadleaf herbicide was applied to the site on the 2nd of August, to reduce crop competition from the legume species and a high population of mustard. Prior to this application, legume regeneration counts were completed (figure 1). This is an indication of the hard seededness of each variety used in the trial, with less hard seededness resulting in a higher population of legumes early. This is a negative trait for this type of production system, with a year of cash crop prior to the next legume phase. It should also be noted that due to the prolonged dry summer and late opening rains, there was reduced ground cover. This resulted in some of the seed bank at the site being blown away, and therefore missed in counts moving forward. Scimitar clover and margarita serradella showed the highest regeneration among the different treatments. The serradella population was potentially remaining seed sown at the beginning of the 2020 growing season, which did not germinate throughout 2020 due to hard seededness. However, the scimitar was likely from the 2020 seed set. This will result in a reduced seed bank coming into the pasture phase next year, reducing the suitability of this clover in a two-year rotation. The vetch cultivars showed the smallest amount of regeneration among the treatments. This may be due to hard seededness, however; is more likely due to the movement of seed via drift over summer. Another treatment showing low plant numbers was the tedera. Plants counted were mainly from the population which established in 2020 and grew over the summer period (figure 2). This species showed good adaptation to dry, hot growing conditions experienced throughout the 2020, 2021 summer. Establishment in the first year was found to be incredibly important for this species, with little to no seed set in the first and second year. The main focus at this trial in the coming season (2022) will be legume regeneration, to assess the suitability of each species for a two-year rotation.

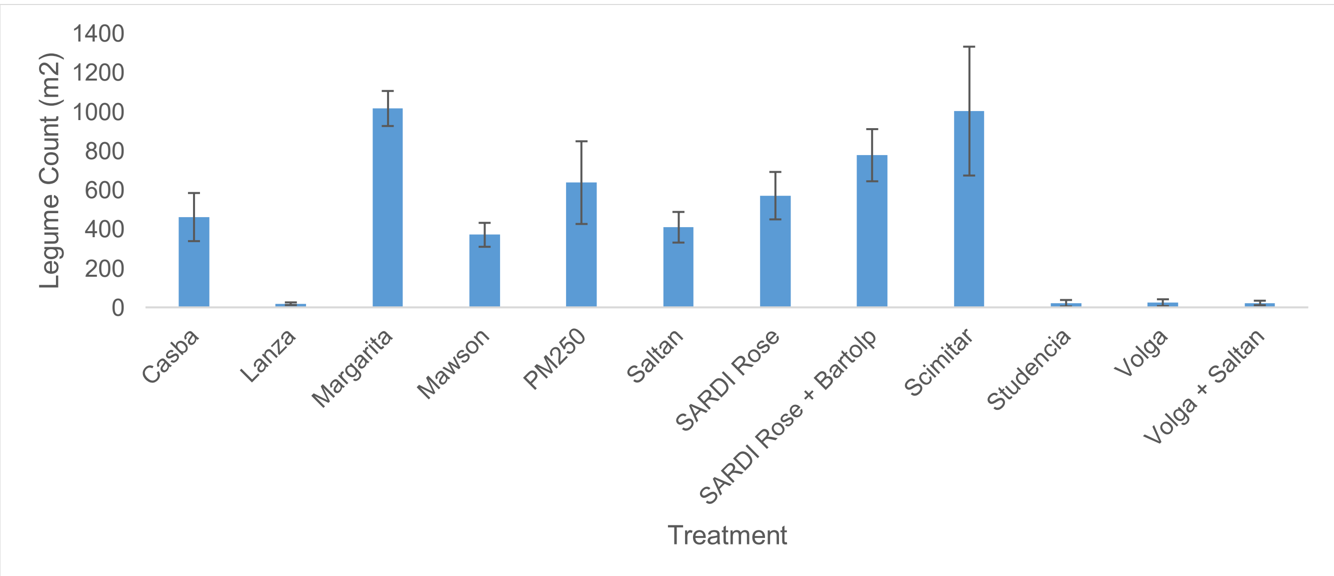



*Figure 1. Legume counts taken on the 15th of July 2021, highlighting regeneration, prior to application of a broadleaf herbicide mix to allow the wheat cash crop to continue.*

*Figure 2. Tendera plot, taken on the 20th of May, after a dry summer.*

Subtle differences in NDVI were observed at the site throughout spring 2021. Whilst no visual difference was observed between treatments in wheat biomass, there was a varying degree of legume regeneration between plots, even after the broadleaf spray was applied, with multiple germinations throughout the one season. This is likely the driver of these observed differences in NDVI values.

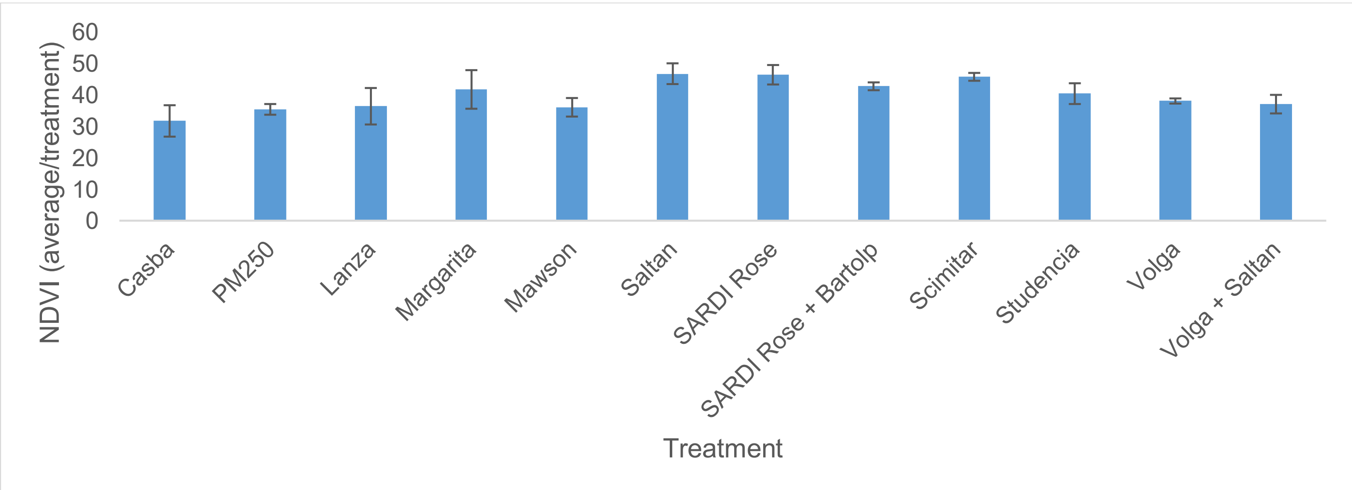
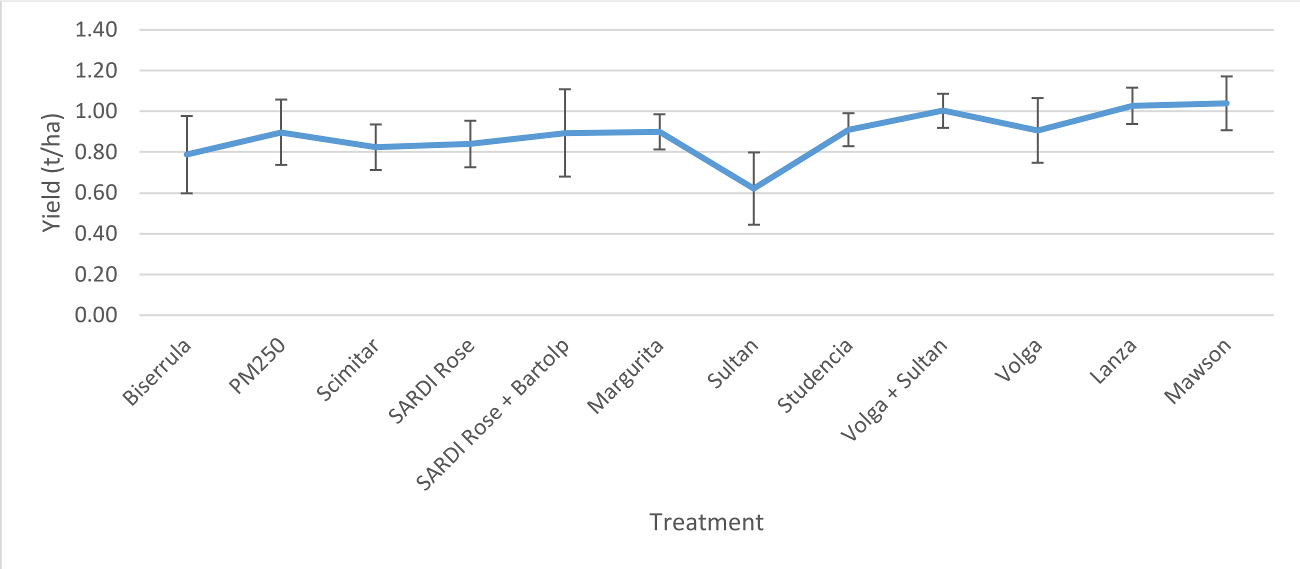



*Figure 3. Average NDVI readings, taken in the 16th of September 2021, across the three replicates, with error bars showing standard deviation between treatments.*


***Acknowledgements***

- Craig, Lyn and Damon Humphris, for providing the site and contributing to project management throughout the year
- SARDI for providing their cone seeder and staff to sow the trial
- S & W Seeds, Barenbrug Heritage Seeds and SARDI for providing seed and inoculant
- Rehn Fairbarn and Stuart Negel for presenting at our field day

**Appendix A.** Yield data gained from plot harvest, averaged from the three replicates, with error bars showing standard deviation between replicates.




**Appendix B.** Soil sample data, taken on the 10th of April to a depth of 10 cm's.

| | | Unit | Desired Level | Level Found | c.mol/kg |
|---|---|---|---|---|---|
| | MIR - Aus Soil Texture | | | Silty loam | |
| | ECEC | cmol/kg | 5.00-25.0 | 12.8 | |
| | Organic Carbon (W&B) | % | 0.900-1.80 | 1.46 | |
| | pH 1:5 water | pH units | 6.50-7.50 | 6.65 | |
| | pH CaCl2 (following 4A1) | pH units | 5.50-6.50 | 6.27 | |
| Extractable N-P-K-S | Nitrate - N (2M KCl) | mg/kg | 20-50 | 63 | |
| | Ammonium - N (2M KCl) | mg/kg | 2.0-10 | 1.1 | |
| | Colwell Phosphorus | mg/kg | 25-29 | 51 | |
| | DGT-P | µg/L | | 78.0 | |
| | PBI + Col P | | 35.0-70.0 | 57.0 | |
| | KCl Sulfur (S) | mg/kg | 8.0-20 | 14 | |
| Exchangeable cations | Calcium (Ca) - AmmAc | mg/kg | 1000-2000 | 1910 | 9.52 |
| | Magnesium (Mg) - AmmAc | mg/kg | 150-200 | 249 | 2.05 |
| | Potassium (K) - AmmAc | mg/kg | 150-220 | 428 | 1.09 |
| | Sodium (Na) - AmmAc | mg/kg | 15.0-120 | 32.1 | 0.140 |
| | Exchangeable aluminium | cmol/kg | 0.10-0.35 | <0.02 | |
| | Exchangeable hydrogen | cmol/kg | 0.10-0.35 | <0.02 | |
| Trace Elements | Boron | mg/kg | 0.50-2.0 | 0.96 | |
| | Iron (Fe) | mg/kg | 10-70 | 22 | |
| | Manganese (Mn) | mg/kg | 1.0-10 | 34 | |
| | Copper (Cu) | mg/kg | 0.50-1.0 | 1.9 | |
| | Zinc (Zn) | mg/kg | 0.50-1.0 | 7.5 | |
| Salt | Salinity EC 1:5 | dS/m | 0.025-0.15 | 0.21 | |
| | Ece | dS/m | 0.10-1.5 | 2.0 | |
| Ratios | Ca:Mg Ratio | | 2.0-8.0 | 4.7 | |
| | K:Mg Ratio | | 0.10-0.50 | 0.53 | |
| | GTRI | | 0.020-0.070 | 0.090 | |

Very Low | Low | Acceptable | High | Excessive

| | | Unit | Desired Level | Level Found | Exchangeable cation % (eCEC) |
|---|---|---|---|---|---|
| Exch. cation % | Calcium | % | 60.0-80.0 | 74.4 | 60.0-80.0 % |
| | Magnesium | % | 10.0-20.0 | 16.0 | 10.0-20.0 % |
| | Potassium | % | 3.00-8.00 | 8.50 | 3.00-8.00 % |
| | Sodium | % | 0.500-6.00 | 1.10 | 0.500-6.00 % |
| | Aluminium | % | 0.500-10.0 | 0.00 | 0.500-10.0 % |
| | Hydrogen | % | 0.300-5.00 | 0.00 | 0.300-5.00 % |

**Appendix C.** Rainfall data for the 2020 and 2021 season recorded 2 km south of the trial site on an adjoining farm.`

| Month | Total Rainfall 2020 | Wet Days 2020 | Total Rainfall 2021 | Wet Days 2021 |
|---|---|---|---|---|
| Jan | 37.5 | 2 | 8 | |
| Feb | 69 | 3 | 0 | |
| Mar | 0 | 0 | 16 | |
| Apr | 59.5 | 6 | 4.5 | |
| May | 25.3 | 6 | 10.5 | |
| Jun | 20.5 | 6 | 59.7 | |
| Jul | 9.5 | 3 | 93.8 | |
| Aug | 61.8 | 11 | 21 | |
| Sept | 59.5 | 3 | 10 | |
| Oct | 97.5 | 6 | 20.3 | |
| Nov | 0 | 0 | 123.8 | |
| Dec | 35.5 | 4 | | |
| | | | | |
| **TOTAL** | 475.6 | | 267.6 | |
| **GS Rainfall** | 333.6 | | | |

# Dryland Legume Pasture Systems (DLPS): Pasture demonstration sites

**Fiona Tomney[1], Morgan McCallum[1], Jessica Gunn[1], David Peck[2,3] and Ross Ballard[2,3]**

[1]SARDI, Minnipa; [2]SARDI, Waite; [3]University of Adelaide

**Location**
Lock
**Rainfall**
Av. Annual: 340 mm
2020 Total: 322 mm
2020 GSR: 277 mm
**Paddock history**
2019: Medic
2018: Wheat
**Soil type**
Sandy loam
**Plot size**
2 m x 24 m x 2 reps

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**Location**
Wirrulla
**Rainfall**
Av. Annual: 375 mm
2021 Total: 366 mm
2021 GSR: 197 mm
2020 Total: 315 mm
2020 GSR: 293 mm
**Paddock history**
2019: Medic
2018: Wheat
**Soil type**
Calcareous grey sandy loam
**Plot size**
2 m x 24 m x 2 reps

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**Location**
Mount Cooper
**Rainfall**
Av. Annual:
2021 Total:
2021 GSR:
**Paddock history**
2020:
2019:
2018:
**Soil type**
Red Loam
**Plot size**
4 m x 200 m x 2 reps

## Key messages

- **Volga vetch produced the most biomass in the establishment year at both sites.**
- **Grain protein, but not grain yield was significantly affected by the type of pasture legume previously grown.**
- **The annual medics were the most persistent species after cropping.**
- **The findings will be used to prioritise further research and development of novel pasture species on sandy soils.**

## Why do the trial?

Over the past three decades there has been a shift from integrated crop-livestock production to intensive cropping in dry areas, which has significantly reduced the resilience of farms in low to medium rainfall areas. Intensive cropping is prone to herbicide resistant weeds, large nitrogen fertiliser requirements, and major financial shocks due to frost, drought or low grain prices.

A pilot project with MLA and AWI in WA and southern NSW has demonstrated how novel pasture legumes such as serradella, biserrula and bladder clover can improve livestock production while reducing nitrogen requirements, weeds and diseases for following crops. The extent to which these new legumes establish, grow and persist on South Australia's alkaline sandy soils requires clarification.

The demonstration sites are primarily an extension tool, unlike research trials requiring detailed data collection. The purpose of these sites is to gather information on regional legume performance, including benefits to the crops that follow.

## How was it done?

The demonstration trials were designed after discussions with local farmers at the Minnipa Agricultural Centre 2018/19 harvest meetings in several locations across upper Eyre Peninsula. It was decided that the two sites chosen should target challenging soil types (particularly sandy soil) for establishing and successfully growing legume pastures in the mixed farming environment. Cultivars were chosen based on recommendations from low to medium rainfall pasture experts, site locality and soil profile information, including recent soil tests undertaken.

***Site 1***
***Lock, SA (Kerran 'Gus' Glover)***

Treatments established in 2019: Best bet variety demonstration - 2 reps x 10 treatments, 2 m x 25 m plots. The pastures were managed for maximum seed set, fenced off from grazing over summer and sown to Spartacus barley in 2020. Pasture treatments were:

- Casbah biserrula sown @ 5 kg/ha
- Toreador disc medic sown @ 7.5 kg/ha
- Seraph (PM-250) strand medic sown @ 7.5 kg/ha
- Sultan-SU barrel medic 2.5 sown @ 2.5 kg/ha
- Sultan-SU barrel medic 10 sown @ 10 kg/ha
- Scimitar spineless burr medic sown @ 7.5 kg/ha
- Volga vetch sown @ 40 kg/ha
- SARDI rose clover & Bartolo bladder clover mix sown @ 3.75 kg/ha
- Volga (40 kg/ha) & Sultan-SU (10 kg/ha) mix
- Margurita French serradella sown @ 7.5 kg/ha

In 2020 on 8 May, the site was sown to Spartacus barley @ 60 kg/ha, with DAP @ 70 kg/ha and 1.8 L/ha glyphosate, 100 ml/ha oxyfluorfen, 2 L/ha trifluralin applied pre-sowing. Soil sampling for soil nitrogen and soil borne diseases occurred on 4 April. GreenSeeker and weed assessments were conducted on 18 August. The site was harvested on 17 November. Lock received a total of 322 mm rainfall for the year with 277 mm falling within the growing season.

In 2021 the trial was monitored for the regeneration and subsequent performance of the legume pasture species after the cereal cropping phase. Plant regeneration counts were completed on 8 July 2021.

***Site 2***
***Wirrulla, SA (Dion Trezona)***

Treatments applied in 2019: Best bet variety demonstration with 2 reps x 10 treatments, 2 m x 25 m plots. The pastures were managed for maximum seed set, were fenced off from grazing over summer and sown to Scepter wheat in 2020. Pasture treatments were:

- Casbah biserrula sown @ 5 kg/ha
- Toreador disc medic sown @ 7.5 kg/ha
- Scimitar spineless burr medic sown @ 7.5 kg/ha
- SARDI rose clover & Bartolo bladder clover mix sown @ 3.75 kg/ha
- Margurita French serradella sown @ 7.5 kg/ha
- DL11 Boron tolerant spineless burr medic sown @ 7.5 kg/ha
- Seraph strand medic sown @ 7.5 kg/ha
- Sultan-SU barrel medic sown @ 2.5k g/ha
- Volga (40 kg/ha) & Sultan-SU (10 kg/ha) sown @ 10 kg/ha
- Sultan-SU barrel medic sown @ 10 kg/ha
- Volga vetch sown @ 40 kg/ha

On 21 May 2020, the site was sown to Scepter wheat with Granuloc Zinc DAP applied @ 60 kg/ha. Soil sampling for soil nitrogen and soil borne diseases occurred on 4 April. GreenSeeker, Canopeo (determines % area green) and weed assessments were conducted on 17 August. The site was harvested on 9 November. Wirrulla received a good amount of rainfall with an annual total of 315 mm and 293 mm of that falling within the growing season.

In 2021 the trial was monitored for the regeneration of the legume pasture species after the cereal cropping phase. Plant regeneration counts were completed on 10 August 2021.

***Site 3***
***Mount Cooper, SA (Angus and Jessica Gunn)***

On 28 May 2021 a new large-scale demonstration trial was sown at Angus and Jessica Gunn's at Mount Cooper. The purpose of this demo trial was to assess the performance of two new pasture legume cultivars using the first commercially available seed. These cultivars were Seraph (PM-250) strand medic and Frano French serradella. Seraph had already been shown to perform well within the DLPS project both in small plot research trials (see EPFSS 2018, p. 153; EPFSS 2019, p. 209 and EPFSS 2020, p. 186). Frano has a flowering time two weeks earlier than the previously available French serradella cultivar Margurita, so could potentially set more seed in a dry location. These new cultivars were compared against an older locally available medic cultivar Caliph barrel medic, and the regenerating medic already present in the paddock.

The Seraph, Frano and Caliph were sown at a high rate of 30 kg/ha in order to mimic the production of a regenerating pasture, which is generally much higher than a newly established one sown at a much lower rate. Plots were sown as double runs (4 m wide) in 200 m strips up and down a slope with two replications using small plot equipment. These demo strips were grazed by sheep in common with the wider paddock.

Plant establishment counts were completed on 29 June 2021.

## What happened?

In 2019, Volga vetch produced the greatest biomass on both soil types (calcareous grey sandy loam at Wirrulla and sandy loam at Lock). Pasture production at Wirrulla in general was low in 2019, with the biomass ranging from 0.80 t/ha Margurita French serradella to 3.23 t/ha Volga vetch. Seed pod set was noticeably low at the Wirrulla site due to a dry finish, compared to the Lock site where the Seraph strand medic, Scimitar spineless burr medic and Casbah biserrula set the most pods. Overall, the majority of species at both sites produced adequate seed set for regeneration in 2021, following a cereal crop. At both sites in 2020 measurements including soil nitrogen, soil disease assessment and GreenSeeker analysis conducted throughout the growing season showed no differences between the treatments (data not shown).

The wheat and barley at Wirrulla and Lock showed consistent emergence (mean plants/m$^2$) across all pasture treatments, with no significant treatment differences observed. Cereal grain yields in 2020 ranged from 1.7 to 1.9 t/ha at Lock and from 1.0 to 1.2 t/ha at Wirrulla but there were no statistically significant differences between treatments.

Grain quality analysis was conducted for both sites and grain protein levels following the pasture treatments showed significant differences between treatments at both sites. At the Lock site, the average protein percentage ranged from 11.5% in the Volga vetch treatment to 10.5% for Scimitar spineless burr medic (Table 2). At Wirrulla grain protein ranged from 11.6% in the Seraph strand medic treatment to 10.8% in the Toreador disc medic.

**Table 1. Grain yield of Spartacus barley (t/ha) at Lock and Scepter wheat (t/ha) at Wirrulla in 2020.**

| Lock | | Wirrulla | |
|---|---|---|---|
| **2019 Treatment** | **Average yield (t/ha)** | **2019 Treatment** | **Average yield (t/ha)** |
| Casbah biserrula | 1.88 | Casbah biserrula | 1.19 |
| Toreador disc medic | 1.85 | Toreador disc medic | 1.13 |
| Seraph strand medic | 1.80 | Scimitar spineless burr medic | 1.12 |
| Sultan-SU barrel medic @ 2.5 kg/ha | 1.78 | SARDI rose clover & Bartolo bladder clover mix | 1.12 |
| Scimitar spineless burr medic | 1.78 | Margurita French serradella | 1.10 |
| Volga vetch | 1.78 | DL11 Boron tolerant burr medic | 1.08 |
| SARDI rose clover & Bartolo bladder clover mix | 1.75 | Seraph strand medic | 1.07 |
| Sultan-SU barrel medic @ 10 kg/ha | 1.73 | Sultan-SU barrel medic @ 2.5 kg/ha | 1.06 |
| Volga & Sultan-SU Mix | 1.69 | Volga & Sultan-SU Mix | 1.06 |
| Margurita French serradella | 1.69 | Sultan-SU barrel medic @ 10 kg/ha | 1.06 |
| | | Volga vetch | 1.04 |
| *LSD (P=0.05)* | *ns* | | *ns* |

**Table 2. Grain protein quality in 2020 from the Lock and Wirrulla sites.**

| Lock | | Wirrulla | |
|---|---|---|---|
| **2020 Treatment** | **Grain protein (%)** | **2020 Treatment** | **Grain protein (%)** |
| Volga vetch | 11.45 a | Seraph strand medic | 11.60 a |
| Sultan-SU barrel medic @ 10 kg/ha | 11.20 ab | Volga vetch | 11.40 a |
| Seraph strand medic | 11.15 a | DL11 Boron tolerant spineless burr medic | 11.35 a |
| Volga & Sultan-SU Mix | 11.15 a | Margurita French serradella | 11.25 ab |
| Casbah biserrula | 11.05 a | Sultan-SU barrel medic @ 2.5 kg/ha | 11.20 ab |
| Margurita French serradella | 11.0 a | Casbah biserrula | 11.15 ab |
| SARDI rose clover & Bartolo bladder clover mix | 10.95 ab | Sultan-SU barrel medic @ 10 kg/ha | 11.15 ab |
| Toreador disc medic | 10.75 ab | SARDI rose clover & Bartolo bladder clover mix | 11.10 ab |
| Sultan-SU barrel medic @ 2.5 kg/ha | 10.5 b | Scimitar spineless burr medic | 11.10 ab |
| Scimitar spineless burr medic | 10.5 b | Volga & Sultan-SU Mix | 10.95 ab |
| | | Toreador disc medic | 10.80 b |
| *LSD (P=0.05)* | *0.76* | | *0.65* |

At Lock the annual medic species showed the best regeneration with Seraph having twice the number of plants as Sultan-SU (Table 3), which is due to the smaller seed size of Seraph combined with slightly lower hardseed levels. The differing seeding rates did not appear to affect the regeneration of the Sultan-SU. Counts of the medic plants may have included naturalised medic. Large biserrula plants were observed outside of the quadrats, indicating an earlier germination on summer rains. Only one serradella plant was observed over the entire site. At this site medics failed to regenerate in the Vetch/Sultan-SU treatment This indicates that competition from the vetch was detrimental to medic seed set and longer medic persistence. This observation may be relevant to competition effects in mixed pastures. The weeds were mostly barley grass and large broadleaf weeds which were predominantly turnip. The weed numbers indicate both broadleaf and grass herbicides should be used. The more the legume dominant the pasture the greater the nitrogen fixation and benefit to subsequent grain crops.

At Wirrulla annual medic species were also the most persistence species after cropping (Table 4.). Toreador disc medic performed well on the sandy site. New disc medic cultivars are being developed for sandy soils. As with the Lock site, the counts of the medic may have included some naturalised medic. The two clover species were small and had a red/yellow colouration. As the plants were too small to accurately discern the differences between rose and bladder clovers, they were counted collectively.

*Table 3. Plant regeneration counts at Lock 8 July 2021.*

| Treatment | Number of (plants /m²) | Number of Grass (weeds/m²) | Number of Broadleaf (weeds/m²) |
|---|---|---|---|
| Sultan-SU barrel medic @ 10 kg/ha | 37.5 | 67.5 | 91.3 |
| Sultan-SU barrel medic @2.5 kg/ha | 38.8 | 75 | 53.8 |
| Toreador disc medic | 16.3 | 35 | 98.8 |
| Scimitar burr medic | 10 | 53.8 | 163.8 |
| Seraph strand medic | 73.8 | 60 | 74.8 |
| Margurita French serradella | 0 | 96.3 | 14 |
| Volga Vetch | 0 | 70 | 10 |
| Volga + Sultan-SU Mix | 1 | 122.5 | 121.3 |
| Casbah biserrula | 0 | 83.8 | 71.3 |
| SARDI rose +Bartolo bladder clover Mix | 0 | 71.3 | 148.8 |

*Table 4. Plant regeneration counts at Wirrulla 10 August 2021.*

| Treatment | Number of Plants /m² | Number of Grass Weeds/m² | Number of Broadleaf Weeds/m² |
|---|---|---|---|
| Sultan-SU barrel medic @ 10 kg/ha | 145 | 162.5 | 37.5 |
| Sultan-SU barrel medic @ 2.5 kg/ha | 165 | 150 | 32.5 |
| Toreador disc medic | 241.3 | 158.8 | 43.8 |
| Scimitar burr medic | 155 | 163.8 | 36.3 |
| Seraph strand medic | 213.8 | 115 | 31.3 |
| Margurita French serradella | 0 | 130 | 48.8 |
| Volga vetch | 8.8 | 92.5 | 32.5 |
| Volga + Sultan-SU Mix | 3.8 V + 133.8 S | 147.5 | 46.3 |
| Casbah biserrula | 38.8 | 148.8 | 37.5 |
| SARDI rose + Bartolo bladder clover Mix | 137.5 | 132.5 | 42.5 |
| DL11 Boron tolerant burr medic | 123.8 | 137.5 | 33.8 |

*Table 5. Plant emergence counts at Mount Cooper 29 June 2021.*

| Treatment | Number of (plants /m²) | Number of Grass (weeds/m²) | Number of Broadleaf (weeds/m²) |
|---|---|---|---|
| Seraph strand medic | 613 | 12 | 17.5 |
| Frano French serradella | 410 | 7.5 | 24.5 |
| Caliph barrel medic | 307 | 13.5 | 16.5 |
| Regenerating medic | 864.5 | 16 | 121 |

The biserrula plants were the last to emerge and were often found hidden under the leaves of the large broadleaf weeds but appeared to be healthy. The broadleaf weeds were mostly wards weed and the grass weeds were mostly rye grass.

At the Mount Cooper site plant emergence counts were completed on 29 June 2021. The weeds were predominantly marshmallow (Table 5).

When the site was visited on 5 August 2021 medic plants were growing uniformly up and down the slope. Frano grew well on the top of the slope, but by mid slope was yellow and had reduced growth. Plant emergence counts had been even across the entire slope. Across the wider DLPS project, French serradella has occasionally performed well on deep sandy soils. Planting a test strip of alternative pasture legumes up and down a slope can be used as way determining which areas of your farm is suited to alternative legume species.

## What does this mean?

Grain protein content, but not grain yield was affected by the pasture treatment that proceeded the wheat crop. Whilst the trials indicate scope to improve grain protein by using pasture species aligned with the soil types, further work is needed to understand the transfer of N between the legume and crop phase.

These demonstration sites compared alternative ley pasture species with strand and barrel medics which are currently the widely used pasture species on the upper EP. Ley pasture species/ cultivars need to be well adapted to the soil type in order to be productive, and have high seed set and suitable hardseed levels to regenerate after a crop. At these sites the medics regenerated well. The alternative species French serradella cultivar Margurita failed to regenerate at Lock and Wirrulla. The new early season cultivar Frano may assist with greater seed set in low rainfall environments. The alternative species biserrula did not regenerate at Lock and had moderate regeneration at Wirrulla. Planting strips up and down a slope at Mount Cooper demonstrates a method that can be used to determine which soil types an alternative can be grown on. By planting strips of alternative species you can determine suitability while minimising seed costs and the risk of a whole paddock failing. When trialling alternative species it is important to evaluate their ability to regenerate and not just their performance in the establishment year. The medic/ vetch treatment was a method in which vetch can provide more feed in the establishment year. However at Lock medic combined with vetch failed to regenerate. This suggests that instead of using vetch it would be better to increase the sowing rate of medic.

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**Section Editor:**
**Phil Davies**
SARDI, Waite

# Pastures

## Dryland Legume Pasture Systems (DLPS): New pasture cultivars

**David Peck[1,3], Fiona Tomney[2], Jeff Hill[1], Kym Zeppel[2] and Ross Ballard[1,3]**

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### Key points

- **Seraph (PM-250), a powdery mildew (PM) resistant strand medic, is commercially available.**
- **Evaluation of spineless burr medics is well advanced, and it is expected that a line will be chosen as a cultivar in autumn 2022.**
- **An arrowleaf clover selection is very promising, showing a 30% increase in dry matter over current variety Cefalu.**
- **A hardseeded Trigonella balansae may be chosen as a cultivar in autumn 2022.**
- **Disc and strand medics with increased ability to fix nitrogen are being developed.**

### Why do the trial?

New ley pasture legume cultivars are being developed to increase pasture adoption and production and thus benefit livestock and subsequent grain crops.

Ley legume pasture cultivars need to have appropriate hardseed levels so that they can persist through 1 to 3 years of crops. They are often bred to overcome significant soil or management constraints. Several other selection criteria include:

1. Seed harvestability and seedling vigour.
2. Seasonal herbage production and N fixation.
3. Time of flowering.
4. Seed production.
5. Suitability for livestock grazing and production, and subsequent grain crops.
6. Tolerance to common soil constraints.
7. Suitable hardseed level.
8. Tolerance to pests and diseases.

We have focused on legume species that perform well on neutral to alkaline soils as these soils are widespread in the low/medium rainfall zones of South Australia and Victoria. Included are traditional medic species and alternative species such as arrowleaf clover that can have seed harvested with grain harvesters. The highest pasture production occurs when the best cultivar of a species, that is well adapted to the soil type and growing season, is combined with good agronomy. This article provides an overview of breeding components of the DLPS project from the southern node and a short overview of breeding components of the western node. It provides details of a new cultivar, advanced cohorts and provides an update on pipeline material.

### How was it done?

Once traits of interest, such as tolerance to a disease or soil constraint, are identified and tolerant material developed, agronomic evaluation is undertaken in multiple target environments to ensure prospective new cultivars are suitably adapted and productive. Initially, a source of tolerance to the constraint has to be identified and is often found by screening diverse genotypes obtained from The Australian Pasture Genebank (APG). Often the accession with the required trait needs to be crossed with other cultivars/accessions to develop lines that combine the new trait with high agronomic performance.

This project has built on the foundations of previous selection and pre-breeding work. Further, in the first year of the project speed breeding methods (up to six generations per year instead of 1-2 generations) were used to generate the material for field evaluation. For each breeding target the material has been evaluated on relevant soil types (eg. sandy or loamy) across the upper EP, Murray Mallee and parts of the mid-North.

## What happened?

### *Seraph strand medic*

Seraph strand medic was commercially available in a limited amount in autumn 2021 and will be readily available in 2022. Seraph has featured in all the DLPS species adaptation, agronomic work, and grazing studies where it was referred to by its breeding code PM-250. The main objective in the development of Seraph was resistance to powdery mildew (PM) which is a widespread disease of annual medics. PM is particularly common in springs following wet summers/autumns. In addition to infected swards being less productive, livestock are known to avoid PM infected medics resulting in reduced livestock growth and fertility. The PM resistant parent was highly productive in its own right and contributed to Seraph achieving increased dry matter production. Even in the absence of PM, averaged across many sites Seraph medic delivered a 15% increase in dry matter production compared to the cultivar (Angel) it replaced. Seraph is also tolerant of SU and Intervix herbicide residues and resistant to bluegreen aphids (BGA). Seraph strand medic is recommended for neutral to alkaline sandy loam soils.

### *Spineless Burr medics*

The DLPS project is evaluating two spineless burr medic cohorts: 1) tolerant of boron (B) and 2) tolerant to red legged earth mites (RLEM). A prior MLA pre-breeding project had screened accessions from the Australian Pastures Genebank (APG) and identified tolerant accessions.

High levels of B are common in the subsoil in neutral to alkaline soils. Although B tolerant cereals, pulses, barrel and strand medics have been developed, all existing burr medic cultivars are intolerant. Speed breeding was used to develop a cohort of B tolerant lines and they have been evaluated in the mid-north, Minnipa, NSW and WA. Their relative B tolerance has been confirmed in glasshouse screens. A short list of five lines is being considered, from which a line will be selected for cultivar release in autumn 2022.

RLEM is a widespread pest of pasture legumes as well as many crops. RLEM are particularly damaging to emerging pastures. Damage is seen as silvering on cotyledons and leaves. Due to the widespread occurrence of RLEM combined with increasing reports of insecticide resistance, efforts have been directed at the development of a tolerant cultivar. A spiny accession highly resistant to RLEM was crossed with a spineless resistant accession. We selected spineless plants with high dry matter production and early flowering. Initial field evaluation was used to shortlist lines and screen for RLEM tolerance and B tolerance. All lines were found to be tolerant to RLEM. Two lines have been short listed with high agronomic performance and RLEM tolerance.

### *Trigonella*

*Trigonella balansae*, a species closely related to annual medic, can hold its pods and approximately 50% of its seed can be harvested with a grain harvester. In historic work APG5045 was identified as having the best agronomic performance but its hardseed levels are too low (~30%) for a ley legume pasture (for medics we aim for 70-90%). In the DLPS project it was included in most legume species adaptation trials, agronomy trials and the Minnipa grazing trials. In general, it failed to regenerate after a single wheat crop supporting the original assessment that its hardseed levels are too low. Two rounds of selection for increased hardseed have subsequently been completed. The new lines have performed well for production in the field in 2020 and 2021. At the end of autumn 2022 we will complete hardseed studies and regeneration counts after the 2021 wheat crop. Data will be reviewed to determine if any of the lines are suitable as a cultivar.

Trigonella is a new species for agriculture and before releasing a cultivar, it needs to pass a grazing study which measures animal performance, animal health and meat tasting. This DLPS work is being led by CSIRO (Perth) and needs to be completed before a decision about cultivar release is made.

### *Arrowleaf clover*

Arrowleaf clover is used in NSW as a ley legume option on mixed farms. Its seed can be aerial harvested. While the earliest flowering cultivar is relatively late flowering it has produced a high amount of DM late in the season which is valuable in finishing lambs. However its winter dry matter is relatively low. In species adaptation trials it has performed well on alkaline soils. It is reported as growing well on a wide range of pH, it is deep rooted and grows well above perched water tables at 1-2 m (may be useful above a saline seep). An earlier cultivar would expand the area where it can be grown, especially on low rainfall mixed farms. Selections from a range of wild material have been made with the aim of earlier flowering with increased winter dry matter production. Field evaluation in 2021 has shown that the new line had ~30% increased dry matter compared to Cefalu throughout the year. Hardseed studies will be completed in late autumn 2022 and a decision made on suitability for cultivar release. The line looks promising and is likely to expand the area that can grow arrowleaf as well as increasing its dry matter production.

***Disc and strand medics with increased nitrogen fixation***

Disc medics are well adapted to deep alkaline sandy soils. Historically the cultivars Tornafield and Toreador were sold, but no cultivar is currently commercially available. Disc medics have consistently performed well on sandy sites in DLPS adaptation trials.

Previously, a survey of soils has shown that many soils where medics are grown contain rhizobia that form symbioses that are sub-optimal for N fixation and limit legume dry matter production compared to the current commercial rhizobia strain. Pre-breeding work identified an accession (from the APG) that more frequently forms effective N fixation symbioses. The line has been used to develop a cohort of disc and strand medics with increased ability to form effective relationships with rhizobia strains. They have had limited field evaluation, but their agronomic performance is promising. In early 2022 we will test lines with a range of rhizobia strains to find the lines best able to form effective rhizobia relationships. Short listed lines will then be tested with rhizobia from a range of soils. It is expected that by the end of the DLPS project we will have demonstrated the potential of the trait and shortlisted lines for cultivar release. It is likely that further work is required to complete cultivar development. If we can demonstrate success with this work the approach can be used for other pasture legumes species and pulses.

***Cultivar development from the Western Node of DLPS***

The western node of the DLPS project is also developing new cultivars. The western node has a focus on species adapted to acidic soils but also includes species for mildly acidic to neutral soils. Cultivar development is advanced for French serradella, early bladder clover and early trigonella.

Murdoch University (western node of DLPS) developed Frano French serradella to be earlier flowering than the cultivar Margurita. It was made commercially available in autumn 2021. Frano is expected to have a large uptake on acidic deep sandy soils in WA and NSW. In SA and Victoria it is expected to have niche role to play on acidic to neutral sandy soils. Like Margurita, Frano pods can be harvested with a grain harvester and planted at 0.5 -1 cm depth in February to allow for seed to soften and establish with opening rain. The pods of this species must be below the soil surface as light inhibits seed softening.

***Fiona Tomney and Brianna Guidera presenting pastures research at the Minnipa Field Day, Septemer 2021.***

## What does it mean?

Ley legume pasture cultivars have been widely adopted on low rainfall mixed farms. The success of future cultivars depends on their suitability to both the grazing and cropping phases in complex mixed farming systems. New cultivars that are being developed to address widespread constraints must also equal or surpass the range of other selection criteria satisfied by existing pasture cultivars. Key attributes of the new cultivars being developed include: larger seed size for early vigour (Seraph, strand and disc medics); increased herbage production (Seraph medic and arrowleaf clover); increased N-fixation (strand and disc medics); tolerance to common soil constraints (B tolerant spineless burr medics, SU and Intervix herbicide residue tolerance in strand and disc medics); increased hardseed levels for ley farming (trigonella, arrowleaf clover); pest tolerance (RLEM spineless burr medics, BGA tolerance in Seraph) and disease resistance (Seraph is resistant to PM).

Seraph strand medic is commercially available. We expect to identify a spineless burr medic and arrowleaf clover in autumn 2022 as suitable for cultivar release. Trigonella is a promising new pasture species but needs to pass duty of care studies before a line for cultivar release can be chosen. New cultivars need 2-3 years of pre-commercial seed increase before they will be commercially available. With the ever-increasing cost of nitrogen fertiliser, it is more important than ever that N fixation is maximised. We hope to have demonstrated increased N fixation in strand and disc medics. Best legume pastures are obtained by sowing the best cultivars for the environment combined with the best agronomy.

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The MLA pre-breeding project B.PBE.0037 identified B & RLEM parents and developed the speed breeding method.

APG as source of donor parents.

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# Dryland Legume Pasture Systems (DLPS): Harvesting annual medic pods

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## Key messages

- **With early desiccation, up to 900 kg of medic pods per hectare was machine harvested at one site, but not the other.**
- **The use of field pea to trestle the medics did not increase medic pod machine harvest yield.**
- **Preliminary minimum sowing rate recommendations for pods harvested on-farm are 76, 38 and 25 kg/ha for pods sown the first, second and third summer after harvest.**
- **This is preliminary research, and we recommend trialling on a small area or waiting for further research results.**

## Why do the trial?

This work investigated if early desiccation of annual medic plants enables a valuable amount of medic pods to be harvested with a conventional crop harvester, and if trestling medics with field peas assists pod harvest.

The cost of seed and low growth of pastures in the establishment year is regularly reported as a constraint to pasture adoption and production of annual medics. Traditionally ley legume pastures are sown using 'germinable' seed after completing the sowing of the cropping program, when the amount of early pasture feed on offer is often low due to emergence after soil temperatures have dropped. Some alternative ley pasture species (eg. French serradella, bladder clover) are amenable to having pods/seeds harvested with a grain harvester, thereby providing 'hard' seed that is suitable for sowing in late summer to establish the pasture earlier on opening rains. In WA and NSW this method using legumes with harvestable seed has provided farmers with a relatively cheap source of seed and increased early feed. However, in adaptation trials on the upper EP, alternative ley legume species have nearly always produced lower dry matter and seed yield than annual medics (EPFSS 2018, p. 153; EPFSS 2019, p. 209 and EPFSS 2020, p. 186). In other work, the DLPS project has found that annual medic pods are also suitable for summer sowing (EPFSS 2020, p. 201 and EPFSS 2021, p. 189). However, medic pods are less easily harvested by a grain harvester because medics drop their pods when they mature. The seed industry harvests medic seeds with a clover (vacuum) harvester. This paper reports experiments examining methods to improve the harvestability of medic pods. In farming systems trials in the DLPS project, medics have increased subsequent grain yields by 0.7-2.9 t/ha (EPFSS 2020, p. 205; EPFSS 2020, p. 213; EPFSS 2021, p. 189. A cheaper source of medic seeds may encourage more sowing of medics and thus benefit to subsequent grain crops.

## How was it done?

A pod harvesting trial was established at Minnipa. We grew the strand medic cultivars Seraph and Jaguar (Jaguar was bred by Pristine Forage Technologies for improved pod retention), barrel medic cultivar Sultan-SU, and spineless burr medic cultivar Scimitar. Medics were sown at 10 kg/ha in a factorial combination of field peas at 0, 0.25 and 0.5 X recommended rate. Plots were rolled after planting to assist harvest. A similar trial was sown at Waite, where Seraph and Sultan-SU were sown in a factorial combination of field peas at nil and 0.25 recommended sowing rate in four replicates.

Basic science reports (Gallardo *et al*. 2003) that medic pods require 400 growing degree days (GDD; sum of average daily temperature) for seeds to be viable and 900 GDD for pods to be ready to fall from the plant. We observed when the first flowers appeared and when peak flowering finished. On a weekly basis we used observed daily temperature, forecast daily temperature and climate data to predict our harvest window. Actual desiccation date was chosen by a weather forecast of four fine days after desiccation. Plots were desiccated with Sprayseed at 3 L/ha. Medic pods were harvested with a small plot harvester four days after desiccating. A sample of total pod yield was taken from small quadrats on the day prior to harvesting but samples have not yet been cleaned and weighed.

Pods have been harvested but a range of seed measures are yet to be completed. Seed measures will include percent of seeds harvested, seed to pod ratio, percent viable seed and seed softening studies.

## What happened?

Figure 1 shows Seraph medic pods four days after desiccating. High pod yields (900 kg pods/ha) were obtained at Waite and lower yields (up to 110 kg pods /ha) at Minnipa (Table 1).

***Figure 1. Seraph medic pods on medic plants ready to harvest, four days after desiccating.***

***Table 1. Machine harvested pod yield (kg/ha) and bulk density of annual medic cultivars. Samples for total pod yield have yet to be processed.***

| Cultivar | Species | Pod yield (kg/ha) | | Bulk density (kg/m³) |
|---|---|---|---|---|
| | | Waite | Minnipa | |
| Seraph | strand medic | 906 | 110 | 460 |
| Jaguar | strand medic | Not included | 73 | 310 |
| Sultan-SU | barrel medic | 895 | 24 | 230 |
| Scimitar | spineless burr medic | Not included | 8 | 330 |

The field pea treatments did not affect pod yield. Minnipa had strong winds the day before harvest, which may have reduced pod yields. Elsewhere in the DLPS project (EPFSS 2020 p. 211) 120 kg/ha (30 kg seed) was harvested from fully senesced Jaguar medic (pod holding) compared to nil from Seraph, in the absence of desiccation. We speculate that early desiccation and favourable conditions until harvest allowed higher medic pod harvest yield to be achieved.

The bulk density (kg/m$^3$) of medic pods is low (230-460). Seraph has very small spines resulting in its higher bulk density than Jaguar. The very short spines of Seraph may assist the flow of pods through planting equipment.

## What does it mean?

Up to 900 kg of medic pods/ha were able to be harvested at Waite, but not at Minnipa. Early desiccation was the likely key to success and was used at both sites, but environmental conditions only favoured pod retention/ harvestability at one site. The DLPS project has reported the successful establishment of medic pastures with summer sowing of 30 kg pods/ha (EPFSS 2020, p. 201; EPFS 2021, p. 189). This suggests that a one hectare seed nursery paddock could potentially produce enough pod to summer sow up to 30 hectares. The findings indicate that it is possible to harvest medic pods, however further research is required to determine if medic pods can be reliably harvested. We also need to complete our processing of per-plot harvester samples to determine what percentage of pods were harvested. This is preliminary research, and we recommend waiting for further research results or trialling on a small area.

GDD are widely used to estimate growth and development of crops, pests and diseases. GDD is the sum of mean daily temperature (add together the maximum and minimum temperature and divide that value by two). Observation of pods in the field agreed with 900 GDD for pods ready to fall made by Gallardo *et al.* (2003) for plants growing in a controlled environment room and on this basis, we assume seeds 400 GDD are viable.

An important measure will be percent viable seed. However we are unable at this time to report percent viable seed as freshly harvested medic seed are dormant (embryo dormancy) which breaks down with the heat of summer. For this work we have used GDD to determine harvest date which we suggest being used when harvesting medic pods. If you opportunistically decide to attempt to harvest medic pods, we suggest you use guides for desiccating pulses or canola to determine desiccation time.

The bulk densities are provided to allow you to determine storage requirements. The bulk density (kg/m3) of medic pods is low (230-460) compared to wheat (800) and barley (680). The bulk density of Seraph (460) is similar to oat (450), but the other cultivars are lower (230-330).

Freshly harvested medic pods contain hardseed which soften in a two-stage process: 1) preconditioning stage whereby seeds progressively dry out due to high temperature and/or length of time stored; 2) softening stage with fluctuating temperature in autumn. Pods need to be sown/broadcast before the end of February to allow them to soften with the fluctuating temperatures in autumn. Medic pods soften more on the soil surface than if buried and hence they can be broadcast which means the planting operation is quick and cheap. It also means that it does not leave the field vulnerable to wind erosion as do alternative species that need to be sown (hardseeded French Serradella and bladder clover need to be sown at 0.5-1 cm as they are have an unusual softening process whereby light inhibits softening).

Research to establish recommended sowing rates of medic pods is needed. However basic science studies on the softening of medic pods can be used to provide preliminary recommendations. In the DLPS project, fresh medic pods were found to have 20% soft seed by the end of autumn. Taylor and Ewing (1992) similarly report for annual medics in the field, ~ 20% of seeds soften per year. Assuming harvested pods behave in a similar way as the field and seed to pod ratio of 0.33, for a minimum sowing rate of 5 kg soft seed per hectare the minimum sowing rate is 76, 38, 25 kg pods/ha for pods sown in first, second and third summer after harvest respectively. Spineless burr medics have a seed to pod ratio of 0.5 and the minimum sowing rates are 50, 25 and 17 kg pods/ha for pods sown in the first, second and third summer respectively.

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## Acknowledgments


This project is supported by funding from the Australian Government Department of Agriculture, Water and the Environment (DAWE) as part of its Rural R&D for Profit program, the Grains Research and Development Corporation (GRDC), Meat and Livestock Australia (MLA) and Australian Wool Innovation (AWI). The research partners include the South Australian Research and Development Institute, Murdoch University, the Commonwealth Scientific and Industrial Research Organisation, the WA Department of Primary Industries and Regional Development, NSW Department of Primary Industries and Charles Sturt University, as well as grower groups.

# Dryland Legume Pasture Systems (DLPS): Adaptive pasture sowing strategies to overcome a shifting seasonal break

**Bonnie Flohr[1], Therese McBeath[1], Jackie Ouzman[1], Bill Davoren[1], Willie Shoobridge[1], Rick Llewellyn[1] Ross Ballard[2] and David Peck[2]**

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**Location**
Lameroo
Robert Pocock

**Rainfall**
Av. Annual: 382 mm
Av. GSR: 270 mm
2021 Total: 267 mm
2021 GSR: 170 mm

**Yield**
French/Schultz yield potential: 1.84 t/ha
Actual 2021 control yield: 1.85 t/ha

**Paddock history**
2020: Lupin/vetch mix
2019: Barley
2018: Wheat

**Soil type**
Deep sand

**Soil test**
pH $CaCl_2$ 7 at 0-10 cm
Profile mineral N (2021 continuous cereal treatment) 77 N kg/ha
Colwell P 22 mg/kg 0 -10 cm
S KCl 6 mg/kg at 0-10 cm
OC 0.6% at 0-10 cm
Salinity Ec 1:5 0.1 dS/m 0-10 cm

**Plot size**
15 m x 1.68 m x 4 reps

**Trial design**
Experimental: randomised complete block

**Yield limiting factors**
Late start of growing season (26 May): impact moderate, below average GSR

## Key messages

- **Analysis of the seasonal break indicates that there has been increasing summer rain and later autumn sowing breaks in the last 30 years for much of the southern and western Australian wheatbelt.**
- **Biomass production was higher for summer-sown trigonella and medic compared to autumn-sown at Lameroo in the 2020 growing season.**
- **Weed density was greatest in summer sown (13 weeds/$m^2$) and twin-sown (8 weeds/$m^2$), compared to autumn-sown (3 weeds/$m^2$) pastures.**
- **Bladder clover and trigonella biomass production was competitive with medic at autumn sowing.**
- **There is potential to sow productive novel legume pastures and establish a pasture seedbank while still achieving a substantial crop 'break effect'.**

## Why do the trial?

Delays in the seasonal break and plant establishment can result in continued summer-autumn feed gaps requiring supplementary feeding and reduced grazing during the winter period when cool temperatures slow pasture growth. A shift towards early sowing systems and a drying trend in autumn in southern Australia are changing traditional farming systems, and growers need adaptive genetic and management strategies for plant establishment that do not rely on the seasonal break. A recent analysis has revealed spatial and seasonal variability in the seasonal break with the earliest median seasonal break (27 March) in New South Wales (NSW) and Victoria, and the latest (3 June) in Western Australia (WA). Notably the Mid-north, York and Eyre regions have experienced a median 8 day delay in seasonal break (Figure 1).

On mixed livestock-cropping farms where sowing of pasture phases can clash with main season cropping programs, novel management may include the use of unscarified 'hardseed' of adapted pasture cultivar options, sown either in late summer (summer sowing) or with the previous crop (twin sowing) (Nutt *et al*. 2021). Novel pasture sowing systems avoid peak crop sowing times, reduce establishment costs and can increase early season feed supply but have had limited evaluation in the SA medium-low rainfall environment. As part of the DLPS (Dryland Legume Pasture Systems) project, summer and twin sowing methods using unscarified hardseed have also been evaluated in Waikerie, SA and Piangil, Victoria. This paper focuses on results from Lameroo in 2020 and 2021 growing seasons. Results from Waikerie in 2019 and 2020 are reported in EPFSS 2020 p. 201. EPFSS 2020 p. 211 reports harvesting seeds/pods of novel legumes and EPFSS 2021 p. 219 reports on harvesting medic pods.

Aim: Evaluation of the suitability of different pasture legume species for establishment using summer and twin sowing methods that provide growers with greater flexibility in pasture establishment, and assessment of grain yield benefit after a 1 year pasture phase.

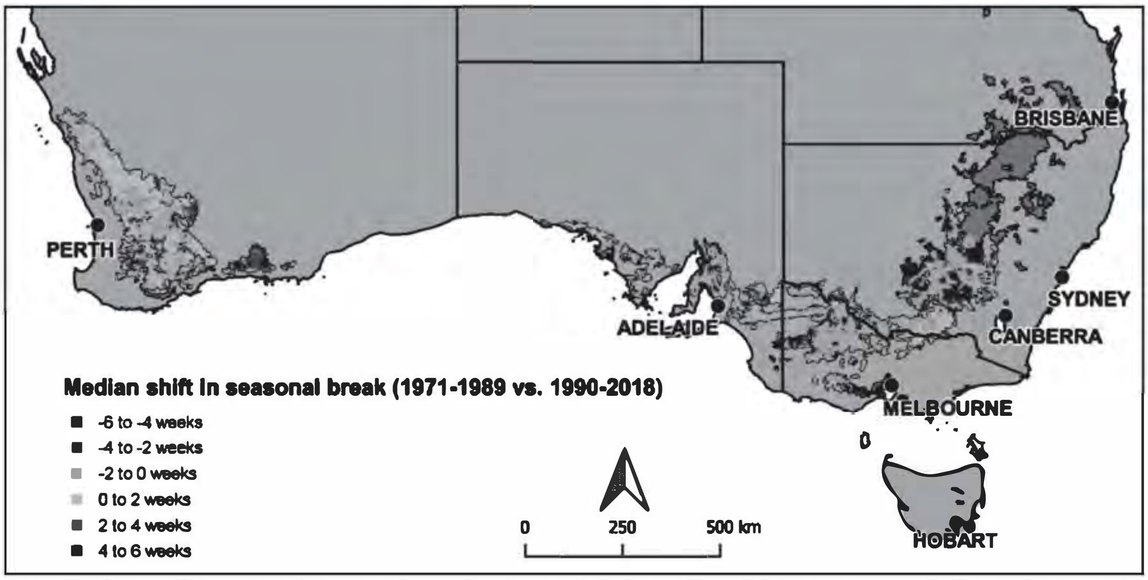


***Figure 1. Median shift in seasonal break between the periods two 1971-1989 and 1990-2018 in cropping regions throughout southern and western Australia based on the 7-day rolling sum of the rainfall:evaporation ratio* (Flohr *et al. 2021).***

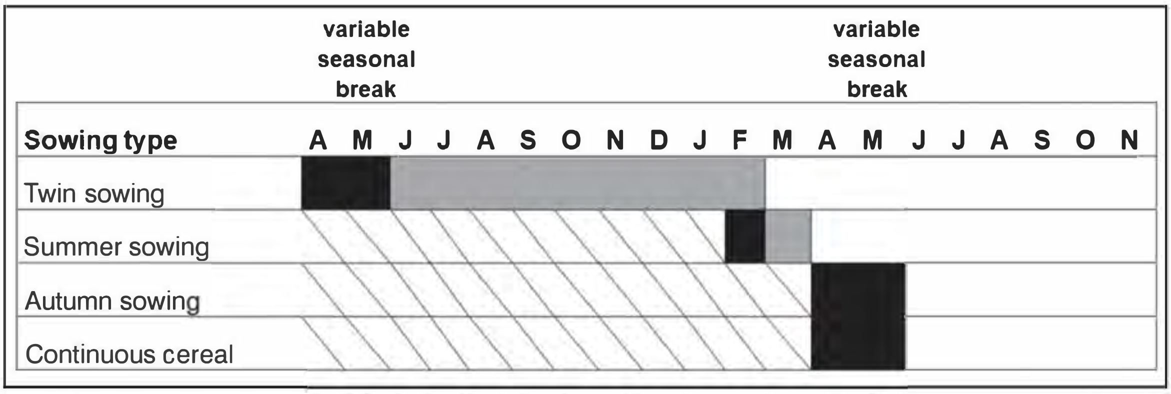


***Figure 2. Timeline of sowing date (black shading), hard seed breakdown (grey shading) and plant growth period (white) of pasture sowing methods tested.***

## How was it done?

### *Seasonal break modelling*

A seasonal break is deemed to occur when the sum of rainfall over any 7-day period exceeded pan evaporation over the same period after 1 March. The seasonal break was analysed for each of the DLPS experimental sites.

### *Novel pasture sowing methods*

Three pasture sowing methods were evaluated at Lameroo (2020) and included legume pasture species that have not been traditionally grown in the region. Soil type at Lameroo is sand (0-10 cm pH $CaCl_2$ is 7). Sowing methods evaluated were: a) twin-sowing (20 May 2019), where 'hard' pasture seed/pod was sown with wheat seed in 2019 for 2020 pasture establishment; b) summer-sowing (18 February 2020), where hard seed/pod was at a depth of 2 cm in February to establish on the autumn break; and c) autumn-sowing (control treatment representing farmer practice, 28 April 2020), where scarified germinable seed was sown on the break of the season (Figure 2). Pasture treatments were compared to system controls of autumn sown brown manure vetch (terminated 15 September 2020), long fallow (16-month chemical fallow) and continuous cereal.

At each site, pasture and weed densities were recorded in June, and multiple measures of biomass production were recorded July-November. At the November biomass recording a seed set estimate was made by sieving seed from biomass and surface soil in the quadrant area. The sowing rates for the legumes are reported in Table 1 and all legumes were inoculated with their specific rhizobia group using peat slurry. Granular inoculant (ALOSCA) was also sown with each legume at a rate of 10 kg/ha. The residual effects of the pasture treatments implemented in 2020 were measured at Lameroo in 2021 when plots were sown to wheat (cv. Scepter) on 26 May 2021 with 20 N kg/ha, and pests and diseases were managed for maximum yield. Plant establishment, biomass production and grain yield were analysed by GenStat 19.

*Table 1. Sowing rates of pod or seed (kg/ha) in Twin and Summer sowing treatments and sown rate of germinable seed (kg/ha) in the autumn sown treatment.*

| Species | Twin and Summer sowing (kg/ha) | Autumn sowing (kg/ha) |
|---|---|---|
| Seraph (PM-250) medic | 30 (pod) | 11 |
| Trigonella 5045 | 12 (seed) | 8 |
| Bartolo Bladder clover | 12 (seed) | 11 |
| SARDI Rose clover | 10 (seed) | 11 |
| Margurita French serradella | 30 (pod) | 8 |
| Studenica Vetch | | 40 |
| Scepter Wheat | | 70 |

*Table 2. Selected sites in the Australian cropping region showing 25-75th percentiles of the seasonal break (1971-2018), the range in days, and median 7-day sum of rainfall (mm) at the seasonal break based on the 7-day rolling sum of the rainfall:evaporation ratio.*

| Location | State | 25th percentile | Median | 75th percentile | Range (days) | Median 7-day rain sum (mm) |
|---|---|---|---|---|---|---|
| Lameroo | SA | 19-Apr | 11- May | 29-May | 40 | 21 |
| Waikerie | SA | 20-Apr | 7-May | 27-May | 37 | 21 |
| Roseworthy | SA | 11-Apr | 1-May | 20-May | 39 | 27 |
| Minnipa | SA | 3-May | 24-May | 9-Jun | 37 | 22 |

## What happened?

### *Seasonal break analysis*

Table 3 shows the median seasonal date, range and rainfall volume that defined the seasonal break for local South Australian sites. The shift in median seasonal break in South Australia ranged from a 3-day delay in the Mallee region, to an 8-day delay in Mid-north, York and Eyre regions during the period 1990-2018.

### *Novel pasture sowing methods*

There were inconsistencies between the species × sowing time combinations that were optimal for pasture production in the 2020 growing season (Figure 3). Average plant establishment in autumn-sown treatments was 72 plants/m$^2$, summer-sown treatments was 29 plants/m$^2$ and twin-sown treatments was 14 plants/m$^2$. In Lameroo, an early break in the first week of March 2020 enabled earlier establishment of pasture species from summer and twin sowing and resulted in higher biomass production for summer-sown trigonella and medic compared to autumn-sown (Figure 3). However, lower plant numbers were less productive compared to autumn sown plant numbers in the bladder clover treatment. Rose clover and serradella established adequate numbers from autumn sowing but overall biomass production was low suggesting the available varieties were not well adapted to the Lameroo environment. Weed density was greatest in summer-sown (13 weeds/m$^2$) and twin-sown (8 weeds/m$^2$), compared to autumn-sown (3 weeds/m$^2$). Pasture production was generally low for all species when twin sowing was implemented, presumably due to excessive seeding depth, an aspect of twin sowing that needs to be addressed before the method can be recommended for pasture establishment. At Lameroo, bladder clover and trigonella production was competitive with medic at autumn sowing and are considered the best novel pasture options for that environment.

The 2021 growing season rainfall was below average at Lameroo (170 mm, long term average 270 mm). The additional ~30 mm of total soil water, and 70 kg/ha soil mineral N available under brown manure vetch and long fallow treatments resulted in an additional 1.5 t/ha wheat grain yield compared to the continuous cereal treatment (Figure 4). The 2020 pasture treatments were not terminated to allow for seed set and therefore used more water than long fallow and brown manure vetch treatments, but still resulted in a 2021 wheat yield benefit of ~0.7 t/ha. Pasture seed production was over 1 t/ha for the best establishment treatment for each species. Autumn sowing generated the highest seed production for all except summer-sown serradella, with medic and trigonella the highest.

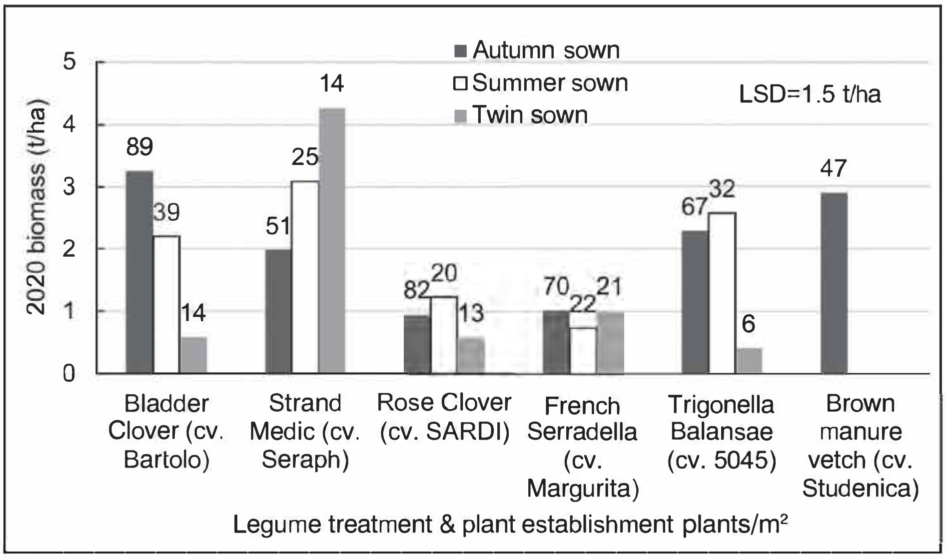


***Figure 3. Biomass production of legume pasture species (15/09/2020) established via autumn, summer and twin sowing methods in Lameroo in 2020 LSD (5%) 1.5 t/ha, P-value <.001. Number above each column is plant number/m², LSD (5%) 14, P-value <.001.***

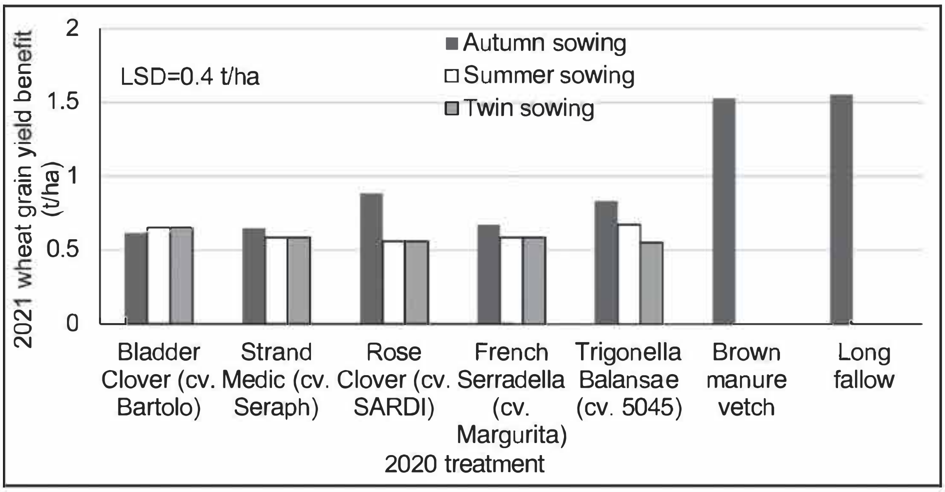


***Figure 4. The 2021 wheat grain yield benefit following 2020 treatments relative to continuous cereal treatment. P-value (5%) <.001.***

## What does this mean?

Characterisation of the seasonal break is an important step for novel cultivar adaptation and management strategies across crop growing regions of southern Australia. Summer 'dry' pasture establishment methods have demonstrated potential in mixed farming systems; however, they are not well-suited for all pasture legume species and weed control challenges need to be addressed. There is potential to sow productive novel legume pastures and establish a substantial pasture seedbank while still achieving a substantial crop 'break effect' (~0.7 t/ha).


## Acknowledgements

The research reported in this publication is made possible by significant contributions of growers through both trial cooperation and the support of Grains Research and Development Corporation (Project number 9175959). The authors acknowledge The Dryland Legumes Pasture Systems project supported by funding from the Australian Government Department of Agriculture, Water and Environment as part of its Rural R&D for Profit program (Project No. RnD4Profit-16-03-010), the GRDC, Meat and Livestock Australia and Australian Wool Innovation. We thank Christina Ratcliff for providing training in QGIS software.


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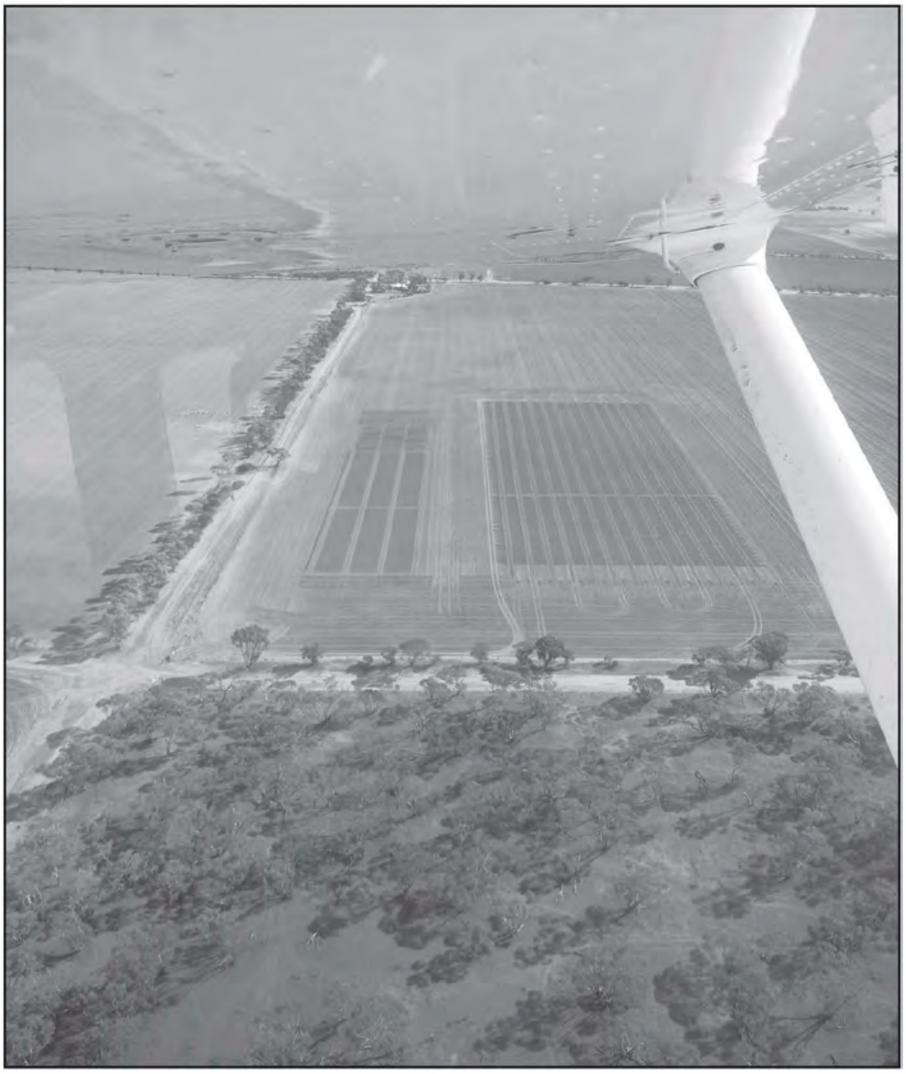

*Early sown NVT cereal and NVT cereal trials at Minnipa Agricultural Centre, 2021.*

# Lentil and vetch seeding rate and variety selection

***Author(s):*** Sarah Day, Penny Roberts
***Funded By:*** UNFS (2021)
***Project Duration:*** *2021*
***Project Delivery Organisations:*** *SARDI*

**Key Points:**

- Variety performance is variable depending on seasonal conditions, and final selection will be based on target end-use, paddock constraints and matching phenology to environment or time of sowing.
- Don't increase seeding rates unnecessarily, as high seeding rates can increase risk of disease and lodging
- Reducing the seeding rate by a quarter will not compromise production potential for spring hay or grain production.

**Background**

Lentil production area has increased by 6300 ha over the last decade in the Upper North region of South Australia. This increase in production area has coincided with a reduction in area sown to field pea, as well as recent high grain prices for lentil and developments in breeding, particularly the release of varieties with improved herbicide tolerance characteristics and varieties better adapted to low rainfall environments. Growing lentil with flexible end use is rising in interest among low rainfall growers, particularly in the Upper North region, which lead to pilot trials at four locations in 2020 to compare biomass and grain production of vetch and lentil sown at multiple seeding rates. These trials demonstrated that seeding rate of lentil and vetch can be reduced to three quarters of the recommended seeding rate in some environments, without compromising biomass and production. The trial was validated at three locations in 2021, including Melrose, with the aim to identify optimal seeding rates and variety selection of vetch and lentil, depending on the targeted end use. This article will focus on results from Melrose in 2021 and Booleroo in 2020.

**Methodology**

The experiment varied seeding rates, comparing the recommended target plant density (Table 1) with a target density of half and three-quarters of the recommended rate, to assess whether input costs could be reduced without compromising grain and forage production potential. Higher than recommended rates were not included, as high plant density crops increase costs, the risk of disease infection and lodging, and also reduce resource efficiency due to larger canopies.

Three varieties each of vetch (Volga, Studenica, Morava) and lentil (PBA Jumbo2, PBA Blitz, PBA Highland XT) with varying phenology characteristics were included to refine variety selection depending on target end use. Measurements taken included site soil characteristics, biomass yield and grain yield. Biomass measurements were taken at late vegetative and early podding (reproductive) growth stages to identify production potential for grazing or hay production. Plots were arranged in a split plot randomised design with three replicates, with crop species randomly assigned in blocks to the whole plot, and variety and plant density randomly assigned to the sub plot. The use of this design ensures that both crop types receive appropriate agronomic management. Data was analysed using a split plot ANOVA model in Genstat 21st Edition.

*Table 1. Target plant density (plants/m$^2$) and seeding rate (kg/ha) of lentil and vetch seeding treatments sown at Booleroo in 2020 and Melrose in 2021.*

| | Lentil | | Vetch | |
|---|---|---|---|---|
| **Seeding Rate** | **Plants/m$^2$** | **Kg/ha*** | **Plants/m$^2$** | **Kg/ha*** |
| Recommended | 120 | 50-70 | 60 | 45-60 |
| Three-quarter | 90 | 35-50 | 45 | 30-45 |
| Half | 60 | 25-35 | 30 | 20-30 |

*A range is given for seeding rate per hectare as this will vary depending on seed size and seed weight.

## Results and Discussion

*Seeding rate*

Biomass production was not reduced where seeding rate was reduced by a quarter for vegetative biomass in 2020 and reproductive biomass in 2020 and 2021 (Figure 1). However, vegetative biomass was reduced by 120 kg/ha when sown at a three-quarter seeding rate in 2021. Grain yield was reduced by 180 kg/ha where crops were sown at half the recommended seeding rate at Melrose 2021 (Figure 2). There were no grain yield differences observed between seeding rates at Booleroo in 2020 (P>0.05).

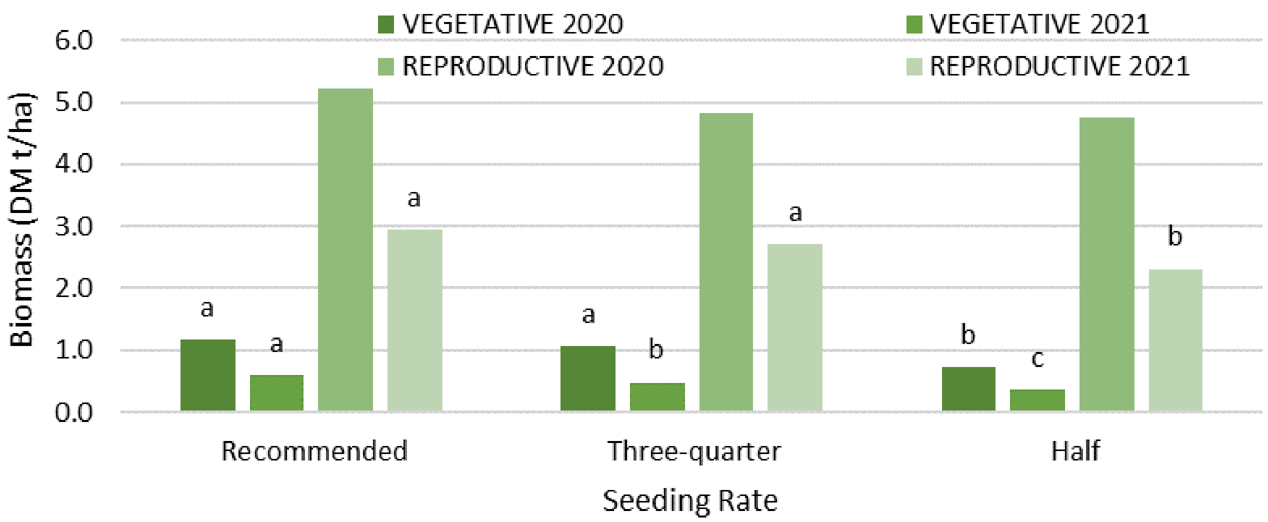

*Figure 1. Biomass production (DM t/ha) response to different seeding rates of lentil and vetch at Booleroo 2020 and Melrose 2021. Columns within the same series labelled with the same letter are not significantly different (P<0.05). Columns with the same series with no labels indicates no significant difference (P>0.05).*

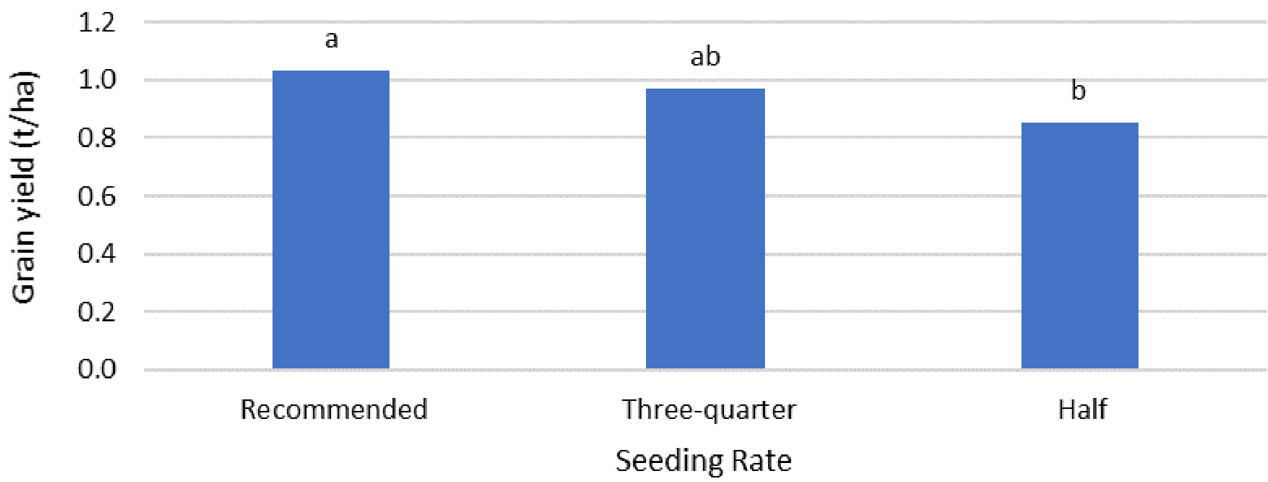


*Figure 2. Grain yield (t/ha) response to different seeding rates of lentil and vetch at Melrose 2021. Bars labelled with the same letter are not significantly different (P>0.05).*

*Variety selection*

Biomass production differences were observed between varieties for reproductive biomass, but not vegetative biomass, at Melrose in 2021 (Table 2). Volga vetch produced the most biomass at Melrose in 2021. This is consistent with responses in other low rainfall pulse trials (Day, Oakey et al. 2020, Day and Roberts 2021, Day, Roberts et al. 2021, Day, Roberts et al. 2021, Day, Roberts et al. 2021). Morava and Studenica had lowest reproductive biomass production for vetch varieties at Melrose in 2021. There were no differences in biomass production between lentil varieties. Lower rainfall in 2021 reduced production potential compared to 2020, with good April rainfall in 2020 being advantageous to early crop establishment.

Volga vetch, Morava vetch and PBA Highland XT lentil were the highest yielding treatments, and equivalent to PBA Jumbo2 lentil, at Melrose in 2021 (Figure 3). Studenica vetch was the lowest yielding variety, with similar yield to PBA Blitz lentil. The mid to late maturing varieties are likely to have benefited from the later spring rain received in 2021 compared to the earlier maturing treatments of Studenica and PBA Blitz. Early varieties were at greater risk of early flower or pod abortion from cold and frosty conditions during these growth phases. No grain yield differences between varieties were observed at Booleroo in 2020, with average grain yield of 2.65 t/ha.

*Table 2. Vegetative (V) and reproductive (R) biomass (DM t/ha) response to variety at Booleroo 2020 and Melrose 2021. Different letters in the same column indicate a significant difference (P<0.05). n.s. = not significant (P>0.05).*

| Crop | Variety | Maturity | Booleroo 2020 | | Melrose 2021 | | |
|---|---|---|---|---|---|---|---|
| | | | V | R | V | R | |
| Lentil | PBA Blitz | Early | 1.07 | 5.26 | 0.44 | 2.70 | b |
| | PBA Highland XT | Early-Mid | 0.87 | 4.41 | 0.47 | 2.51 | bc |
| | PBA Jumbo2 | Mid | 1.04 | 5.12 | 0.54 | 2.77 | b |
| Vetch | Studenica* | Very early | N/A | | 0.51 | 2.44 | bc |
| | Volga | Early | 1.08 | 5.08 | 0.48 | 3.32 | a |
| | Timok* | Mid | 1.04 | 5.32 | N/A | | |
| | Morava | Late | 0.86 | | 0.47 | 2.21 | c |
| LSD (P<0.05) | | | n.s. | n.s. | n.s. | 0.49 | |

*Timok was included in the trial in 2020 and replaced with new Studenica in 2021. N/A = not applicable

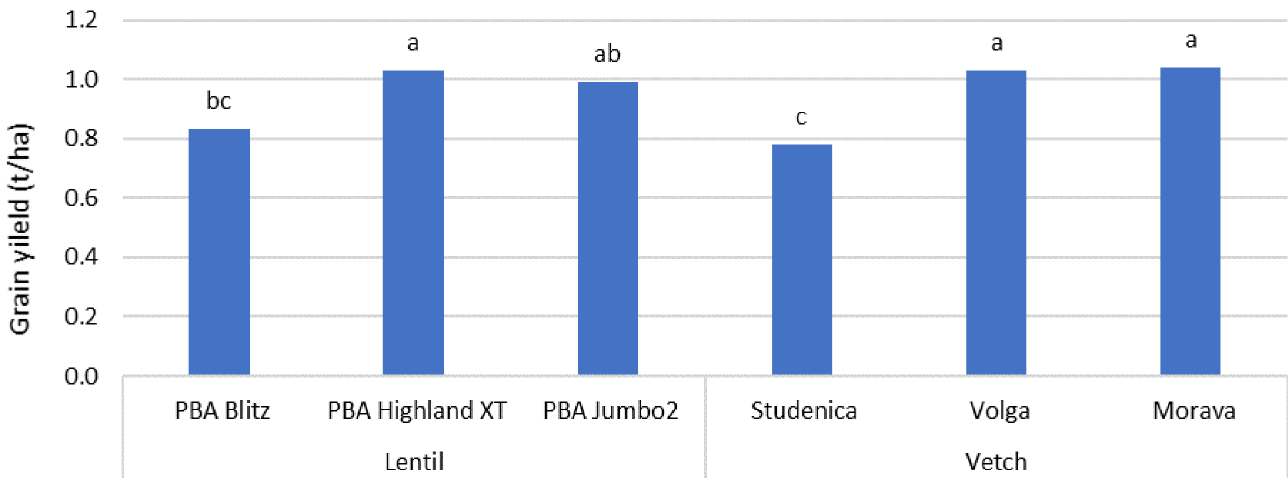


*Figure 3. Grain yield (t/ha) response to variety at Melrose 2021. Bars labelled with the same letter are not significantly different (P>0.05).*

**Conclusion**

Grain legume species and variety selection is complex and final choice will depend on a grower's attitude toward risk, target end use, time of sowing, and paddock constraints (e.g., herbicide residues, salinity). Lentil varieties with improved herbicide or salt tolerance are available to growers and have a unique fit in farming systems to address herbicide residues or soil constraints. A broad range of phenology in vetch provides varieties suited to a range of sowing times and target end uses.

If targeting crop use for early winter grazing, maintaining recommended seeding rates is important to ensure early weed suppression, and to maintain early biomass production. Higher than recommended seeding rates can lead to increase disease risk and crop lodging. For spring hay or grain production, seeding rate can be reduced by a quarter of the recommended rate without compromising production potential. However, it is important to not reduce seeding rates too low, as this can reduce production and leave the crop exposed to weed and aphid infestations.

***Acknowledgements***

The research undertaken is made possible by the significant contributions of UNFS and growers through both trial cooperation and the support of UNFS and SARDI, and the authors would like to thank them for their continued support. The continued assistance in trial management from SARDI Agronomy Clare is gratefully acknowledged and appreciated.

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# Managing Septoria tritici blotch in the low and medium rainfall zones

***Author:*** Tara Garrard

***Funded By:*** GRDC project: DJP2104-004TRX

***Project Title:*** Managing Septoria tritici blotch in the low and medium rainfall zones

***Project Duration:*** 2021 - 2023

***Project Delivery Organisations:*** SARDI, Waite Research Centre

**Key messages:**

- Understanding yield losses caused by Septoria tritici blotch in the low and medium rainfall zones is critical in disease management decision making
- Trials run at Booleroo Centre (LRZ) and Hart (MRZ) in the 2021 growing season showed no significant yield loss due to the disease in varieties rated from SVS through to MR

**Background**

Previous research on septoria tritici blotch (STB) in wheat has been targeted at the high rainfall zone where yield losses from the disease are high. However, the prevalence of the disease is widespread and there is less known about the yield losses and economics of disease management in the low and medium rainfall zones. Developing our understanding of seasons where yield losses are significant will aid growers in decision making when managing the disease.

GRDC have invested in research on STB of wheat in the low and medium rainfall zones in the Southern Region (GRDC project: DJP2104-004TRX). Agriculture Victoria and SARDI are working together with input from FAR Australia and NSWDPI to conduct this work. The research aims to better understand the disease outside of the high rainfall zone (HRZ) to enable smarter integrated disease management strategies and to lower unnecessary chemical inputs.

Integrated disease management (IDM) work into STB includes spore trapping and stubble monitoring to better understand the epidemiology of the pathogen. This monitoring requires multiple seasons of data before results can be meaningful. These data will therefore be presented in future years as well. Plot trials have focused on better understanding the interaction between variety disease resistance rating and yield loss, as well as optimal fungicide timing. The yields from variety trials from the 2021 season are presented in this paper.

## Methodology

The yield loss by variety trials will be run for the three years of the project, but only the first year of trials have been completed so far.

Six varieties were selected based on their disease resistance ratings to STB. Ratings for stripe rust and powdery mildew were taken into consideration as well. Varieties and STB resistance ratings were as follows: Impala^A SVS, Scepter^A S, Hammer CL Plus^A MSS, LRPB Lancer^A MS, Orion^A MRMS and Sunlamb^A MR.

Trials were designed by Statistics for the Australian Grains Industry (SAGI) South and involved disease-inoculated plots and disease-controlled plots to develop plus and minus disease for each variety. Treatments were replicated six times and were blocked by disease treatment, plots were 10 m x 1.5 m. In South Australia, trials were located at Hart Field Site and Booleroo Centre.

Plus-disease plots were inoculated at seedling and mid tillering stages using a conidial suspension in water applied as a spray. Fungicides were applied to minus-disease plots at GS 31 and 39. The GS 31 spray consisted of Elatus Ace (250 gai/L propiconazole + 40 gai/L benzovindiflupyr) @ 500 mL/ha and the GS 39 spray was epoxiconazole (500 gai/L) @125 mL/ha. Disease assessments were conducted at flowering by assessing percentage of leaf area infected on each leaf of 10 plants/plot. Preliminary single site statistical analysis was conducted with Genstat 20th Edition.

## Results and Discussion

Conditions at both Booleroo Centre and Hart Field Site were not conducive for extensive disease development in the 2021 growing season. This was likely due to below average rainfall in early spring, which is critical for STB disease development in the upper canopy. As a result, disease levels were barely detectable at the Booleroo site and at Hart, the SVS variety Impala had only 11.3% disease (Tables 1) and the rest of the varieties even less. Growing season rainfall (April to October) was 217 mm at Booleroo and 232 mm at Hart.

*Table 1. STB mean whole plot disease severity – calculated from % leaf area at Hart Field Site and Booleroo in 2021.*

| Rating | Variety | Mean disease severity % | | | |
|---|---|---|---|---|---|
| | | Hart Field Site | | Booleroo Centre | |
| | | + Disease | - Disease | + Disease | - Disease |
| SVS | Impala^A | 11.3 | 0.0 | 0.09 | 0.00 |
| S | Scepter^A | 8.7 | 0.0 | 0.11 | 0.00 |
| MSS | Hammer CL Plus^A | 2.2 | 0.0 | 0.00 | 0.00 |
| MS | LRPB Lancer^A | 1.7 | 0.0 | 0.00 | 0.00 |
| MRMS | Orion^A | 1.1 | 0.0 | 0.02 | 0.00 |
| MR | Sunlamb^A | 0.1 | 0.0 | 0.02 | 0.00 |

Grain yields at Hart appeared slightly higher in the minus-disease plots than in the plus-disease plots (Figure 1). However, statistical analysis found no significant differences in the trial. Booleroo yields were very variable but minus-disease yields were slightly lower than plus-disease yields in all varieties except Impala (Figure 2). There were no significant differences in yields at the site.

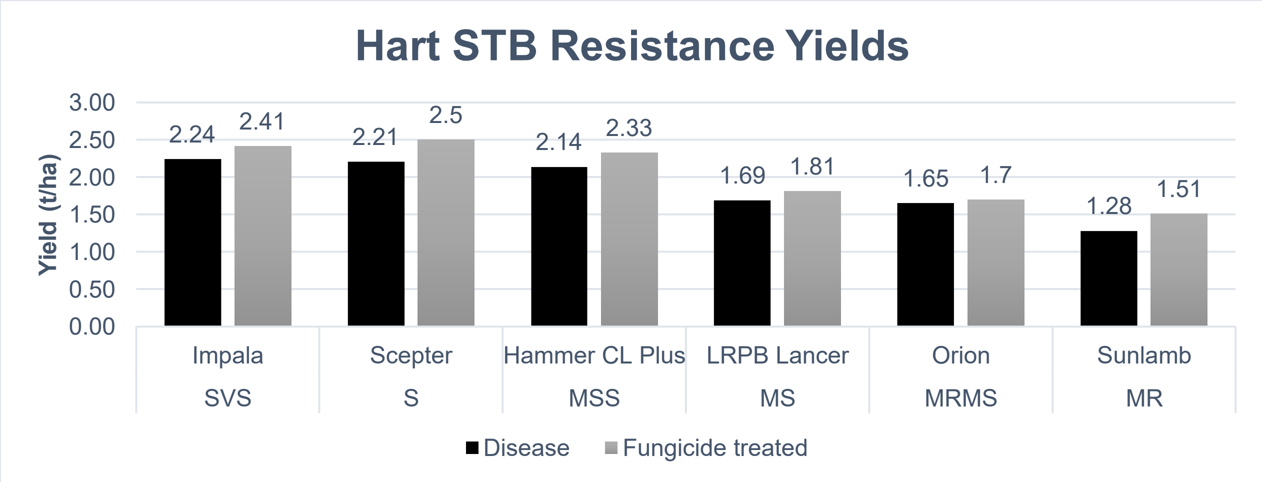


*Figure 1. Mean yields of 6 wheat varieties associated with STB and its control at Hart Field Site in 2021. No significant differences were detected*

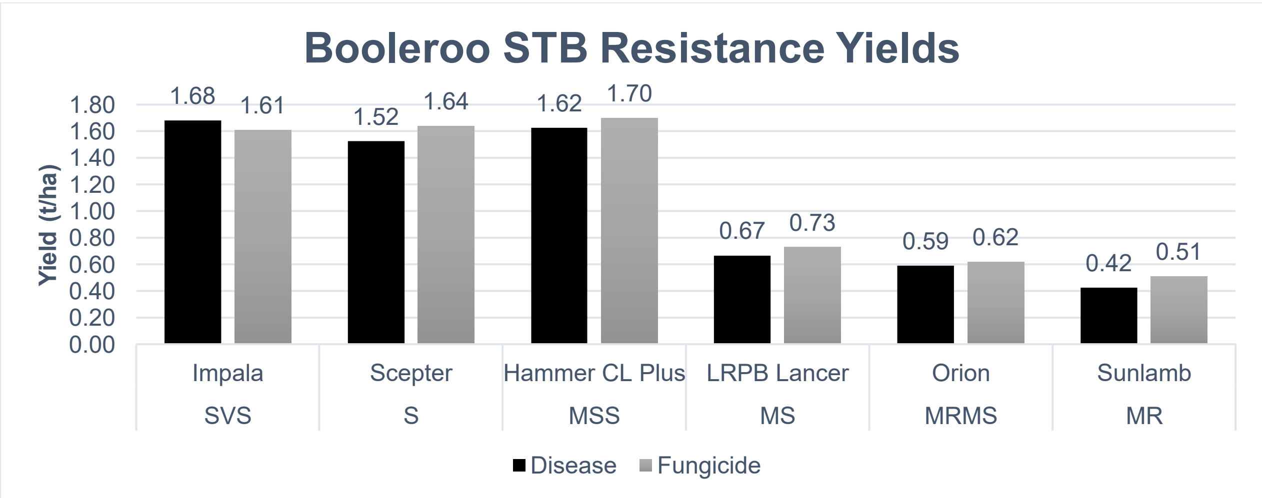


*Figure 2. Mean yields of 6 wheat varieties associated with STB and its control at Booleroo Centre in 2021. No significant differences were detected*

These trials provide growers with the first year of trial data for STB disease development in low and medium rainfall zones. In the 2021 season, conditions were not conducive to disease development at these locations and resulted in no statistically significant yield losses. This is important data to inform decision making, as in 2021, fungicide sprays would not have been economic in these areas as yield differences were not significant.

These trials are also being run at medium and low rainfall sites in Victoria. It is expected that after three years of trials, there will be multi-environment data that is able to give growers information about which seasons, varieties and situations are conducive for STB yield losses.

**What does this mean?**

In 2021 at the low and medium rainfall sites tested, seasonal conditions were not conducive for enough disease development to result in significant yield loss, even in SVS and S varieties. Further years of data will better develop our understanding of which years provide conducive disease development so that fungicide use can be targeted to these seasons.

**Acknowledgements**

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, the authors would like to thank them for their continued support. The authors would also like to acknowledge the collaborators on the STB project including Agriculture Victoria, FAR Australia, Hart Field Site Group, Upper North Farming Systems, Birchip Cropping Group and AgXtra.

**Appendix**

**Location**

Hart Field Day site, Mid North of SA

**Rainfall**

Av. Annual: 405 mm

Av. GSR: 297 mm

2021 Total: 401 mm

2021 GSR: 231 mm

**Soil type**: Clay loam

**Paddock history**

2021: Wheat

2020: Oats

2019:

**Plot size**

12 m x 1.7 m x 6 replicates

**Location**

Booleroo Centre, Upper North of SA

**Rainfall**

Av. Annual: 391 mm

Av. GSR: 277 mm

2021 Total: 334 mm

2021 GSR: 217 mm

**Soil typ**e: Red loam

**Paddock history**

2021: Wheat

2020: Lentils

2019:

**Plot size**

12 m x 1.7 m x 6 replicates

# Cover cropping in the Upper North
# Implications for disease

***Author(s):*** Dr Margaret Evans (Evans Consulting)

***Funded By:*** National Landcare Program, Ag Ex Alliance

***Project Duration:*** 2019-2021

***Project Delivery Organisations:*** Darren Pech (Elders), Matt Nottle (UNFS, farmer cooperator),

**Key Points:**

- Adopting cover cropping in Upper North farming systems appears likely to have few short to medium term effects on soilborne diseases of cereals, pulses and pastures when compared with conventional rotation options. The exception to this might be blackspot of peas, where pathogen concentrations and yield loss risk levels increased from 2019 to 2021.
- Long term treatment effects cannot be predicted from this trial.
- Further assessment at other sites and in other seasons will be needed to confirm these findings, as rainfall was extremely low in 2019 and very low over winter in 2020.
- Prior to treatment, the pathogens causing crown rot, take-all and white grain disorder were present at levels high enough to cause concern for yield losses in cereals. Rhizoctonia root rot risk levels were highly variable, but were of concern for some plots. Crown rot was of most concern as it was present at high risk levels.
- Prior to treatment, the pathogen causing pythium root rot was present at levels high enough to cause concern for yield losses in pulses/canola/pasture legumes.
- Changes in pathogen concentrations over time were generally influenced more by changes in sampling methods (forced by lack of visible cereal stubble in 2021) and seasonal conditions (very dry) than by treatments *per se*.
- Despite a decrease in inoculum levels due to a 2 year break from cereal, crown rot risk levels remained high which indicates a 3-4 year break from cereal is needed to reduce very high inoculum concentrations to a low risk level. This highlights the difficulties of managing crown rot under the low rainfall conditions of the Upper North.
- Termination treatments (chemical fallow; crimp roll; speed till) prior to harvest in 2020 had no obvious effects on concentrations of any pathogens at the start of 2021. The effects of these treatments (particularly for crown rot) are likely to take longer than 6 months to result in improved breakdown of inoculum which means that measurable effects may only occur after 12 months or more.
- Knowing starting inoculum levels assisted in interpreting results as there were higher pathogen concentrations in the demonstration area than in the termination area and there was variability amongst individual plots within those areas pre-treatment.

- The presence of white grain disorder in the trial suggests inoculum of this disease might still be widespread and may have potential to cause issues if seasonal conditions are conducive to expression. Trial results demonstrate the effectiveness of a break (particularly a two year break) from cereal at reducing inoculum of this disease.
- Pythium root rot inoculum increased over the trial period
- PREDICTA® B soil analysis continues to be a powerful research and broad-acre disease management tool.

**Background**

Mixed species cover cropping offers a new approach in the Australian context. It is a key component of some farming systems overseas but is yet to be adopted widely in southern Australia. Benefits of cover crops include improving soil organic carbon, structure and health, while decreasing weed and disease levels for following crops. Although cover crops are most likely to be effective in higher rainfall areas, understanding their management, role and potential in low rainfall areas such as the Upper North is important.

Many potential cover crops exist and while growers are beginning to investigate these, they lack basic local knowledge to make informed decisions. This has led to the Upper North Farming Systems (UNFS) grower group being involved in the project "Warm and cool season mixed cover cropping for sustainable farming systems in SE Australia".

Where low rainfall, intensive cropping, stubble retention and reduced tillage are combined, stubble and plant root systems take longer to break down. This means that soil/stubble-borne diseases e.g. crown rot, take-all and rhizocotonia root rot can become increasingly difficult to manage. It is assumed that cover crops reduce disease levels, but this effect has not been quantified in Australia. To understand the role of cover crops in the farming systems of the Upper North, it is critical to understand the effects of cover crops on soil/stubble-borne diseases of cereals, pulses, legumes and oilseeds.

The aim was to quantify changes in inoculum levels of soil/stubble-borne diseases over time due to cover crop treatments using DNA analysis of soil samples (this assessment method is independent of seasonal conditions and plant types present).

**Methodology**

Three treatments were applied in a field trial at Booleroo Centre during 2019 and 2020:

1. Wheat 2019; medic (self-sown/regenerating) 2020
2. Mixture of 4-5 non-cereals 2019; canola 2020
3. Mixture of 4-5 non-cereals 2019; mixture of 4-5 non-cereals 2020

In 2020, three termination treatments (crimp roll, chemical fallow, speed till) were applied prior to harvest. Each termination treatment was applied in a narrow single strip across one end of the main cover crop trial plots and plots in this area were designated as "termination plots". The majority of the cover crop trial area was harvested in the normal manner and plots in this area were designated as "demonstration plots". Soil samples were taken from plots at the start of 2019 and at the start of 2021 (see Table 1 for details).

*Table 1. Soil sampling details for the demonstration plots (DP) allowed to go through to harvest and termination plots (TP) in a cover crops field trial undertaken at Booleroo Centre, 2019-2021.*

| | **2019** | **2021** |
|---|---|---|
| Areas sampled | DP area (3 treatments in 4 rep's); area assigned for TP (12 plots as for DP). | 3 DP treatments and 3 TP treatments (over each of the DP treatments) in each of 4 rep's. |
| Total plots sampled | 24 | 48 |
| Sample date | 14 April, post-sowing | 12 May, pre-sowing |
| Soil cores taken on cereal rows | Yes | No[1] |
| Stubble added | Yes | No[1] |

[1] Cereal rows and cereal stubble were not visible in 2021.

Soil samples (Table 1) were taken with a 10 mm diameter Accucore sampler to a depth of 10 cm. Soil cores were taken on 5 diagonal legs along each plot . Three soil cores were taken at each of 3 points along each diagonal and combined to make a single sample of 45 cores for each plot. In 2019 only, 1 stubble piece was taken at each of the 3 points along each diagonal and added to the soil sample (15 stubble pieces per sample). Samples were submitted to the PREDICTA® B service at the South Australian Research and Development Institute for q-PCR DNA analysis.

**Results and discussion**

All yield loss risk categories and potential yield losses associated with those risk categories were taken from the PREDICTA® B Broadacre Soilborne Disease Manual, Version 10.4.

Raw data, data summaries, heat maps (visual representation of risk levels in each plot for selected diseases), risk categories for each pathogen and photographs are provided in the Excel spreadsheet (CR UNFSG cover crop trial 2019 2021) associated with this report.

**<u>Presence and absence of pathogens</u>**

PREDICTA® B analysis employs 24 tests that detect pathogens causing diseases in broadacre crops and 12 of these returned positive results at the Booleroo site in 2019 and 2021. Ten of the pathogens cause disease in cereals (1-10) and three cause disease in legumes/pulses/oilseeds (10-12):

1. *Fusarium pseudograminearum* crown rot
2. *Fusarium culmorum/graminearum* crown rot/head blight
3. *Rhizoctonia solani* AG8 rhizoctonia root rot

| | |
|---|---|
| 4. *Gaeumannomyces graminis var. tritici* | take-all wheat strain (Ggt) |
| 5. *Pratylenchus neglectus* | root lesion nematodes (RLN) |
| 6. *Pratylenchus thornei* | root lesion nematodes (RLN) |
| 7. *Bipolaris sorokiniana* | common root rot (CRR) |
| 8. *Pyrenophora tritici-repentis* | yellow spot |
| 9. *Eutiarosporella tritici-australis* | white grain disorder (WGD) |
| 10. *Pythium* clade f | pythium root rot |
| 11. *Didymella pinodes, Phoma pinodella* | blackspot field peas |
| 12. *Macrophomina phaseolina* | charcoal rot |

Of these diseases, the ones most likely to cause significant yield losses in cereals in the Upper North and to be affected by cover crop treatments applied at the Booleroo trial site are crown rot (*Fusarium pseudograminearum* + *F.culmorum/graminearum*), rhizoctonia root rot, take-all and root lesion nematodes.

Twelve of the tests for pathogens causing disease in cereals (1-8) and legumes/pulses/oilseeds (9-12 returned negative (below detection) results in 2019 and 2021:

| | |
|---|---|
| 1. *Heterodera avenae* | cereal cyst nematode (CCN) |
| 2. *Ditylenchus dipsaci* | stem nematode |
| 3. *Gaeumannomyces graminis* var. *avenae* | take-all oat strain (Gga) |
| 4. Fusarium pseudograminearum Type 2 | crown rot |
| 5. *Eutiarosporella darliae/pseudodarliae* | white grain disorder (WGD) |
| 6. *Oculimacula yallundae* | true eyespot |
| 7. *Pratylenchus penetrans* | root lesion nematode (RLN) |
| 8. *P. quasitereoides* | root lesion nematode (RLN) |
| 9. *Phytophthora medicaginis* | phytophthora root rot |
| 10. *Ascochyta rabiei* (synonym *Phoma rabiei*) | ascochyta blight of chickpeas. |
| 11. *Sclerotinia sclerotiorum* | sclerotinia stem rot (white mould) |
| 12. *Phoma koolunga* | blackspot (ascochyta blight) |

Some of these pathogens do not usually occur in low rainfall areas (e.g. eyespot, stem nematode) and some are not usually detected in South Australia (e.g. take-all of oats, *Pratylenchus quasiterioides*). Cereal cyst nematode is not often a problem in current farming systems, but levels need to be monitored as this nematode can quickly build up from very low levels and cause major yield losses.

**<u>Site variability pre-treatment - start of 2019</u>**

The demonstration area generally had higher inoculum levels for crown rot (Tables 1 and 2) and pythium root rot and lower levels for yellow spot and common root rot than did the termination area (data not presented). Variation amongst individual plots was lowest for crown rot and root lesion nematodes, higher for take-all and highest for rhizoctonia root rot (Table 1). For other diseases (data not presented), variation amongst individual plots was lowest for pythium root rot, blackspot and crown rot (*F. culmorum/graminearum*), higher for charcoal rot and highest for common root rot, yellow spot and white grain disorder.

*Table 1: Spatial map of risk categories and inoculum levels pre-treatment (start of 2019) in each plot of the trial area for selected cereal diseases (the road and fenceline were closest to the plots represented at the top of this figure). Demonstration plots went through to harvest, Termination plots had termination treatments (e.g. speed till) applied prior to harvest.*

| Crown rot | | Take-all | | Rhizoctonia root rot | | Root lesion nematodes | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | *Pratylenchus neglectus* | | *Pratylenchus thornei* | |
| Demonstration | Termination | Demonstration | Termination | Demonstration | Termination | Demonstration | Termination | Demonstration | Termination |
| 4.15 | 3.39 | 1.36 | 1.02 | 1.21 | 0.97 | 4 | 1 | 4 | 13 |
| 4.13 | 3.76 | 1.22 | 0.97 | 1.13 | 1.35 | 3 | 2 | 5 | 12 |
| 4.21 | 3.70 | 1.32 | 1.11 | <0.5 | 1.20 | 1 | 4 | 10 | 8 |
| 3.84 | 3.99 | 1.20 | 1.19 | 1.28 | 1.80 | 2 | 3 | 11 | 10 |
| 3.81 | 3.80 | 0.99 | 1.01 | 1.10 | 0.58 | 1 | 2 | 9 | 9 |
| 4.10 | 4.15 | 1.31 | 1.30 | 1.47 | 1.42 | 4 | 2 | 10 | 12 |
| 3.89 | 3.78 | 1.06 | 0.91 | 1.71 | <0.5 | 2 | 3 | 18 | 15 |
| 4.09 | 3.70 | 1.20 | 1.05 | <0.5 | <0.5 | 3 | 2 | 10 | 6 |
| 3.96 | 1.42 | 1.23 | 0.97 | 0.88 | <0.5 | 2 | 20 | 7 | 4 |
| 4.19 | 3.62 | 1.14 | 1.15 | 2.10 | 1.82 | 3 | 8 | 8 | 5 |
| 3.96 | 3.43 | 0.99 | 1.13 | 1.37 | <0.5 | 2 | 8 | 12 | 3 |
| 3.84 | 3.90 | 1.17 | 1.15 | 1.59 | 1.50 | 3 | 4 | 7 | 5 |
| $Log_{10}$ pg DNA / g sample | | | | | | Nematodes / 100 g sample | | | |
| Below detection | | Low risk | | Medium risk | | High risk | | | |

Variability between areas and amongst plots influenced average inoculum concentrations for the 4 replicates for proposed treatments at the start of 2019 (prior to trial commencement). Notably, averages for crown rot and take-all inoculum were higher in the demonstration plot area than in the termination plot area and for common root rot were lower in the demonstration plot area than in the termination plot area (Table 2). Inoculum averages were much higher than expected in the termination plot area for *F. culmorum/graminearum* in the W 2019 SSMedic 2020 treatment and for blackspot of peas in the treatment M4-5Sp 2019 M4-5Sp 2020 (Table 2). In both these cases, one plot had medium/high inoculum levels while in all other plots inoculum of these diseases was below detection.

There were no obvious trends across the 12 treatment plots with respect to risk categories or pathogen concentrations for the five stem/root diseases most likely to cause yield losses in cereals at the trial site (Table 1). Data (not presented) also indicated there were no trends for risk categories or pathogens concentrations across the site for the other pathogens discussed in this report. The exception was an area in the termination plots furthest from the fenceline that had slightly higher inoculum levels for common root rot and white grain disorder. The lack of trends makes data interpretation easier as treatment effects are unlikely to be confounded by underlying trends across the site.

The variability between trial areas and amongst plots must be considered when interpreting results from this trial.

*Table 2: Average inoculum concentrations and risk levels prior to commencement of the cover crop trial at Booleroo Centre, 2019.*

| Proposed treatments for 2019 and 2020 | Crown rot | Take-all | Rhizoctonia root rot | Root lesion nematodes P. neglectus | Root lesion nematodes P. thornei | Common root rot | Pythium root rot | Yellow spot | White grain disorder | Crown rot (F. culmorum) | Black spot peas | Charcoal rot |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Demonstration plot area** | | | | | | | | | | | | |
| M4-5Sp 2019 MSp 2020 | 9340 | 14 | 26 | 2 | 11 | 0 | 193 | 7 | 481 | 0 | 5 | 5 |
| M4-5Sp 2019 Canola 2020 | 11224 | 16 | 41 | 3 | 8 | 1 | 147 | 3 | 1155 | 1 | 2 | 6 |
| W 2019 SSMedic 2020 | 12016 | 17 | 17 | 3 | 9 | 2 | 166 | 2 | 288 | 1 | 3 | 7 |
| **Termination plot area** | | | | | | | | | | | | |
| M4-5Sp 2019 MSp 2020 | 6331 | 11 | 13 | 3 | 9 | 8 | 123 | 20 | 186 | 0 | 46 | 5 |
| M4-5Sp 2019 Canola 2020 | 4923 | 12 | 38 | 8 | 7 | 18 | 96 | 11 | 439 | 0 | 2 | 18 |
| W 2019 SSMedic 2020 | 5835 | 14 | 10 | 3 | 9 | 21 | 113 | 147 | 304 | 209 | 2 | 4 |
| | pgDNA / g sample | | | nematodes / 100 g sample | | pgDNA / g sample | | kDNA copies / g sample | | pgDNA / g sample | | kDNA copies |

Risk levels for diseases where potential yield losses have yet to be established for each risk category: Below detection | Low level | Medium level | High level

Risk levels for diseases where potential yield losses are known for each risk category: Below detection | Low risk | Medium risk | High risk

## Inoculum changes over time

*Note:* Soil samples at the start of 2019 were taken on-row and had cereal stubble added. Soil samples at the start of 2021 were not taken on-row and did not have cereal stubble added. This difference occurred because crop rows and cereal stubble from 2019 were not visible at the start of 2021 due to the very poor growing conditions in 2019.

There was very low rainfall in 2019, little rainfall during winter in 2020 and there were differences in soil sampling methods prior to and after treatment application. These factors would have had a direct effect on changes in inoculum levels over time. For each pathogen, the response of inoculum levels to the climatic and sampling factors would differ, depending on pathogen biology and inoculum location (i.e. whether inoculum is in stubble, roots, soil).

The influences of climatic conditions and changes in sampling methods makes it difficult to assess direct treatment effects on inoculum changes over time. For this reason, changes in inoculum over time are discussed in general in this section and no conclusions are made about specific treatment effects.

***Disease inoculum associated with infected residues above and below ground*** - expect decreases in inoculum from 2019 to 2021 as an artefact of the lack of stubble in soil samples in 2021 and suspect minor additional decreases due to soil samples not being taken on the old cereal rows in 2021. Diseases in this category included:

- ***Crown rot*** inoculum decreased from 2019 to 2021. The decrease was generally large, suggesting it was not due to sampling methods alone. Despite the large decrease, the high risk level for this disease was not reduced (Table 3). Dry conditions, particularly in 2019, would have slowed decomposition of infected residues and reduction of crown rot inoculum under the non-cereal treatments. Dry conditions at the start of 2019 would have lowered infection rates in the treatment sown to wheat, but infected plants would have had high concentrations of the pathogen in their residues.
- ***Take-all*** inoculum decreased from 2019 to 2021 and this decreased risk levels from medium/low to low/below detection (Table 3). In the treatment sown to wheat in 2019, the dry spring

conditions would not have been conducive to expression of take-all, but some increase in inoculum might still be expected in that treatment.

- ***Common root rot*** inoculum was below detection or at low risk levels in both years, with no obvious changes over time (Table 4).

***Disease inoculum mainly in soil or associated with infected residues below ground*** - expect minor decreases in inoculum from 2019 to 2021 due to soil samples not being taken on the old cereal rows in 2021. Diseases in this category included:

- ***Rhizoctonia root rot*** inoculum was highly variable with respect to changes in risk levels and inoculum concentrations over time in the trial plots (Table 3). This suggests there was little influence of sampling method on results and is consistent with the patchy nature of rhizoctonia root rot expression.
- ***Pythium root rot*** inoculum decreased from 2019 to 2021, and this generally decreased risk levels from high in 2019 to medium at the start of 2021 (Table 4).
- ***Root lesion nematode*** numbers and risk levels changed little over time (Table 3), with some suggestion of slight increases for *P. neglectus* and slight decreases for *P. thornei*. These changes were not large enough to affect risk levels.
- ***Blackspot of peas*** inoculum was below detection in 2019, but in 2021 a number of samples returned low risk levels, with some increase in inoculum concentrations in all plots (Table 4). It is probable that this increase would have occurred in 2020, as 2019 was extremely dry and would not have been conducive to blackspot expression.
- ***Charcoal rot*** inoculum was below detection or present at low levels in some plots, with no obvious changes over time (Table 4). This disease can colonise the roots of many plant species, including winter cereals, without causing symptoms and is usually only a problem for summer crops e.g. sorghum, mungbean. The presence of low levels of charcoal rot is not of concern in drier areas such as the Upper North.

***Disease inoculum mainly associated with infected residues above ground*** – expect decreases in inoculum from 2019 to 2021 as an artefact of the lack of stubble in soil samples in 2021. Diseases in this category included:

- ***White grain disorder*** inoculum decreased from 2019 to 2021 and this reduced risk levels from medium/high to low/below detection in most plots in 2021 (Table 4). The decrease in inoculum concentrations was often quite large and probably not due to changes in sampling method alone. This is consistent with only one treatment including wheat and with that crop being sown in 2019, which was extremely dry and not conducive to expression of white grain disorder.
- ***Yellow spot*** inoculum was present at low risk/below detection levels in 2019 and in most plots had decreased to below detection levels by 2021 (Table 4). This is consistent with only one treatment including wheat and with that crop being sown in 2019, which was extremely dry and not conducive to yellow spot expression.

*Table 3: Risk categories and inoculum levels pre-treatment (2019) and post-treatment (2021) in each demonstration plot for selected cereal diseases (the road and fenceline were closest to the plots represented at the top of this figure). Note – the pathogen concentrations for determining crown rot risk levels are adjusted where no stubble is added to the soil sample (as in 2021 at Booleroo Centre).*

| Crown rot | | Take-all | | Rhizoctonia root rot | | Root lesion nematodes *P. neglectus* | | Root lesion nematodes *P. thornei* | |
|---|---|---|---|---|---|---|---|---|---|
| 2019 | 2021 | 2019 | 2021 | 2019 | 2021 | 2019 | 2021 | 2019 | 2021 |
| 4.15 | 3.06 | 1.36 | 0.70 | 1.21 | 1.77 | 4 | 10 | 4 | 3 |
| 4.13 | 1.92 | 1.22 | 0.61 | 1.13 | 0.08 | 3 | 6 | 5 | 2 |
| 4.21 | 2.00 | 1.32 | 0.71 | <0.5 | 0.00 | 1 | 6 | 10 | 3 |
| 3.84 | 1.71 | 1.20 | 0.74 | 1.28 | 1.81 | 2 | 6 | 11 | 4 |
| 3.81 | 1.78 | 0.99 | 0.60 | 1.10 | 1.04 | 1 | 6 | 9 | 5 |
| 4.10 | 2.58 | 1.31 | 0.82 | 1.47 | 1.02 | 4 | 3 | 10 | 5 |
| 3.89 | 2.16 | 1.06 | 0.75 | 1.71 | 1.18 | 2 | 6 | 18 | 7 |
| 4.09 | 2.64 | 1.20 | 0.64 | <0.5 | 1.54 | 3 | 4 | 10 | 5 |
| 3.96 | 2.23 | 1.23 | 0.73 | 0.88 | 0.79 | 2 | 10 | 7 | 2 |
| 4.19 | 1.80 | 1.14 | 0.82 | 2.10 | 1.13 | 3 | 11 | 8 | 2 |
| 3.96 | 2.78 | 0.99 | 0.86 | 1.37 | 1.76 | 2 | 6 | 12 | 5 |
| 3.84 | 2.22 | 1.17 | 0.52 | 1.59 | 1.08 | 3 | 12 | 7 | 3 |
| $Log_{10}$ pg DNA / g sample | | | | | | Nematodes / 100 g sample | | | |

Below detection | Low risk | Medium risk | High risk

*Table 4: Risk categories and inoculum levels pre-treatment (2019) and post-treatment (2021) in each demonstration plot for selected diseases of broadacre crops (the road and fenceline were closest to the plots represented at the top of this figure). Booleroo Centre cover crop trial.*

| Yellow spot | | White grain disorder | | Common root rot | | Pythium root rot | | Black spot peas | | Charcoal rot | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2019 | 2021 | 2019 | 2021 | 2019 | 2021 | 2019 | 2021 | 2019 | 2021 | 2019 | 2021 |
| 0.43 | <0.3 | <0.3 | 0.25 | 0.93 | 0.28 | 121 | 94 | 8 | 11 | 6 | 5 |
| 0.44 | <0.3 | 2.47 | <0.3 | <0.6 | 0.49 | 130 | 63 | 3 | 8 | 9 | 2 |
| <0.3 | <0.3 | 2.61 | 0.32 | <0.6 | <0.6 | 173 | 131 | 0 | 7 | 5 | 6 |
| <0.3 | <0.3 | 2.48 | <0.3 | <0.6 | <0.6 | 194 | 78 | 6 | 32 | 8 | 18 |
| 1.15 | <0.3 | 2.22 | <0.3 | <0.6 | <0.6 | 221 | 111 | 15 | 25 | 3 | 0 |
| <0.3 | 0.40 | 2.72 | 0.42 | <0.6 | <0.6 | 200 | 152 | 0 | 11 | 9 | 12 |
| 0.73 | <0.3 | <0.3 | <0.3 | <0.6 | <0.6 | 235 | 93 | 0 | 62 | 2 | 4 |
| 0.84 | 0.56 | 1.98 | 0.59 | <0.6 | <0.6 | 191 | 106 | 4 | 14 | 13 | 5 |
| 0.55 | <0.3 | 2.59 | <0.3 | <0.6 | <0.6 | 124 | 37 | 0 | 22 | 6 | 3 |
| 0.74 | 0.32 | 3.56 | <0.3 | <0.6 | 0.99 | 141 | 56 | 0 | 0 | 15 | 4 |
| <0.3 | <0.3 | 2.72 | 1.63 | <0.6 | <0.6 | 154 | 75 | 0 | 6 | 4 | 4 |
| 0.97 | <0.3 | 3.13 | <0.3 | <0.6 | <0.6 | 143 | 110 | 5 | 8 | 8 | 8 |
| $Log_{10}$ kDNA copies/g sample | | | | $Log_{10}$ pg DNA/g sample | | pg DNA/g sample | | | | kDNA copies/g sample | |

Risk levels for diseases where potential yield losses have yet to be established for each risk category

Below detection | Low level | Medium level | High level

Risk levels for diseases where potential yield losses are known for each risk category

Below detection | Low risk | Medium risk | High risk

**<u>Treatment effects on inoculum levels</u>** (PREDICTA® B soil analysis at the start of 2021)

*Note:* the sampling method was the same for all treatments in 2021, so direct comparison of treatment effects on inoculum levels can be made.

***Crown rot*** *Hosts* – winter cereals; many grasses

*Fusarium pseudograminearum* was the dominant cause of crown rot in the Booleroo Centre trial. *F. culmorum/graminearum*, which also causes crown rot, was below detection, except for one plot in 2019 (Table 5; 2019 data not presented).

The risk of yield loss from crown rot remained high at the start of 2021, regardless of treatment even where there was a two year break from cereal (Table 5). This highlights how difficult it is to manage crown rot in the low rainfall Upper North farming system.

Although the risk category did not decrease, the treatments with 2 years of non-cereal had lower concentrations of crown rot inoculum than did the W 2019; SSMedic 2020 treatment (Table 5). The 2019 wheat crop would have increased inoculum levels and with the regenerating medic in 2020, there was no sowing pass to break up cereal stubble and encourage faster breakdown of the infected cereal residues. If 2019 had higher rainfall, the treatments with a two-year break from cereal may have been more effective and reduced the crown rot concentrations enough to also reduce the risk category.

The suggestion that termination treatments reduced crown rot inoculum more than the demonstration treatments (Table 5) is an artefact of higher initial inoculum levels in the demonstration plots (Table 2).

It is probable that sowing cover crops in the Upper North will assist in reducing crown rot, but this would still be a long-term management strategy and reducing the number of wheat crops may not be economic.

*Table 5: Treatment effects on risk levels and disease inoculum concentrations (raw data, not $Log_{10}$ transformed) at the start of 2021 in the Booleroo Centre cover crops trial. Note – the inoculum concentrations for determining crown rot risk levels are adjusted where no stubble is added to the soil sample (as in 2021 at Booleroo Centre).*

| Treatment 2019 and 2020 | Crown rot | Take-all | Rhizoctonia root rot | Root lesion nematodes *P. neglectus* | Root lesion nematodes *P. thornei* | Common root rot | Pythium root rot | Yellow spot | White grain disorder | Crown rot (*F. culmorum*) | Black spot peas | Charcoal rot |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Demonstration plots** | | | | | | | | | | | | |
| M4-5Sp 2019 MSp 2020 | 117 | 5 | 10 | 7 | 4 | 1 | 111 | 0 | 1 | 1 | 25 | 4 |
| M4-5Sp 2019 Canola 2020 | 92 | 5 | 21 | 8 | 3 | 3 | 59 | 1 | 0 | 0 | 15 | 10 |
| W 2019 SSMedic 2020 | 643 | 6 | 40 | 6 | 4 | 1 | 107 | 2 | 13 | 0 | 11 | 8 |
| **Termination with chemical fallow** | | | | | | | | | | | | |
| M4-5Sp 2019 MSp 2020 | 38 | 3 | 24 | 7 | 4 | 1 | 75 | 1 | 0 | 0 | 4 | 17 |
| M4-5Sp 2019 Canola 2020 | 41 | 2 | 12 | 7 | 3 | 1 | 65 | 1 | 0 | 0 | 3 | 5 |
| W 2019 SSMedic 2020 | 93 | 5 | 45 | 13 | 4 | 0 | 90 | 0 | 21 | 3 | 20 | 9 |
| **Termination with crimp rolling** | | | | | | | | | | | | |
| M4-5Sp 2019 MSp 2020 | 43 | 3 | 21 | 12 | 5 | 0 | 76 | 3 | 0 | 0 | 11 | 7 |
| M4-5Sp 2019 Canola 2020 | 38 | 2 | 13 | 14 | 2 | 0 | 58 | 1 | 0 | 0 | 1 | 9 |
| W 2019 SSMedic 2020 | 83 | 4 | 47 | 14 | 4 | 0 | 53 | 5 | 4 | 0 | 6 | 10 |
| **Termination with speed tilling** | | | | | | | | | | | | |
| M4-5Sp 2019 MSp 2020 | 65 | 7 | 6 | 4 | 5 | 0 | 75 | 2 | 0 | 1 | 30 | 19 |
| M4-5Sp 2019 Canola 2020 | 26 | 3 | 13 | 5 | 3 | 0 | 46 | 0 | 0 | 0 | 20 | 7 |
| W 2019 SSMedic 2020 | 215 | 7 | 52 | 6 | 2 | 1 | 43 | 0 | 55 | 1 | 2 | 13 |
| | pgDNA / g sample | | | nematodes / 100 g sample | | pgDNA / g sample | | kDNA copies / g sample | | pgDNA / g sample | | kDNA copies |

Risk levels for diseases where potential yield losses have yet to be established for each risk category: Below detection | Low level | Medium level | High level

Risk levels for diseases where potential yield losses are known for each risk category: Below detection | Low risk | Medium risk | High risk

***Rhizoctonia root rot*** *Hosts* – winter cereals; grasses

The risk of yield loss from rhizoctonia root rot at the start of 2021 was low to medium (Table 5). The cover crop treatment W 2019 SSMedic 2020 consistently had higher inoculum levels than treatments which had a two year break from cereal. This suggests that a two-year break from cereal may reduce the risk of damage from rhizoctonia root rot for the next cereal crop, but the economics of this advantage will also need to be quantified.

***White grain disorder*** *Hosts* – winter cereals

The risk of yield loss from white grain disorder at the start of 2021 (Table 5) was below detection levels for treatments with two years of non-cereals, but the risk was generally medium where wheat was sown in 2019. This demonstrates the efficacy of a break from cereal in managing the risk of this disease. White grain disorder (which caused significant issues in 2011/2012) was present at high risk levels in the trial, suggesting this disease might still be widespread in the area and may have potential to cause issues if seasonal conditions are conducive to expression.

***Pythium root rot*** *Hosts* – grain crops and pastures

The risk of yield loss from pythium root rot at the start of 2021 was generally medium, with 2 treatments in the demonstration plots having high risk levels (Table 5). Although it appears that M4-5Sp 2019; Canola 2020 in the demonstration area had lower pathogen concentrations than did the other treatments in that area, this is an artefact of much higher initial inoculum levels in 2 replicates for each of those treatments (data not presented). Other than this, treatment effects on inoculum concentrations were not obvious (Table 5). Although cereals are hosts for pythium root rot, they do not usually show significant yield losses, while pulses and canola do.

***Blackspot of peas*** *Hosts* – pulses, pasture legumes

Inoculum levels were low at the start of 2021 and there is no clear evidence for treatment effects (Table 5). Blackspot is caused by a pathogen complex and it is important to know which species are present as the host range differs amongst these pathogens.

***Take-all*** *Hosts* – winter cereals; grasses

Inoculum levels were very low at the start of 2021 (Table 5), making it impossible to assess treatment effects on pathogen concentrations.

***Root lesion nematodes*** *Hosts* – broad range, includes grain crops, pastures

Numbers were very low at the start of 2021 (Table 5), making it impossible to assess treatment effects on root lesion nematode (*P. neglectus, P. thornei*) numbers.

***Common root rot*** *Hosts* – broad range, includes winter cereals

Inoculum was below detection at the start of 2021 (Table 5), making it impossible to assess differences amongst treatments.

***Yellow spot*** *Hosts* – bread wheat, durum wheat, triticale

Inoculum levels were very low at the start of 2021 (Table 5), making it impossible to assess treatment effects on pathogen concentrations.

***Charcoal rot*** *Hosts* – broad range, includes grain crops

Inoculum levels were very low at the start of 2021 (Table 5), making it impossible to assess treatment effects on pathogen concentrations. This pathogen causes disease in summer crops such as sorghum, soybean and sunflower but can colonise the roots of winter cereals and many other plant species without causing symptoms.

**Acknowledgements**

Project funding - National Landcare Program - Smart Farming Partnerships initiative funding Round 1 via subcontract with Ag Ex Alliance.

**References**

Broadacre Soilborne Disease Manual version 10.2. 2019. Technical editors – Alan McKay (SARDI), Allan Mayfield (Allan Mayfield Consulting Pty Ltd), Laura Davies (SARDI) and Shawn Rowe (SARDI).

**APPENDIX I – 2019 UNFS Cover Crops soil sampling report.**

## UNFS cover crop field trial evaluations – implications for disease
## Booleroo Centre, 2019

Margaret Evans (SARDI), Matt Nottle (UNFS), Darren Pech (Elders), Ruth Sommerville (UNFS).

**Key messages**

- Crown rot, then take-all and rhizoctonia are the most important soil-borne cereal diseases in the cover crop trial and in commercial paddocks at Booleroo Centre.
- Inoculum of these diseases are spatially variable in plots across the cover crop trial as well as on a paddock scale. This variability between plots could affect trial results, making it important to monitor diseases and inoculum levels in the cover crop trial.
- Root lesion nematodes do not present a significant risk to cereal crops or the cover crop field trial at Booleroo Centre.
- Paddock history (even going back 5 years) does not always explain the crown rot inoculum levels in commercial paddocks.

**Why do the work?**

Mixed species cover cropping offers a new approach in the Australian context. It is a key component of some farming systems overseas but is yet to be adopted widely in southern Australia. Benefits of cover crops include improving soil organic carbon, structure and health, while decreasing weed and disease levels for following crops.

Many potential cover crops exist and while growers are beginning to investigate these, they lack basic local knowledge to make informed decisions. This has led to the Upper North Farming Systems (UNFS) grower group being involved in the project “Warm and cool season mixed cover cropping for sustainable farming systems in SE Australia”.

Where low rainfall, intensive cropping, stubble retention and reduced tillage are combined, stubble and plant root systems take longer to break down. This means that soil/stubble-borne diseases e.g. crown rot (CR), root lesion nematodes (RLN), take-all (TA) and rhizocotonia (Rh) become increasingly difficult to manage. It is assumed that cover crops reduce disease levels, but this effect has not been quantified in Australian farming systems. To understand the role of cover crops in South Australian farming systems it is critical to understand the effects of those cover crops on soil/stubble-borne cereal diseases.

On this basis, the cereal disease work undertaken in 2019 aimed to quantify:

- Starting inoculum levels of soil/stubble-borne cereal diseases in the cover crops trial.
- Inoculum levels of soil/stubble-borne cereal diseases (particularly CR and RLN) in commercial paddocks and to determine the influence of paddock history and management on those levels.

**How was it done?**

The standard PREDICTA® B paddock sampling protocol was used and samples were taken with a 10 mm diameter Accucore sampler to a depth of 10 cm. Cores were taken in 5 diagonal legs, preferentially on-row. Three soil cores and 1 stubble piece were taken at each of 3 points along each diagonal and combined to make a single sample (45 cores, 15 stubble pieces) for each trial plot or paddock. Samples were submitted for q-PCR DNA analysis.

Soil samples were taken from 12 paddocks on 1 April 2019 and from the cover crop field trial plots after crop emergence on 14 April 2019. Paddocks were selected from around the edges of Matt Nottle's property, where the cover crop trial is located. Paddock history, stubble management, paddock preparation and general comments were recorded for each paddock.

**Results and discussion**

As would be expected, stem nematode, the oat strain of take-all and eyespot were not present in any samples. Cereal cyst nematode also was not present in any samples and that is good, as this nematode can quickly build up from very low levels and cause major yield losses.

<u>Cover crop field trial</u>

The diagram below shows the risk of yield loss from each of 5 pathogens causing cereal diseases. Each square represents a plot within the trial and colours indicate the risk of yield loss – green = low risk; orange = medium risk; red = high risk; white = below detection.

| | | Crown rot | | Take-all | | Rhizoctonia | | *Pratylenchus neglectus* | | *Pratylenchus thornei* | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Rep | Treatment | Demonstration | Termination | Demonstration | Termination | Demonstration | Termination | Demonstration | Termination | Demonstration | Termination |
| 1 | Wheat | 4.15 | 3.39 | 1.36 | 1.02 | 1.21 | 0.97 | 4 | 1 | 4 | 13 |
| | Wheat | 4.13 | 3.76 | 1.22 | 0.97 | 1.13 | 1.35 | 3 | 2 | 5 | 12 |
| | Mix 4-5 species | 4.21 | 3.70 | 1.32 | 1.11 | <0.5 | 1.20 | 1 | 4 | 10 | 8 |
| 2 | Wheat | 3.84 | 3.99 | 1.20 | 1.19 | 1.28 | 1.80 | 2 | 3 | 11 | 10 |
| | Mix 4-5 species | 3.81 | 3.80 | 0.99 | 1.01 | 1.10 | 0.58 | 1 | 2 | 9 | 9 |
| | Wheat | 4.10 | 4.15 | 1.31 | 1.30 | 1.47 | 1.42 | 4 | 2 | 10 | 12 |
| 3 | Mix 4-5 species | 3.89 | 3.78 | 1.06 | 0.91 | 1.71 | <0.5 | 2 | 3 | 18 | 15 |
| | Wheat | 4.09 | 3.70 | 1.20 | 1.05 | <0.5 | <0.5 | 3 | 2 | 10 | 6 |
| | Wheat | 3.96 | 1.42 | 1.23 | 0.97 | 0.88 | <0.5 | 2 | 20 | 7 | 4 |
| 4 | Wheat | 4.19 | 3.62 | 1.14 | 1.15 | 2.10 | 1.82 | 3 | 8 | 8 | 5 |
| | Wheat | 3.96 | 3.43 | 0.99 | 1.13 | 1.37 | <0.5 | 2 | 8 | 12 | 3 |
| | Mix 4-5 species | 3.84 | 3.90 | 1.17 | 1.15 | 1.59 | 1.50 | 3 | 4 | 7 | 5 |

CR is the biggest risk at the site, followed by TA. As is normal for Rh, the risk across the site is very patchy but generally is less than for CR and TA at this site. The root lesion nematodes (RLN) *Pratylenchus neglectus* and *P. thornei* are generally a low risk.

It is clear that the inoculum levels for TA and Rh vary from plot to plot and that there is one plot with much lower CR inoculum than is seen in all the other plots. These differences in inoculum levels can directly influence trial results. By understanding starting levels of disease inoculum in each plot, it becomes possible to use this information to assist in interpreting results and in understanding the best use of cover crops in South Australian farming systems.

Paddock sampling

Findings were consistent with those seen in the cover crop trial area – CR, followed by TA and Rh were the main disease issues. CR was present in 82% of paddocks at levels likely to cause yield losses (high risk - 64%; medium risk - 18%). TA was of less concern, being present in 90% of paddocks but only at medium (45%) and low (45%) risk of causing yield losses. RH was of least concern, being present in 72% of paddocks but only at medium (36%) and low (36%) risk of causing yield losses. This suggests that results from the cover crops trial are likely to apply  widely in the Booleroo Region.

| One paddock sampled in two sections | | |
|---|---|---|
| | **East** | **West** |
| Crown rot | 0.71 | 2.92 |
| Take-all | 0.47 | 0.22 |
| Rhizoctonia | 1.89 | 1.40 |
| *P. neglectus* | <0.1 | <0.1 |
| *P. thornei* | <0.1 | <0.1 |
| **Paddock history** | | |
| 2018 | Lentils Jumbo | |
| 2017 | Wheat Trojan | |
| 2016 | Canola TT | |
| 2015 | Barley Hindmarsh | |
| 2014 | Wheat Scout | |

Stubble was retained and crops direct sown in all paddocks except for one that was in continuous pasture. Five-year paddock histories did not provide a consistent explanation for the presence or absence of high levels of CR inoculum and this requires more examination of paddock use in relation to seasonal conditions in each of the 5 years. The diagram on the left shows that distribution of disease inoculum is uneven on a paddock scale. This means that the distribution is uneven on a large (paddock) scale as well as on a small (trial plot) scale.

**Acknowledgements**

Project funding - National Landcare Program - Smart Farming Partnerships initiative funding Round 1 via subcontract with Ag Ex Alliance.

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MIXED COVER CROPS
FOR SUSTAINABLE FARMING

# Warm and cool season mixed cover cropping for sustainable farming systems in south-eastern Australia
# Invertebrate survey

**Author:** Michael Nash

**Funded By:** National Landcare Program; Smart Farming Partnerships initiative funding Round 1 via subcontract with Ag Ex Alliance

**Project Title:** Warm and cool season mixed cover cropping for sustainable farming systems in south-eastern Australia

**Project Duration:** 2018-2022

**Project Delivery Organisations:** CSIRO, Whatbugsyou

**Treatments:**

| | 2019 | 2020 | 2021 |
|---|---|---|---|
| Fallow – no cover crop | Wheat | Medic | Wheat |
| Single – 1 cover crop sp. | Mix | Vetch/canola | Wheat |
| Mix – 5 spp. cover crop | Mix | | Wheat |

**5 species:** Smart Radish, Bouncer Brassica Rape, Subzero forage rape, Chicory, Volga vetch

*Plate 1. Tullgren extraction of macroinvertebrates from soil cores*

*This project is supported by Ag Excellence Alliance through funding from the Australian Government's National Landcare Program, Grains Research and Development Corporation and the South Australian Department for Environment and Water.*

**Invertebrate Results**

Sampling in the final cash crop took place later than anticipated, after 10 mm of rain on the 17th Oct 2021. Total numbers (abundance) extracted from the soil cores collected in each plot (3 cores 50 mm dia. by 100 mm deep) were mostly due to the presence of Hypogastrura, a springtail that often is found in high numbers and forms a black / purple scum on puddles (Fig. 1). There was no response in the number of springtail species observed to plant diversity (Fig. 2). Opposite to what was expected, lower soil moisture at depth after the single specie cover crop treatment did not result in lower abundance when soil invertebrates were sampled. Only surface-dwelling invertebrates were recorded and soil cores were collected after rainfall, which may explain the result. The lower number of predatory mites was associated with a lower number of prey (soft body mites), however this may have been due to the greater number of predatory rove beetles, which could not be related to treatment (Fig. 2). The presence of a functioning predator community indicates the pesticide usage at this site has limited disruption to natural enemy communities, which is reflected by the low disruption index calculated.

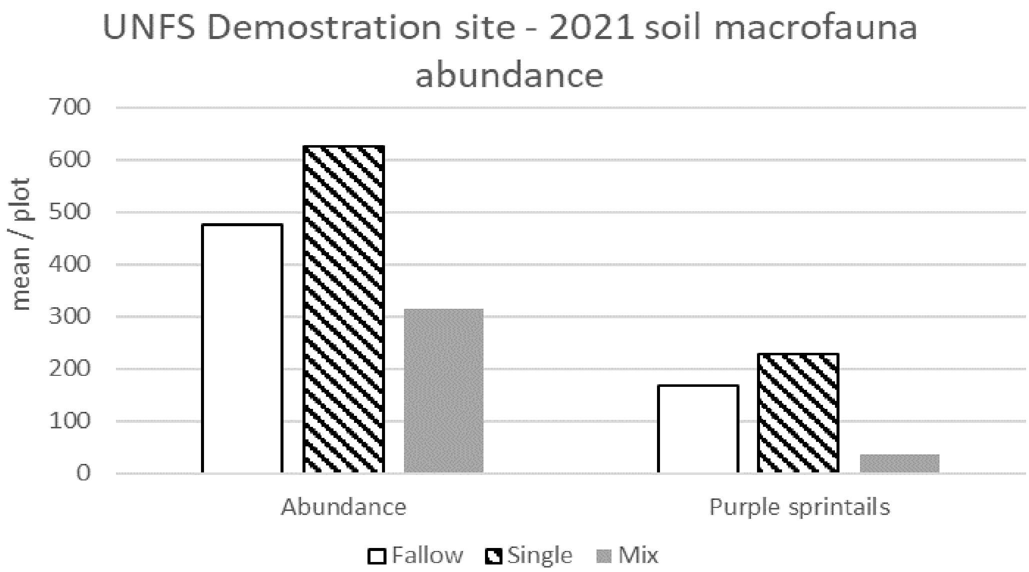


*Figure 1. Mean number of all macroinvertebrates (abundance) and a species of springtail extracted from 2,360 cm$^3$ of soil collected from each plot from the three crop treatments. Fallow being no cover crop, single being 1 cover crop species & Mix being a multi species cover crop. No significant differences were observed between treatments (ANOVA P > 0.05)*

*This project is supported by Ag Excellence Alliance through funding from the Australian Government's National Landcare Program, Grains Research and Development Corporation and the South Australian Department for Environment and Water.*

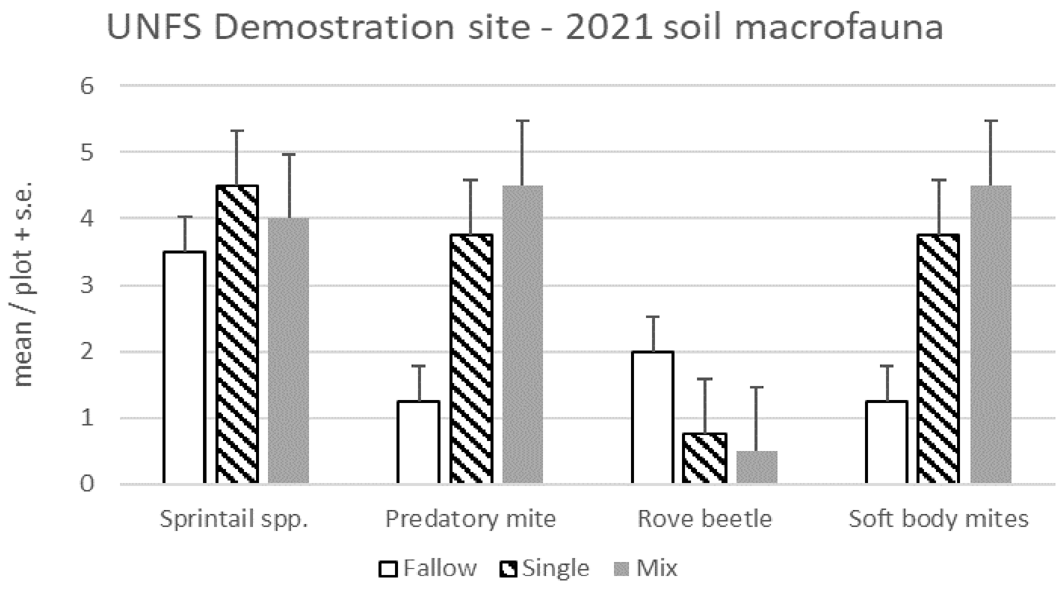


*Figure 2. Mean number of individual species (abundance) extracted from 2,360 cm$^3$ of soil collected from each plot from the three crop treatments. Fallow being no cover crop, single being 1 cover crop species & Mix being a multi species cover crop. No significant differences were observed between treatments (ANOVA P > 0.05).*

**Conclusions:**

The lack of soil macroinvertebrate response to cover crop treatment fits with no discernible differences observed in soil biological parameters from associated soil monitoring data. The increased dissolved organic N in the cover crop treatments was not associated with increase in invertebrate abundance. Other factors seemed to have influenced the abundance of soil macroinvertebrates at this demonstration site. The presence of predatory mites and beetles could have provided some regulation of pest species in this wheat crop, as pests were rarely detected (odd false wireworm).

**Acknowledgements**

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- Ag Excellence Alliance through funding from the Australian Governments National Landcare Program, Grains Research and Development Corporation and South Australian Department for Environment and Water

*This project is supported by Ag Excellence Alliance through funding from the Australian Government's National Landcare Program, Grains Research and Development Corporation and the South Australian Department for Environment and Water.*

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| Hon | Dan | Van Holst Pellekaan | | Port Augusta |
| Mr | Daniel | Vater | | AGT |
| Mr | Henry | Voigt | | CentreState Exports |
| Mr | Andrew | Walter | Lydia | Melrose |
| Mr | Ken | Walter | Denise | Melrose |
| Ms | Sharon | Watt | | GRDC |
| Mr | Stephen | Whillas | | E.P.I.C. |
| Mr | Craig | Woolford | | Wirrabara |
| Mr | Andrew | Zanker | | Laura |
| Mr | Bryan | Zanker | | Booleroo Centre |
| Mr | Eric | Zanker | Raelene | Booleroo Centre |
| Mr | Jason | Zohs | Kim | Crystal Brook |
| Mrs | Kim | Zohs | Jason | Crystal Brook |
| Mr | Michael | Zwar | | Ag Tech Services |
| Mr | Samuel | Young | | Port Pirie |
| Mr | Wayne | Young | | Port Pirie |

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