Upper North Farming Systems

2018 RESULTS

UPPER NORTH FARMING SYSTEMS ANNUAL RESEARCH AND EXTENSION COMPENDIUM

CONTENTS

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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

Contact List

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A Message from the Chair

We are pleased to provide this compendium of results of trials and related issues relevant to farming systems in the Upper North from the 2018 season – one of our toughest seasons in living memory.

Our mission is to lead primary producers of the Upper North of SA to improve sustainability, profitability and viability of our faming systems. When you look through this compendium and reflect on the events run by the UNFS in the past 12 months, I firmly believe the group is on the right track. However, to keep UNFS viable into the future we will continue to rely on our members to provide our committees with feedback and raise issues on what is relevant to their farming enterprise.

The research, development and extension conducted by UNFS is not possible without the support of funding bodies, project partners and sponsors – all of whom are listed in the front of this compendium. I would like to take this opportunity to thank all of you for your on-going support. The UNFS continues to search for new funding opportunities with project partners and will welcome any new sponsors willing to come on board.

I thank our staff (Ruth Sommerville, Hannah Mikajlo, Mary Timms, Kristina Mudge) for their excellent efforts in project leadership, group governance, finance and administration. They have done an outstanding job, and we are fortunate to have such great people working for UNFS.

I would finally like to thank all committee members for their time and effort in keeping the group together and making things happen. The continued success of UNFS is only possible through your ongoing efforts and support.

Matt McCallum,

Chairperson, Upper North Farming Systems

Upper North Farming Systems Project and Grants 2018

(including projects undertaken in the 2017-2018 FY)

UNFS Project #	Other Names/ References	Full Name	Funding Source	Project Manager
211	GRDC Stubble Initiative	Maintaining Profitable farming systems with retained stubbles in Upper North SA	GRDC	Ruth Sommerville
216	Controlled Traffic	Application of CTF in the low rainfall zone	ACTFA	Matt McCallum
219	Upskilling UNFS women	Upskilling the women of the Upper North to be future ready, sustainable, more productive farmers	SAGIT	Jess Koch
220	Wheat Time of Sowing trial	Upper North Time of Sowing and Yield Loss from Frost/Heat stress	SAGIT	Hannah Mikajlo
223	Pasture Options Demonstration	Demonstrating improved pasture options for the Upper North	PIRSA/Ag Excellence Alliance	Andrew Kitto
224	Micronutrients in the Upper North	Increasing the knowledge and understanding of micronutrient deficiency in the Upper North	SAGIT	Matt Foulis
226	Pulse Check	Southern Pulse Extension Project	GRDC, subcontracted by BCG	Barry Mudge

Upper North Farming Systems 2018

Event Summary

Date	Event	Location	Participants	Details/Topics
20/3/2018	UNFS Pulse Check Discussion Group	Booleroo Centre	16	Second Pre-seeding pulse check discussion meeting with guest speakers Daniel Hillebrand and Matt Foulis
16/4/2018	Micronutrient and Acidity workshop	Laura	17	Awareness raising workshop held with the Laura Ag Bureau
25/6/2018	Stubble Initiative Final Event	Wirrabara	46	Final event for Stubble Initiative project. Launch of Stubble booklet and soil acidity factsheet.
23/8/2018	UNFS Melrose Hub Crop Walk	Melrose	21	Tour of various pulse crops in the Melrose region including Dustin & Matt from Northern Ag providing their thoughts on rotations, diseases, pests etc. Issues identified moisture stress, temperature, soil constraints & weed management.
30/8/2018	UNFS Annual Members Expo	Booleroo Centre	60	Sam Trengove, Where does PA fit in the Upper North. Michael Richards, Snail control - moving at a rapid pace. Michelle Cousins, Electronic ear tags and virtual fencing. Deb Scammell & Jess Crittenden, Livestock Nutrition. Sam Trengove, Harvest Weed Seed Management. Greg Butler, Water Injection seeding system. Kenton Porker, TOS. Balco, Hay Market Update.
6/9/2018	Pulse Check Group	Wilmington	19	Third pulse check group meeting for 2018 (pre-canopy closure)
25/9/2018	UNFS Eastern Spring Crop Walk	Booleroo Centre	28	Visiting 3 trial sites—Matt McCallum's Micronutrient trial, Time of Sowing trial and Matt Nottle's Pasture trial
25/9/2018	UNFS Western Pulse Workshop	Wandearah	30	Implications of TOS and frost on lentils in lower rainfall areas (Michael Brougham, Elders); Implications of different levels on PAW on sowing decisions for lentils (Penny Roberts, SARDI); Herbicide tolerance and potential of new traits in breeding lines (Dili Mao, SARDI); Management of pulse to control Group C damage (Chris Davey, YPAG); Multi-species trial– rotational implications of different break crops (Sarah Day, SARDI).
30/10/2018	UNFS Ladies on the Land workshop—Introduction to Precision Agriculture	Booleroo Centre	15	Breaking down Precision Agriculture into easily understood and practical information. Ways to improve your business using PA including better data record keeping.
16/10/2018	Pulse Check Workshop	Wandearah	17	Fourth Pulse Check group meeting (pre-harvest) Andrew Kitto presented on harvester set-up and operation.
19/12/2018	UNFS Staff and Committee Christmas Dinner	Laura	40	End of year dinner to thank staff and the committee members for their contributions and to recognise departing employee Hannah Mikajlo and past committee member Ian Ellery

UNFS 2017/2018 Financial Year Reports

INCOME STATEMENT
FOR THE YEAR ENDED 30 JUNE 2018

	Note	2018 $	2017 $
INCOME			
Group Income			
Interest		1,759.60	1,491.51
Machinery Hire		3,141.73	2,583.45
Membership		5,181.59	4,477.04
Merchandise		27.27	240.91
Project Administration		58,046.51	5,951.00
Project Income		5,000.00	-
Field Days		5,020.00	7,731.81
Commercial Paddock		7,389.40	22,907.97
Sponsorship		18,181.82	1,500.00
Sundry Income		75,300.00	-
		179,047.92	46,883.69
OTHER INCOME			
Project Income			
Pasture Production Zoning		-	2,000.00
Lower Rainfall Bus Trip		-	167.27
Yield Prophet		6,200.00	11,250.00
GRDC Stubble Initiative		130,200.00	195,300.00
Controlled Traffic		-	3,083.45
Overdependence Agrochemicals		-	30,000.00
Ladies on the Land Workshop		800.00	2,700.00
Time of Sowing Trial		24,385.00	24,385.00
Production Wise		1,150.00	-
Pasture Options Demo		5,000.00	-
Weed Seed Burning		-	7,500.00
Micronutients in Upper North		23,500.00	-
Soil Acidity in Upper North		17,000.00	-
Pulse Check		13,086.00	-
Reallocation of Stubble Initiative Expenses		55,574.01	-
		276,895.01	276,385.72
		455,942.93	323,269.41

UNFS 2017/2018 Financial Year Reports cont.

INCOME STATEMENT
FOR THE YEAR ENDED 30 JUNE 2018

	Note	2018 $	2017 $
EXPENDITURE			
Group Expenses			
Administration		14,891.68	38,401.55
Audit Fees		2,450.00	5,700.00
Minor Equipment & Maintenance		1,647.62	1,434.82
Insurance		2,001.95	204.60
Merchandise Expense		-	2,067.45
Publications		2,389.54	912.50
Field Days		4,228.35	12,077.23
Commercial Paddock		2,814.48	940.35
Bank Fees		120.00	120.00
Depreciation		6,052.00	1,274.00
Total Wage Expense		3,694.44	-
		40,290.06	63,132.50
Project Costs			
GRDC Stubble Initiative		390,509.25	63,708.75
Yield Prophet		10,569.40	12,160.85
Pasture Production Zoning		-	1,000.00
Nitrous Oxide		-	951.00
Controlled Traffic		-	819.47
Overdependence Agrochemicals		1,628.15	37,421.85
Post Stubble Demo		3,497.80	5,280.00
Ladies on the Land		817.89	7,756.54
Time of Sowing Trial		19,333.01	10,766.13
Production Wise		785.32	116.00
Pasture Options Demo		1,356.27	408.28
Weed Seed Burning		5,922.11	1,577.89
Micronutrients in Upper North		11,475.24	-
Soil Acidity in Upper North		17,000.00	-
Pulse Check		4,524.65	-
		467,419.09	141,966.76
		507,709.15	205,099.26
(Loss) Profit before income tax		(51,766.22)	118,170.15
(Loss) Profit for the year		(51,766.22)	118,170.15
Retained earnings at the beginning of the financial year		312,620.67	194,450.52
Retained earnings at the end of the financial year		260,854.45	312,620.67

The accompanying notes form part of these financial statements.

UPPER NORTH FARMING SYSTEMS

BALANCE SHEET
AS AT 30 JUNE 2018

	Note	2018 $	2017 $
ASSETS			
CURRENT ASSETS			
Cash and cash equivalents	3	235,377.17	280,771.89
Trade and other receivables	4	9,679.39	4,356.03
TOTAL CURRENT ASSETS		245,056.56	285,127.92
NON-CURRENT ASSETS			
Property, plant and equipment	5	22,554.46	29,706.46
TOTAL NON-CURRENT ASSETS		22,554.46	29,706.46
TOTAL ASSETS		267,611.02	314,834.38
LIABILITIES			
CURRENT LIABILITIES			
Trade and Other Payables	6	6,756.57	2,213.71
TOTAL CURRENT LIABILITIES		6,756.57	2,213.71
TOTAL LIABILITIES		6,756.57	2,213.71
NET ASSETS		260,854.45	312,620.67
MEMBERS' FUNDS			
Retained earnings	7	260,854.45	312,620.67
TOTAL MEMBERS' FUNDS		260,854.45	312,620.67

NOTES TO THE FINANCIAL STATEMENTS
FOR THE YEAR ENDED 30 JUNE 2018

		2018 $	2017 $
3	**Cash and Cash Equivalents**		
	Freedom Bank Account 92540	26,965.69	14,120.41
	Business Bank Account 93340	208,411.48	266,651.48
		235,377.17	280,771.89
4	**Trade and Other Receivables**		
	GST Account	9,679.39	4,356.03
		9,679.39	4,356.03
5	**Property, Plant and Equipment**		
	Plant & Equipment - at Cost	31,232.46	31,232.46
	Less Prov'n for Depreciation	(8,678.00)	(1,526.00)
		22,554.46	29,706.46
	Total Plant and Equipment	22,554.46	29,706.46
	Total Property, Plant and Equipment	22,554.46	29,706.46
6	**Accounts Payable and Other Payables**		
	Current		
	PAYG Withheld	4,722.00	1,439.00
	Superannuation Liability	1,989.12	774.71
	Membership Paid in Advance	45.45	-
		6,756.57	2,213.71
7	**Retained Earnings**		
	Retained earnings at the beginning of the financial year	312,620.67	194,450.52
	(Net loss) Net profit attributable to the association	(51,766.22)	118,170.15
	Retained earnings at the end of the financial year	260,854.45	312,620.67

INDEPENDENT AUDITOR'S REPORT
TO THE MEMBERS OF UPPER NORTH FARMING SYSTEMS

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 2018, and the income and expenditure statement for the year then ended, and notes to the financial stataments 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 2018 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

I draw attention to note 1 to the financial report, which describes the basis of accounting. The financial report is prepared to assist the association in . As a result, the financial report may not be suitable for another purpose. My report is intended solely for the association and should not be distributed to or used by parties other than the association. My opinion is not modified in respect to this matter.

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.

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 23rd day of August 2018

Unaudited 2018-2019 Financial Statements

Upper North farming Systems

Profit and Loss Statement

1st July 2018 - 30th June 2019

INCOME		
Events	$	1,000.00
Interest	$	1,173.69
Machinery Hire_Vehicle Use	$	3,072.30
Membership	$	5,022.48
Merchandise	$	112.27
Project Administration	$	14,077.90
Project Income	$	153,156.26
Sale of Capital Items	$	14,545.45
Sponsorship	$	10,861.52
TOTAL INCOME	**$**	**203,021.87**
EXPENSES		
Administration	$	38,896.42
Audit Fees	$	2,750.00
Bank Fees	$	120.00
Event Expenses		
Event Catering	$	1,139.77
Event Expense	$	1,345.09
Field Day Expenses	$	1,909.27
Presenter	$	1,120.00
TOTAL Event Expenses	**$**	**5,514.13**
Hub Expenses	$	101.75
Insurance	$	2,759.95
Minor Asset Purchase & Repairs	$	908.17
Project Expenses		
Communications	$	500.00
Consultants	$	1,450.00
Project Management	$	4,565.00
Travel	$	4,468.80
Other Project Expenses	$	17,862.23
TOTAL Project Expenses	**$**	**28,846.03**
Publications	$	3,686.64
Wages		
Computer_Data Allowance	$	380.00
Superannuation	$	2,721.94
Wages Project Officer	$	31,398.30
Other Wages	$	120.00
TOTAL Wages	**$**	**34,620.24**
TOTAL EXPENSES	$	118,203.33
OVERALL TOTAL	**$**	**84,818.54**

The unaudited financial information set forth above is preliminary and subject to adjustments and modifications. Adjustments and modifications to the financial statements may be identified during the course of the audit work, which could result in significant differences from this preliminary unaudited financial information.

Upper North Farming Systems																	
Cashflow by Tag 1/7/18 to 30/06/19																	
This information is preliminary and subject to adjustments and modifications identified during the course of the audit work, which could result in significant differences from this preliminary unaudited financial information.																	
Category Description	101 Group Managment	103 Field Days & Tours	104 Commercial Paddock	209 Yield Prophet	211 Stubble Initiative	219 Ladies on the Land Workshops	220 Time of Sowing Trial	223 Pasture Options Demo	224 Micronutrients	226 Pulse Check	227 Cover Crop	228 Barley Grass Trial	229 Dryland Legumes	231 Weather Station Network	232 Barley TOS	233 Fodder Crop Trials	OVERALL TOTAL
INFLOWS																	
Interest	1174																1,174
Events		1,000															1,000
Machinery Hire_Vehicle Use	3072																3,072
Membership	5022																5,022
Merchandise	112																112
Project Administration	14078																14,078
Project Income		1,000	4,776	150	65,100	2,700	25,294		30,600	18,537	5,000						153,156
Sale of Capital Items	14545																14,545
Sponsorship	9962	900															10,862
Sundry Income																	-
TOTAL INFLOWS	47966	2,900	4,776	150	65,100	2,700	25,294	-	30,600	18,537	5,000	-	-	-	-	-	203,022
																	-
OUTFLOWS																	-
Administration	22731	3,213		5,010		-	2,529		3,060	1,854	500						38,897
Audit Fees	2750																2,750
Bank Fees	120																120
Event Expenses																	-
Event Catering		769				370											1,140
Event Expense		515				830											1,345
Field Day Expenses		909					500		500								1,909
Presenter						1,120											1,120
Hub Expenses		102															102
Insurance	2760																2,760
Minor Equipment & Maintenance	908																908
Project Expenses																	-
Communications										500							500
Consultants									700	750							1,450
Project Management						85	255	43	128	85	850	213	255		2,000	653	4,565
Travel	916	135					2,017	275	687	112	327						4,469
Other Project Expenses	750		1,419				383	1,455	7,132	5,123	850			750			17,862
Publications	1687						1,000		500	500							3,687
Wages																	-
Computer_Data Allowance	350									30							380
Superannuation	2722																2,722
Wages Administration Officer																	-
Wages Project Officer	17014	1,501				7	8,780	551	2,958	707							31,518
TOTAL OUTFLOWS	52708	7,144	1,419	5,010	-	2,413	15,463	2,324	15,665	9,661	2,527	213	255	750	2,000	653	118,203
																	-
OVERALL TOTAL	-4742	-4244	3357	-4860	65100	287	9830	-2324	14935	8876	2473	-213	-255	-750	-2000	-653	84,818
																	-
OPENING BALANCE as at 1/7/18	236,165	19,619	21,044	4,860	- 65,100	1,526	18,671	3,235	12,025	8,561	-						260,605
MOVEMENT	- 4,742	- 4,244	3,357	- 4,860	65,100	287	9,830	- 2,324	14,935	8,876	2,473	- 213	- 255	- 750	- 2,000	- 653	84,818
CLOSING BALANCE as at 31/05/19	**231,423**	**15,375**	**24,401**	**0**	**0**	**1,813**	**28,501**	**912**	**26,960**	**17,437**	**2,473**	**-213**	**-255**	**-750**	**-2,000**	**-653**	345,424

Wheat Time of Sowing Trial at Booleroo Centre, 2018: Frost and Heat Effects on Crop Development and Yield

Author: Jana Dixon, Rural Directions Pty Ltd
Funded By: South Australian Grains Industry Trust
Project Title: Upper North Time of Sowing and Yield Loss from Frost/Heat Stress
Project Duration: 2016 – 2018
Project Delivery Organisations: Upper North Farming Systems (UNFS)
Trial Location: *"Jamie's Block", Mount View Road Booleroo Centre.*
Trial Manager: Hannah Mikajlo

Key Messages

- The highest average yield for the trial was achieved by Scepter and Trojan when sown in early May.
- Yield penalties for main season spring wheats (Scepter, Trojan and Cutlass) were experienced when sowing was delayed from May into June.
- The true winter wheat variety, Longsword, performed best when sown in mid-April.
- All plots were affected by frost - more significantly when anthesis occurred prior to the optimal flowering window of early September.
- High grain protein and quality was achieved by all variety x time of sowing (TOS) combinations, (excluding Hatchet at TOS1, due to frost damage).

Background

The interaction between time of sowing and variety selection in wheat relates directly to flowering time and, in turn, influences grain yield and quality in any given season. Whilst the optimal flowering period for wheat varies with seasonal conditions, it is generally defined as the period prior to the onset of significant heat and moisture stress, and after the period of highest frost risk. In the Upper North region of South Australia, optimal flowering conditions occur from early to mid-September.

By understanding the maturity characteristics and development requirements of the various wheat varieties available, sowing time can be manipulated to achieve anthesis in the optimal flowering period. This can then allow for an extended sowing window to achieve a timelier seeding operation, and the opportunity to take advantage of early breaking rains and stored soil moisture.

This is the final year of the South Australian Grains Industry Trust (SAGIT) funded UNFS Time of Sowing Trial. The project commenced in 2016 and ran for three years. Each year has provided a unique set of seasonal conditions to compare the interaction of wheat variety x time of sowing in any given season.

Methodology

This year the trial was located at the UNFS TOS trial site north east of Booleroo Centre. The trial was arranged in a split plot design, on a paddock with uniform red clay loam soil. Three different times of sowing, and five different wheat varieties were replicated four times each, to give a total of 60 plots. The five commercial wheat varieties included in this trial were; Trojan, Scepter, Cutlass, Hatchet CL Plus and Longsword, as summarised in **Table 1** below. The times of sowing were; mid-April (16/4/18 – TOS 1), May (10/5/18 – TOS 2) and mid-June (15/6/19 – TOS 3).

The site was on a field pea stubble from 2017 and surrounded by buffer zones sown to Scepter wheat at

TOS 1. Prior to sowing, the site was treated with 800mL of Gramoxone® and 118g/ha of Sakura®. All plots were sown with a primary sales plot seeder on loan to UNFS, at a seeding rate of 70kg/ha, along with 26.4 units of nitrogen and 14 units of phosphorus, (70kg/ha DAP and 30kg/ha urea).

Following the significant dry period from January to April 2018, there was very limited soil moisture for the plots to be established on. In the two days prior to TOS1, 3mm fell on the site. Once TOS1 plots were sown, 9mm of simulated rainfall was applied, using the watering truck, to germinate the plots. The TOS2 plots were also sown into marginally dry conditions on 10 May, and the TOS3 plots were sown after 24mm of rain in early June.

The site received 80kg/ha of urea on 18 July, and was sprayed for broadleaf weeds with 50mL/ha of Lontrel® and 700mL/ha of Amicide Advance® 700 on 26 July.

During the growing season crop canopy temperature was measured with a temperature sensor at canopy height, providing minimum and maximum daily temperatures (see **Figure 5**). The trial was monitored for visual frost damage of the wheat heads. These observations were recorded as the percentage of total heads with visual frost damage, (**see Figure 6**).

The plots were harvested on 10 December by SARDI, with yield data from the field recorded. Grain quality analysis was completed by Viterra at the Gladstone silos, in accordance with commercial delivery standards.

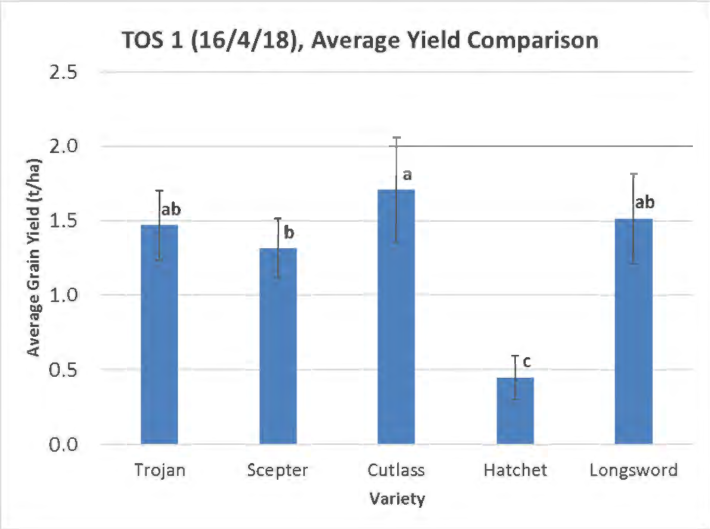
Grain yield and protein data was analysed for statistical significance using Analysis of Variance (ANOVA) at the 5% significance level.

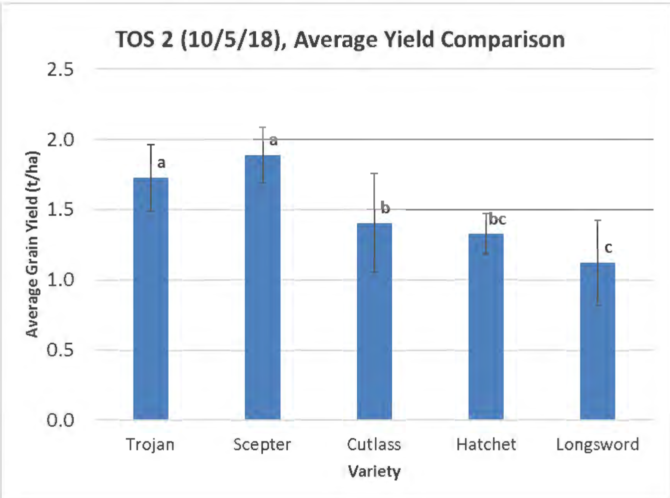
Table 1: Summary of the commercial wheat varieties in the 2018 UNFS Time of Sowing Trial at Booleroo Centre.

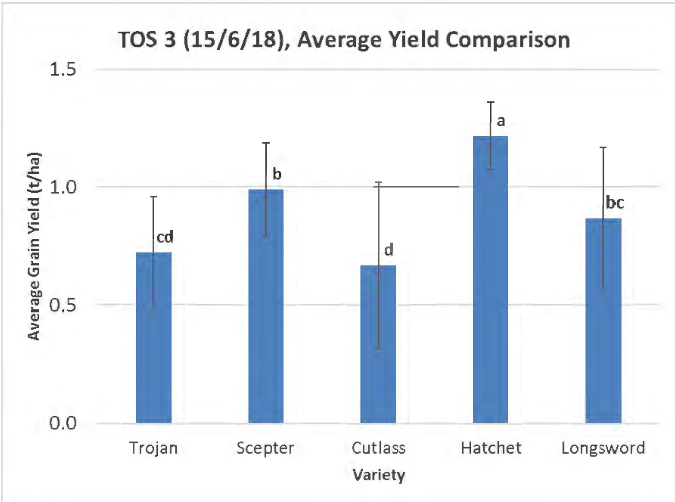
Variety	**Maturity**	**Comments**
Trojan	Mid-fast maturing spring wheat. Weak vernalisation, moderate photoperiod controls	Relatively high yielding. Unique photoperiod gene allows for earlier sowing, whilst still flowering in optimal conditions. APW quality.
Scepter	Fast maturing spring wheat. Moderate vernalisation, weak photoperiod controls.	The industry benchmark for main season wheat, replacing Mace in 2015. AH quality.
Cutlass	Mid-to-late maturing spring wheat. Weak vernalisation, strong photoperiod controls.	Slow maturing spring wheat, with good adaption in SA. Similar maturity to Yitpi. Early sowing opportunities, generally not before April 20. APW quality.
Hatchet CL Plus	Very-fast maturing spring wheat. Very weak vernalisation and photoperiod controls.	Clearfield tolerant variety. Developed from Axe, with earlier maturity. AH quality.
Longsword	Fast-maturing winter wheat. Vernalisation requirement.	Winter wheat requiring a cold period (vernalisation), derived from Mace. Early sowing and grazing opportunities. Feed quality.

Results and Discussion

Yield results from the 2018 trial are shown for each time of sowing in **Figures 1-3**, as well as in **Table 2** below. ANOVA and Least Significant Difference (LSD) analysis indicates a statistically significant difference in yield between the wheat varieties at each time of sowing.







Figures 1-3: Yield comparisons between the five different wheat varieties, for each time of sowing. Error bars showing minimum and maximum replicate values.

ANOVA Analysis (5% significance): TOS1 P<0.001, TOS2 P=0.0015, TOS3 P<0.001.

The nature of the 2018 season provided clear differences in yield between varieties at each sowing window. At the early sowing window (TOS1) the mid-late maturing variety Cutlass, outperformed the industry benchmark spring wheat, Scepter (statistically significant). Cutlass is a longer season variety and can achieve flowering closer to optimal conditions when sown in April, whereas Scepter lacks photoperiod controls and will flower too soon when sown early. There was no significant difference in yield between Scepter, Trojan and Longsword at TOS1, or Cutlass, Trojan and Longsword, (see Figure 1).

In the optimal sowing period for main season spring wheat in the Upper North area (early May – TOS2), Trojan and Scepter out-yielded all other varieties, with statistical significance. This demonstrates that these high-yielding main season spring varieties still hold the yield benchmark in this area. At TOS2, the strong performance of Scepter and Trojan was then followed by Cutlass, Hatchet and Longsword, (see Figure 2).

Whilst all varieties outperformed Hatchet at TOS1, this was the opposite scenario at TOS3, with Hatchet being the only variety to exceed an average yield of 1t/ha from mid-June sowing. Weak photoperiod and vernalisation controls allow for fast development, seeing Hatchet achieve near optimal flowering conditions, despite the late sowing. Together Scepter and Longsword were the next highest yielding, followed by Trojan and Cutlass.

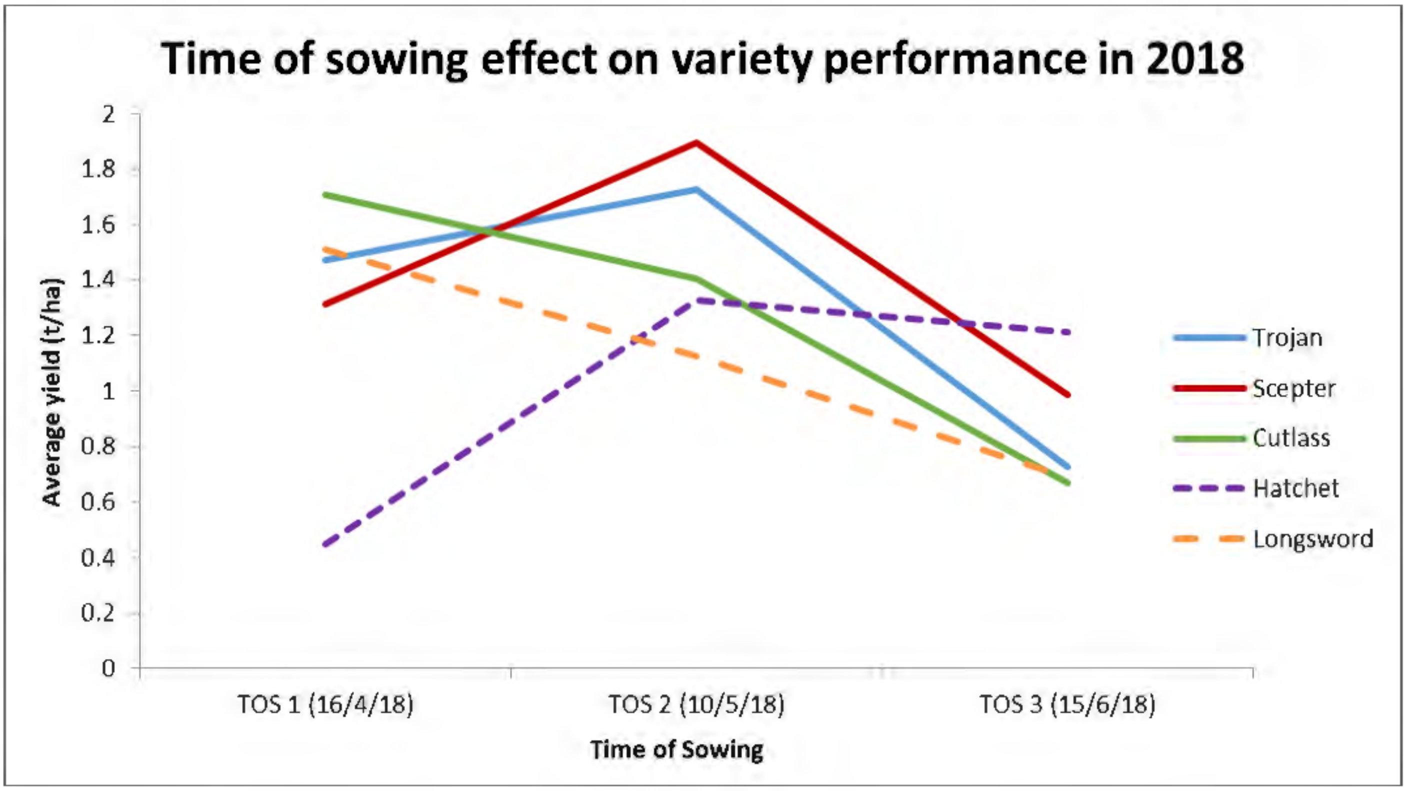


Figure 4: Yield comparison, in t/ha, between the five wheat varieties, at each time of sowing. ANOVA analysis (5% significance): Trojan $P<0.001$, Scepter $P<0.001$, Cutlass $P<0.001$, Hatchet $P<0.001$, Longsword $P=0.017$.

For each of the five varieties, there was a statistically significant difference in grain yield from variation in time of sowing in 2018.

Trojan performed best when sown in mid-April and early May, with yields being statistically similar between TOS1 and TOS2. A level of photoperiod control allows Trojan to show versatility in sowing time and performance, and for a spring wheat, can achieve closer to optimal flowering conditions when sown early. However, as expected, delaying sowing into June resulted in a 1t/ha yield penalty for Trojan. **Scepter** produced the highest average yield for the trial when sown at the optimal time in early May (TOS2). This yield of 1.88t/ha was statistically greater than the yields of Scepter at both TOS1 and TOS3. There was no significant difference in the yield performance of **Cutlass** at TOS1 and TOS2, however, as expected for a longer season variety, both early times of sowing significantly outperformed the mid-June sowing window. **Hatchet** did not show a statistically significant yield penalty when sowing was delayed from mid-May into June. Being a short season variety with minimal photoperiod requirements, Hatchet moved into reproductive stage quickly in 2018, with early sown plots showing up significant levels of frost damage, (see Figure 6), hence resulting in a yield penalty from April sowing. In contrast, **Longsword** performed best when sown in April, due to the longer season nature of a winter wheat, with vernalisation requirements to be met. The average grain yield at TOS1, 1.5t/ha, was significantly greater than yields at TOS2 and TOS3, with a linear yield decline as a response to delaying sowing, (see **Figure 4)**.

Grain quality results from the 2018 trial are shown in **Table 2** below. The data was analysed with ANOVA and LSD tests. The dry seasonal conditions saw protein remain high across all combinations. The effects of frost and heat stress, at grain fill, resulted in increased protein concentration in the grain, as seen particularly at TOS3. At the June sowing window there was no significant difference (P=0.536) between protein % for all varieties, with a tight finish increasing protein concentration in the grain. Screening percentages were all below 5% and did not impact on the classified grade. A low test weight was only an issue for Hatchet at TOS1, seeing a downgrade to AUH2. This is due to the significantly high number of frost damaged heads recorded during the season, (see **Figure 6**).

Table 2: Grain quality characteristics and grade for each of the 5 wheat varieties across three times of sowing.

	Yield (t/ha)		Protein (%)		Test weight (kg/hL)		Screenings (%)		Grade	
									Classified	Actual*
TOS1 (16/4/18)										
Cutlass	1.710	*a*	12.40	c	81.30	*a*	0.50	*c*	H2	APW1
Longsword	1.510	*ab*	13.20	bc	79.40	*b*	0.20	*d*	H1	FED1
Trojan	1.470	*ab*	12.70	c	81.00	*a*	0.70	*b*	H2	APW1
Scepter	1.310	*b*	13.90	b	79.50	*b*	0.90	*ab*	H1	H1
Hatchet	0.450	*c*	17.40	a	75.70	*c*	0.80	*b*	AUH2	AUH2
P-value	*<0.001*		*<0.001*		*<0.001*		*<0.001*			
LSD (P=0.005)	*0.370*		*1.122*		*1.119*		*0.184*			
TOS2 (10/5/18)										
Scepter	1.890	*a*	11.60	*c*	81.40	*a*	0.60	*a*	H2	H1
Trojan	1.720	*a*	12.40	*c*	81.10	*a*	0.50	*ab*	H2	APW1
Cutlass	1.400	*b*	13.60	*b*	81.00	*a*	0.30	*c*	H1	APW1
Hatchet	1.320	*b*	15.40	*a*	79.80	*b*	0.40	*bc*	H1	H1
Longsword	1.120	*c*	15.80	*a*	77.70	*c*	0.40	*bc*	H1	FED1
P-value	0.00147		<0.001		<0.001		*0.023*			
LSD (P=0.005)	*0.278*		*0.904*		*0.837*		*0.140*			
TOS3 (15/6/18)										
Hatchet	1.220	*a*	14.70	*a*	79.80	*a*	0.80	*c*	H1	H1
Scepter	0.990	*b*	14.40	*a*	79.90	*a*	0.80	*c*	H1	H1
Longsword	0.870	*b*	15.20	*a*	78.10	*b*	1.40	*b*	H1	FED1
Trojan	0.720	*c*	14.30	*a*	79.30	*a*	2.00	*a*	H1	APW1
Cutlass	0.670	*d*	15.20	*a*	79.20	*a*	1.70	*ab*	H1	APW1
P-value	*<0.001*		*0.536*		*0.025*		*0.003*			
LSD (P=0.005)	*0.167*		*1.146*		*0.915*		*0.531*			

NB. Grades are classified with Viterra Receival Standards 2018/19.
* Actual grade is the maximum deliverable grade based on variety grade certification (see Table 1).

Seasonal Conditions

For Booleroo Centre and much of the surrounding district, the 2018 season will be remembered for extremely dry and frosty conditions. Rainfall was significantly lower than average, with annual rainfall at Booleroo Centre being less than the lowest 5th percentile of years (BOM), see **Table 3** below. Growing season rainfall (April – October) was 148.5mm, well below an average GSR of 277.3mm. Marginal stored soil moisture was available at seeding time, particularly after a significantly dry period from Jan – April 2018.

The dry conditions were paired with a high frequency of frost events during both vegetative and reproductive stages of wheat growth. The canopy height temperature sensor showed 12 frost events in May, 18 in June, 19 in July, 14 in August and 9 in September, before the sensor failed on 12 September, (see **Figure 5**). Further temperature measurements are estimated from the canopy height temperature sensor at the UNFS weather station approximately 6km away from the trial site. From 12 September to the end of October, the canopy height temperature sensor fell below 1°C on approximately 5 occasions.

The impact of frost during the reproductive phase was monitored by assessing the number of heads with visual frost damage, and was expressed as percentage of total heads damaged, (see **Figure 6**). The severity of frost damage is influenced by both maturity and sowing time of the wheat varieties. If the combinations of maturity x TOS align, so that flowering is in a peak frost period (i.e. August), a greater percentage of frost damaged heads will be realised. This was the case of Hatchet sown in mid-April (TOS1), with 17% of heads showing visual damage, and 15% showing significant damage (>1/3 of head damaged).

Whilst the canopy height temperature sensor was faulty for much of the flowering period, once it began working on 12 October, 20 days exceeding 30°C in the crop canopy were recorded until the end of November. During the period when the temperature sensor failed (12 September – 12 October), 12 days exceeded 30°C at canopy height at the nearby UNFS weather station.

Table 3: Booleroo Centre rainfall data for 2018, and average for all years (mean), in mm.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2018	7.6	3.0	2.0	12.8	25.5	35.4	13.4	37.6	10.2	13.6	37.0	16.8	214.9
Average	22.0	21.6	17.5	27.1	39.1	46.8	42.0	45.3	41.1	35.9	28.5	24.7	392.2

Source: Bureau of Meteorology

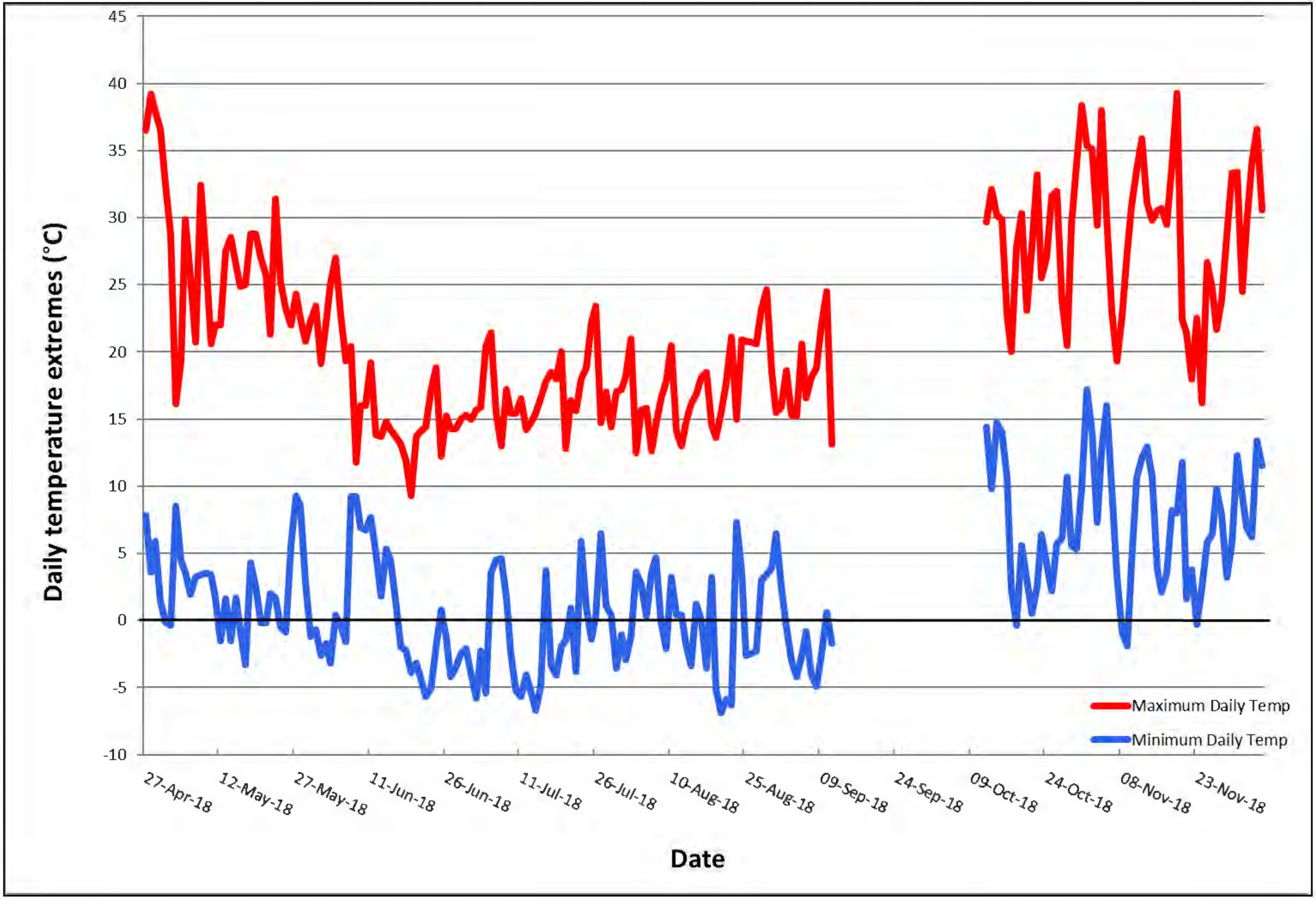


Figure 5: Daily minimum and maximum temperature recordings from the canopy-height temperature sensor located at the trial site in 2018.

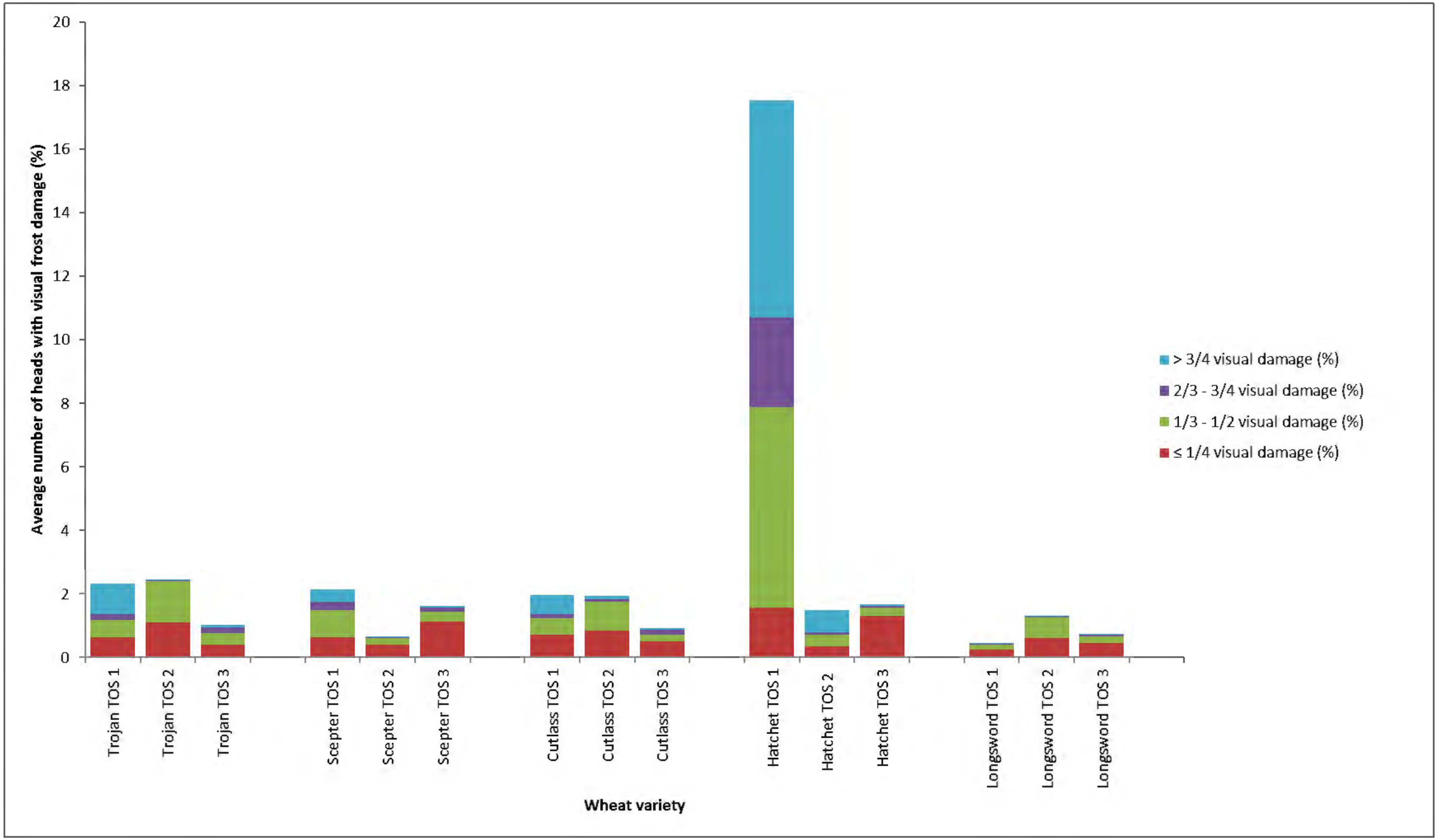


Figure 6: Average number of wheat heads with any visual frost damage, represented as a percentage (%) of total heads, for each wheat variety and time of sowing in 2018.

Summary

The 2018 season was challenging, with a dry summer and autumn period making establishment difficult, as well below average growing season rainfall resulting in low yielding, but high quality grain production. Frost had a large impact during the growing season, with all varieties and TOS combinations showing visible damage. Early maturing varieties such as Hatchet, had significant frost damage when sown in mid-April. The highest average yield came from Scepter sown in its optimal window in early May, which was statistically no different to that of Trojan sown in early May. This indicates the industry benchmark for this area continues to be held by Scepter, sown in its optimal window. Cutlass was the only variety to out-perform the yield of Scepter, when sown in mid-April (TOS 1), with statistical significance. The true winter variety, Longsword also performed best when sown in mid-April, as expected for a winter variety requiring vernalisation or a chilling period. The fast spring variety, Hatchet, was the highest yielding variety for mid-June sowing, whereas delaying sowing into June resulted in a yield penalty for the other longer season varieties.

The yields achieved by the various wheat varieties, sown earlier or later than the normal period in the Upper North, still did not outperform Scepter sown in early May in the 2018 season. This indicates that whilst there are opportunities to utilise the different phenology characteristic of such varieties, careful consideration into the appropriate sowing window is important to maximise yield potential. Consider the risk versus reward factors of including another wheat variety into a cropping rotation. Such considerations include; extending the sowing program, making use of early rainfall and soil moisture, rotation or disease benefits, grazing or hay potential, grain quality benefits/disadvantages, the capacity to hold extra seed on-farm, and adding further complication into a rotation should all be considered when selecting varieties.

Acknowledgements

- The South Australian Grains Industry trust for its funding and support in implementing the trial.
- SARDI for use of the plot seeder and for harvesting the trial.
- Todd and Brooke Orrock for their provision of the trial site and significant efforts to implement the trial and manage the site throughout the season.
- Joe Koch and the UNFS Operations Committee for assisting with the trial seeding and extension events.
- Hannah Mikajlo for her work as the trial project officer.

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Wheat Time of Sowing Trial at Booleroo Centre, 2016, 2017 and 2018 Combined Results: Frost and Heat Effects on Crop Development and Yield

Author: Jana Dixon, Rural Directions Pty Ltd
Funded By: South Australian Grains Industry Trust
Project Title: Upper North Time of Sowing and Yield Loss from Frost/Heat Stress
Project Duration: 2016 – 2018
Project Delivery Organisations: Upper North Farming Systems (UNFS)

Key Messages

- It is expected that Scepter sown in its optimal window (early May), is still the benchmark combination for wheat yield in the Upper North area. This is despite only being replicated in 2018.
- Longsword, the newly released winter wheat variety, was unable to out-yield Cutlass (late maturing spring wheat), at any time of sowing across the three years.
- The best sowing time for each variety is when flowering coincides with optimal conditions in early to mid-September in the Upper North district. This is when frost risk has decreased, and moisture and heat stress is minimal, however it will vary significantly in any given year.
- In seasons with above average growing season rainfall and optimal soil moisture during spring, high yields can be achieved across a wide sowing window, due to optimal flowering and extended grain fill conditions. This was realised in 2016, with similar yields across all sowing times for each variety.

Background

The Upper North region of South Australia is generally characterised by medium to low rainfall and heavy clay/clay loam soil types. As a result, the onset of heat and moisture stress at flowering, along with medium to high frost risk during August, sees a narrow window of optimal flowering conditions for wheat. Main season spring wheat is generally sown in early May to achieve anthesis during optimal conditions in early to mid-September.

Delaying sowing from late-May and into June can also result in reduced yield potential and poor grain quality due to flowering and grain fill occurring in moisture and heat stressed conditions. Alternatively, early sowing opportunities generally cannot be utilised by sowing main season spring varieties prior to the first of May, due to significant frost risk experienced when flowering occurs in August. In the Upper North region, east of the Flinders Ranges, there has yet to be a suitable time of sowing (TOS) x variety combination proven to fit an early sowing window and match the yield of the current benchmark variety (previously Mace, now Scepter), sown in its optimal window.

The benefits of being able to sow wheat in April, and still achieve competitive yields have been realised in other cropping regions, such as NSW. Research by James Hunt has indicated that winter wheats which require a vernalisation 'chilling' period, or long-season spring wheat with photoperiod controls, can achieve similar yields to mid-fast spring varieties sown in May. The recent trends of declining autumn and spring rainfall, along with increasing farm sizes, has seen the need for a more flexible seeding operation whilst still be able to achieve optimal flowering conditions. Long season wheats established in April/early May can make the most of stored soil moisture, and also provide early weed competition by establishing in warm autumn conditions. Longer season wheats that can be established in April, are also being utilised in mixed farming systems as dual-purpose crops for grazing, without significant yield penalties.

This trial is aimed at comparing how different varieties with varying phenology (photoperiod and vernalisation controls) perform when sown at three different sowing windows. This three-year UNFS Time of Sowing Trial, funded by the South Australian Grains Industry Trust (SAGIT) was completed in 2016, 2017 and 2018. Each year has provided unique and variable growing season conditions to compare the interactions between variety and TOS in the Upper North region.

Refer to the 2016, 2017 and 2018 UNFS Annual Results Book for detailed reports on each season.

Methodology

The UNFS TOS trial site was located on the same property near Booleroo Centre for each of the three years. The trial site locations were selected on paddocks with uniform soil types and topography, and low weed populations. The sites were on red clay/clay loam soils, typical in the Upper North district.

Each year, five wheat varieties were compared at three different sowing times. The varieties represent a mix of early and late maturing varieties, with varying photoperiod and vernalisation controls, (see **Table 2)**. The sowing times represent an early sowing date for wheat in the Upper North district; in mid-April (TOS1), a standard sowing window in early May (TOS2), and a later sowing date in late May/mid-June (TOS3), see **Table 1** for sowing dates.

The trials were arranged in a split-plot design, with the three replications of each treatment in 2016, and four replications in 2017 and 2018. Each year the plots were sown with a primary sales plot seeder on loan to UNFS. In 2016 and 2018 a watering truck was used to irrigate the early sown plots to ensure timely establishment was achieved. Harvest was completed by SARDI each year, and samples were taken to Viterra for grain quality analysis in accordance to commercial delivery standards. Grain yield and protein data was analysed for statistical significance using Analysis of Variance (ANOVA) at the 5% significance level.

Each year various measurements were recorded throughout the growing season. Such as; establishment date, soil temperature at sowing, soil tests, growth stage, anthesis date and frost damage. See detailed results in the 2016, 2017 and 2018 UNFS Annual Results Book along with further methodology details.

Table 1: Summary of sowing dates for each season of the UNFS Time of Sowing Trial.

	TOS1	TOS2	TOS3
2016	15/4	5/5	24/5
2017	18/4	8/5	26/5
2018	16/4	10/5	15/6

Table 2: Summary of the commercial wheat varieties used in the UNFS Time of Sowing Trial at Booleroo Centre.

Variety	Maturity	Comments
Trojan	Mid-fast maturing spring wheat. Weak vernalisation, moderate photoperiod controls	Relatively high yielding. Unique photoperiod gene allows for earlier sowing, whilst still flowering in optimal conditions. APW quality.
Mace *2016, 2017*	Fast maturing spring wheat. Moderate vernalisation and weak photoperiod controls.	Main season benchmark wheat prior to the introduction of Scepter. AH quality.
Scepter *2018*	Fast maturing spring wheat. Moderate vernalisation, weak	The industry benchmark for main season wheat, replacing Mace in 2015.
Cutlass	Mid-to-late maturing spring wheat. Weak vernalisation, strong photoperiod controls.	Slower maturing spring wheat, with good adaption in SA. Similar maturity to Yitpi. Early sowing opportunities, generally not before April 20. APW quality.
Hatchet CL Plus	Very-fast maturing spring wheat. Very weak vernalisation and	Clearfield tolerant variety. Developed from Axe, with earlier maturity.
Longsword	Fast-maturing winter wheat. Vernalisation requirement.	Winter wheat requiring a cold period (vernalisation), derived from Mace. Early sowing and grazing opportunities.

Results and Discussion

Seasonal Conditions

Table 3: Booleroo Centre rainfall data for 2016, 2017 and 2018 (in mm). Green shading represents above average, red shading represents below average.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	GSR
2016	44.8	4.2	61.8	6.6	50.8	64.8	30.6	67.8	126.4	29.1	15.8	91.8	594.5	376.1
2017	55.4	11.6	2.6	68.2	27.8	10.8	15.6	32.8	4.8	16.4	39.6	63.4	349.0	176.4
2018	7.6	3.0	2.0	12.8	25.5	35.4	13.4	37.6	10.2	13.6	37.0	16.8	214.9	148.5
Average	22.0	21.6	17.5	27.1	39.1	46.8	42.0	45.3	41.1	35.9	28.5	24.7	392.2	277.3

Source: Bureau of Meteorology

This trial took place during three vastly different growing seasons. Growing season rainfall and stored soil moisture varied hugely each season, along with frost severity, and minimum and maximum daily temperatures.

In summary, **2016** was characterised by significantly above average annual rainfall, being a decile 10 rainfall year. Growing season rainfall was 100mm above average, with a particularly wet and cool August and September period, resulting in near optimal grain fill conditions. Whilst there was frost damage observed in a number of plots, no detailed measurements were recorded.

Significant spring and summer rainfall, and an above average April rainfall saw the **2017** season start strong, with successful establishment at each TOS. However, rainfall for the rest of the growing season, from May – Oct, was well below average, coupled with a significant number of frost events. The 2017 growing season was 100mm below average, and annual rainfall was slightly below average, with crops relying largely on stored soil moisture.

The calendar year of **2018** was on the opposite end of the scale to 2016, and was a Decile 1 rainfall year. Generally, stored soil moisture was minimal and the extremely dry start to the year, and late break in the season, saw difficulties in plant establishment. Rainfall continued to be significantly below average for the remainder of the growing season. Frost incidence was extremely high in the winter months, along with several frost events in September causing flowering frost damage.

The canopy height temperature sensor at the trial site recorded a complete record in 2017 only. In 2016 and 2018 the temperature sensor failed during the peak flowering window. In 2016 frost events are estimated from the nearest BOM temperature station at Yongala (frost event being <2°C at weather station height). In 2018, frost and heat events are more accurately estimated from the canopy height temperature sensor at the UNFS weather station.

In 2017, from 26 July to 10 October, the daily minimum canopy temperature fell below 1°C on 46 occasions. In 2016, during this same period, the BOM station at Yongala recorded 19 events when the minimum temperature fell below 2°C. In 2018, 26 frost events (<1°C at the UNFS canopy height senor) were recorded from the 26 July to 10 October period.

Heat stress during grain fill can be gauged by observing the number of days >30°C during the flowering window. In 2016 the temperature sensor recorded 10 days up to 10 October where crop canopy temperature exceeded 30°C. In 2017, the canopy temperature sensor at the UNFS weather station recorded the maximum daily temperature to exceed 30°C on six occasions in the September and October period, and on four occasions in 2018.

Grain quality

Refer to the 2016, 2017 and 2018 UNFS Annual Results book for the full breakdown of grain quality analysis each season. See Table 1 for the maximum quality classification for each of the varieties.

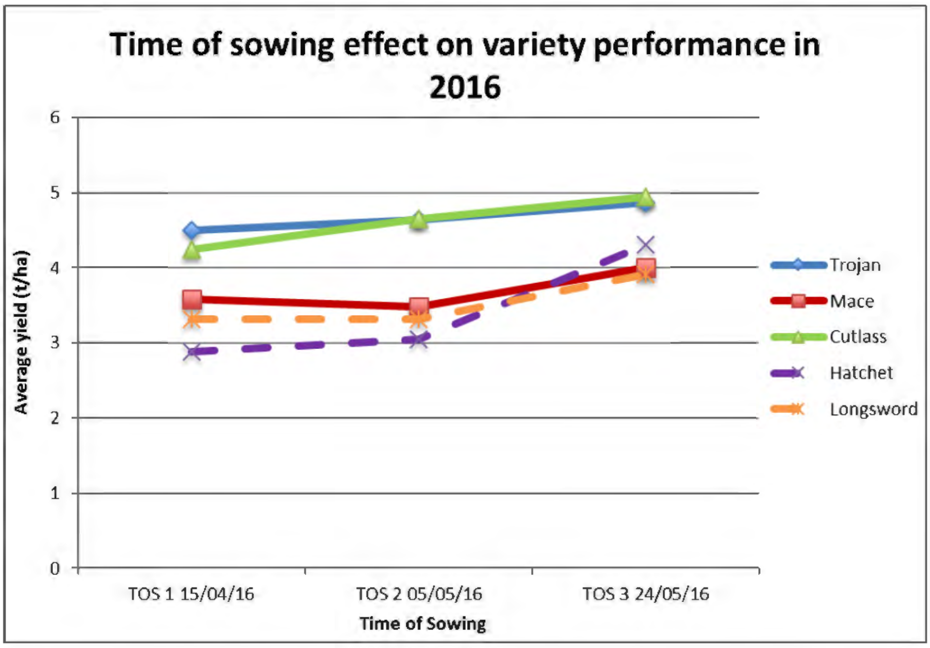
- In **2016** a yield dilution effect was realised, with protein decreasing as higher yields were achieved; all variety and TOS combinations achieved high test weights and low screenings.
- In the **2017** season, low test weights and high protein saw all combinations achieve AUH2 quality, (theoretically). Cutlass at TOS2 and TOS3 achieved APW1 due to a higher test weight.
- High test weights and high protein saw most combinations in **2018** potentially achieve H1 or H2 quality. Hatchet at TOS1 was downgraded to AUH2 due to frosted grain and a low test weight.

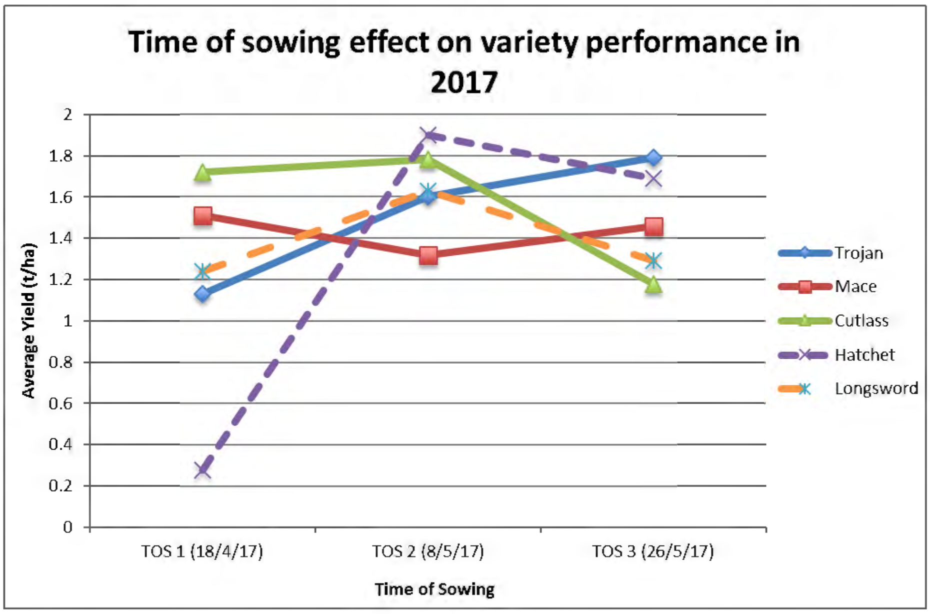
Yield Graphs

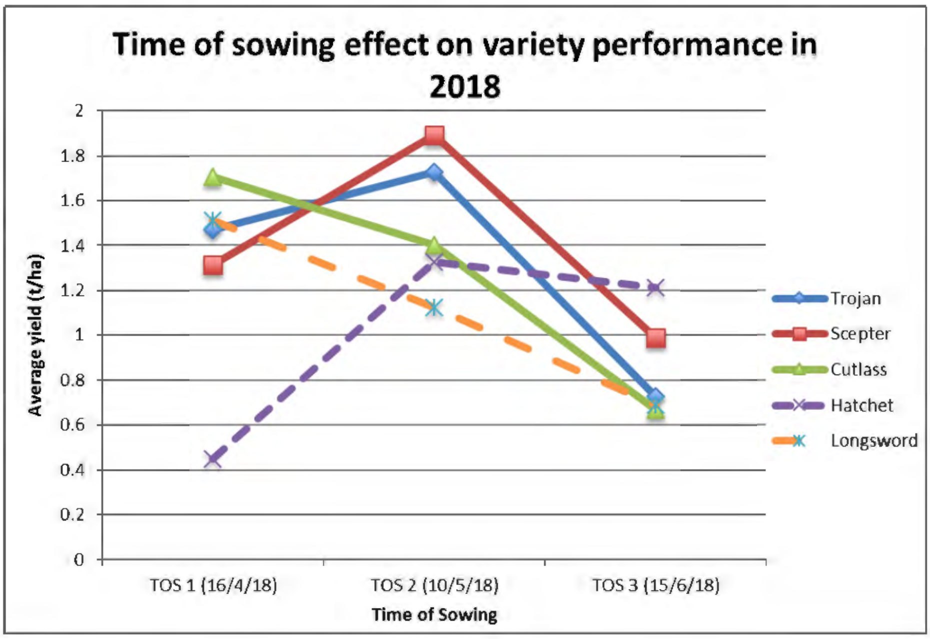
Figures 1-3: Yield comparison, in t/ha, of each of the five wheat varieties, across the three times of sowing in 2016, 2017 and 2018, respectively.

NB: TOS3 in 2018 was over a fortnight later (20days) than the sowing dates for TOS3 in 2016 and 2017 seasons.

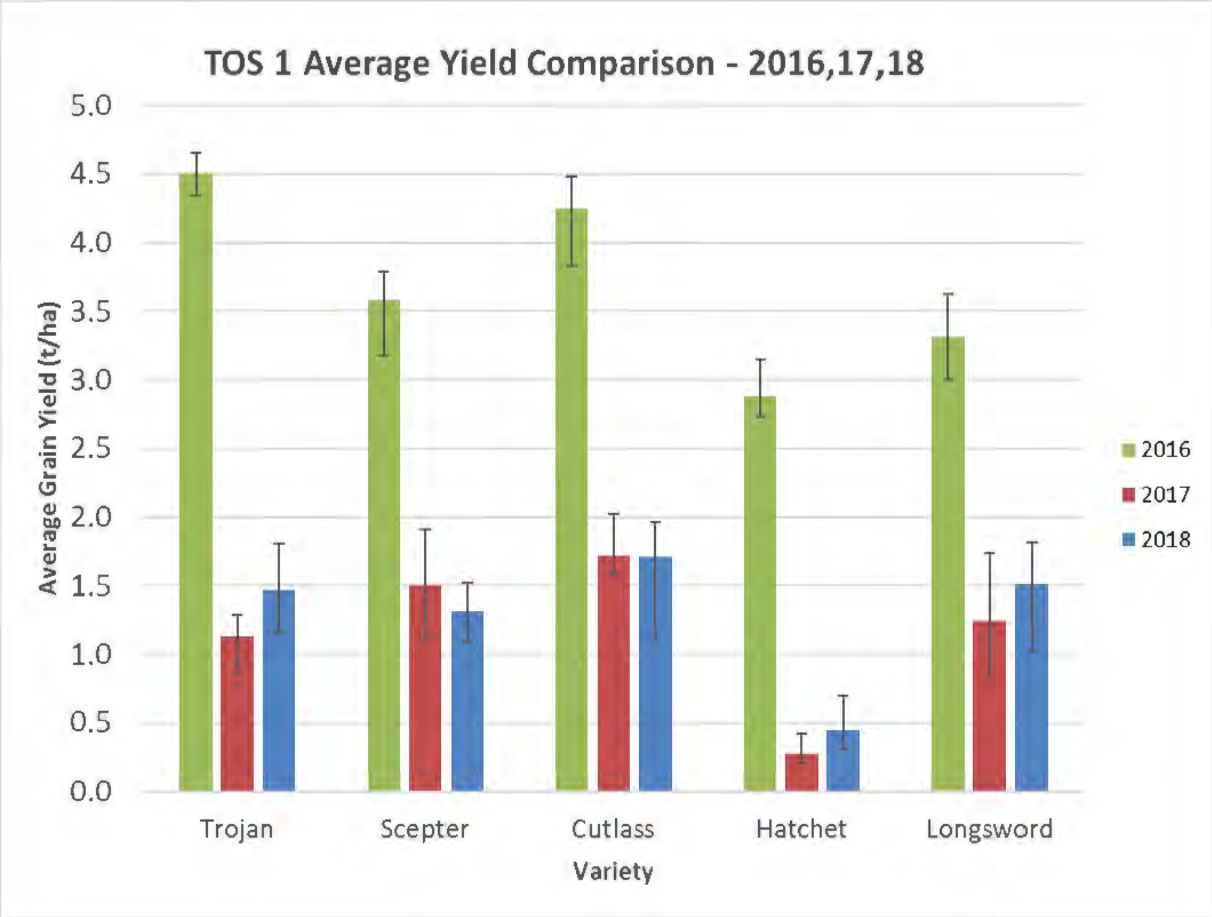
ANOVA analysis (5% significance)
2016: Trojan P=0.657, Mace P=2.34, Cutlass P=4.62, Hatchet P=11.888, Longsword P=0.116.
2017: Trojan P=0.057, Mace P=0.649, Cutlass P=0.048, Hatchet P<0.001, Longsword P=0.323.
2018: Trojan P<0.001, Scepter P<0.001, Cutlass P<0.001, Hatchet P<0.001, Longsword P=0.017.

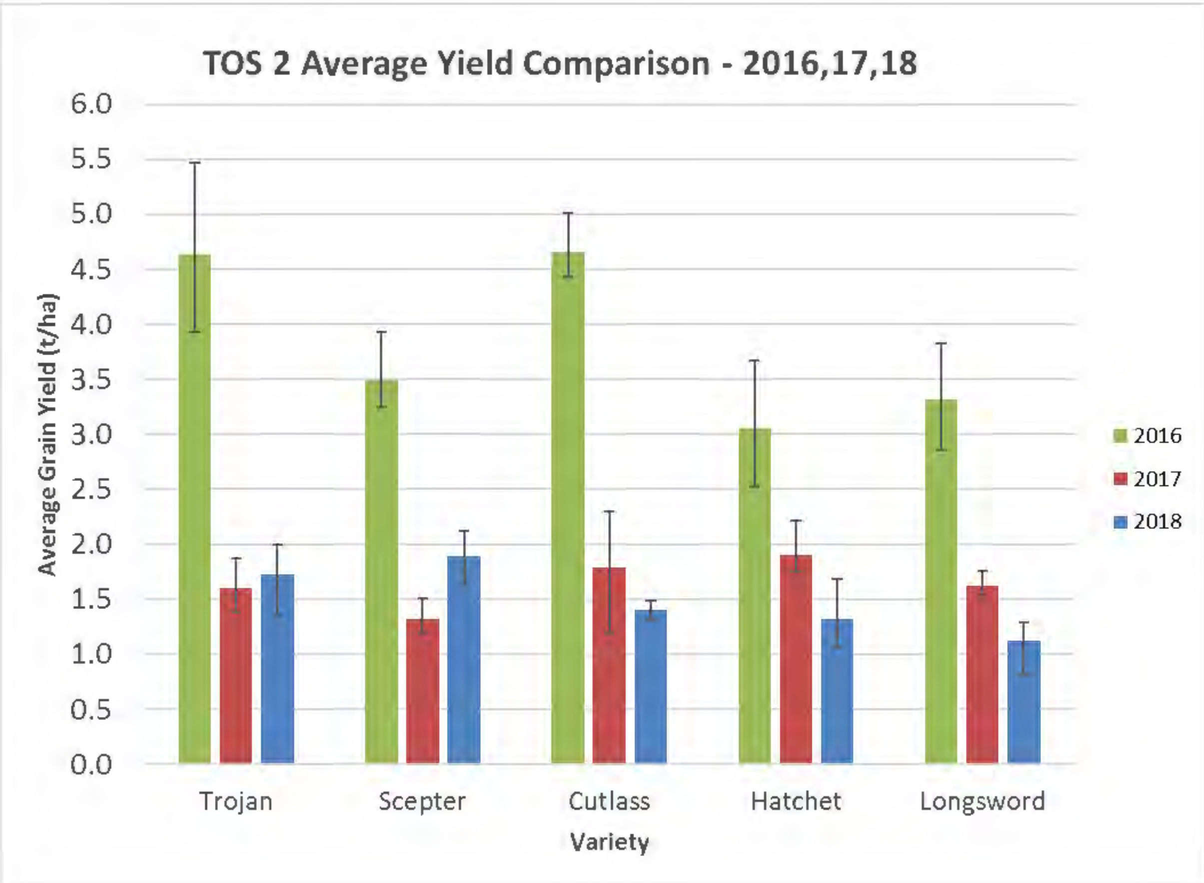


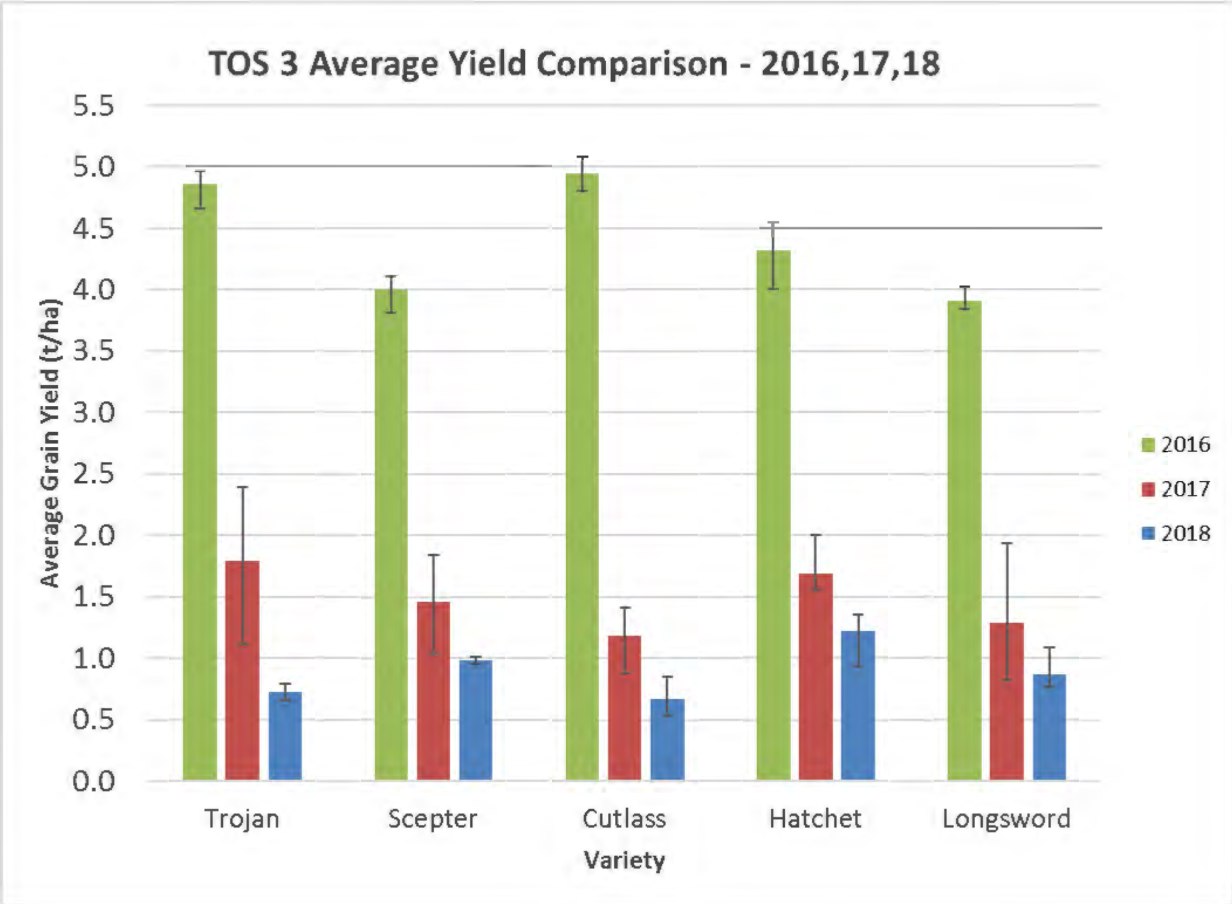




Figures 4-6: Yield Comparisons between the five different wheat varieties at each of the three times of sowing in 2016, 2017 and 2018 seasons. Error bars showing minimum and maximum values.







NB: TOS3 in 2018 was over a fortnight later (20days) than the sowing dates for TOS3 in 2016 and 2017 seasons. NB: 'Scepter' data shown in 2016 and 2017 is actually the Mace variety.

ANOVA analysis (5% significance)
TOS 1; 2016 P<0.003, 2017 P<0.001, 2018 P<0.001
TOS 2; 2016 P<0.001, 2017 P=0.058, 2018 P=0.0015
TOS 3; 2016 P<0.003, 2017 P=0.182, 2018 P<0.001.

What is the best Time Of Sowing for each variety?

Trojan was a high yielding variety at all sowing dates in 2016, although achieving ASW1 quality due to low protein. In 2017, Trojan took a yield penalty from sowing early in April, due to flowering coinciding with peak frost conditions in August. When sowing was delayed into mid-June, in 2018, Trojan took a yield penalty, like most other main season varieties. For flowering to occur in optimal conditions in early to mid-September, *the optimal sowing window for Trojan is in the early May period*.

In 2016 and 2017 **Mace** yielded the same across all sowing dates in the given season, (no significant difference). In 2017, the early sown Mace (18 April) experienced approximately double the head damage due to frost, compared to the late May sown plots. **Scepter** grown in 2018 performed best when sown in the optimal window on 10 May. The plots at TOS2 experienced the least amount of frost damage, by avoiding flowering during the heavy frost period in late August/early September, and also avoiding the significant frost event at the end of September. *The optimal sowing time for Scepter is in the early May period.*

Cutlass is the latest maturing spring wheat in the trial. In 2016, it was the highest yielding variety across all sowing dates, along with Trojan. A yield penalty was experienced in 2017 and 2018 when sowing was delayed until late May/mid-June. This is due to flowering in late September/early October and experiencing the onset of heat stress at grain fill. Although moderate frost damage was experienced from the two earlier sowing times in 2017 and 2018, the yield lost from frost didn't outweigh the increased yield potential achieved from early sowing a long season spring variety such at Cutlass. Furthermore, *Cutlass will likely perform best when sown approximately between TOS1 and TOS2, from mid-April to the first week in May* for flowering to occur in early to mid-September.

With **Hatchet** being a fast-maturing spring wheat, it is unsurprising that yield penalties were experienced from early sowing in 2017 and 2018. Both these years were particularly frosty, and significant frost damage throughout the growing season was experienced. Hatchet was the only variety to have a statistically significant yield difference between sowing times in 2016, with yield increasing from late May sowing. However, in 2016 Hatchet still did not outperform Trojan and Cutlass at TOS3. In 2018 Hatchet was the highest yielding variety at mid-June sowing, however it still did not out-yield Scepter/Trojan at TOS2. *In an average year, it is expected that Hatchet will perform best when sown in mid to late May.* It is not expected that Hatchet will outperform benchmark main season varieties (Scepter) sown in their optimal window.

Longsword is the only true winter wheat with a vernalisation requirement in the trial. In 2016 and 2017 there was no significant difference in yields across the three TOS. However, in 2018, by sowing Longsword in mid-April, a statistically higher yield was achieved when compared to May - June sowing. It is interesting to note that in 2017 and 2018 all Longsword plots, across the three TOS, recorded the lowest levels of frost damage when compared to the other four varieties. This indicates the stability of flowering across the sowing dates, ranging from mid-September to early October. Whilst there does seem to be an opportunity to utilise winter wheat phenology at an early sowing window, Longsword was still not able to out-yield the alternative long season spring variety, Cutlass at any TOS across the three years. *The trial in 2018 indicates that the best time to sow Longsword is in mid-April. This supports work done in the recent GRDC project; Management of Early sowing wheat 9175069, indicating the highest yields from winter wheat come from early to late April establishment.*

In this GRDC project, Longsword was the best performing winter wheat in 2018, at Booleroo Centre, and is the most suited variety for environments of <2.5t/ha. For winter wheats to be competitive in the Upper North area, they must be able to achieve similar, or greater yields than the industry benchmark, Scepter sown in early May. This may require further plant breeding effort and the continuation of trials, such as the UNFS TOS Trial, across several seasons, to make a valid comparison. Longsword is also only feed quality, which is another factor limiting the interest in such a variety. No Biomass assessments were made as part of this trial and as such its value as a grain and graze option is not explored in this report.

What is the best time to sow wheat in any given year?

This will depend on what variety x TOS combination will achieve flowering in the optimal window for the Upper North region. Optimal flowering conditions vary each season, particularly due to the inconsistent nature of frost events, during September and October, coinciding with anthesis. The onset of heat and moisture stress occurs generally from late September onwards. Hence the optimal window for wheat flowering in the Upper North area is from early to mid-September. Understanding the phenology and maturity characteristic of the commercial wheat varieties available will allow growers to achieve a high yield potential by achieving anthesis near optimal conditions.

What is the best variety x TOS combination?

Currently Scepter is the industry benchmark for wheat yield in the Upper North, along with many other districts across South Australia. The optimal sowing window in any given year is in early May. With Scepter only being introduced into the trial in 2018, this combination was only shown in one set of seasonal conditions. However, grower and industry experience will confirm the strong yield and quality performance of Scepter in recent years. Both Trojan and Cutlass, sown in their optimal windows across the three years, are expected to remain competitive with that of Scepter, however are both only APW1 quality.

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Pasture Options Demonstration at Booleroo Centre
2017-2018

Author: Rebecca Moore (Two Ways Rural Media)/ Hannah Mikajlo (UNFS)
Funding body: PIRSA/Ag Excellence Alliance Grower Group Award 2017
Project title: Demonstrating Improved Pasture Options for the Upper North
Project duration: 2017-2018
Delivery organisation: Upper North Farming Systems

Key messages:

- When used strategically, different pastures (especially a mix of early and late season varieties) can bridge feed gaps and help meet production goals, while reducing reliance on supplementary feeding.
- Leafmore forage rape and Bouncer brassica both performed well in a UNFS demonstration, providing a high-quality diet.
- Preferential grazing will occur with pasture mixes so management strategies such as rotational grazing help optimise plant and animal performance.
- Different pasture species have specific agronomic requirements so do your research and talk to your agronomist to optimise management.
- Pastures designed for different environments can still perform in lower rainfall zones.

Background

Upper North Farming Systems (UNFS) put 19 different pasture species and varieties through their paces in 2017-2018 to give growers options to help fill feed gaps in low-rainfall environments.

Mixed farming enterprises are common in the Upper North of South Australia, where growers concentrate on low-risk, low-input systems. Pasture programs include two-three phase rotations (usually cereal for one-two years followed by a break crop) and self-sown and potentially unmanaged pastures, primarily grassy weeds.

UNFS vice chairman Matt Nottle hosted a demonstration site at his farm near Booleroo Centre in 2017 and 2018 to see how a range of pasture options, including new varieties and varieties not commonly used in the region, performed in the local environment. The demonstration showed the value of sown and managed pastures to fill feed gaps, increase paddock diversity at a low cost and contribute to mixed enterprises for both grazing and breaks in cropping rotations.

Methodology

UNFS researched suitable species and varieties including cereals, brassicas and legumes **(see pasture list)** to include in the demonstration. Some varieties were only used for one year of the demonstration, while others were run in both years.

The pastures were sown on neutral/calcareous soils in 1.4m x 100m single strip species, using a plot seeder. The plots were sown with 80kg DAP. As this was a demonstration rather than a trial, the plots were not replicated.

Sections of the plots were grazed during late winter and early spring, and managed over the two years using electric fencing.

Samples were collected from some of the plots and sent to the Australian Precision Ag Laboratory (APAL) and Livestock Logic for nutrient and feed testing. The results are shown below in **Tables 1-3.**

The parameters of most relevance from the feed testing relate to the quality and quantity of pastures:

- Metabolisable energy (ME): the feed energy actually used by the animal, calculated from digestible organic matter percentage, and expressed as megajoules per kilogram of dry matter (MJ/kg DM).
- Crude protein: the amount of true protein (composed of amino acids) plus non-protein nitrogen, expressed as a percentage of dry matter.
- Neutral detergent fibre (NDF): the total amount of cell wall material or plant structure in feed. Usually, the lower the NDF, the more an animal will eat.

In the first year (**Table 1**), Longsword wheat, Dictator 2 Barley, Vortex ryegrass, Bouncer brassica, Leafmore forage rape and Studenica vetch were tested. Vortex ryegrass, Bouncer brassica, and Leafmore forage rape had slightly higher ME levels. Leafmore forage rape had the highest crude protein value, while Longsword wheat and Dictator 2 barley had considerably more NDF than the other varieties.

All varieties used in 2018 were analysed (**Table 2**). Studenica vetch, Bouncer brassica, Leafmore forage rape, Balance chicory and Scimitar medic had the highest ME readings. Bouncer brassica and Leafmore forage rape had the highest crude protein levels, while Longsword wheat again had the highest fibre content.

Image 1: Inspecting the Pasture Options Demonstration in 2018. Photo Hannah Mikajlo

On Farm Application

UNFS held crop walks and field days at the demonstration site, and invited Hamish Dickson, Principal Consultant - livestock nutrition and management at AgriPartner Consulting, to break-down the results of feed tests to give growers food for thought.

"Vetch and grassy pastures are common in the Upper North but this demonstration opened up discussion about how other pasture varieties performed in the local environment," Hamish said.

"It provided useful information about the quantity and quality of feed produced by different pastures so growers could weigh up the options against their individual production goals."

Hamish's top five take-home messages from the pasture demonstration were:

1. Know what you need…

Identify your individual production goals to determine the feed requirements of each class of stock at each time of year, and then look for suitable pasture options to match feed demand with feed supply.

The protein requirements of livestock vary according to their type, weight and production stage (growth, reproduction, lactation).

"For example, weaner lambs need 16% protein in their diet and lambing ewes require at least 11% protein (depending if they are single or twin bearing)," Hamish said. "The pastures tested in the demonstration all had above 20% protein in the 2017 feed tests, which is sufficient for these grazing systems."

In the pasture demonstration feed tests, Bouncer brassica and Leafmore forage rape both had high ME values and low NDF. This means they offer a high quality, low fibre diet that is more digestible.

"Lambs grazing these pastures could put on 400g/day, compared to 300g/day on pastures such as the vetch, sulla or chicory," Hamish said. "To put it another way, if a grower wanted to put 15kg on lambs, they would reach this weight target two weeks sooner on the brassicas and could be turned-off earlier to free up those paddocks for other stock or avoid seasonal feed gaps."

This can bring an economic saving, as pastures that match animal nutrition requirements minimises the need for supplementary feeding. This has an added benefit for mixed enterprises in terms of time and labour as supplementary feeding carries a labour component which may clash with other periods of peak activity, such as seeding and harvest.

2. …and when you need it

Pasture varieties and species mature at different times, so look for options which deliver quality feed when you need it most, such as filling a seasonal feed gap or optimising livestock productivity.

"If you lamb in July-August, your peak feed demand will obviously be later than someone who lambs in autumn," Hamish said. "Consider varieties such as clovers which are late maturing, whereas cereals would be a good fit for earlier lambing as they get out of the ground sooner."

3. Mix and match but be aware of selective grazing

Pasture mixes with different species and different maturing varieties allow growers to spread out feed, however livestock tend to selectively graze higher value plants.

Hamish suggested a rotational grazing system with higher stocking rates for shorter periods to give pastures time to rest, and selecting the class of livestock for grazing a paddock according to their nutrient requirements and the feed on offer.

4. Understand how growth stage impacts feed quality

Traditional grassy pastures do play an important role in mixed enterprises, for example barley grass can provide high quality feed with 12.0 ME and 25-30% protein.

"Barley grass is a fast-growing species and quality declines quickly so it provides great quality feed early in the growing season, but obviously also presents seed contamination issues which need to be managed in the spring," Hamish said.

The impact of growth stage on feed quality is important to consider when interpreting feed test results. For example, in the demonstration Longsword wheat didn't perform well in terms of ME but this could be due to the fact it was flowering when tested so feed quality had declined.

5. Find the agronomic recipe for success

Different pasture species require different agronomic approaches to get the most out of them.

"Some seeds are not cheap so to get a good return on your investment, it's important to understand their fertiliser and chemical requirements and any other management requirements such as optimal leaf stage for grazing," Hamish said.

TIPS AND TOOLS

Useful resources to understand animal feed requirements and pasture quality include:

UNFS fact sheet: Native Grass Nutrition summarises feed test results of 12 common native grasses growing in the Upper North of SA: https://unfs.com.au/wp-content/uploads/2017/02/UNFS_Nutrition_Native_Grasses_1_Fact_Sheet.pdf)

Making More From Sheep covers establishing new pastures and grazing to maintain productive pastures (Module 6) as well as matching feed supply to animal demand (Module 7): www.makingmorefromsheep.com.au

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Participating farmer: Matt Nottle

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PASTURE LIST

The varieties included in the demonstration were:

Longsword Wheat: a fast maturing winter wheat recently released by AGT. It has a wide sowing window, although it is most suited to being sown in late March or early April. Relatively late to flower, once Longsword goes through a vernalisation (cold) period it matures quickly. The flexible sowing window also allows for a longer safe period for grazing. As of the 2018 season, Longsword has not yet received a milling quality classification and so is only deliverable as feed.

Dictator 2 Barley: the newest specialty forage barley released from Heritage Seeds, Dictator 2 is an awnless, two-row barley with dark coloured seeds. It recovers well from grazing and is a quick feed option when sown in early autumn. Dictator 2 has better palatability than the original Dictator barley variety.

Vortex Ryegrass: a mid-late flowering ryegrass, Vortex has high autumn, winter and early spring dry matter production. It has extremely good seedling vigour and is suitable for farmers requiring fast establishment, early grazing and silage/ hay production. Vortex was developed by Heritage Seeds.

Tetrone Ryegrass: available from Pasture Genetics, Tetrone establishes quickly and has high levels of winter production , particularly when planted early. It is suitable for grazing, silage or hay production, and has high levels of soluble carbohydrate and metabolisable energy.

Origin Fescue: Origin fescue is a perennial grass that remains dormant over summer but grows significantly between autumn and spring. Origin fescue is relatively tolerant of droughts, seasonal waterlogging and salinity. Available from Pasture Genetics.

Kasbah Cocksfoot: a hardy perennial grass available from Heritage Seeds that is well adapted to dry conditions and acid soils. It has good seedling vigour and early growth, and produces most of its biomass during autumn and winter.

Holdfast GT Phalaris: developed by the CSIRO, Holdfast GT phalaris has good seedling vigour, establishes quickly and easily, and is very palatable to livestock. It has a low level of summer dormancy and is a winter active variety.

Balance Chicory: a perennial from Pasture Genetics, Balance chicory establishes rapidly and has vigorous winter growth. It has a high mineral content, a good protein/energy ratio and is highly digestible.

Mawson Sub Clover: a long-term permanent pasture option developed by SARDI. Mawson sub clover matures early and is adapted to low-medium rainfall environments.

Wilpena Sulla: a highly palatable biennial legume with excellent forage quality, available from PGG Wrightson Seeds. Wilpena sulla is summer dormant, does not cause bloating and can potentially fix high levels of nitrogen in the soil.

SARDI Grazer Lucerne: a winter active lucerne developed by SARDI. It is a highly persistent, long-term pasture option with excellent grazing tolerance.

GTL 60 Lucerne: bred by Pasture Genetics, GTL 60 lucerne is grazing tolerant with high forage values, high palatability and good disease and pest resistance ratings.

Jaguar Strand Medic: an early maturing variety with a greater pod and leaf holding ability than other strand medics. This allows it to regain higher levels of forage for longer. Jaguar performs well in sands and loams, is highly nutritive and has a high protein content. Its vigour helps with weed suppression.

Scimitar Burr Medic: a spineless burr medic with high herbage levels and good seed production. Scimitar has an erect growth habit and copes well with saline soils provided they are not waterlogged.

Bouncer Brassica: a fast growing, leafy, and high-energy brassica hybrid. It can be grazed early and has a fast recovery rate.

Leafmore Forage Rape: a leafy forage brassica with a vigorous establishment rate and high yield. It recovers well from grazing and is highly palatable.

Currie Cocksfoot: an old, traditional variety, Currie has moderate summer dormancy and drought tolerance.

Studenica Vetch: a new variety developed by SARDI.

Cobra Balansa Clover: an early to very early flowering variety with better winter growth compared to other balansa clovers. Cobra has a high seed yield and can self-regenerate in long-term pasture phases. It is fairly good at tolerating salt and water logging, and can be grown in zones with as little as 200mm annual rainfall.

Table 1. 2017 feed test results.

Parameter		Results (DM)					
		Longsword Wheat	Dictator 2 Barley	Vortex Ryegrass	Bouncer Brassica	Leafmore Forage Rape	Studenica Vetch
Total Dry Matter (DM)	(% DM)	18.5	27.8	24	17.7	20	25.5
Moisture	(% DM)	81.5	72.2	76	82.3	80	74.5
Digestible Dry Matter (DDM)	(% DM)	78	81	85	86	88	83
Digestibility of Organic Dry Matter (DOMD)	(% DM)	73	76	79	80	81	77
Metabolisable Energy (ME)	(MJ/kg DM)	11.7	12.4	13.1	13.2	31.5	12.7
Crude Protein (N x 6.25) (CP)	(% DM)	24.2	21.8	21.8	22.4	29.4	22.7
Neutral Detergent Fibre (NDF)	(% DM)	53	46	40	23	23	36
Acid Detergent Fibre (ADF)	(% DM)	26	23	19	14	13	23
Water Soluble Carbohydrate (WSC)	(% DM)	11	17	19	18	12	14
Ash	(% DM)	11	12	11	12	12	10

Table 2. 2018 feed test results.

Parameter		Results (DM)											
		Longsword Wheat	Studenica Vetch	Bouncer Brassica	Leafmore Forage Rape	Balance Chicory	Mawson Sub Clover	Wilpena Sulla	SARDI Grazer Lucerne	GTL 60 Lucerne	Jaguar Medic	Scimitar Medic	Balansa Clover
Total Dry Matter (DM)	(% DM)	42	32	17	19	15	36	24	36	35	34	30	23
Moisture	(% DM)	58	68	83	81	85	64	76	64	65	66	70	77
Digestible Dry Matter (DDM)	(% DM)	81	89	88	91	88	79	76	79	81	80	85	83
Digestibility of Organic Dry Matter (DOMD)	(% DM)	75	82	81	84	81	74	71	74	75	74	79	78
Metabolisable Energy (ME)	(MJ/kg DM)	12.3	13.6	13.5	14	13.4	11.9	11.4	12	12.2	12.1	13	12.7
Crude Protein (N x 6.25) (CP)	(% DM)	27.8	25	34.1	36.2	30.2	27.8	24.7	30	30.7	23.8	30.3	29.2
Neutral Detergent Fibre (NDF)	(% DM)	51	33	25	24	32	37	27	32	32	36	30	27
Acid Detergent Fibre (ADF)	(% DM)	24	20	13	13	19	20	16	20	19	21	14	16
Water Soluble Carbohydrate (WSC)	(% DM)	10	15	9	9	9	7	8	8	7	10	10	8
Ash	(% DM)	10	9	12	12	13	11	9	12	11	8	11	11

Table 3. 2018 nutrient test results

Crop	Nitrate N	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium	Sodium	Sulfur	Boron	Copper	Zinc	Manganese	Iron	Aluminium	Cobalt	Molybdenum	Chloride
	mg/kg	%	%	%	%	%	%	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%
Studenica Vetch	58	4.2	0.23	1.69	1.1	0.3	0.52	0.23	30	2.6	15	56	480	670	0.29	<0.40	0.69
Cobra Balansa Clover	557	4.6	0.32	3.19	2.49	0.48	0.83	0.35	23	6	17	93	470	590	0.65	<0.40	1.5
Longsword Wheat	<30.0	4.5	0.33	2.33	0.25	0.2	0.015	0.42	31	5.1	25	68	180	150	<0.16	1.1	0.5
Bouncer Brassica	2500	5.8	0.71	4.92	0.96	0.33	0.81	0.79	28	6.1	38	42	260	280	0.28	<0.40	1.4
Leafmore Forage Rape	597	5.7	0.64	3.72	0.72	0.3	0.25	1	26	4.8	40	41	150	130	0.21	<0.40	1
Balance Chicory	1030	4.8	0.46	5.68	1.02	0.33	0.87	0.44	35	12	31	93	490	570	0.33	<0.40	3.2
Mawson Subclover	174	4.1	0.21	2.33	2.3	0.47	0.57	0.3	31	5.8	18	100	880	1200	0.46	<0.40	0.96
Wilpena Sulla	<30.0	3.6	0.18	1.81	1.41	0.42	2.1	0.8	58	7.7	13	98	650	930	0.4	4.2	4
SARDI Lucerne	465	4.6	0.27	2.86	3.06	0.3	0.15	0.35	74	7.2	20	93	1200	1800	0.6	<0.40	0.48
GTL60 Lucerne	335	4.7	0.28	2.77	2.62	0.31	0.22	0.36	65	8.2	22	79	780	1100	0.48	0.68	0.54
Jaguar Medic	208	4	0.24	2.3	2.37	0.38	0.15	0.25	53	3.8	16	85	1000	1500	0.45	<0.40	0.64
Scimitar Medic	496	4.4	0.26	2.92	1.83	0.31	0.12	0.31	54	4.4	21	82	510	650	0.3	<0.40	0.64

Grower Case Study

Pasture options give food for thought

Matt Nottle, Booleroo Centre

Author: Rebecca Moore, Two Ways Media

Grower-led research was in action at Booleroo Centre in 2017-18, with a pasture demonstration hosted by Upper North Farming Systems vice chairman Matt Nottle.

The project stemmed from Matt's observations of dominant grazing systems on mixed farming operations in the region.

"Many farmers are heavily reliant on barley grass as early feed in late autumn and early winter," he said.

"I was curious why this is common practice, when there are so many other pasture species on the market. I wanted to know what alternative varieties and species suit our environment and could provide options to fill early and late feed gaps."

This curiosity paved the way for a pasture demonstration, supported by funding from Ag Excellence Alliance and using seed donated by plant breeding companies.

Matt, his wife Alice and their two young sons farm in partnership with his parents Lenore and Trevor.

They operate a mixed farming enterprise across 1600 hectares at Melrose and Booleroo Centre. Their properties feature red brown loam and red clay and historically receive 375mm of annual rainfall.

This year, the Nottles' cropping program is 570ha wheat, 430ha barley, 80ha export hay, and 250ha legumes.

They run around 470 breeding ewes – about two thirds are joined to Merinos and the remainder to White Suffolk rams. Their grazing program includes summer stubbles, vetch and a vetch/barley mix as well as 160ha of leased grazing country at Wirrabara.

In the Upper North, the grazing pinch-points are from late March through to opening rains (often not until May) and in early summer before stubbles are available for stock. This is where Matt was keen to see pasture options to bridge feed gaps and maintain stock productivity.

"The idea was never to go away from best practice and the tried and tested pastures – barley, oats, vetch and medic/clover are proven performers here, but we wanted to see if there was an opportunity to mix things up a bit," Matt said.

He said it was also a chance to put more efficient farming practices to the test: "We wanted to see how varieties that haven't been grown in this area performed, even if they were bred for higher rainfall areas. Generations change, breeding technologies are more advanced and farmers are more efficient with rainfall so we felt it was timely to revisit what varieties are suitable for our environment, now."

Matt's observations from the demonstration was that Leafmore forage rape and Bouncer brassica both performed well. Feed tests results showed high protein and energy and low fibre, creating a quality and digestible feed for livestock. He also has his eye on the new SARDI vetch, Studenica.

As part of the demonstration, 25m of the 100m plots were sectioned off with electric fencing to see potential biomass while the rest was grazed intermittently.

“The brassicas, Longsword winter wheat, Dictator 2 barley and Studenica vetch all had impressive growth throughout the winter,” Matt said. “Unfortunately with a dry spring both years some species like the perennial grasses and lucernes didn’t get a chance to really come into their own, but shouldn’t be disregarded because they all showed ability to survive long dry periods over summer.”

Stock performance and grazing patterns were not recorded as part of the project, but Matt’s observations were that sheep selectively grazed and preferred the forage rape before moving onto the vetch/legumes and finally the grasses.

Matt said the demonstration reinforced to him how pastures can be strategically used as part of a dynamic, flexible mixed farming enterprise.

“If we have good summer rainfall and early opening rains, there is an opportunity in dryland mixed farming to plant strategic pastures to take advantage of additional moisture,” he said.

“The opportunity has not been there for us in recent years, with no subsoil moisture and minimal opening rains, but we now have a better idea now of what pastures we could support in this environment.

“For us, mixed species are the best chance to spread risk and stretch out feed availability.”

Matt said the important factors in making sound pasture decisions are forward planning to take advantage of opportunistic rainfall, and a thorough understanding of individual production goals so pasture selection can match animal feed requirements.

UNFS has extended the pasture demonstration with two additional sites at Caltowie and Belalie North, planted in 2019.

This project was made possible through the PIRSA sponsored Ag Excellence Alliance Grower Group Award in 2017 prizemoney awarded in recognition of Upper North Farming Systems contribution to the industry.

PRIMARY INDUSTRIES & REGIONS SA PIRSA

Ag Excellence Alliance

Micro–Nutrients in the Upper North

2018

Author: Jana Dixon, Rural Directions Pty Ltd

Funded By: South Australian Grains Industry Trust

Project Title: Increasing the knowledge and understanding of micronutrient deficiency in the Upper North (UNF117)

Project Duration: 2017 - 2019

Project Delivery Organisations: Upper North Farming Systems (UNFS)

Project Manager: Matt Foulis, Northern Ag

Key Points:

- There was no yield response or difference in plant tissue results to any of the foliar applications of copper and zinc on wheat.
- Whilst there was no yield response to zinc or molybdenum treatments in lentils, there was a statistically significant increase in zinc and molybdenum levels in the plant tissue tests from IcON Zinc 100 and Signature Moly 300 treatments, respectively.
- When water is a limiting factor to plant growth, any potential response to micronutrient applications will be limited due to the effects of moisture stress on plant growth.
- An economic response to foliar micronutrient applications is only achieved when the yield response outweighs the cost of product and application. This was not achieved in the 2018 trial.

Background

The role of micronutrients for plant growth and yield is to provide small amounts of trace elements to assist with essential plant functions. Essential micronutrients for plant growth are; iron, manganese, zinc, copper, boron, molybdenum, 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.

A recent literature review has 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 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 through 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 anthesis. Zinc deficiency will show up more in cold conditions early on in the season, with symptoms in cereals looking like stunted growth and yellow stripes on leaves turning into necrotic lesions. Both copper and zinc deficiencies can be exacerbated through the use of Group B herbicides.

Molybdenum is also a micronutrient that growers in the Upper North region have shown interest in.

Molybdenum has been identified for its role in nodulation and performance in pulse crops. Although soil types in the Upper North are not typical for showing up molybdenum deficiency (generally in acid, sandy soils), there has been some anecdotal and grower experience that has shown a positive growth response to foliar applications on pulse crops.

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. Naturally there won't be an economic response to micronutrient application each season, with other significant factors such as moisture stress, and the effects of heat and frost underpinning crop productivity in the Upper North region.

Methodology

Stage 1 of this SAGIT funded project involved a literature review, and a grower workshop, detailing the current research on micronutrient nutrition relevant to the Upper North area. The literature review, which summarises the potential micronutrient deficiencies in the Upper North region, can be found in the 2017 UNFS Annual Results book. The insights gained from Stage 1 have helped shape the trial designs to be carried out in Stage 2 of the project. This stage involves various trial work, and further investigation and validation of current research, with trials being completed in the 2018 and 2019 seasons.

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

Table 1: Micronutrient treatments compared at each of the trial sites. The responses were compared to a 'control' treatment at each site with no product applied.

Product	Strength (g/L)	Rate (L/ha)	Nutrient Applied (g/ha)
Wheat trial sites – Carey & McCallum			
Sentinel Zinc	60	2.50	150
		1.00	60
Sentinel Copper	60	2.50	150
		1.00	60
IcON Zinc	1500	0.10	150
IcON Copper	1015	0.10	101.5
Lentil trial site – Koch			
Signature Molybdenum	100	0.15	15
		0.30	30
IcON Zinc	1500	0.10	150

See Appendix 1 for further details on the products used.

The treatments were replicated three times each at the three trial sites, with the sites designed in a split plot layout. Sowing of the trials was completed with a Primary Sales Plot Seeder on loan to UNFS. The plots were harvested by SARDI, with the grain yield data being analysed for statistical significance using analysis of variance (ANOVA) at the 5% significance level (see **Figures 1 -3** below).

The micronutrient products were applied as foliar applications at a water rate of 100L/ha using a hand boom spray with coarse droplets. The wheat trial plots at the Carey and McCallum sites were sprayed on

20 July (8-13km/h winds, 14°C). The foliar applications at the lentil site were applied on 10 August (8-11km/h winds, 17°C).

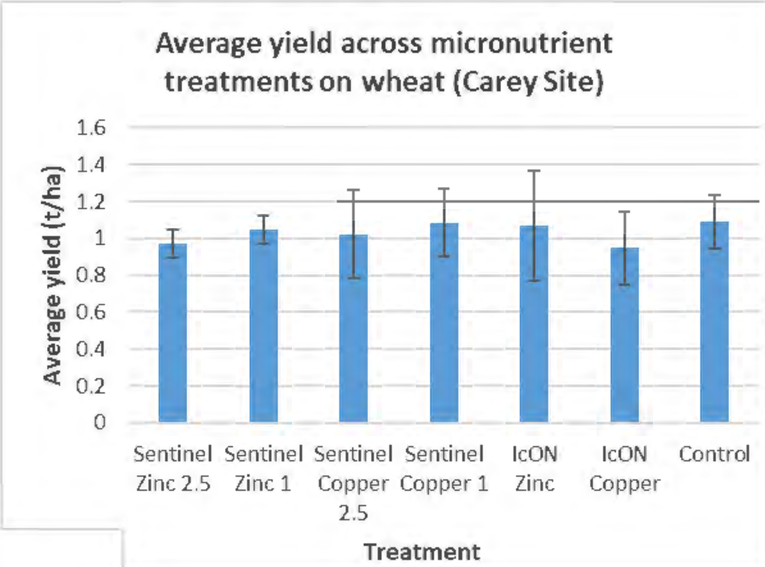
Tissue sampling took place at each of the three sites, approximately 6 – 8 weeks after the foliar treatments were applied. A tissue sample was taken in each plot, giving three replicates per treatment at each trial site, see **Tables 3-5** below. The plant tissue sample results were analysed for statistical significance using ANOVA at the 5% significance level.

Topsoil soil tests (0-10cm) were taken at each trial site location, to give an idea of current soil micronutrient status, see **Table 2** below.

Results and Discussion

Yield Graphs

Figures 1 and 2: Average grain yield comparison of various zinc and copper foliar treatments on wheat, compared to the control treatment; at the McCallum and Carey sites, respectively. Error bars show standard deviation.
ANOVA analysis (5% significance): McCallum P=0.98, Carey P=0.95



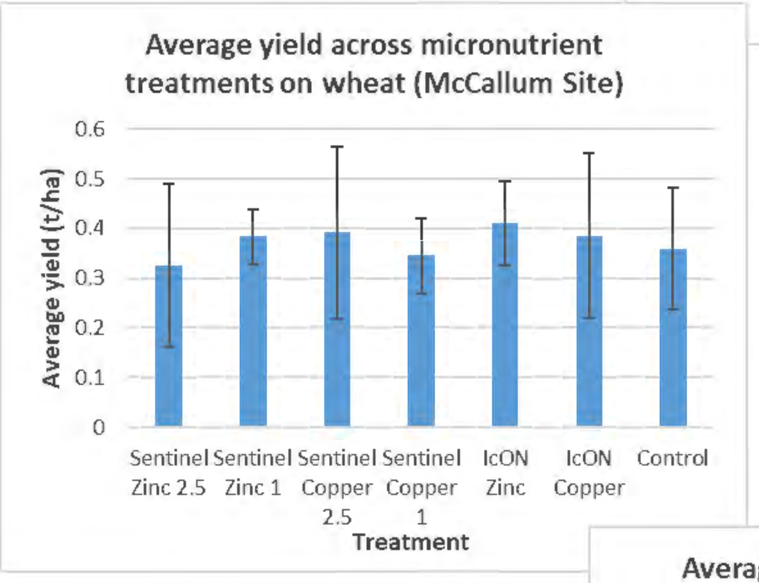
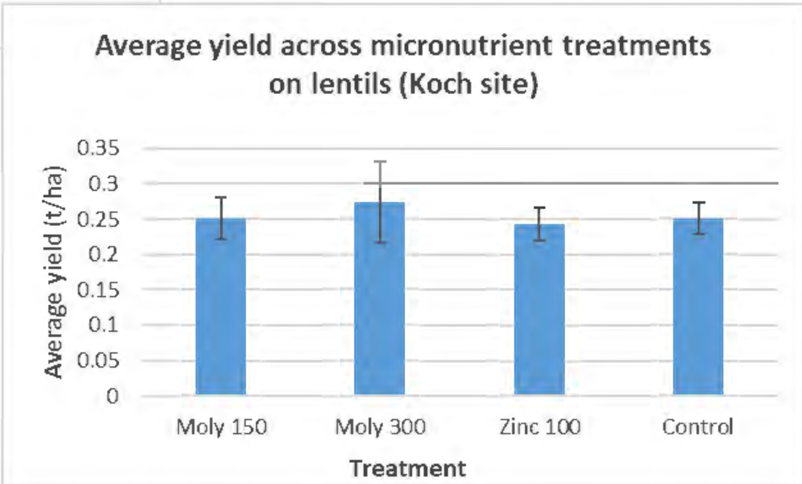


Figure 3: Average grain yield comparison of two molybdenum and one zinc treatment on lentils, compared to a control treatment. Error bars show standard deviation.

ANOVA analysis (5% significance): P=0.76



There was no significant difference in grain yield between the micronutrient treatments at each of the three sites. Both the wheat, and the one lentil trial site were under significant moisture stress for most of the 2018 growing season. 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.

Soil Test Results

Soil testing can be used a guideline to indicate where significant micronutrients deficiencies or toxicities may show up and, potentially, limit crop growth and yield. However, as these trace elements are present in such small levels in the soil, current testing procedures are limited in how accurate they can be in estimating levels in the soil. In addition to this, critical levels for the micronutrient sampled will vary significantly between soil properties, making soil tests often difficult to interpret on their own. However, when coupled with plant tissue test results, they can provide reasonable estimates to what the current micronutrient levels may be influencing plant growth.

Table 2: Summary of topsoil (0-10cm) test results from the SoilMate lab at each of the three trial sites.

	McCallum	Carey	Koch	Sufficiency Range
Date Sampled	*1/4/2019**	*11/2/2018*	*31/03/19**	
pH ($CaCl_2$)	8.00	7.70	7.80	5.2 – 7.7
EC (1:5 H_20) dS/m	0.39	0.17	0.21	0.0 – 0.8
Cl (1:5 H_20) mg/kg	290	17.0	24.0	0 – 250
Organic Carbon % (w&b)	1.15	1.20	1.16	1.0 – 2.0
Colwell P (mg/kg)	12.0	15.0	29.0	25 – 100
DGT P (ug/L)	1.00	35.0	26.0	60 – 100
PBI	130	96.0	91.0	15 – 280
DTPA Copper (mg/kg)	0.82	0.62	0.70	1.0 – 5.0
DTPA Zinc (mg/kg)	0.54	0.33	1.10	0.8 – 5.0
DTPA Manganese (mg/kg)	5.30	6.80	8.30	6.0 – 50

**When soil samples were taken after the trial was completed, samples were taken on areas of the paddock surrounding the trial site.* NB: All samples showed non-toxic levels of aluminium and boron and adequate levels of other macronutrients tested. Currently no soil tests can accurately indicate molybdenum levels.

Soil type across the three sites are neutral to slightly alkaline in nature with moderate PBI's (phosphorus buffering index). As a general statement the three sites are all red clay/ clay loam soil types, with each site showing adequate organic carbon levels. The McCallum site was slightly more alkaline, with a higher PBI and significantly low phosphorus levels. This site also showed up slightly deficient manganese levels. All sites showed up copper levels below the sufficiency range, and the McCallum and Carey sites also showed up low levels of zinc. These observations are in line with trends from other soil test results analysed in the literature review completed in stage 1 of the project.

Tissue Test Results

Plant tissue sampling is the most accurate method of assessing plant nutrition at a single moment in time.

The target range for each micronutrient will vary with crop type, crop growth stage, and what part of the plant was sampled. Plant tissue tests don't necessarily reflect the micronutrient status that shows up in soil test results, as micronutrient uptake varies with plant root uptake in different seasonal conditions. Foliar applications of micronutrients aim at increasing the targeted micronutrient level in the plant tissue through direct uptake from the leaf surface. Before applying specific foliar micronutrient treatments, it is suggested to conduct plant tissue samples early in the season to understand plant nutrient level prior to application. However, in this scenario the plant tissue samples were taken after the foliar micronutrient applications to compare the response to the treatments.

Table 3: Plant tissue test results for the micronutrient treatments on wheat at the McCallum trial site. Sampling took place on 5/9/18. Interpretation standards used from APAL (Australian Precision Ag Laboratory) are at the tillering growth stage, with the whole shoots sampled.

	Zinc			Copper		
Foliar Treatment	**Average Result (mg/kg)**	**Target range (mg/kg)**	**Status**	**Average Result (mg/kg)**	**Target range (mg/kg)**	**Status**
Control	31.00	25-70	Normal	7.53	7-15	Normal
Sen Zinc 1	32.00	25-70	Normal	7.73	7-15	Normal
Sen Zinc 2.5	30.33	25-70	Normal	7.60	7-15	Normal
Icon Zinc	30.33	25-70	Normal	7.47	7-15	Normal
Sen Copper 1	34.33	25-70	Normal	7.73	7-15	Normal
Sen Copper 2.5	30.67	25-70	Normal	7.63	7-15	Normal
Icon Copper	30.33	25-70	Normal	7.57	7-15	Normal

NB: there was sufficient manganese levels in the plant tissue results across all of the treatments. *ANOVA analysis (5% significance): Zinc results P = 0.12, Copper results P = 0.90.*

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 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.

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 tests at the Carey trial site also showed up 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 present at an adequate level in the wheat tissue samples.

Table 4: Plant tissue test results from APAL for the micronutrient treatments on wheat at the Carey trial site. Sampling took place on 19/9/18, at the head emergence growth stage, with the upper leaf blade being sampled.

	Zinc			Copper		
Foliar Treatment	**Average Result (mg/kg)**	**Target Range (mg/kg)**	**Status**	**Average Result (mg/kg)**	**Target Range (mg/kg)**	**Status**
Control	16.33	18-50	Marginal	6.27	3-8	Normal
Sen Zinc 1	16.67	18-50	Marginal	6.50	3-8	Normal
Sen Zinc 2.5	17.67	18-50	Marginal	6.00	3-8	Normal
Icon Zinc	16.33	18-50	Marginal	6.23	3-8	Normal
Sen Copper 1	17.00	18-50	Marginal	6.17	3-8	Normal
Sen Copper 2.5	16.33	18-50	Marginal	5.90	3-8	Normal
Icon Copper	16.33	18-50	Marginal	6.27	3-8	Normal

NB: tissue test results for magnesium showed up to be marginally deficient across all treatments. Sodium levels also showed up to be consistently deficient across all treatments. *ANOVA analysis (5% significance): Zinc results P = 0.86, Copper results P = 0.52.*

Table 5: Plant tissue test results from APAL for the micronutrient treatments on lentils at the Koch trial site. Sampling took place on 3/10/19, during anthesis, with the youngest mature leaf being sampled.

	Zinc			Molybdenum		
Foliar Treatment	**Average Result (mg/kg)**	**Target Range (mg/kg)**	**Status**	**Average Result (mg/kg)**	**Target Range (mg/kg)***	**Status**
Control	16.67	40 - 90	Deficient	0.40		
IcON Zinc 100	25.67	40 – 90	Deficient	0.40		
Moly 150	18.00	40 – 90	Deficient	0.55		
Moly 300	17.67	40 - 90	Deficient	0.93		

*target range unknown. *ANOVA analysis (5% significance): Zinc results P<0.001, Molybdenum results P=0.002.*

There was a statistically significant difference in zinc levels between treatments, in the lentil tissue samples. The IcON Zinc 100 treatment resulted in a higher zinc level in the plant tissue, particularly when compared to the control treatment. It is noted that all zinc levels in the tissue tests are showing up to be deficient in the lentil plots. The soil tests taken on the Koch property 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.

Molybdenum levels in the tissue samples were also statistically different between treatments. When the Moly 300 treatment was applied, a much higher molybdenum reading was recorded in the tissue samples, more than double the reading of the control treatment. Again, there was no significant difference between the lentil yield results between any of the treatments. The response of improved nodulation from increased molybdenum nutrition was not investigated in this trial.

Summary

The 2018 season was a difficult year to see the effect of micronutrient applications in both wheat and lentil trials. Crop growth in the Upper North region was limited by significant moisture and frost stress throughout the growing season. Along with these limitations, it could be expected that there was poor foliar uptake of the micronutrients applied in the trial, due to decreased transpiration of the moisture stressed plants.

The wheat tissue samples at both sites did not show any differences in copper or zinc levels between the treatments tested. However, in the lentil trial, there were responses to both zinc and molybdenum applications in the plant tissue tests. The tissue samples showed increased zinc levels from the IcON Zinc 100 treatment and increased molybdenum levels from the Signature Molybdenum 300 treatment, both when compared to control. Whilst this did not result in increased yields in the 2018 season, there is some anecdotal evidence to suggest the positive effects of these micronutrients treatments in other seasons. Further investigation into the influence of molybdenum applications on the nodulation and nitrogen fixation in lentils may be useful to look at.

Foliar application is one method of providing additional micronutrients to crops that indicate deficiencies. Solid or liquid micronutrient applications at seeding may be warranted when soil types are highly responsive to particular nutrients. However, in regions that are not typically known for micronutrient deficiencies, such as the Upper North, foliar applications are a cost-effective way of providing micronutrients when a deficiency is indicated. Before considering applications, it is best to monitor symptoms, eliminate other stresses that may be mistaken for a micronutrient deficiency, take tissue samples early in the season, and consider the yield potential being limited. Keep in mind that soil test results are only an indicator of micronutrient levels and ideally should be coupled with tissue test results.

This trial is a 3 year trial and will continue in 2019 at Booleroo Centre and Baroota.

Acknowledgements

South Australian Grains Industry Trust for making the trial possible through its funding.

Matt Foulis at Northern Ag for managing the trial on behalf of Upper North Farming Systems.

UNFS Operations Committee for developing the project scope.

Joe Koch, Breezy Hill, JP Carey, White Cliffs and Matt McCallum for providing the trial sites, applying the treatments and managing the paddocks throughout the year.

Jana Dixon for writing up the results.

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SAGIT

Appendix

Costings used for analysis. *Approximate prices only as of June 2019.*

Sentinel Copper by Wilchem

60g/L Copper as EDTA Chelate

$6.10/L
1L/ha rate: $6.10/ ha

2.5L/ha rate: $15.25/ha

Sentinel Zinc by Wilchem

60g/L Zinc as EDTA Chelate

$5.41/ L
1L/ha rate: $5.41/ ha

2.5L/ha rate: $13.53/ha

IcON Copper by Sonic Essentials

1015g/L Copper

Highly concentrated.

$54/ L
100mL/ha rate: $5.4/ha

IcON Zinc by Sonic Essentials

1500g/L Zinc

Highly concentrated.

$29/ L
100mL/ha rate: $2.90/ha

Signature Molybdenum by Wilchem

100g/L of Molybdenum as Amino Acid Chelate.

$2.45/L
150mL/ha rate: $0.37/ha

300mL/ha rate: $0.74/ha

SOUTHERN PULSE EXTENSION PROJECT—"Pulse Check"

Author: Rachel Trengove, Southern Pulse Extension Project Officer, UNFS

Funded By: Grains Research and Development Corporation

Project Title: GRDC Southern Pulse Extension Project

Project Duration: *2017-March 2020*

Project Delivery Organisations: *BCG, UNFS*

Background

Grain growers are being supported to diversify into pulse crops in non-traditional production areas of Victoria and South Australia through Grains Research and Development Corporation (GRDC) initiative.

The Southern Pulse Extension project is a GRDC investment that aims to provide growers and their advisers with the information and resources they need to make informed decisions and maximize possible production and income potential from pulses.

At the core of the project is the establishment of twelve "Pulse Check" discussion groups across Victoria and South Australia.

The Pulse Check groups meet at least four times a year over two years to discuss issues relating to pulse crop production, management and marketing. They are focused on a "back to basics" approach to pulse production through practical in-field learning and group discussion.

Each group consists of growers and advisers with varying experience in production of lentils or chickpeas. Those with no or limited experience are particularly encouraged to take advantage of a unique opportunity to learn from more experienced growers in their region and experts in the industry.

Pulse trial sites have been incorporated into Pulse Check group activities.

Since the commencement of the project, UNFS has hosted several pulse check group workshops. Given the diversity of the Upper North region, the meetings are being alternated between the western and eastern sides of the Flinders Ranges. There is value in joining together everyone together from across the district to share ideas and knowledge.

Pulse Check Group Extension Activities for 2018

Pulse Check meetings for 2018 are listed below including topics covered and attendance:

Pulse Check meeting 1 – Pre-seeding

20th March 2018 – Booleroo Centre Football Club
Lentil and chickpea pre-seeding discussion meeting.
Guest presenters: Matt Foulis (Northern Ag) and Daniel Hillebrand (YP Ag)
Participants: 16

Pulse Check Meeting 2 – Post-seeding

20th June 2018 – Lentil Agronomy Trial Site – Warnertown Presenters: Matt Foulis (Northern Ag) and Daniel Hillebrand (YP Ag), Penny Roberts and Sarah Day
(SARDI, Clare)
Topics covered:

- Local paddock walks and a look at trials
- Discussed post seeding crop establishment and weed control
- Check for early pests, weeds, disease, discussed management strategies
- Looked at time of sowing trial

Participants: 17

Pulse Check Meeting 3 - Pre-canopy Closure

6th September 2018 – Field Day at Wilmington
Participants: 19

Pulse Check Meeting 4

11th September 2018 – Bus trip to look at lentil growing sites on upper Yorke Peninsula
Participants: 30

Pulse Check Meeting 5

25th September 2018 – Field Day at Warnertown Pulse Trial site
Organised by Rebecca Freeman and covered the Pulse check group pre-canopy closure meeting
Topics covered:

- Implications of TOS and frost in lower rainfall environments – Michael Brougham (Elders)
- Implications of different levels of PAW on sowing decisions for lentils – Penny Roberts (SARDI)
- Herbicide tolerance and potential of new traits in breeding lines – Dili Mao (SARDI)
- Management of pulses to control Group C damage – Chris Davey (YP Ag)
- Multi-species trial: rotational implications of different break-crops – Sarah Day (SARDI)
- Pulse marketing update – Pulse Australia Member

Participants: 30

Pulse Check Meeting 6 - Pre-harvest

16th October 2018
An informal meeting was held with discussion and harvester demonstration. Andrew Kitto presented on lentil harvester settings and operation as well as fire control methods
Participants: 17

The pulse check groups are proving successful in helping local farmers gain the confidence and skills necessary to adopt new pulse varieties, or to improve on their current practices. There are four more Pulse Check meetings planned between now and March 2020 when the project finishes which will aim to further build growers and advisors knowledge and understanding of the key aspects of pulse production.

Acknowledgements:

- Southern Pulse Extension Project Manager, Prue Cook, BCG.
- Barry Mudge, UNFS Member and Project Coordinator (in-Kind) 2018.

Low Rainfall Zone Species by Variety Pulse Trials Warnertown 2018

Author: Sarah Day and Penny Roberts, SARDI

Project Title: Maintaining profitable farming systems with retained stubbles in Upper North SA

Funded By: Grains Research and Development Corporation

Project Delivery Organisation: SARDI on behalf of UNFS

Seasonal Snapshot

2018 saw drier than average climate conditions. Long-term data indicates that annual and growing season rainfall was well below average (Figure 1). Rainfall was well below average in the months leading up to seeding, combined with low levels of stored soil moisture the result was less than optimal plant emergence. The dry conditions continued throughout the season, resulting in low grain yields. Growing season rainfall (GSR) for May to October recorded at the Warnertown trial site was 116 mm, while the long-term average is 236 mm. Due to low in-season rainfall, foliar disease was not an issue at this site in 2018. Wheat was grown in 2017, with a medium stubble load remaining at seeding.

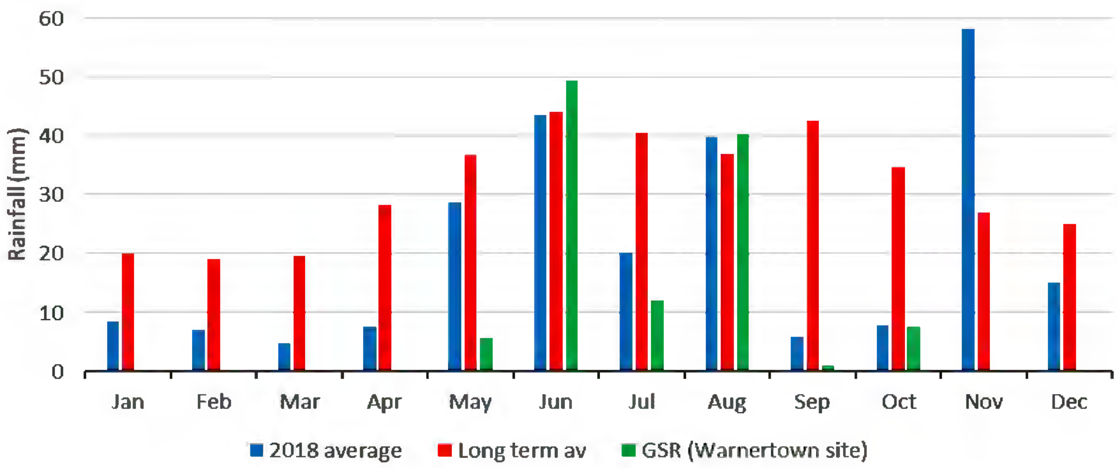

Figure 1. 2018 monthly average rainfall and long term average rainfall recorded at Nurom weather station (BOM), and growing season rainfall (May to October) recorded at the trial site.

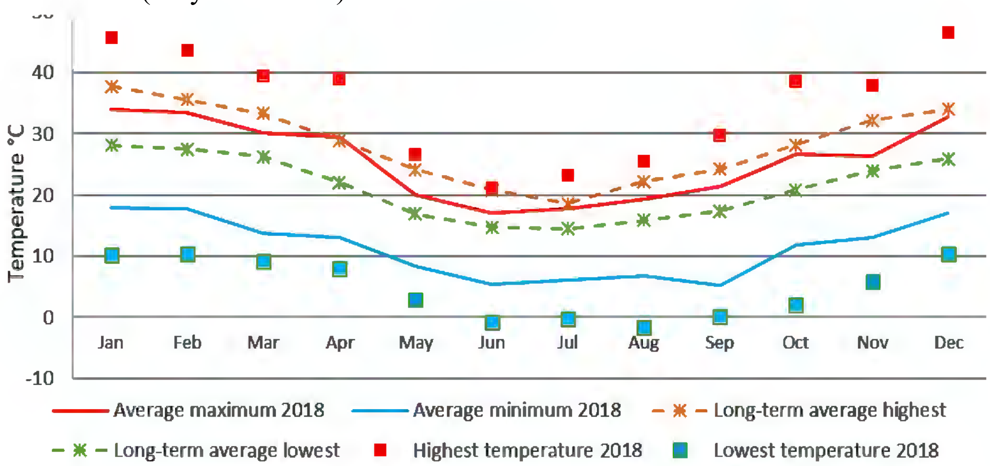

Figure 2. Average monthly maximum and minimum temperatures and absolute maximum or minimum at the Warnertown trial site (Port Pirie Aerodrome) in 2018 compared with the long term average of Port Pirie Nyrstar (station closed). Source: BOM

TRIAL SUMMARIES

Species-by-variety trial, LRZ Upper Mid North (Warnertown), South Australia

Aim

To identify best break crop options for different climate, soil type and biotic stress situations within major cropping regions of the southern low rainfall zone.

Key Messages

Faba bean had a high gross margin in 2018 in concurrence with high demand and grain prices. Importantly, calculating gross margin with long-term grain price resulted in faba bean remaining profitable.

Treatments

Table 1. Species and varieties included in the trial. Varieties were selected following consultation with advisors, researchers and breeders, and include options with herbicide tolerance characteristics, and those with potential for alternative end-uses (dual purpose/forage).

Species	Varieties
Lentil	PBA Blitz, PBA Hallmark XT, PBA Hurricane XT, PBA Bolt, PBA Jumbo2, PBA Flash
Field Pea	PBA Wharton, PBA Butler, PBA Twilight, PBA Coogee, PBA Percy, Kaspa
Vetch	Rasina, Timok, Volga
Faba Bean	PBA Samira, PBA Marne, Nura
Chickpea	PBA Monarch, PBA Striker, Genesis090
Canola	Nuseed Diamond, Hyola 559TTT, ATR Bonito, ATR Stingray, Pioneer 44Y90 (CL), Pioneer 43Y92 (CL)

Table 2. Site details, Warnertown SA 2018.

Sowing Date	15 May 2018
Plant Density (plants/m^2)	Lentil: 120 Field Pea: 55 Faba Bean: 24 Vetch: 60 Chickpea: 35 (kabuli), 50 (desi)
Row Spacing (cm)	23
Fertiliser (kg/ha)[1]	80

Results and Interpretation

Field pea continues to express its yield and biomass production stability in low rainfall environments (Figures 3 and 4). Field pea and vetch, in particular, have multiple alternative end-use options in dry seasonal conditions that can be utilised to recover crop input costs, or benefit the subsequent crop. Results indicate that faba bean may have potential to be a successful and profitable crop in low rainfall environments (Figure 5).

Difference were observed for biomass yield response between crop species ($P<0.001$) and variety ($P=0.006$). Biomass cuts were taken at late flowering to early podding growth stage to identify potential use as a hay, silage or manure crop. Field pea are known for having early vigour and high biomass potential, and had the highest biomass yield at Warnertown in 2018 (Figure 3). Faba bean also had high biomass at this site, with biomass yield 27% lower than field pea. Vetch, lentil, chickpea and canola had relatively low biomass yield, 42-48% lower than field pea.

Vetch, like field pea, is a versatile crop and has potential alternative end-use options to grain. However, at Warnertown, vetch biomass production was 42% lower than field pea. Volga vetch biomass was 37% and 41% higher than Rasina and Timok, respectively. PBA Wharton field pea had 28% and 37% higher biomass production than PBA Percy and Kaspa, respectively. Faba bean, chickpea and lentil had similar biomass yield between respective varieties.

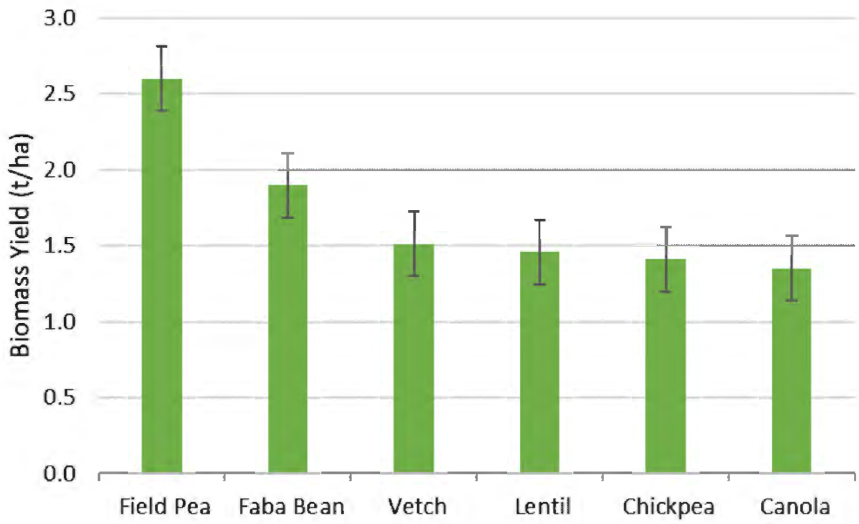

Figure 3. Biomass yield response of crop species at Warnertown, 2018. Error bars represent least significant difference (0.42, P<0.05).

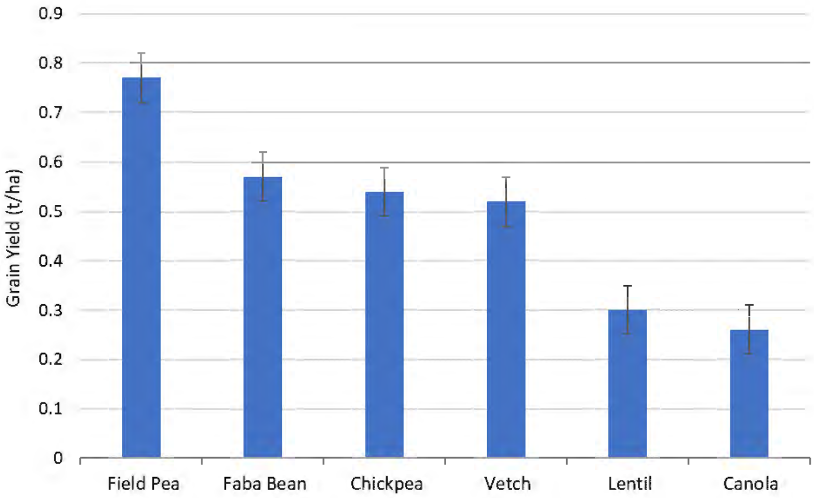

Figure 4. Grain yield response of crop species at Warnertown, 2018. Error bars represent least significant difference (0.10, P<0.05).

Differences were observed for grain yield response between crop species (P<0.001). Field pea had the highest grain yield response, with a mean yield of 0.77 t/ha (Figure 4). Faba bean, chickpea, and vetch had grain yield 26-32% lower than field pea. Lentil and canola had the lowest grain yield response, with yield 61% and 66% lower than field pea, respectively.

Differences were observed for gross margin response between crop species (P<0.001). Faba bean had the highest gross margin (Figure 5), in concurrence with current high demand and grain prices for faba bean. With a 5-year long-term grain price, faba bean remain profitable with a gross margin of $39/ha. Field pea and chickpea were the only other profitable crops. Vetch, lentil and canola had a negative gross margin, reflecting their low grain yields and or low grain prices.

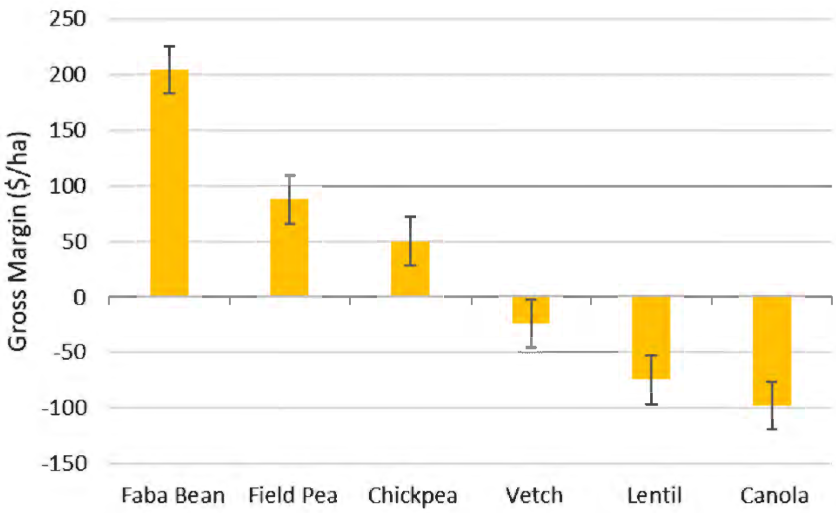

Figure 5. Gross margin response of crop species at Warnertown, 2018. Error bars represent least significant difference (43.5, P<0.05).

<u>Lentil stored soil moisture, LRZ Upper Mid North (Warnertown), South Australia</u>

Aim

To assess grain yield and biomass production of PBA Jumbo2 and PBA Hurricane XT lentil in the low rainfall zone under different stored soil moisture conditions.

Key Messages

Increased soil moisture showed significant increase in biomass and grain yield of lentil at Warnertown in 2018.

Treatments

Varieties: PBA Jumbo2, PBA Hurricane XT

Soil moisture: Nil/no irrigation (Figure 6), Half field capacity (Figure 7), Field capacity (Figure 8)

Table 3. Site details, Warnertown SA 2018.

Sowing Date	15 May 2018
Plant Density (plants/m^2)	120
Row Spacing (cm)	23
Fertiliser (kg/ha)[1]	80

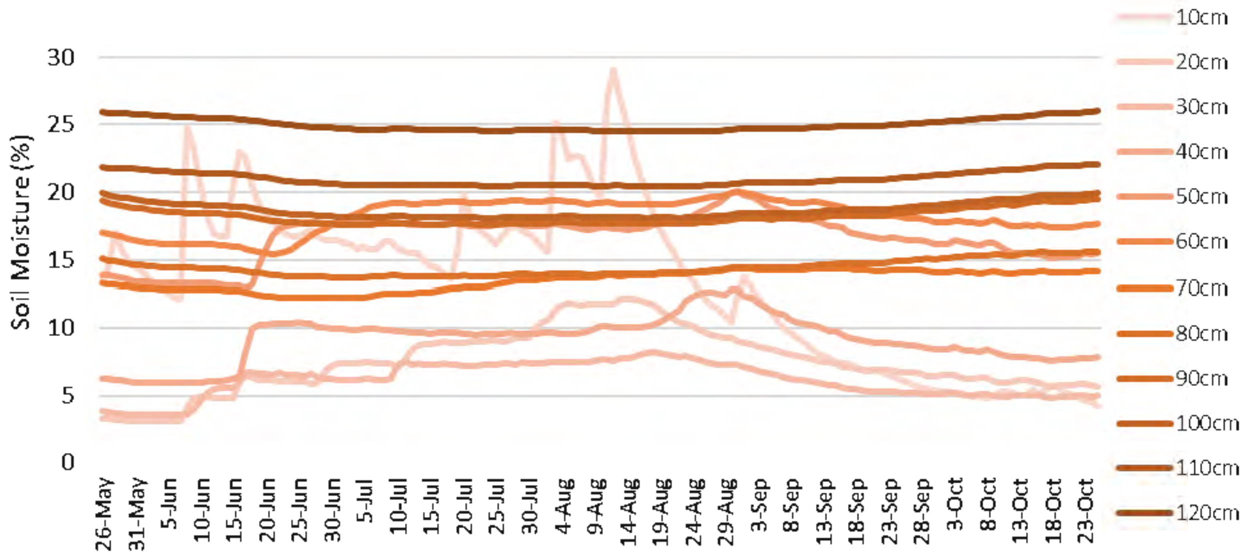

Figure 6: Soil moisture probe data from nil treatment plot, measured at 10cm intervals, at Warnertown, 2018.

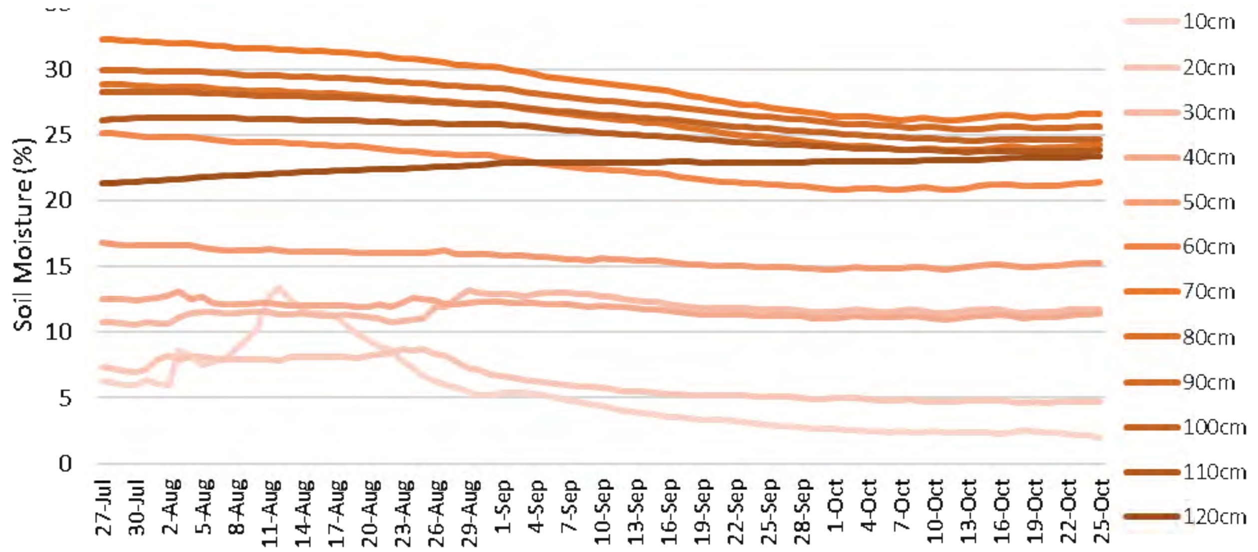

Figure 7: Soil moisture probe data from half field capacity treatment plot, measured at 10cm intervals, at Warnertown, 2018.

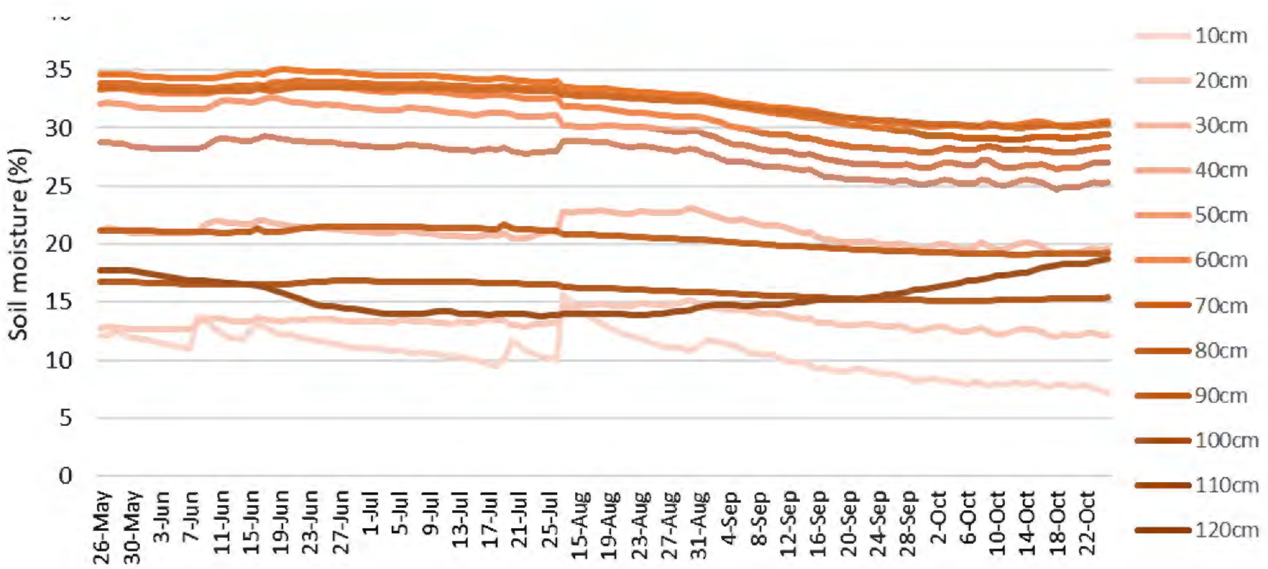

Figure 8: Soil moisture probe data from field capacity treatment plot, measured at 10cm intervals, at Warnertown, 2018.

Results and Interpretation

Biomass yield differences were observed between each soil moisture treatment, with the highest biomass yield under full soil capacity conditions (Figure 9). There was a 29% reduction in biomass yield from the half field capacity treatment and a 64% reduction in biomass yield from the nil treatments, compared to full soil capacity. Stored soil moisture level had no impact on the overall grain quality of the harvested lentil.

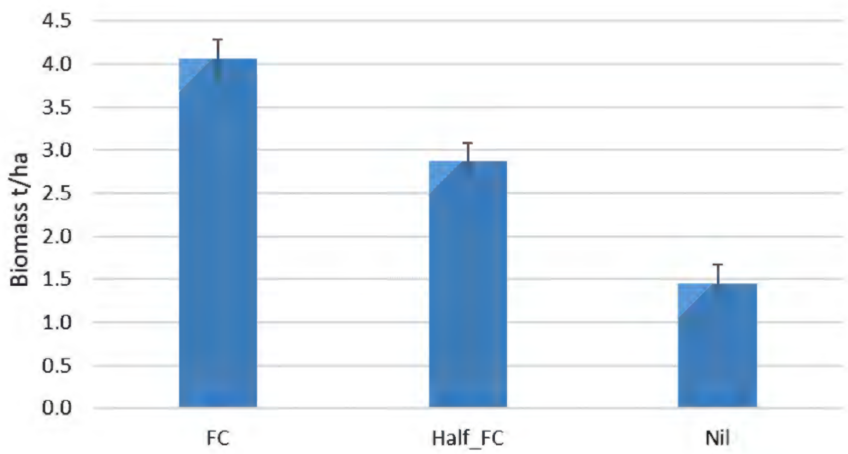

Figure 9: Biomass yield response to soil moisture treatments at Warnertown, 2018. FC = field capacity, half_FC = half field capacity. Error bars represent least significant difference (0.433, $P<0.05$).

PBA Jumbo2 was higher yielding than PBA Hurricane XT for all soil moisture treatments (Figure 10). PBA Jumbo2 has improved early vigour over PBA Hurricane XT, and is the highest yielding red lentil currently commercially available in Australia. At field capacity, PBA Jumbo2 yielding 1.45 t/ha, 59% higher than PBA Hallmark XT. PBA Jumbo2 under half field capacity conditions yielded 0.99 t/ha and was found to be statistically indifferent to PBA Hurricane XT under field conditions. PBA Jumbo2 has a considerable yield advantage over the commonly grown variety PBA Hurricane XT. It is important to note that XT herbicide tolerant lentil incur a grain yield penalty of approximately 5%.

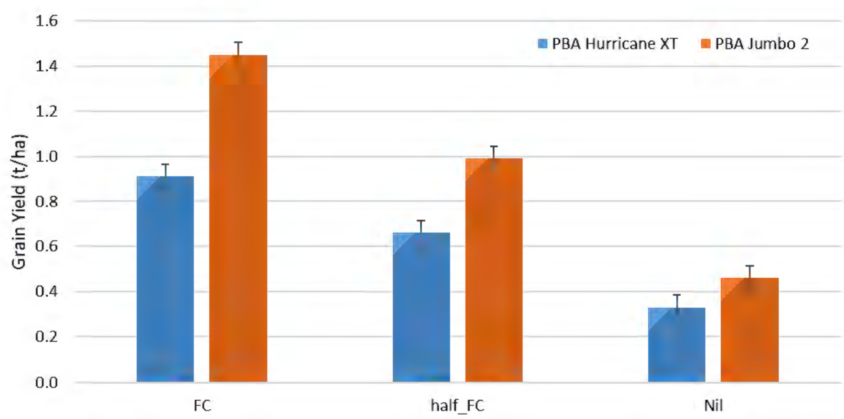

Figure 10: Grain yield interaction between lentil variety and soil moisture treatments at Warnertown, 2018. FC = field capacity, half_FC = half field capacity. Error bars represent least significant difference (0.111, $P<0.05$).

Lentil stubble management, LRZ Upper Mid North (Warnertown), South Australia

Aim

To identify optimum stubble management strategy for maximizing profitability and performance of lentil in the southern low rainfall zone.

Key Messages

Retaining standing stubble improved grain yield response over slashing and removal of stubble, at Warnertown, 2018.

Treatments:

Standing stubble
Slashed stubble
Removed stubble

Table 4. Site details, Warnertown SA 2018.

Sowing Date	15 May 2018
Plant Density (plants/m^2)	120
Row Spacing (cm)	23
Fertiliser (kg/ha)[1]	80

Results and Interpretation

Normalised difference vegetation index (NDVI) values recorded during the growing season showed improvements in vigour in both standing and slashed stubble treatments over the removed stubble (data not shown). However, slashed and removed stubble treatments had a similar grain yield response and early NDVI indicated that improved vigour did not necessarily convert to improved yield. Slashed and removed stubble treatments were 34% and 39% lower yielding than the standing stubble treatments, respectively (Figure 11). PBA Jumbo2 was higher yielding than PBA Hurricane XT (Figure 12). No interaction between variety and stubble treatment was observed, but it is clear that the variety choice and stubble treatment both had a significant impact on lentil yield at Warnertown.

We observed a greater level of pod loss in the removed and slashed stubble treatments than in the standing treatment (Figure 13). This is likely due to the added wind protection from the standing stubble preventing pod loss and shattering. Variety choice had no influence on pod loss in the trial, and both PBA Hurricane XT and PBA Jumbo2 are rated as moderately resistant to pod loss and resistant to shattering at maturity.

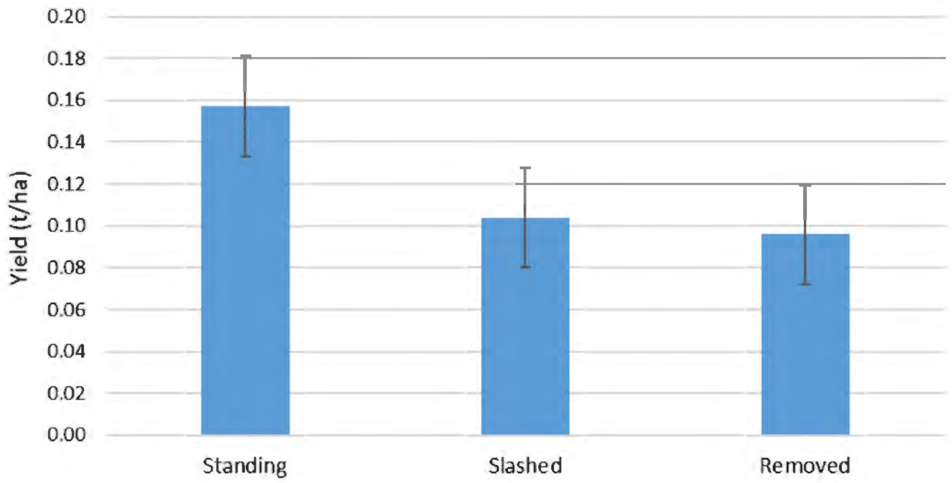

Figure 11: Grain yield response of lentil to stubble treatments, at Warnertown 2018. Error bars represent least significant difference (0.048, P<0.05).

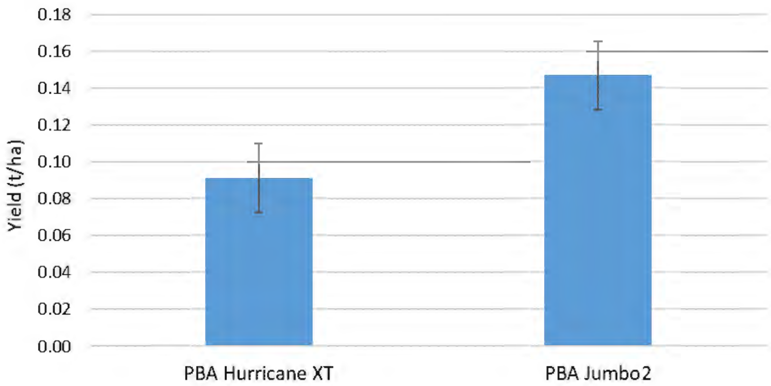

Figure 12: Grain yield response to lentil variety, at Warnertown 2018. Error bars represent least significant difference (0.037, P<0.05).

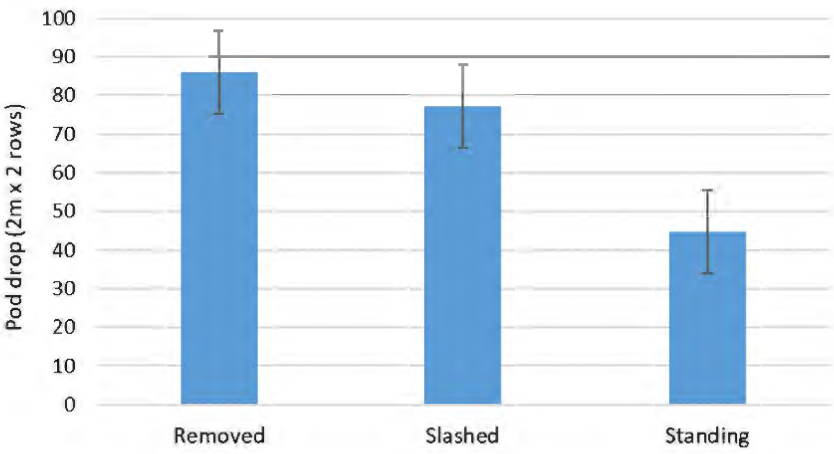

Figure 13: Pod drop response of lentil to stubble treatments, at Warnertown 2018. Error bars represent least significant difference (21.5, P<0.05).

Lentil time of sowing, LRZ Upper Mid North (Warnertown), South Australia

Aim

To determine optimum time of sowing (TOS) for maximum yield benefits and limited grain quality penalties for PBA Hurricane XT and PBA Jumbo2 lentil.

Key Messages

- PBA Jumbo2 showed significant yield improvement over PBA Hurricane XT in the low rainfall environment at Warnertown in 2018.
- Mid-April sowing resulted in higher grain yield and fewer wrinkled seed coats than May sowing for both PBA Hurricane XT and PBA Jumbo2. However, the percentage of lentil screenings less than 2mm was higher with earlier sowing of lentil.

Table 5. Time of sowing treatment dates and varieties included in the trial.

Sowing Date TOS 1:	18th April 2018
TOS 2:	1st May 2018
TOS 3:	15th May 2018
Variety	PBA Hurricane XT PBA Jumbo2

Table 6. Site details, Warnertown SA 2018.

Plant Density (plants/m^2)	120
Row Spacing (cm)	23
Fertiliser (kg/ha)[1]	80

Results and Interpretation

At time of sowing one (TOS 1) PBA Jumbo2 yielded 109% higher than PBA Hurricane XT (Figure 14). At times of sowing two and three (TOS 2 and TOS 3), there was no significant difference in grain yield response between the two varieties. Grain yield of PBA Hurricane XT in TOS 1 was 35% higher than TOS 2, while grain yield of PBA Jumbo2 TOS 1 was 245% higher than TOS 2.

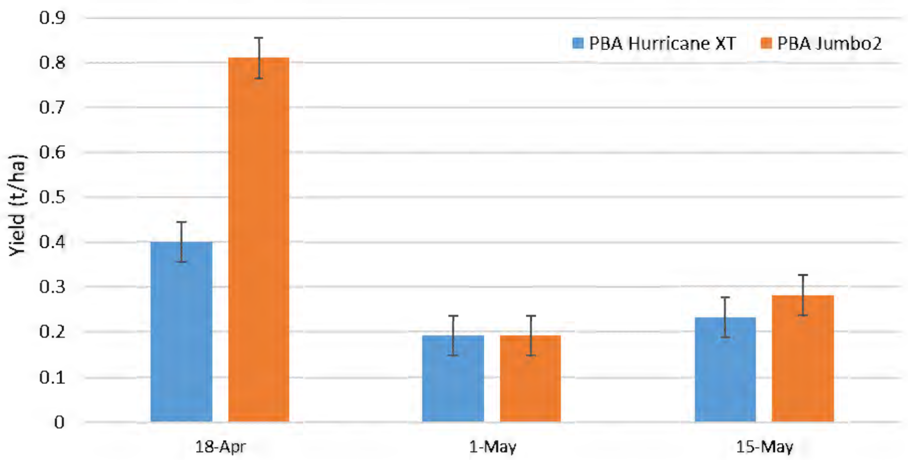

Figure 14: Grain yield response of lentil varieties, PBA Jumbo2 and PBA Hurricane XT, at three times of sowing, at Warnertown in 2018. Error bars represent least significant difference (0.090, P<0.05).

Grain quality assessments indicated a time of sowing effect on percentage screenings less than 2mm (Figure 15) and wrinkled seed coat (Figure 16). Early sowing was found to have significantly less wrinkled seeds per sample than later sowing times. However, later sowing had a significantly lower percentage of screenings per sample. To achieve lentil receival Grade 1 the total defective seed, which includes screenings less than 2mm and wrinkled coat, must be less than four percent. Combined percentage of wrinkled seed coat and screenings indicate that lentil from TOS 1 and TOS 2 would be rejected for Grade 1, but accepted as Grade 2. Only TOS 3 had a low enough percentage of defective seeds to be accepted for Grade 1. TOS 1 resulted in a much higher grain yield response in lentil. However, grain quality was improved with later sowing.

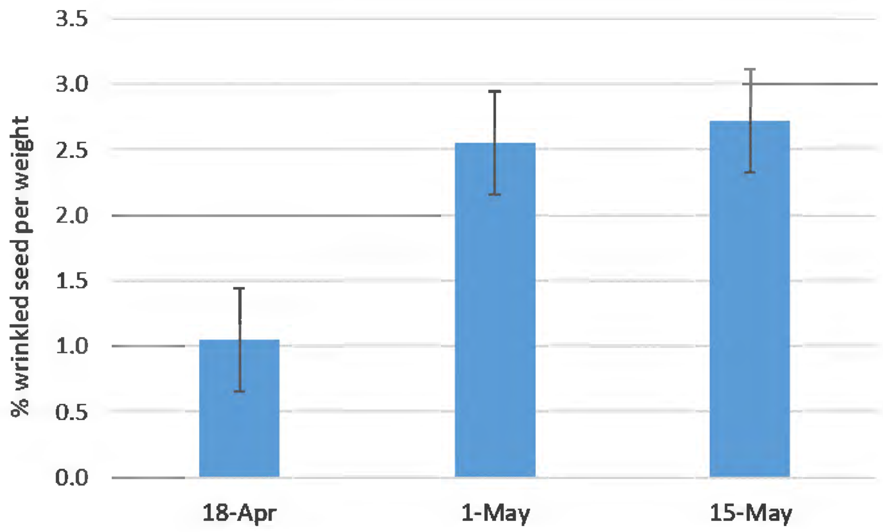

Figure 15: Percentage by weight of seed with wrinkled seed coat in response to time of sowing. Error bars represent least significant difference (0.786, P<0.05).

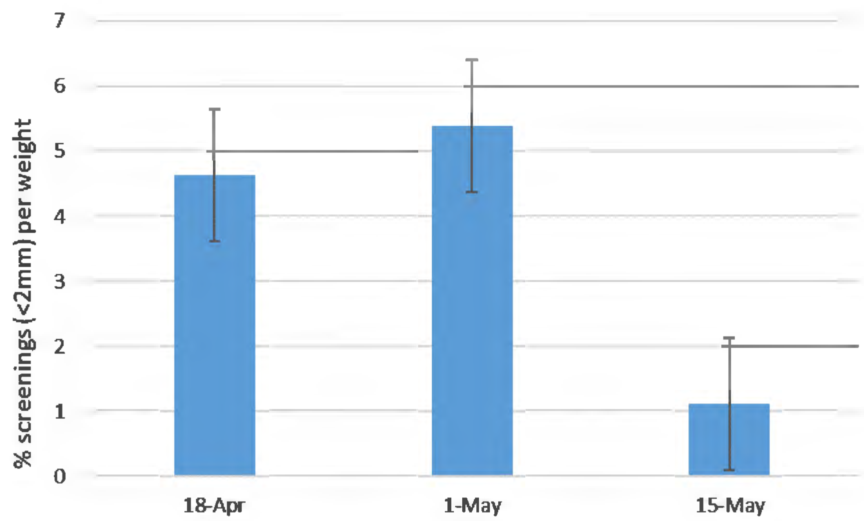

Figure 16: Percentage by weight of screenings less than 2mm in response to time of sowing. Error bars represent least significant difference (2.034, P<0.05).

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Strengthening the grower group network in South Australia to deliver RD&E

Executive Summary

Dr Jay Cummins

The importance that local farming systems groups linked to the Ag Excellence Alliance (AgEx) play within their local communities has long been recognised in terms of supporting farmer practice change. The role of the groups is to assist in providing access to the latest research findings and validating/adapting this information to suit local farming conditions. A research study commissioned by the Agricultural Excellence (AgEx) Alliance network (with additional funding provided by PIRSA) was undertaken for the purpose of identifying how such groups and networks can best operate in a sustainable manner. Outcomes from the study were directed as follows;

1. Develop a better understand the unique characteristics and functions of each grower groups (including the benefits, challenges and opportunities), as well as strengths and weaknesses.
2. Understand what groups value most in terms of their activities and functions, and what characteristics should carry forward into the future.
3. Identify the future needs of the grower group networks (from technical, training and coordination/management perspectives) to help enhance overall performance and impact.

There were three phases to the study; phase one involved undertaking focus group studies across the AgEx grower group network; phase two comprised an on-line member feedback survey and phase three involved seeking feedback relating to interim study findings and recommendations from the Project Steering Committee and attendees at the annual AgEx Forum.

Focus group discussions conducted across 18 farming systems groups associated with the AgEx Alliance identified the following challenges and attributes;

1. The extension environment is rapidly changing as responsibility shifts from the government sector to industry groups and farming systems groups themselves.
2. The impact of reduced government funding has impacted significantly upon the Agricultural Bureau network of SA (ABSA), with some groups falling into recession, and the perception amongst some farmers that the network has lost its relevance to meeting the needs of farmers (who were now largely members of other farming systems groups).
3. Developing an understanding of the profile of the characteristics of farmer members of the various farming systems groups (farmer typologies, adoption behaviours) resulted in and identification of the future need to undertake targeted market segmentation approaches when designing projects and identifying how best to engage with farmers.

4. From the focus group discussions, it is evident that there is quite a variance in the level of understanding of farmer adoption processes and extension techniques. There is the need to adopt a far greater tactical approach to developing extension methodologies that will lead to on-farm change and adoption.
5. It is evident that often the extension process is oversimplified by groups, with the groups themselves often not fully understanding the complexity of the extension system, and the decision-making processes that farmers endure when contemplating adoption decisions.
6. In effect farmers will 'vote with their feet', since participation by farmers in any group network will be reflective of the perceived value of the activity, the relevance and the opportunity for farmers themselves to influence and direct the activities and be active participants.
7. All groups are facing increasing challenges to effectively communicate with their members, largely due to the overburden of information farmers are swamped with. Many groups consider that 'more is less' when it comes to holding events and activities for their members.
8. It is evident that the role and participation rates of women in the various farmer groups associated with the AgEx has not reached its' full potential by any means. Over time attitudinal shifts are required to achieve this; often this is generational change (as has been clearly demonstrated in the case of AGKI) whereby a younger cohort of farmers and farming women can be attracted to such farming systems groups.
9. Whilst a key endeavour for AgEx is to provide a platform for groups to work together cooperatively to access funding in joint projects, often this ideal 'goes by the wayside' with groups independently submitting applications in competition with one another. Further effort is required to build up trust and create a far greater spirit of cooperation so that there can be a higher degree of collaborative efforts.
10. From this study, it is evident that those farmers that are attracted to the group networks associated with AgEx member groups can be largely described as being innovative and progressive farmers who have a positive attitude towards their future as a farmer; carefully manage risk on farm, but are willing to invest in new technologies; are open to new ideas and technologies; openly share information and importantly are willing to invest a significant amount of time into supporting local group networks.
11. The various groups that make up AgEx Alliance provide a significant contribution to the 'social fabric' of local rural communities. Their contributions go far beyond serving as a farming systems group that focuses on on-farm research, development and extension. This is explained further.

It is important that these positive elements are capitalised upon. Providing further support and strengthening the network in the longer term will lead to significant benefits in terms of supporting change on-farm and assisting the industry and communities to become even more resilient.

It is evident that the most successful and progressive groups who participated in the study are characterised by sound governance and accountability, shared leadership, open communication, inclusion of younger farmers and both men and women in the management of their groups. There was also a strong sense of local presence and identity being considered to be an important characteristic that motivated participants to be engaged in local farming systems groups.

It is evident that building trust and transparency is an important element in ensuring future success for the AgEx Alliance. This builds up over time, through open and personal communication, which fortunately are key attributes that the members of the AgEx committee have. Additional resources should be directed towards initiating regular communication that is personal and inviting in nature.

Findings from the on-line member survey identified that the strength and benefits associated with the farming systems groups lies in their local relevance and ability to address local issues of importance to their membership base. Increasingly information accessed through social media platforms is becoming more popular amongst group members. There is no consolation however to the practical information contained in Crop Harvest Report booklets or physically attending group field day and training events.

The opportunity to apply a more progressive approach towards creating an environment for fostering on-farm innovation systems seems to be missing with many of the groups. Whilst many groups have successfully introduced a range of practices in recent years (soil water monitoring and moisture conservation, no-till and precision agriculture techniques to name a few), the majority of groups hold a very conservative view in terms of identifying specific opportunities that may be available that offer the potential to significantly increase on-farm productivity and profitability into the future.

There is the need to lift the vision of what potential there is for growers to increases in productivity and profitability and to identify emerging technologies and opportunities into the future. Part of this lies in setting higher yield targets and identifying the opportunities where innovation can play a role. There is an opportunity for AgEx to provide a facilitating role in this process, and so suitable intervention strategies need to be developed as a matter of high priority.

The methodologies adopted in the study were highly participatory in nature, and successfully engaged representatives from each of the farming systems groups. The focus group discussions provided the opportunity for groups to review and reflect their past achievements, their level of operations and impact and importantly identify how they can achieve greater impact in the work that they undertake. This in itself was an extremely valuable exercise, and coming out of this is the identified need to develop a review workshop process that groups can undertake on a periodic basis.

The study proved to be an extremely valuable process, allowing an independent review and assessment of 'where groups are at', and importantly provide recommendations in terms of how the group network can be further supported and strengthened. These aspects form the basis of the following recommendations arising from this study. It is important that these recommendations are prioritised and a plan for implementation is developed by the AgEx Committee, and where appropriate additional resources and support be identified to assist in the implementation of these.

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

Authors: Nigel Wilhelm[1], Peter Fisher[2], Chris Bluett[3] and Rebecca Mitchell[2]

Delivery Organisations: [1]SARDI, Minnipa Agricultural Centre; [2]Agriculture Victoria, Bendigo; [3]Australian Controlled Traffic Farming Association

Project Details: Application of Controlled Traffic Farming in the low rainfall zone.

UNFS is a project partner in the delivery of this project. Re-printed with permission from the EPARF Annual Summary 2018.

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

Key messages

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

Why do the trial?

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

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

How was it done?

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

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

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

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

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

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

What happened?

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

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

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

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

	Establishment (plants/m2)	Depth of seeding (mm)	Dry weight of shoots at tillering (t/ha)	Flowering biomass (t/ha)	Grain yield (t/ha)
Control	135	35	0.18	3.64	2.32
Single trafficking on dry soil	130	31	0.22	3.96	2.38
Single trafficking on wet soil	111	36	0.15	3.34	2.13
Multi trafficking on wet soil	118	39	0.14	3.09	2.19
Ripping	140	31	0.21	3.39	2.14
LSD (P=0.05)	*ns*	*ns*	*ns*	*ns*	*ns*

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

What does this mean?

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

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

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

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

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

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

Acknowledgements

Thanks to MAC farm staff for the implementation and management of the research site and to Ian Richter, Brett Hay and Naomi Scholz for undertaking the monitoring of crop performance and soil condition. GRDC is the major funder of this project, which is managed by the Australian Controlled Traffic Farming Association.

EPARF
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Subsoil Amelioration – Four years on

Authors**:** Stuart Sherriff and Sam Trengove, Trengove Consulting

Published: Hart Field Site Results Book 2018

Key Findings

- The application of high rates of chicken litter or synthetic fertiliser to the surface or subsoil (in 2015) did not increase grain yields in 2018 above the untreated controls.
- At the Hill River sites, the long-term cumulative grain yields over the four years were higher in response to the application of chicken litter or synthetic fertiliser amendments in 2015. This was mostly due to high wheat yields in 2016.
- Across seven trials in the Mid-North and Upper Yorke Peninsula there have been inconsistent yield responses from subsoil amelioration. The impact of season and crop type has also had a large effect on yield response.

Why do the trial?

Subsoil constraints are known to have a large impact on grain yields in the Mid-North of SA. Trials in other regions including south western Vic have reported large yield responses (up to 60% yield increase in 1st year) from treatments of deep ripping and deep placement of high rates (up to 20 t/ha) of chicken litter. The grain yield response is thought to be coming from increasing the plant available water holding capacity of these soils by improving the structure of the subsoil. Although the cost associated with implementing these treatments is high, with these reported yield gains it is possible to pay for the treatments in the first season.

How was it done?

Seven randomised complete block design trials with three replicates of the same eight treatments (Table 1) were established in March 2015. The trials were located in three different geographic areas including two near Clare at Hill River, two at Hart and three at Bute. At each location the trials were located on different soil types which are described below.

Table 1. Treatment list for the 7 subsoil manuring sites established in 2015.

Treatment	Nutrition	Ripping	Placement
1	Nil	No	Nil
2	Nil	Yes	Nil
3	20 t/ha chicken litter	No	Surface
4	20 t/ha chicken litter	Yes	Surface
5	20 t/ha chicken litter	Yes	Subsoil
6	3 t/ha synthetic fertiliser	No	Surface
7	3 t/ha synthetic fertiliser	Yes	Surface
8	3 t/ha synthetic fertiliser	Yes	Subsoil

Sites and soil types

Hart East	Calcareous gradational clay loam Subsoil constraint: High pH and moderate to high ESP below 30cm
Hart West	Calcareous loam Subsoil constraint: High pH, Boron and ESP below 30cm

Bute Northwest	Calcareous transitional cracking clay Subsoil constraint: High pH, Boron and ESP below 30cm
Bute Mid	Calcareous loam Subsoil constraint: High pH, Boron and ESP below 60cm
Bute Southeast	Grey cracking clay with high exchangeable sodium at depth Subsoil constraint: High pH, Boron and ESP below 30cm
Hill River East	Black cracking clay
Hill River West	Loam over red clay Subsoil constraint: Moderate ESP below 60cm and moderate Boron below 90cm

Plot size	2.5 m x 12.0 m
Seeding date	Hill River: 18th April Hart: 30th May Bute: 2nd May
Main treatments applied in 2015	As per treatment list (Table 1)
2018 crop and annual fertiliser	Hill River: 1.9 kg/ha 45Y91, 100 kg/ha 28:13 kg/ha IBS + 2 t/ha chicken litter and 1 t/ha gypsum pre seeding + 80 kg/ha urea 2nd July + 100 kg/ha Urea 27th July Hart: 70 kg/ha Commander barley, 100 kg/ha DAP + 65 kg/ha Urea 25th July Bute Mid: 90 kg/ha Trojan wheat, 90 kg/ha DAP + 50 kg/ha Urea 19th July Bute SE: 90 kg/ha Trojan wheat, 80 kg/ha DAP Bute NW: 80 kg/ha Mulgara oats, 80 kg/ha DAP

The initial treatments (Table 1) were established prior to sowing in 2015. Ripping and subsoil treatments were applied with a purpose built trial machine loaned from Victoria DPI. The machine is capable of ripping to a depth of 600mm and applying large volumes of product to a depth of 400 mm. Chicken litter was sourced from three separate chicken sheds for ease of freight, the average nutrient content is shown in Table 2. After the treatments were implemented the plots at all sites were levelled using an offset disc. Since 2015 only seed and district practice fertiliser rates have been applied to all plots.

In 2018 the Hart sites were sown with narrow points and press wheels on 250 mm spacing. The Bute sites were sown using a concord seeder on 300mm spacing with 150 mm sweep points and press wheels and at Hill River the sites were sown using parallelogram knifepoint and press wheel seeder on 250 mm spacing.

The rate of chicken litter (20 t/ha) used in these trials was based on the rate being used in south western Victoria where the large yield responses had been observed. To assess if responses to chicken litter were attributed directly to the nutrition in the chicken litter, the 3 t/ha synthetic fertiliser treatment was designed to replicate the level of nutrition that is found in an average analysis of 20 t/ha of chicken litter. This treatment was made up of 800 kg/ha mono ammonium phosphate (MAP), 704 kg/ha muriate of potash (MoP), 420 kg/ha sulphate of ammonia (SoA) and 1026 kg/ha urea.

Measurements in 2018 include grain yield and quality at the Hart and Hill River sites and grain yield and quality at the Bute Mid and NW sites and hay yield at the Bute SE site.

Table 2. Average nutrient concentration from three chicken litter sources used in subsoil manuring trials established in 2015.

Nutrient		Nutrient concentration dry weight	Moisture content	Nutrient concentration fresh weight	Kg nutrient per tonne fresh weight
N	Nitrogen	3.8 %	8%	3.50 %	35.0
P	Phosphorus	1.72 %		1.58 %	15.8
K	Potassium	2.31 %		2.13 %	21.3
S	Sulfur	0.55 %		0.51 %	5.1
Zn	Zinc	0.46 g/kg	8%	0.42 g/kg	0.4
Mn	Manganese	0.51 g/kg		0.47 g/kg	0.5
Cu	Copper	0.13 g/kg		0.12 g/kg	0.1

Results

Hill River sites

Canola grain yield at the East site (brown cracking clay) averaged 1.9 t/ha. There were no significant treatment effects.

At the West site (loam over red clay), treatment differences were only significant at the 10% level (Table 2) where there was an 8.5% reduction in grain yield as a result of deep ripping. There was no consistent effect of nutrition, either chicken litter or synthetic fertiliser, on grain yield.

Table 2. Canola grain yield and quality for Hill River West subsoil amelioration trial in 2018.

Treatment	Chicken litter (t/ha)	NPKS	Ripping	Grain yield (t/ha)	Oil (%)	Protein (%)
1	0	No	None	1.97	44.0	20.9
2	0	No	Deep rip	1.84	43.5	22.0
3	20	No	None	1.95	41.5	23.2
4	20	No	Deep rip	1.94	41.9	23.2
5	20	No	Deep rip & place	1.88	41.6	23.2
6	0	3t/ha combo	None	2.07	43.2	21.9
7	0	3t/ha combo	Deep rip	1.71	42.2	22.7
8	0	3t/ha combo	Deep rip & place	1.77	42.4	22.5
LSD (0.10)				0.20	1.5	1.3

Bute sites

In 2018 the Bute NW site was sown to Mulgara oats for a seed crop and the Mid and SE sites were sown to Trojan wheat. Due to frost damage the SE site was cut for hay.

In-season NDVI of the Bute NW site (September) showed a reduction in plots that were deep ripped in 2015, excluding plots treated with chicken litter on the surface. This trend continued to grain yield where all plots that were ripped were lower yielding. Plot yields of treatments applied to the surface or the subsoil were equal.

The Bute Mid site was the highest yielding trial with grain yields ranging from 3.67 to 3.93 t/ha. Green seeker NDVI indicated that there was a significant nutrition response, with the highest values coming from the chicken litter treatments. In this trial ripping did not have an impact on grain yield. Placement of

Table 3. NDVI, Grain yield and quality for the Bute Northwest and Mid subsoil amelioration sites 2018.

Nutrition	Ripping	Placement	Bute NW Oat			Bute Mid Wheat		
			NDVI 5th Sept	Grain yield (t/ha)	Protein (%)	NDVI 5th Sept	Grain yield (t/ha)	Protein (%)
Nil	None	Nil	0.87	2.16	14.2	0.76	3.77	11.5
Nil	Yes	Nil	0.84	1.43	14.4	0.76	3.77	12.2
20 t/ha chic. lit.	None	Nil	0.87	1.66	15.1	0.84	3.87	14.5
20 t/ha chic. lit.	Yes	Surface	0.87	1.17	15.0	0.81	3.90	14.4
20 t/ha chic. lit.	Yes	Subsoil	0.86	1.15	15.3	0.80	3.67	13.9
3 t/ha syn. fert.	None	Nil	0.87	2.03	14.5	0.80	3.93	13.7
3 t/ha syn. fert.	Yes	Surface	0.85	1.45	15.0	0.79	3.77	13.9
3 t/ha syn. fert.	Yes	Subsoil	0.85	1.21	14.9	0.79	3.70	14.2
LSD (0.05)			*0.02*	*0.36*	*0.5*	*0.02*	*0.16*	*0.6*

nutrition in the subsoil did result in lower yields than when applied to the surface. As expected, and for other sites, protein was elevated in the nutrition treatments, with chicken litter yield responses being slightly higher than those from the synthetic fertiliser.

Due to frost, the Bute SE site was cut for hay. NDVI in September indicated higher biomass in the chicken litter treatments when applied to the surface with a smaller response from the synthetic fertiliser. Hay yield responses were similar to the NDVI but were less significant.

Table 4. Greenseeker NDVI and hay yield for the Bute south east subsoil amelioration site 2018.

Nutrition	Ripping	Placement	Bute SE Wheat hay NDVI 4th Sept	Bute SE Wheat hay Hay yield (t/ha)
Nil	None	Nil	0.57	3.4
Nil	Yes	Nil	0.50	3.0
20 t/ha chic. lit.	None	Nil	0.63	3.6
20 t/ha chic. lit.	Yes	Surface	0.60	3.7
20 t/ha chic. lit.	Yes	Subsoil	0.53	3.2
3 t/ha syn. fert.	None	Nil	0.61	3.4
3 t/ha syn. fert.	Yes	Surface	0.56	3.5
3 t/ha syn. fert.	Yes	Subsoil	0.54	3.3
LSD (0.05)			*0.05*	*0.5*

<u>Hart Sites</u>

At the Hart West site, the application of 20 t/ha chicken litter (applied in 2015) resulted in a 34% reduction in barley grain yield when it was applied to the surface (Table 5). When placed in the subsoil the yield reduction was smaller. The synthetic fertiliser applied at the same time did not reduce grain yields. Although protein responses were only significant at the 10% level there is a trend showing plots treated with some form of nutrition had elevated protein. As per the grain yield, retention was reduced when chicken litter was applied to the surface and screenings were elevated. Ripping had little effect on the grain yield or quality at this site.

At the Hart East site, grain yields were lower, averaging 0.54 t/ha, potentially due to the effects of wide spread frost in the region given its lower elevation. However, there were similar levels of yield reduction (45%) when the chicken litter was applied to the surface. As expected, protein was elevated as a result of application of either chicken litter or synthetic fertiliser. Test weight was significantly reduced with the application of chicken litter to the surface. Grain size was generally reduced by application of either amendment.

Table 5. Grain yield and quality for the Hart subsoil amelioration sites 2018.

Nutrition	Ripping	Placement	Hart West Grain yield (t/ha)	Hart West Protein (%)	Hart West Retention (%)	Hart West Screenings (%)	Hart East Grain yield (t/ha)	Hart East Protein (%)	Hart East TW (kg/hL)	Hart East Retention (%)	Hart East Screenings (%)
Nil	None	Nil	1.31	16.7	85.7	1.5	0.83	18.7	62.9	79.0	6.1
Nil	Yes	Nil	1.12	18.2	82.9	2.0	0.75	19.7	61.9	67.2	9.1
20 t/ha chic. lit.	None	Nil	0.86	20.6	76.0	3.0	0.46	20.9	59.4	54.2	13.8
20 t/ha chic. lit.	Yes	Surface	0.76	19.9	74.1	3.3	0.30	22.4	59.4	44.6	17.2
20 t/ha chic. lit.	Yes	Subsoil	1.07	19.3	83.2	1.9	0.55	21.2	62.5	55.4	11.2
3 t/ha syn. fert.	None	Nil	1.08	19.3	83.6	2.0	0.60	20.5	61.3	64.3	9.3
3 t/ha syn. fert.	Yes	Surface	0.98	19.5	82.2	2.3	0.44	21.6	61.8	49.9	12.2
3 t/ha syn. fert.	Yes	Subsoil	1.06	19.1	82.8	2.0	0.39	21.4	61.5	47.1	14.7
LSD (0.05)			*0.30*		*4.0*	*0.8*	*0.19*	*1.3*	*1.4*	*12.7*	*4.2*
LSD (0.10)				*0.20*							

Summary and discussion for 2018

Ripping effects were either not significant or detrimental to yields at all sites. At Hill River there was little impact from the application of either chicken litter or synthetic fertiliser and ripping reduced yield at one site. At the Bute sites, there was a reduction in hay and grain yield at two of three sites as a result of ripping. Hart sites had a greater negative response from chicken litter than the synthetic fertiliser and ripping also resulted in lower yields. These results suggest that the effects of the synthetic fertiliser are diminishing in comparison to the chicken litter. This indicates a slower release and longer lasting effect from the chicken litter, albeit a negative effect in 2018.

Given the significant investment in treatments of this nature, it is important to look at the long-term responses from soil amelioration. Figures 1 – 3 show cumulative grain yields for the seven sites from 2015 until 2018. These graphs show that the nutrition response at the Hill River sites in the high yielding season of 2016 caused the main differences in cumulative yield. At these two sites therehas been little or no response to ripping or the placement position of the amendment. At other sites (Hart and Bute) most of the responses to ripping or the addition of either amendment have been insignificant or negative when compared to the nil treatment (T1).

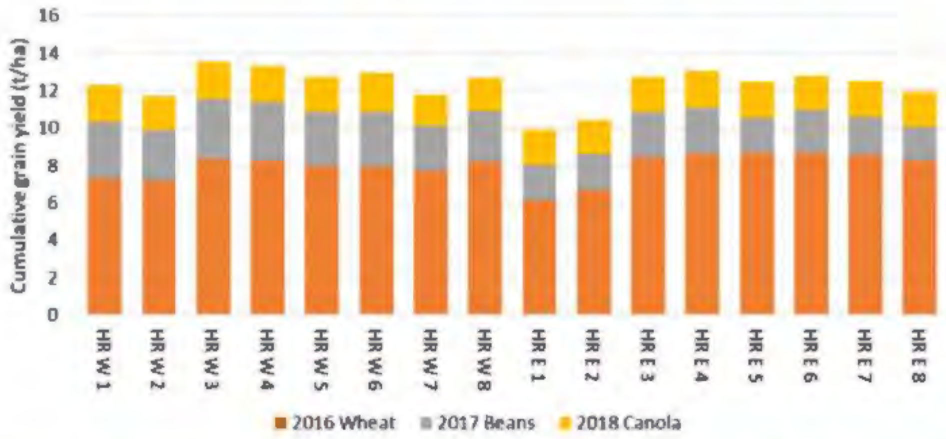

Figure 1. Cumulative grain yield (t/ha) for the Hill River subsoil amelioration sites from 2016 to 2018. LSD (0.05) for Hill River West (HR W) = 0.9 and Hill River East (HR E) = 0.9. For treetments see Table 1.

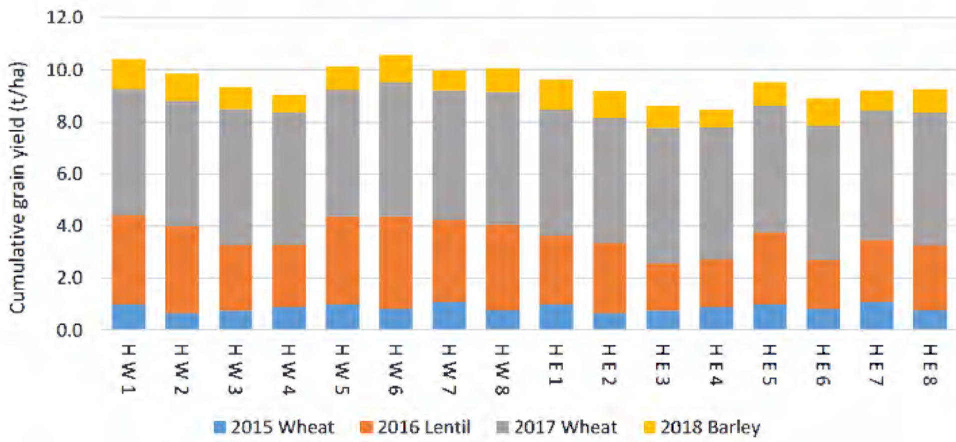

Figure 2. Cumulative grain yield (t/ha) for the Hart subsoil amelioration sites from 2015 to 2018. LSD (0.05) for Hart West (H W) = 0.9 and Hart East (H E) = 0.7. For treatments see Table 1.

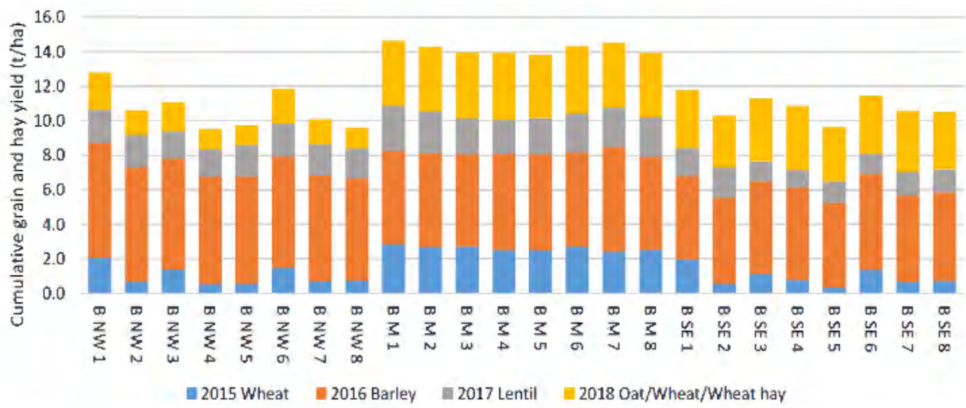

Figure 3. Cumulative grain and hay yield (t/ha) for the Bute subsoil amelioration sites from 2015 to 2018. In 2018 NW was oats, Mid was wheat and SE was wheat hay. LSD (0.05) for Bute north west (B NW) = 0.7, LSD (0.10) for Bute mid (B M) = 0.7 and Bute south east (B SE) = 0.7. For treatments see Table 1.

Chicken litter effects on lentils

Lentil grain yields at Hart in 2016 and Bute in 2017 were reduced by an average of 29% and 23% respectively in response to chicken litter applied to the surface (Figure 4). This reduction was initially thought to be from high biomass production, resulting in higher levels of disease. However, observations throughout the growing season at Bute indicated similar disease levels throughout all treatments. It is not clear why the synthetic fertiliser applied to the surface did not have the same negative impact as chicken litter.

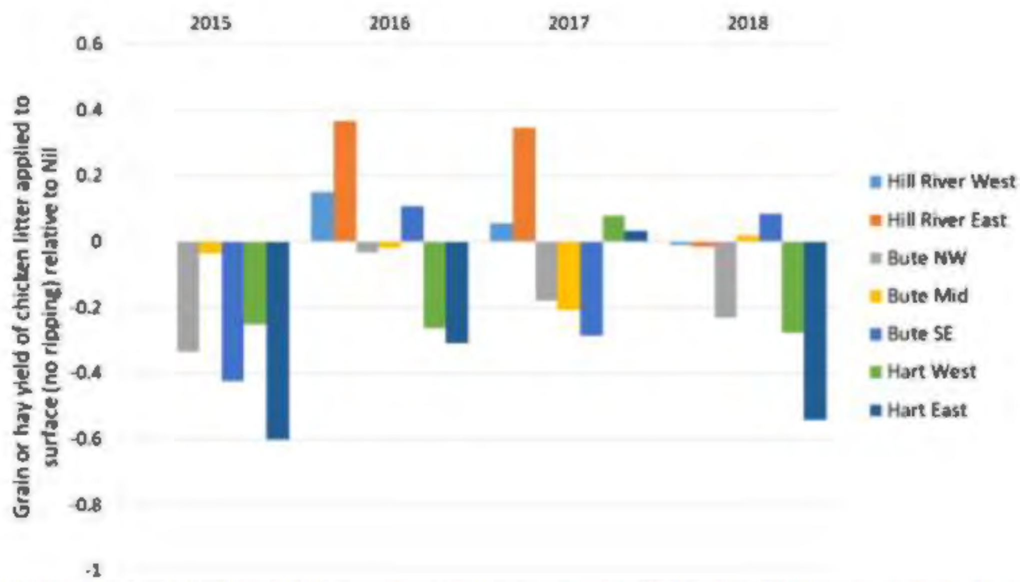

Figure 4. Grain and hay yield response of surface applied chicken litter (20 t/ha) relative to the nil treatment for subsoil manuring sites 2015 – 2018.

Deep ripping effects

Although generally not significant over the four years, the response to deep ripping alone was slightly negative at all but the Hill River East site. The large yield reductions in 2015 of up to 72% were a result of poor establishment due to the cloddy seed bed in the first year. However in subsequent seasons, crop establishment was good.

Chicken litter placement effects

Deep placement of chicken litter improved yields at Hart in the dry years of 2015 and 2018 (Figure 6). The deep placement delayed crop access to the amendment and delayed crop response, effectively reducing the canopy size compared to surface placement. This delayed response and interaction with reduced early soil moisture use is thought to explain the response to deep placement. Deep placement of chicken litter also improved yields of lentils at Hart (2016) and Bute (2017) compared with surface application.

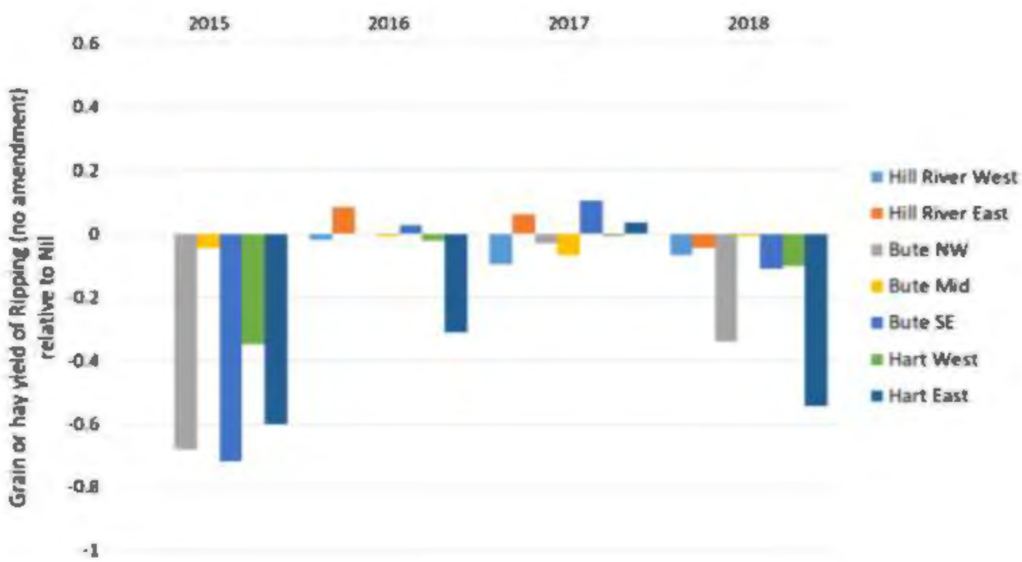

Figure 5. Grain and hay yield response to ripping in the absence of an ameliorant relative to the nil treatment for subsoil manuring sites 2015 – 2018.

This was due to surface application negatively effecting lentil yields rather than subsoil placement being positive. At the Hill River sites in 2016, when there was the greatest response to the application of an amendment, the depth of placement was not important (Figure 6). This indicates that the grain yield responses achieved at this site were likely due to increased nutrition and not amelioration of the subsoil.

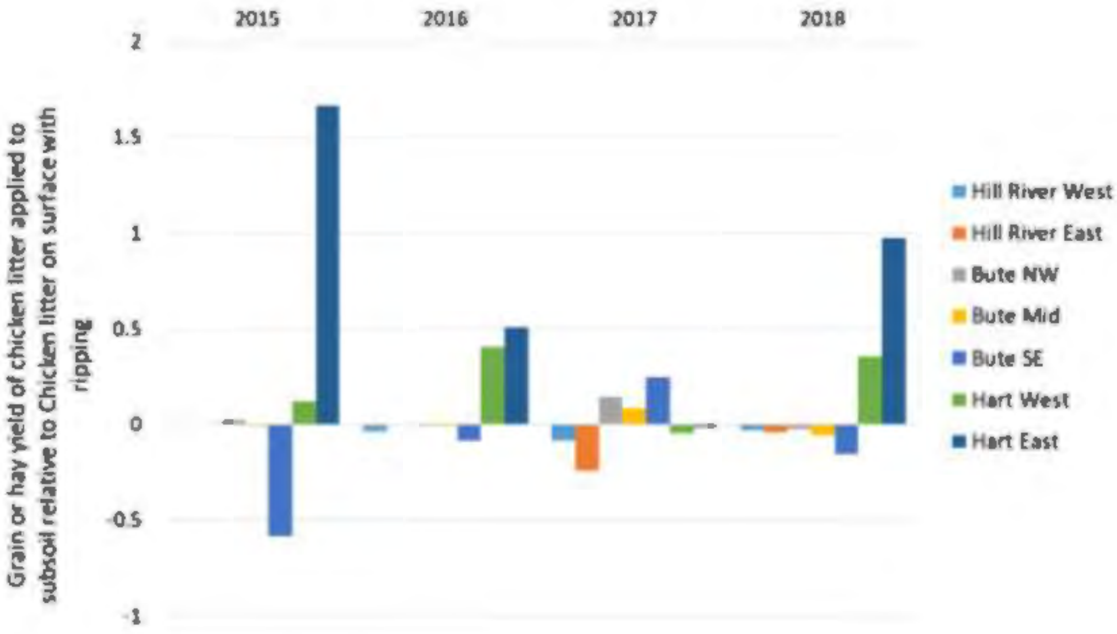

Figure 6. Grain and hay yield response to placing 20 t/ha of chicken litter in the subsoil relative to the placing 20 t/ha chicken litter on the surface for subsoil manuring sites 2015 – 2018.

Chicken litter vs. synthetic fertiliser

Grain and hay yields from synthetic fertiliser treatments applied to the surface have generally been equal or greater than that of the plots treated with chicken litter (Figure 7). The greatest difference in grain yields between these treatments was produced at the Hart West site and was 1.0 t/ha or 40%. This occurred in the lentil phase and can be attributed to yield reductions from chicken litter rather than yield increases from synthetic feritilser. A similar effect occurred at the

Figure 7. Grain and hay yield response of 3 t/ha of synthetic fertiliser applied to the surface relative to applying 20 t/ha of chicken litter to the surface, with no ripping, for subsoil manuring sites 2015 – 2018.

Bute sites in 2017. Other increases in grain yield from synthetic fertiliser compared to chicken litter may be attributed to; poorer emergence at Hart in 2015 as a result of toxic levels of fertiliser being applied to the surface resulting in reduced canopy and retained soil moisture for the end of the season. Because of the low yields at the Hart sites in 2018, the large relative differences are only 0.23 and 0.24 t/ha for the East and West sites respectively.

Figure 7 is a photograph of a soil pit at the Hart West site showing how the 20 t/ha chicken litter appears to have changed little from when it was placed there in 2015. This also indicates that there has been little amelioration of the subsoil. Soil pits at other sites have not been excavated.

Summary / implications

Subsoil amelioration using the method of ripping chicken litter or synthetic fertiliser into the subsoil has not led to increased grain yields at any of the seven sites set up in 2015. In most cases the ripping process required to place the amendment into the subsoil caused significant soil disturbance and resulted in reduced grain yields. The amendment itself applied either to the surface or at depth did increase yields significantly in the high yielding season of 2016 at the Hill River sites, but other than that most responses have been neutral or negative. Given these results undertaking these treatments on these soil types on a paddock scale is not recommended.

Acknowledgements

Trial co-operators Bill Trengove, Matt Dare and Craig Jaeschke, Vic DPI for loan of the subsoil manuring machine, Jim Maitland for providing chicken litter at the Hart site and Australian Growers Direct for providing facilities for grain quality analysis.

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Figure 7. Subsoil applied chicken litter (20 t/ha) at the Hart West site. Photo taken on October 2018, after three years and seven months in the soil.

Managing Early Sown Long Season Wheats

Results from the Mid-North in 2018

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Project Delivery: Hart Field-Site Group [1], SARDI[2] and La Trobe University[3]

Project Details: Development of crop management packages for early sown, slow developing wheats in the Southern region' (ULA9175069).

Funded By: Grains Research and Development Corporation

Key Findings

- Winter wheats sown early (pre-April 20) were able to yield similar to Scepter sown in its optimal window.
- Different winter wheats are required for different environments.
- At Hart, the fast – mid developing variety Illabo has been the highest yielding winter wheat across two seasons.

Why do the trial?

The time at which wheat flowers is very important in determining yield. Crops that flower too early have increased risk of frost damage and insufficient biomass, while crops which flower too late have increased risk of high temperatures and water stress which can restrict grain formation and grain- filling. As autumn breaks are declining in frequency and magnitude in the southern grains region, and the size of farming enterprises are increasing, getting a wheat crop established so that it flowers during the optimal flowering period for peak yield can be difficult. However, an opportunity exists in South Australia to take advantage of stored moisture over the summer and rain events in March and April to start sowing crops earlier than what is currently practiced.

Over the last few decades wheat breeding efforts have focused on mid-fast developing spring varieties (for example Scepter) that need to be sown in the first half of May to flower during the optimal period (late September for Hart) for grain yield. Sowing earlier than April 20 requires winter varieties that are slower developing. The ability to sow wheat outside our traditional window opens up opportunities to improve whole farm yield and manage risk.

Breeders have responded to this change in farming system and are now developing material suited to earlier sowing. Previous research has shown that winter varieties (e.g. Wedgetail and Rosella) bred for NSW are not suited to SA conditions. This project compares performance of new winter wheats sown early compared to current spring benchmarks sown on time.

How was it done?

Location: Hart

Plot size	1.75 m x 10.0 m	**Fertiliser**	DAP (18:20) + 2% Zn @ 75 kg/ha UAN (42:0) @ 60 L/ha on 5th July UAN (42:0) @ 55 L/ha on 2nd Aug
Seeding date	20th March (irrigated) 3rd April (irrigated) 14th April (irrigated) 1st May		

Location: Booleroo Centre	Plot size	1.75 m x 10.0 m	Fertiliser	DAP (18:20) + 2% Zn @ 75 kg/ha
	Seeding date	21st March (irrigated) 4th April (irrigated) 18th April (irrigated) 2nd May (irrigated)		

At each location the trial was a split plot design with four replicates of nine varieties (Table 1) at four times of sowing. Where irrigation was required the equivalent of 10 mm rainfall was applied using dripper line in-furrow post-seeding to ensure germination. Fungicides and herbicides were applied as necessary to keep the canopy free of disease and weeds.

All plots were assessed for plant establishment, heading date, grain yield and quality (except Booleroo due to insufficient grain sample for processing).

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

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

HART RESULTS AND DISCUSSION

The trial was sown into marginal soil moisture after low summer and pre-seeding rainfall. To ensure germination would occur, the first three times of sowing were irrigated.

Plant establishment increased with seeding date from 102 plants/m2 in mid-March to 152 plants/m2 in early May (data not shown). All varieties performed similarly across the times of sowing, averaging 127 plant/m2. The only variety to have reduced plant establishment (99 plant/m2) was ADV15.9001. In other outputs of this project seeding rates of 50 and 150 plants/m^2 were compared. The main finding from this research was 50 plants/m2 was sufficient to allow maximum yields to be achieved (Porker et al. 2019). In general, there is no yield benefit from having plant densities greater than 50 plant/m2 for winter wheats.

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

Scepter was the fastest developing spring variety, yielding 2.4 t/ha when sown at its optimal time (early May). Slower developing springs (e.g. Trojan and Cutlass) generally performed best from sowing dates after mid-April and yielded less than the best performing winter varieties when sown prior to this date. The numbered line LPB14-0392 (very slow spring) performed well at Hart again this season however has been less stable in yield and flowering date compared to winter varieties in other experiments.

A number of winter wheats sown in mid-early April were able to yield as well as Scepter sown in early May. Both ADV15.9001 and Illabo had consistent grain yields of 2.3-2.4 t/ha (Table 2). Similar to 2017 Longsword flowered earlier compared to Illabo and did not achieve the same yields (Figure 1). Longsword however, has performed well in lower rainfall areas such as Loxton and Minnipa. Both Kittyhawk and DS Bennett performed well at Hart under tough seasonal conditions but based on flowering date are slightly later than required for the Hart environment (Figure 1).

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

Grain protein levels range from 8.1 – 13.1% across all varieties and time of sowing. Changes in grain protein were generally attributed to yield dilution effects (lower yield=higher protein). DS Bennet contained the lowest protein level of all varieties, averaging 8.8% across all times of sowing. In general, majority of varieties and times of sowing were able to achieve a minimum test weight of 76 kg/hL (minimum level for AH and APW classification). In particular, Kittyhawk consistently had the highest test weight (>79 kg/hL) across all varieties.

Table 2. *Grain yield and quality for all wheat varieties at different times of sowing at Hart in 2018. Treatments shaded in grey and not significantly different from the highest treatment.*

Variety	Mar 20th	Apr 3rd	Apr 17th	May 1st	Mar 20th	Apr 3rd	Apr 17th	May 1st
	Grain yield (t/ha)				Protein (%)			
Scepter	1.3	1.8	2.1	2.4	12.5	12.2	11.9	9.5
Trojan	1.5	1.9	2.1	2.0	12.8	12.0	11.0	10.5
Cutlass	2.0	2.4	2.4	2.3	11.0	9.8	9.8	10.2
LPB14-0392	2.2	2.4	2.5	2.0	11.1	10.2	10.3	11.0
Longsword	1.8	2.2	2.0	1.9	13.1	11.8	12.2	11.8
ADV15.9001	2.3	2.4	2.3	2.1	9.7	9.3	9.1	9.3
Illabo	2.0	2.3	2.4	1.9	11.8	10.6	10.5	11.1
Kittyhawk	2.0	2.1	2.1	1.6	10.2	10.0	10.5	11.4
DS Bennett	1.9	1.9	2.2	1.5	8.5	8.8	8.1	9.9
LSD (P≤0.05)	0.24				1.1			
	Test weight (kg/hL)				Screenings (%)			
Scepter	75.1	75.7	76.9	78.9	2.9	2.6	3.1	3.4
Trojan	75.2	77.1	78.2	79.1	1.0	0.9	1.7	2.2
Cutlass	78.0	78.4	79.1	79.6	1.9	2.3	2.4	2.2
LPB14-0392	76.5	77.3	77.0	78.3	2.8	2.5	2.8	2.9
Longsword	76.5	78.0	77.4	78.6	1.0	0.7	0.8	1.2
ADV15.9001	76.9	77.9	77.7	78.5	3.2	2.7	3.1	2.7
Illabo	75.2	76.7	77.1	77.6	1.6	1.7	1.7	2.1
Kittyhawk	79.6	80.3	80.7	80.6	2.3	1.7	2.0	1.8
DS Bennett	78.0	78.1	79.1	78.7	3.7	3.6	3.7	3.5
LSD (P≤0.05)	1.1				0.5			

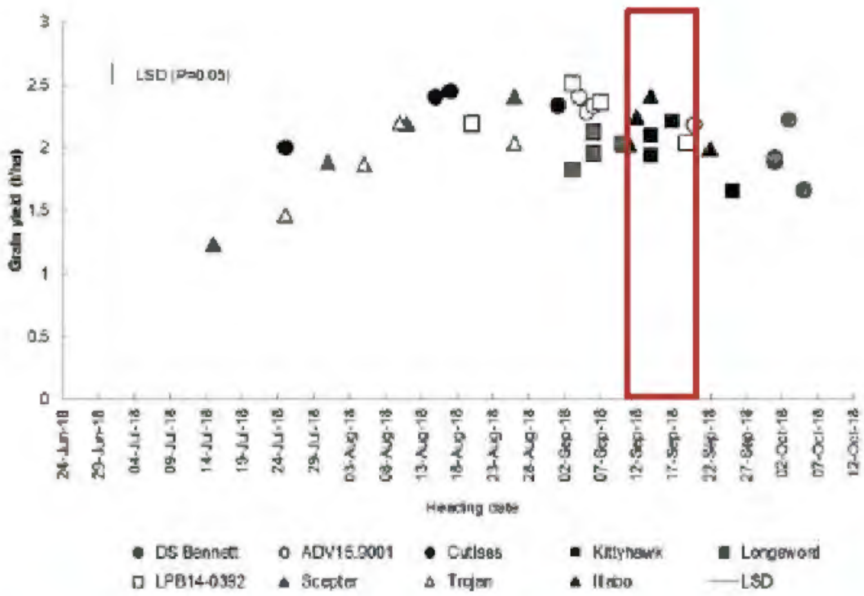

Figure 1. Average yield and heading date for all varieties and times of sowing. The red rectangle highlights the optimal flowering period for Hart.

There were some exceptions, particularly for treatments sown in mid-March. Screening levels across the trial were low, with all varieties falling below the 5% level (maximum level for maximum grade).

BOOLEROO RESULTS AND DISCUSSION

Achieving good plant establishment has been a challenge at Booleroo, particularly from March sowing dates. All four times of sowing were irrigated to achieve germination. Due to the lack of rainfall and high soil temperatures during March and April, times of sowing one and two appeared dead on the surface by the end of May. However, below the soil surface the coleoptile (section above the seed) remained alive (Figure 2) in the majority of plants. In early June the site received 30 mm across 10 days and many plants regenerated along with a secondary germination. At the final establishment count the plants populations were 67, 84, 111 and 136 plants/m2 across time of sowing one to four.

Figure 2. Plot of Scepter wheat sown 21st March (left) and plants removed from the plot (right) taken on 22nd May, 2018.

The regeneration of plants and death of the main stem had an interesting impact on phenology. For the spring varieties such as Scepter and Trojan it effectively pushed the 'reset button' due to the fact they were in the reproductive phase when severe moisture stress hit. This meant they restarted their lifecycle at the time of rain in early June. As a result across all times of sowing, Scepter flowered within 10 days of each other which was not expected (Figure 3). As observed in 2017, Scepter was the best performing variety within the trial at Booleroo ranging from 0.6 – 0.8 t/ha (Table 3). Both Trojan and Cutlass sown in early

May performed similar to Scepter.

Overall the research project has shown the fastest developing winter wheat Longsword has been the most consistent performing winter wheat in low yielding (<2.5 t/ha) sites such as Booleroo, Minnipa and Loxton. In 2018 Longsword was also the best performing winter wheat and yielded similar to Scepter sown in its optimal window highlighting the need for faster developing winter wheats for environments similar to Booleroo.

Table 3. Grain yield and quality for all wheat varieties at different times of sowing at Booleroo in 2018. Treatments shaded in grey and not significantly different from the highest treatment.

Variety	March 21st	April 4th	April 18th	May 5th
	Grain yield (t/ha)			
Scepter	0.74	0.79	0.64	0.71
Trojan	0.51	0.71	0.62	0.76
Cutlass	0.51	0.66	0.60	0.70
LPB14-0392	0.19	0.24	0.36	0.23
Longsword	0.42	0.64	0.61	0.57
Illabo	0.37	0.23	0.38	0.28
Kittyhawk	0.35	0.37	0.30	0.30
DS Bennett	0.28	0.27	0.15	0.23
ADV08.0008	0.24	0.30	0.29	0.28
LSD(P≤0.05)	0.15			

Within the current suite of winter wheats there are few varieties well adapted to Booleroo's environment. Across all of the early sown wheat experiments in SA, Booleroo has been the most challenging for winter wheat production. In 2017, Booleroo was the only site where winter wheats did not perform similar to Scepter and yielded 0.7 t/ha less.

Test weight, screenings and protein were not determined due to insufficient grain sample size for processing.

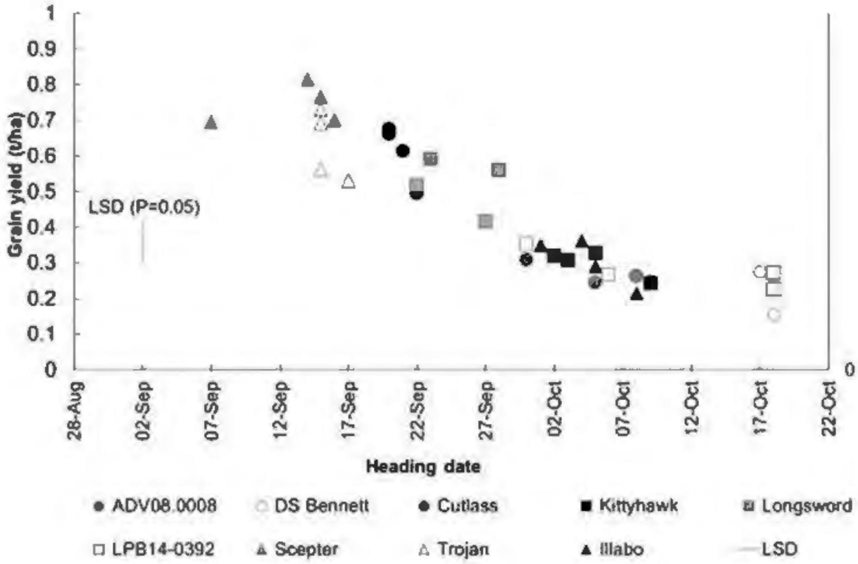

Figure 3. Average yield and heading date for all varieties and times of sowing at Booleroo Centre in 2018.

Summary

Across the entire project (eights sites in SA and VIC) the best performing winter wheat varieties depended upon yield environment, development speed and the severity and timing of frost / heat stress. In over 20 experiments the best performing winter wheat at each site was able to achieve yields similar to Scepter sown in its optimal window. The only exception to this was at Booleroo in 2017 where Scepter outperformed the winter wheats.

In environments greater than 2.5 t/ha, mid-slow developing wheat varieties were favoured for example Illabo at Hart. In environments less than 2.5 t/ha such as Booleroo the faster developing Longsword is favoured. However, the results for Booleroo have not consistently shown that winter wheats are suitable for this environment.

Acknowledgements

The authors thank GRDC for project funding 'Development of crop management packages for early sown, slow developing wheats in the Southern region' (ULA9175069). We also thank the SARDI Clare team for their assistance with trial management and the Booleroo host grower.

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Harvest weed seed collection in broad acre paddocks

Authors: Amanda Cook and Ian Richter

Delivery Organisation: SARDI Minnipa Agricultural Centre

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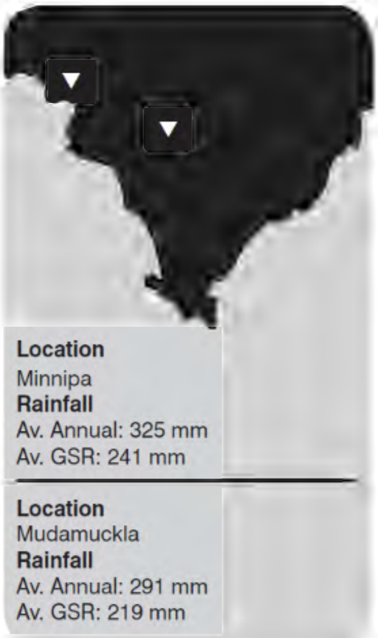
Eyre Peninsula
Agricultural Research Foundation Inc.



Key messages

- Harvest weed seed collection showed barley grass is harder to capture using harvest weed seed collection techniques due to its habit of shedding seed early.
- Burning windrows decreased the number of weed seeds present in the soil seedbank at Minnipa in 2017.
- Harvest weed seed collection allows for the capture of ryegrass weed seed and cereal screenings, potentially increasing feed utilisation for stock when placed in chaff dumps or rows.

Why do the demonstration?
Barley grass and ryegrass are the major grass weeds in cereal cropping regions on upper Eyre Peninsula. An integrated approach to weed management (IWM) is required to slow the development of herbicide resistance and aims to lower the weed seed bank with the use of non-chemical techniques such as harvest weed seed management, including narrow windrows, chaff cart dumps and burning stubble. This is a summary of paddock surveys of harvest weed seed collection samples taken in 2016, 2017 and 2018 as a part of the GRDC Stubble Initiative project 'Maintaining profitability in retained stubbles on upper Eyre Peninsula' (EPF00001).

How was it done?
Samples were collected post- harvest each season, with both soil and chaff samples taken to be assessed in weed seed trays during the following growing season. In- crop paddock monitoring for grass weed populations was undertaken and grass weeds were assessed at 10 GPS points along transects for weed density with six counts taken at each sample point.

Assessing weed seed capture and burning in narrow windrows
Soil samples for weed seed banks were collected in February 2017 along a transect across the paddocks comprising of 10 GPS-located sampling points. The core soil sampling method was described by Kleemann *et al.* (2014). Prior to narrow windrows being burnt, a 5 m section of chaff was removed (non-burnt area) within each paddock (see EPFS Summary 2015, p150-151 for further details) and weed seeds in soil or chaff were germinated in 2017. Germinating trays, 35 cm x 29 cm, were partially filled with sterilised soil mix and the collected weed seed bank soil or chaff was then spread over the top to 1 -2 cm depth, with another light coating of the sterilised soil mix spread over the soil or chaff. The trays were placed in a rabbit proof open area and watered if required during the season. Trays were assessed for weed germination approximately every four weeks. Counted weeds were removed from the trays. Control plots with barley grass seed collected from Minnipa Agricultural Centre (MAC) oil mallee area (sprinkled into trays) were located across the germination area to assess timing of barley grass germination relative to a non-cropped population.

Assessing weed seed capture in chaff dumps after harvesting

Chaff was collected from chaff dumps with 10 samples per dump, taken approximately 40 cm into the dump (which were approximately 1 m high), to determine the weed seed species being collected at harvest. Fifty grams of chaff were added to each germination tray with three replications.

Table 1 *Plant counts at Mudamuckla and Minnipa before harvest 2016, and at Tcharkuldu in 2017*

Location	Barley grass (plants/m2)	Rye grass (plants/m2)	Cereal crop (plants/m2)
Paddock 33	5.3	33	93
Paddock 95	0.4	12	99
MAC S4	6.9	0.3	110
MAC S1	7.4	0.1	110
MAC S7	4.3	1.3	87
MAC Airport	2.3	1.7	115
Tcharkuldu	259	0.6	190

What happened?

The weed populations were generally lower in the paddocks sampled (Table 1), except Paddock 33 at Mudamuckla which had higher levels of ryegrass present (33 plants/m2) and the Tcharkuldu paddock in 2017 had high levels of barley grass (259 plants/m2). MAC generally had low levels of ryegrass and some barley grass present.

Table 2 *Mean weed seed counts in 2017 weed seed trays from chaff dumps and soil collected from Mudamuckla at harvest 2016*

Location	Barley grass (plants/50 g chaff or soil)	Rye grass (plants/50 g chaff or soil)	Self-sown cereal (plants/50 g chaff or soil)	Brome grass (plants/50 g chaff or soil)
Paddock 33 chaff dumps	0.3	12.2	14.6	0.04
Paddock 95 chaff dumps	1.4	3.8	18.3	0.6
Paddock 33 soil	7.0	12.3	0	0
Paddock 95 soil	0.7	1.2	0	0.07

Table 3 *Weed seed counts in 2017 weed seed trays from chaff dumps and soil collected at harvest 2016 from Minnipa Agricultural Centre windrows (burnt in autumn 2017)*

Paddock	2016 Crop	Sample	Barley grass (plants/50 g soil)	Rye grass (plants/50 g soil)	Self-sown cereal (plants/50 g soil)
MAC S4	Trojan Wheat	Inter row (before burning)	2.6	0.2	0.5
		In row before burning (soil collected before burning)	0.6	0.2	0.1
		In row burnt (soil collected after burning)	0.8	0.2	0.5
MAC S1	Mace Wheat	Inter row (before burning)	2.6	0.2	0.5
		In row before burning (soil collected before burning)	0.6	0.2	0.1
		In row burnt (soil collected after burning)	0.5	0	0.3
MAC S7	Mace Wheat	Inter row (before burning)	5.1	0.1	0.1
		In row before burning (soil collected before burning)	0.5	0.3	0.8
		In row burnt (soil collected after burning)	0	0	0
MAC Airport	Wheat	Inter row (before burning)	1.6	6.5	0.1
		In row before burning (soil collected before burning)	0.8	0.4	0.5
		In row burnt (soil collected after burning)	0	0.2	0.1
Oil Mallee	Uncropped	Barley grass check plots	144	0	0

The weed seed tray results from Mudamuckla (Table 2) show there were greater barley grass numbers in the paddock than collected in the chaff dump, indicating seed had dropped before harvest or shattered at harvest time and did not enter the header to be captured. The ryegrass weed seed numbers in the soil were similar to those in the chaff dump indicating mature plants had either dropped seed heads which avoided harvest or small plants were lower than the harvest height. The self-sown cereal was greater within the chaff dumps than in the paddock soil, indicating the screenings were collected into the chaff fraction of the harvest system.

Table 4 Weed seed counts in 2018 weed seed trays from chaff dumps and soil collected from Tcharkuldu at harvest 2017

	Barley grass (plants/50 g chaff or soil)	Rye grass (plants/50 g chaff or soil)	Self-sown cereal (plants/50 g chaff or soil)
Chaff dumps	30	1.7	13.5
Soil near chaff dump	40	0.3	0.2
Soil off header row (paddock)	27	1.5	**0**
In header row soil and chaff	34	1.2	2.2

The weed seed trays from the MAC paddocks (Table 3) show the inter row or general paddock area has greater barley grass weed seed numbers than in-row with the chaff fraction. Burning the chaff rows decreased the weed seed numbers, except in MAC S4.

In the paddock at Tcharkuldu (Table 4) with a high barley grass population there was little difference in the barley grass numbers in the chaff dumps or in the header chaff row than in the nearby paddock soil, indicating the barley grass had shed seed before harvest or was too low (less than 15-17 cm) to be collected at harvest. There were more cereal screenings within the chaff dump.

What does this mean?

The harvest weed seed collection results have showed that barley grass, due to its habit of dropping seed early, is harder to capture using harvest weed seed collection techniques. The ability to detect barley grass within the chaff dumps as easily as other seed may also be a factor as barley grass has a burrowing habit, which may result in seed being potentially located lower in the chaff dump/closer to the soil than other seed. More research on the distribution of weed seeds species in chaff dumps could be undertaken in the future. Burning windrows decreased the number of weed seeds present in the soil seedbank at Minnipa in 2017.

Harvest weed seed collection allows for the capture of ryegrass and cereal screenings, and placing the plant material into rows potentially allows for greater feed utilisation for stock rather than grain and straw being distributed randomly across the paddock. Again further research into farming systems efficiencies of harvest windrows, chaff dumps and livestock needs to be undertaken to effectively reduce weeds in low rainfall farming systems.

Acknowledgements

This research was funded by GRDC as a small component of the Stubble Initiative. Thank you to Steve Jeffs, Katrina Brands, Fiona Tomney, Rochelle Wheaton and Brett Hay for helping with the data collection from the weed seed trays. Thanks to the farmers involved for having the research and monitoring on their properties.

SAGIT

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SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

Effect of sowing time x seed rate x herbicides on ryegrass management in wheat

Authors: Gurjeet Gill1, Ben Fleet[1], Amanda Cook[2] and Ian Richter[2]

Delivery Organisations: [1]University of Adelaide; [2]SARDI Minnipa Agricultural Centre

Location
Minnipa - Bruce Heddle
Rainfall
Av. Annual: 283 mm
Av. GSR: 202 mm
2018 Total: 244 mm
2018 GSR: 186 mm
Paddock History
2018: Medic pasture surrounding, wheat trial
2017: Wheat
2016: Canola
2015: Medic
2014: Wheat
Yield
Potential: 2.6 t/ha (top yielding plot across both trials
Soil Type
Grey calcareous loam
Plot Size
1.5 m x 10 m x 3 reps
Trial Design
Experimental, split, split plot
Yield Limiting Factors
Anuual ryegrass and dry start to season

Key messages

- Annual ryegrass (ARG) plant density and wheat grain yield at Minnipa was influenced by time of sowing, herbicide treatment and the interaction between time of sowing and herbicide.
- There was a significant impact of delayed seeding to late June, with a reduction in ARG plant density and higher efficacy of pre-emergence herbicides measured.
- There were large benefits of delayed sowing on weed control. However, these benefits came at a significant cost in wheat grain yield.

Why do the trial?

Change in sowing time can have multiple effects on crop-weed competition. Delayed sowing can provide opportunities to kill a greater proportion of the weed seedbank before seeding the crop, but weeds that establish in late sown crops can be more competitive on a per plant basis. This is one of the reasons why farmers who have adopted early seeding have reported excellent results in crop yield and weed suppression. Therefore, it is important to investigate sowing time in combination with other practices across different rainfall zones. The review of Widderick *et al*. (2015) has recommended research on sowing time in many crops. Delayed sowing can also reduce crop yield so the gains made in weed control may be completely nullified by the yield penalty.

There has been some research already on crop seed rate on weed suppression but none of these studies have investigated the benefits of higher crop density in factorial combinations with sowing time and herbicide treatments. Crop seed rate is an easy tactic for the growers to adopt provided they are convinced of its benefits

Table 1 Key trial treatments and management operations undertaken at Minnipa in 2018

Operation	Details
Location	Minnipa, SA
Seedbank soil cores	8 April 2018
Plot size	1.5 m x 10 m
Trial design	Split plot x 3 replicates
Seeding date	TOS 1: 11 May 2018 TOS 2: 25 June 2018
Fertiliser	Applied at sowing, DAP (18:20) @ 60 kg/ha
Variety	Scepter wheat
Seeding rate x 3	100 seeds/m^2 150 seeds/m^2 200 seeds/m^2
Herbicides x 3	11 May and 25 June, 2018 (applied just before seeding) Sakura 118 g/ha + Avadex 1.6 L/ha IBS Control (knockdown treatment only)

to weed management and profitability. Furthermore, growers in the low rainfall areas tend to be reluctant to increase their seed rate due to concerns about the negative impact of high seed rate on grain screenings. This field trial at Minnipa was undertaken to investigate factorial combinations of sowing time, seed rate and herbicides on the management of annual ryegrass in wheat.

How was it done?

Measurements taken were pre-sowing weed seedbank, crop density, weed density, ARG spike density, ARG seed production, wheat grain yield. All data collected during the growing season was analysed using the Analysis of Variance function in GenStat version 15.0.

What happened?

In 2018, annual rainfall received at Minnipa was 14% below the long-term average of 283 mm and the disparity for the growing season rainfall from the long-term average of 202 mm was only 8%. The 86 mm of rainfall received in August was more than double the long-term average and rainfall in October (29 mm) and November (30 mm) was also greater than the long-term average.

Wheat plant density

There was a significant interaction between sowing time and wheat seed rate (Figure 1). At the low seed rate, both sowing times produced an identical plant density (64-68 plants/m2), which was 32-36% below the target density. However, the gap from the target seed rate increased to 37% at the highest seed rate in TOS 1 and 47% in TOS 2. Lower than expected crop establishment in this trial appeared to be related to below average rainfall at the site in May and June.

Annual ryegrass plant density and seedbank

The average seedbank of annual ryegrass (ARG) at the site was 716 ± 38 seeds/m2. ARG plant density was significantly influenced by the time of sowing ($P<0.001$), herbicide treatment ($P<0.001$)and the interaction between the time of sowing and herbicide ($P<0.001$).

There was a large impact of the six week delay in seeding on ARG plant density (Figure 2). This was particularly evident in the untreated control in which ARG density decreased from 262 plants/m2 in TOS 1 to 139 plants/ m2 in TOS 2. This large response of ARG density to delayed sowing is most likely related to many small rainfall events in June, which would have caused weed emergence. The reduction in ARG plant density due to delayed seeding was also apparent in the herbicide treatments (Figure 2) with both herbicide treatments providing greater efficacy in TOS 2.

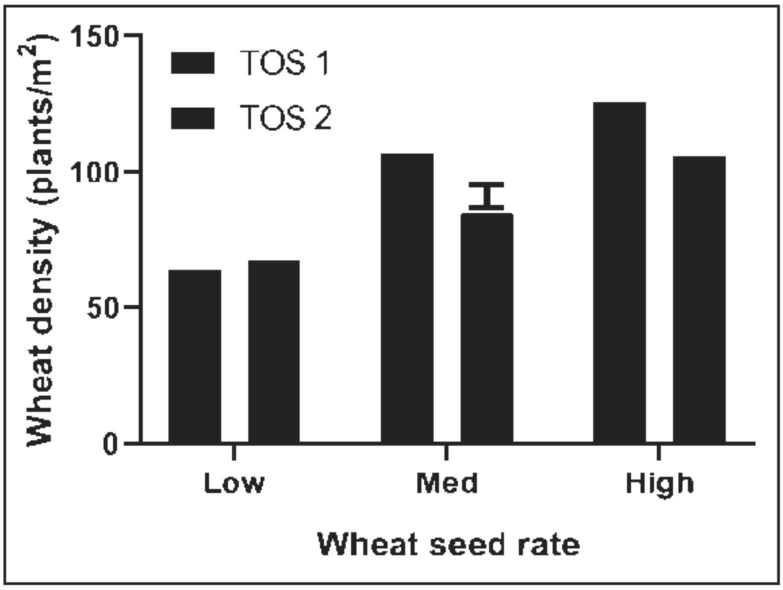

Figure 1 The effect of seed rate on wheat plant density in time of sowing 1 (TOS 1) and time of sowing 2 (TOS 2). The vertical bar represents the LSD (P=0.05).

The recruitment index (RI) of ryegrass (the ratio between ARG seedbank and plant density) was also significantly affected by the interaction between the time of sowing and herbicide treatments ($P<0.001$). In the untreated control, RI for ARG was 0.46 (i.e. 46% recruitment) which declined to 0.22 (22% recruitment) in TOS 2. This large difference in ARG establishment in two sowing dates again points to high pre- sowing weed establishment, which was effectively controlled by the knockdown treatment of glyphosate.

Annual ryegrass spike density and seed production

ARG spike density was significantly influenced by the time of sowing (P=0.012), herbicide treatment (P<0.001) as well as the interaction between the TOS and herbicide treatment (P<0.001). However, there was no effect of wheat seed rate on ARG spike density (P=0.212). When averaged across the seed rates and herbicide treatments, the six week delay in seeding at Minnipa reduced ARG spike density from 102 spikes/m2 to 34 spikes/m2 (67% reduction).

Herbicide treatments were also more effective in TOS 2, with the Sakura + Avadex treatment resulting in the production of only two ARG spikes/m2 (Figure 3). These results clearly highlight the ability of Boxer Gold and Sakura to effectively manage moderate levels of ARG seedbank under adequate soil moisture conditions.

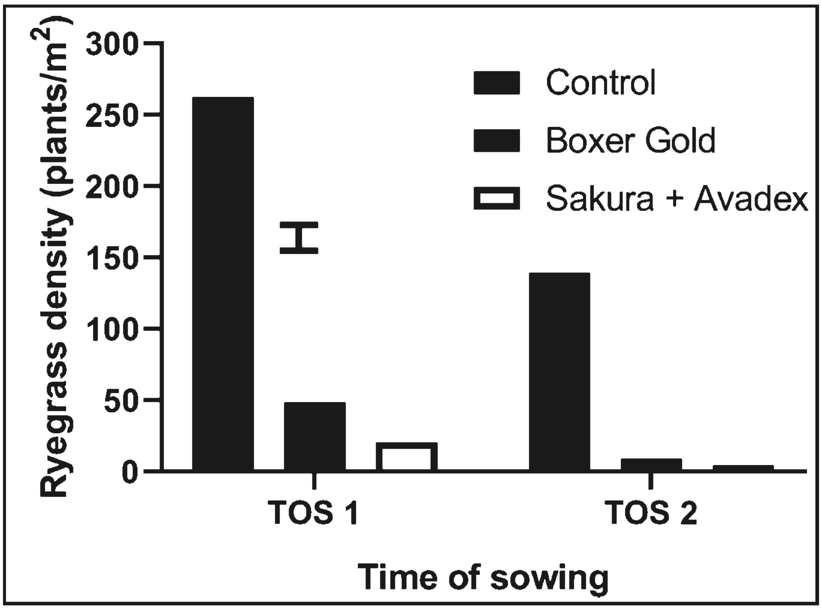

***Figure 2** The interaction between the time of sowing and herbicide treatments (P<0.001). The vertical bar represents the LSD (P=0.05).*

Consistent with the trends observed for ARG spike density, ARG seed production was also significantly influenced by the time of sowing (P=0.047), herbicide treatments (P=0.001) and the interaction between the TOS and the herbicide treatments (P=0.023). Pre-emergence herbicides performed much better in TOS 2 where the density of ARG plants had been reduced by the delay in seeding (Figure 4). In the treatment of Sakura + Avadex, ARG only produced 53 seeds/m2 in TOS 2, compared to 830 seeds/ m2 in TOS 1.

Wheat grain yield

Wheat grain yield at Minnipa was significantly influenced by the time of sowing (P=0.002), seed rate (P<0.001), herbicide treatment (P<0.001) and the interaction between the time of sowing and herbicide treatments (P<0.001). Averaged across the seed rates and herbicide treatments, wheat produced grain yield of 1.67 t/ha in TOS 1, compared to 1.06 t/ha in TOS 2 (Figure 5). Even though the amount of rainfall received in May and June was well below the long- term average, the six week delay in sowing reduced wheat yield by 36%. Wheat yield increased as seed rate increased from low (1.25 t/ha), to medium (1.41 t/ha) and high (1.44 t/ha). Even though this increase was only 13%, it was statistically significant.

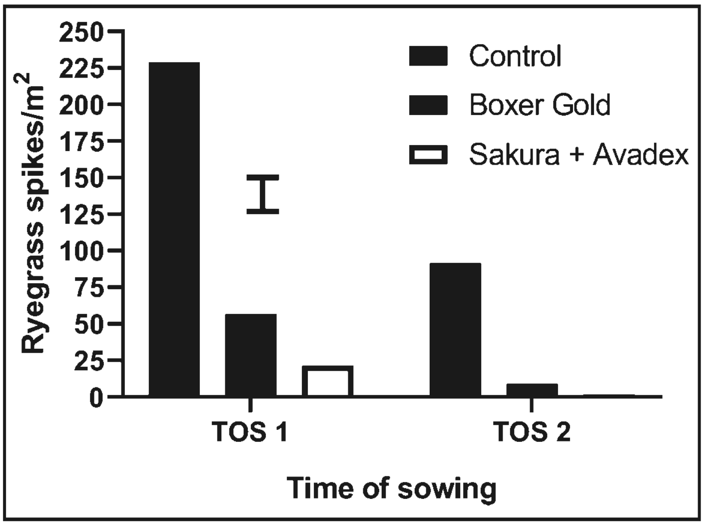

***Figure 3** The effect of interaction between the time of sowing and herbicide treatments (P<0.001) on ARG spike density. The vertical bar represents the LSD (P=0.05).*

What does this mean?

As stated earlier, there were large benefits of delayed sowing on weed control by herbicides in terms of ARG plant density, spike density and seed production. However, these benefits came at a significant cost in wheat grain yield. All herbicide treatments showed a significant reduction in yield due to the six week delay in sowing. Sakura + Avadex provided superior control of ARG than Boxer Gold, but there were no differences in wheat yield between these treatments.

Even though the untreated control plots had a greater ARG plant density in TOS 1 (262 plants/m2) than TOS 2 (139 plants/m2), still wheat produced 0.32 t/ha more grain yield in TOS 1 than TOS 2.

These results clearly highlight the superior competitive ability of wheat against ARG at earlier sowing. It could also be argued that yield loss of wheat due to delayed sowing was greater than the yield loss due to ARG competition. Therefore, it would not be advisable to delay sowing wheat to manage ARG unless weed seedbanks are excessively large. It would be preferable to target the optimum sowing date for wheat in the region and use the most effective herbicide options available to control ARG.

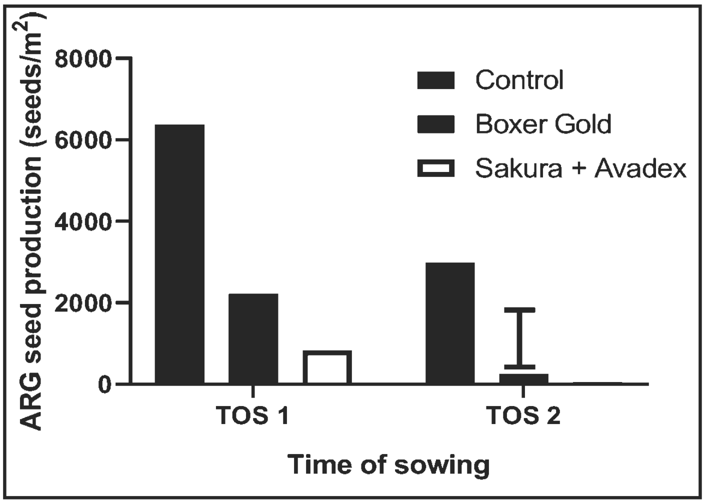

***Figure 4** The effect of interaction between the time of sowing and herbicide treatments (P<0.001) on ARG seed production. The vertical bar represents the LSD (P=0.05).*

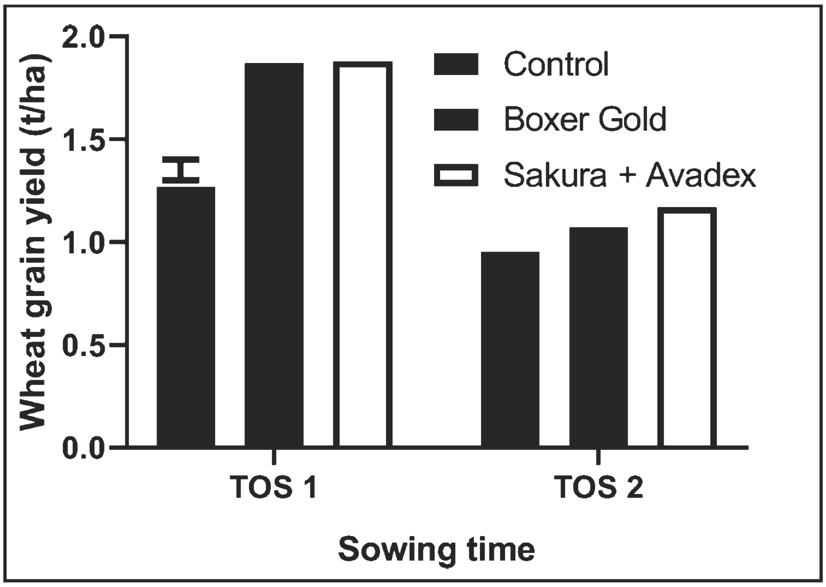

***Figure 5** The effect of interaction between the time of sowing and herbicide treatments (P<0.001) on wheat grain yield. The vertical bar represents the LSD (P=0.05)*

Based on grain yields achieved and APW prices for last year, TOS 1 treated with Boxer Gold provided $291/ha greater gross margin than TOS 2 treated with the same herbicide.

Acknowledgement

The authors thank Bruce and Kathryn Heddle for hosting the site. Malinee Thongmee and Hue Thi Dang (University of Adelaide), Fiona Tomney, Steve Jeffs and Katrina Brands (SARDI) for their technical input to the trial. We also acknowledge the investment from GRDC for the research into 'Cultural management for weed control and maintenance of crop yield' (9175134).

Break Crop Production in Southern Low Rainfall Environments

Author*:* Sarah Day

Delivery Organisation: SARDI, Clare

Funding: GRDC (DAS00162-A)

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

Key messages

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

Why do the trial?

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

How was it done?

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

The trial was sown at Minnipa on 21 June 2018 using an experimental plot seeder with 27 cm row spacing.

Biomass measurements were taken in early October at late flowering to early podding growth stage to identify potential use as a hay, forage or manure crop. Harvesting of the trial was conducted on 16 November 2018.

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

What happened?

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

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

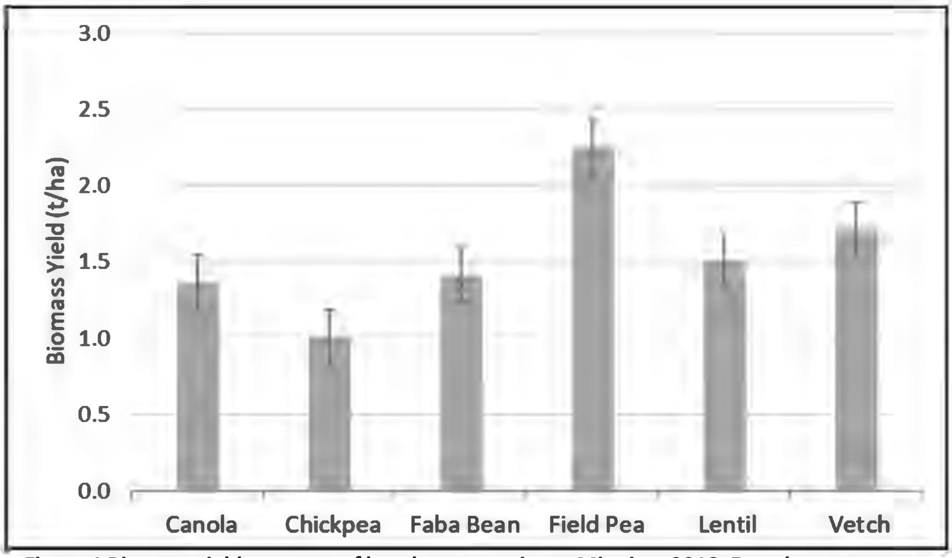

Figure 1 Biomass yield response of break crop species at Minnipa, 2018. Error bars represent least significant difference (0.238 t/ha)

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

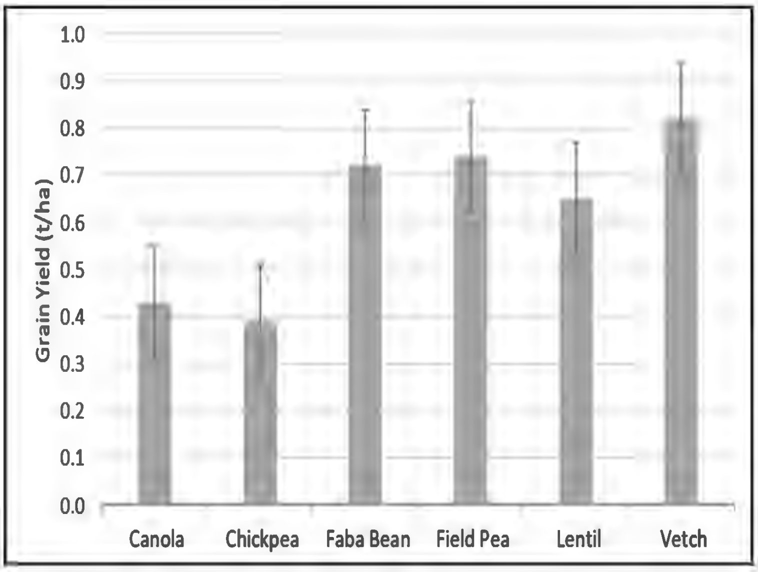

Figure 2 Grain yield response of break crop species at Minnipa, 2018. Error bars represent least significant difference (0.356 t/ha).

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

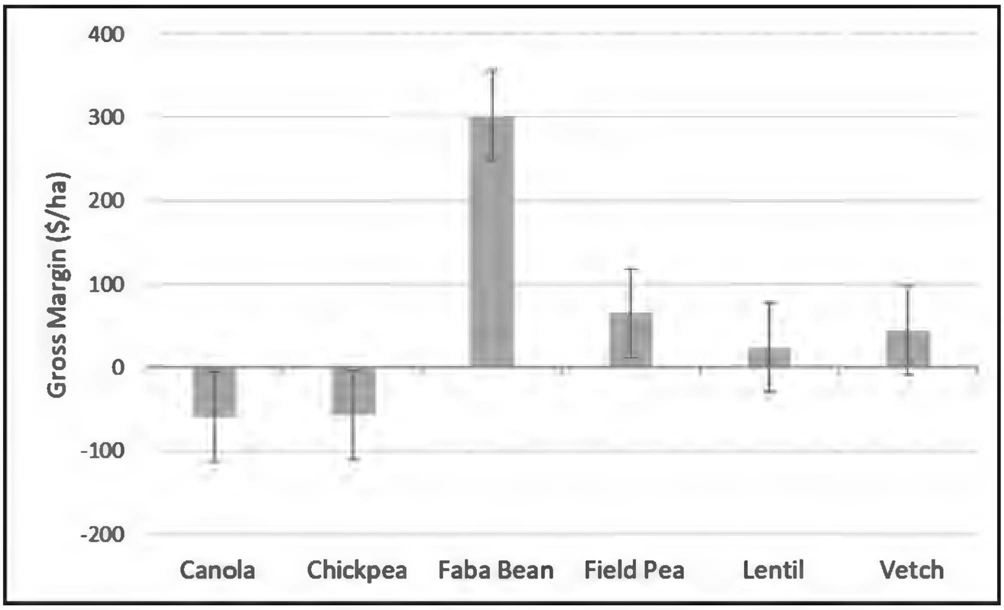

Figure 3 *Gross margin response of break crop species at Minnipa, 2018. Error bars represent least significant difference ($107.50/ha).*

What does this mean?

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

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

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

Acknowledgements

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EPARF Eyre Peninsula Agricultural Research Foundation Inc.

Dryland Legume Pasture Systems: Legume adaptation

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UNFS is a delivery partner in the DLPS project.

Location
Minnipa Agricultural Centre, paddock S8
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2018 Total: 269 mm
2018 GSR: 208 mm
Paddock History
2017: Scepter wheat
2016: Medic pasture
2015: Mace Wheat
Soil Type
Red sandy loam
Soil Test
$pH_{(H20)}$ (0-10 cm) 8.4
Plot Size
5 m x 1.5 m x 4 reps

Key messages

- **This is a component of a new five year Rural Research and Development for Profit funded project supported by GRDC, MLA and AWI; and involving Murdoch University, CSIRO, SARDI, Department of Primary Industries and Regional Development; Charles Sturt University and grower groups.**
- **This trial aims to assess a diverse range of annual pasture legumes in order to determine whether there are more productive and persistent options for the drier areas (<400 mm) of the mixed farming zone of southern Australia.**
- **Several new legume species established well under very difficult conditions, but in general were not as productive as the medics or vetch.**
- **In the 2018 growing season, Caliph barrel medic was the best adapted pasture legume species to the conditions at Minnipa.**
- **Astragalus was the best adapted alternative legume species, although it was poorly nodulated.**
- **Zulu arrowleaf clover also performed well, however its peak dry matter production and flowering time may be too late for SA conditions.**

Why do the trial?

Legume pastures have been pivotal to sustainable agricultural development in southern Australia. They provide highly nutritious feed for livestock, act as a disease break for many cereal root pathogens, and improve fertility through nitrogen (N) fixation. Despite these benefits pasture renovation rates remain low and there is opportunity to improve the quality of the pasture base on many low to medium rainfall mixed farms across southern Australia. A diverse range of pasture legume cultivars are currently available to growers and new material is being developed. Some of these legumes, such as the annual medics, are well adapted to alkaline soils and have high levels of hard seed, which allow them to self-regenerate from soil seed reserves after cropping (ley farming system). Other legume cultivars and species are available and being developed that offer improved seed harvestability, are claimed to be better suited to establishment when dry sown and/or provide better nutrition for livestock. Regional evaluation is needed to determine if they are productive and able to persist in drier areas (<400 mm annual rainfall) and on Mallee soil types common to the mixed farming zone of southern Australia.

The Dryland Legume Pasture Systems project will both develop and evaluate a range of pasture legumes together with innovative establishment techniques, measure their downstream benefits to animal and crop production and promote their adoption on mixed farms.

How was it done?

The trial at Minnipa in paddock S8 was arranged in a fully randomised block design, with four replications. Similar trials have been established at Loxton (SA), Piangal (Vic), Kikoira (NSW) and Condobolin (NSW). Data was analysed using Analysis of Variance in GENSTAT version 19. The least significant differences were based on F probability=0.05.

Thirty different pasture legume species (Table 1) were sown to provide a broad range of legume species and attributes. The chosen species are a mixture of old varieties, new varieties, pre- releases, legumes with new traits, and pasture gene-bank selections based on their likely adaptation to rainfall and soil type. Some legume cultivars developed in Western Australia have also been included. These have performed well in WA and more recently in NSW, on their acid-dominant soils, but have had limited evaluation in South Australia where neutral to alkaline soils prevail.

The trial was sown on 27 June under relatively dry conditions, having received 22 mm of rain in the three weeks prior to seeding. All seed was inoculated with the best available strain of rhizobia and lime pelleted before sowing.

Prior to sowing, plots were sampled at 0-10 cm to provide basic soil chemistry and a soil disease profile. The trial site was sprayed before sowing with 1.5 L/ ha Weedmaster (Glyphosate) + 80 ml/ha Nail and 300 ml/100 L of LI 700, to kill any naturalized medic plants that had germinated.

The plots were scored for coverage and vigour of growth on 19 September and measured to assess ground cover (using Green Seeker) on 21 September 2018. Plants requiring specific rhizobia: *Astragalus hamosus, Lotus ornithopodiodies* and *Lotus arenarius*; plus the WA cultivars: Margurita French serradella, Casbah biserrula and Bartolo bladder clover, were sampled on 25 September 2018 for measurement of nodulation. Seventeen of the most promising pasture lines were sampled on 26 September 2018 for spring dry matter (DM) production.

Once dried and weighed, the DM samples were sent to Adelaide to be assessed for their nutritive value, however the results are not yet available. Plots were sampled to estimate seed production for all entries on 3 December 2018.

What happened?

Plant establishment and production

Dry (July receiving only 25 mm of rain) and windy conditions delayed plant emergence for approximately one month after sowing. Plant density counts were completed on 7 August (Table 2). Although still small, seedlings of all lines had emerged after 39 mm of rain in first week of August. However, there were differences between the lines for both vigour and number. Many smaller seeded lines such as the Casbah biserrula, Minima medic, Prima gland clover and the hybrid clover (balansa X nigrescens), were less vigorous.

Others, including the two lines with the highest plant density counts, Toreador disc medic (177 plants/ m2) and Zulu arrowleaf clover (176 plants/m2), were very small but healthy, with some seedlings at the one leaf stage. Trigonella 5045 (86 plants/m2) and the earlier maturing line, Trigonella 37928 (81 plants/m2)

Table 1 Annual pasture legume species sown in the legume adaptation trial at Minnipa in 2018

Pasture species	Notes
Harbinger Strand medic	Old cultivar; West Coast ecotype
Herald Strand medic	Old cultivar; aphid resistant
Jaguar Strand medic	Pod and leaf holding medic from Pristine Forage Technologies
PM250 Strand medic	Powdery mildew resistant; tolerant of sulfonylurea (SU) herbicide residues; specifically developed for SA dryland Mallee farming systems
Pildappa Strand medic	West Coast ecotype, previously considered for release
Caliph Barrel medic	Old cultivar
Cheetah Barrel medic	Pod-holding medic from Pristine Forage Technologies
Sultan SU Barrel medic	Tolerant of SU residues; Boron tolerant; good aphid resistance
Boron Burr medic	Boron tolerant; spineless
Scimitar Burr medic	Old cultivar; spineless
Toreador Disc medic	Developed for sandy soils
Minima medic	Widely naturalised in dry areas; spineless
SARDI Rose Clover	Developed in upper mid-north; not widely sown in Mallee but reports of good performance
Rose Clover Early 35623	Experimental; early flowering and aerial seeded
Bartolo Bladder Clover	WA cultivar; aerial seeded, limited testing in the southern region
Prima Gland Clover	WA cultivar
Zulu Arrowleaf Clover	WA cultivar; earliest flowering line
Tammin Subterranean Clover	New cultivar; high level of hard-seed and tolerant of Red-legged Earth Mite
Balansa Clover X nigrescens clover	Experimental; an aerial seeded hybrid
Volga Common Vetch	Old cultivar
Studenica Common Vetch	New vetch specifically developed for drier areas
Capello Woolly Pod Vetch	Old cultivar
Casbah Biserrula	WA cultivar; with limited testing in the southern region
Margurita French Serradella	WA cultivar suited to acid soils
Santorini Yellow Serradella	WA cultivar; hard-seeded suited to acid soils with limited testing in the southern region
Trigonella balansae 5045	New species, aerial seeded
Trigonella balansae Early 37928	New species, early line; aerial seeded
Astragalus	Experimental Australian Pasture Genebank selection; new rhizobia
Lotus arenarius	Experimental Australian Pasture Genebank selection
Lotus ornithopodiodies	Experimental Australian Pasture Genebank selection

had relatively low plant density counts and were showing signs of moisture stress. Tammin subterranean clover had a very poor emergence with only 42 plants/m2. This line continued to perform poorly. Caliph barrel medic, the best performing line in the trial, showed early promise with a plant density count of 147 plants/ m2 and healthy looking plots with seedlings at the 1-2 leaf stage.

Following more favourable conditions (38 mm late August) plots were scored (x/100) for coverage and vigour of growth on 19 September. Studenica common vetch had the best score of 90, followed by Caliph barrel medic with 84, with Capello woolly pod vetch, Cheetah barrel medic, Volga common vetch, Sultan barrel Medic, Scimitar burr medic and Toreador disc medic all scoring above 50. PM250 strand medic was just lower with a score of 49. The poorest plots (Margurita French serradella and Tammin subterranean clover) scored less than 10.

Plots were measured to assess ground cover using a Green Seeker on 21 September. As no lines apart from the Woolly pod vetch had achieved 100% plot coverage, these readings were fairly low. Capello woolly pod vetch, Caliph barrel medic, Studenica common vetch, Cheetah barrel medic and Astragalus had the highest readings.

DM cuts were performed on the seventeen most promising pasture lines (Table 3). Caliph barrel medic and Studenica vetch, produced the highest DM. Caliph barrel medic produced 1.30 t/ha of DM, which was double that of the site mean of 0.65 t/ha. Studenica common vetch produced nearly double the DM of the commonly grown Volga vetch. These results were consistent with earlier observations of ground cover and vigour.

The trial suffered two pest attacks. Firstly by Cowpea aphids which appeared on all lines but at higher density on the vetches, and then by Native Budworm. Fortunately both of these pests were brought under control and did not appear to have caused any lasting damage.

The spring DM cut provided a reasonable assessment of the maximum production of most legumes in the trial, especially the medics; however will have underestimated the production of some species that responded to late rains. The serradellas, biserrula, astragalus, lotus and some clovers, were observed to continue growing after the DM assessment. Most notable, was the growth of Zulu arrowleaf clover which continued throughout November and had not fully senesced at the time of seed production measurements in early December. It would have been interesting to have taken late DM cuts on these later maturing lines, especially on the Zulu arrowleaf clover, although whether the extra production provided by these later flowering and possibly deeper rooted legume species occurs in seasons that lack late rains, needs to be clarified.

Of the medics, the barrel species were the first to senesce, whilst PM250 lasted the longest. In late October it was still reasonably green with lots of flowers.

After sampling for DM, it was decided to remove Capello woolly pod vetch from the trial, as there were concerns that it could become an established weed. It was sprayed out with Weedmaster (glyphosate), and hence does not appear as an entry in Table 4.

Seed production was measured on 3 December (Table 4). All lines flowered, with most considered to have set enough seed to enable regeneration next year. Zulu arrowleaf clover had the highest seed production with 44,253 seeds/ m2. Bartolo bladder clover (24,032 seeds/ m2), Casbah biserrula (17,599 seeds/m2), Prima gland clover (16,182 seeds/m2), Lotus arenarius (13,219 seeds/ m2) and Astragalus (12,643 seeds/m2) were also prolific seed producers. The two Vetch lines produced the lowest amount of seed. Regeneration in 2019 will be strongly influenced by the breakdown of hardseed, which varies between legumes and is modified by environmental conditions. Regeneration will be measured as an important aspect of adaptation.

Pasture legume nodulation

Legume species that were likely to be responsive to inoculation, in the absence of any naturalised soil rhizobia, were assessed (six plants per plot) for nodulation (Table 5). Biserrula and the two species of Lotus were found to be adequately nodulated, with these species averaging more

Table 3 Dry matter (t/ha) measurements at Minnipa 26 September 2018

Pasture species	Dry matter (t/ha)
Caliph Barrel Medic	1.30 a
Studenica Common Vetch	1.20 a
Cheetah Barrel Medic	1.02 b
EP Harbinger Strand Medic	0.93 bc
Toreador Disc Medic	0.88 bcd
Capello Woolly Pod Vetch	0.78 cde
PM250 Strand Medic	0.72 de
Pildappa Strand Medic	0.71 e
Scimitar Burr Medic	0.68 e
Volga Common Vetch	0.68 e
Jaguar Strand Medic	0.65 ef
Astragalus Early	0.50 f
Trigonella 5045	0.30 g
SARDI Rose Clover	0.24 gh
Bartolo Bladder Clover	0.18 gh
Casbah Biserrula	0.12 h
Margurita French Serradella	0.08 h
LSD (P=0.05)	0.16

than five nodules per plant and not exhibiting any symptoms of nitrogen deficiency. Bladder clover and French serradella were less well nodulated, with individual plants found not to have any nodules. In the case of French serradella, nodulation was similarly erratic at other sites and would probably benefit from an increased rate of inoculation.

The fact that bladder clover was better nodulated at other field sites might be explained by the root disease damage observed on the plants from Minnipa, which may have contributed to the decreased nodulation at this site. Astragalus failed to nodulate, but still managed to grow reasonably well. Further work to overcome the nodulation issue will be needed to enable a valid evaluation of this legume.

What does this mean?

Despite a challenging start with the dry and windy weather, all of the legume lines established, flowered and set some seed; and have therefore provided some indication of their potential in a challenging season.

The ranked performance of the most promising legume species at the Minnipa trial site is shown in Table 6. This was determined by averaging the ranking of each legume for seeding emergence, green seeker, plot vigour, DM and seed production.

Caliph barrel medic has so far proved to be the best adapted cultivar to the conditions on Minnipa Agricultural Centre, producing the most DM, along with Studenica common vetch. It also performed well in terms of plant establishment, plot coverage, vigour and seed production. Studenica common vetch, whilst producing the same amount of DM as Caliph, fell down the rankings for its poor plant establishment and seed production.

Annual medic species occupied the top five positions in the ranking table. These initial rankings may change in the longer term due to factors such as seed set, hard- seeded breakdown and seasonal variations, but nonetheless highlight that the medics performed well under very low rainfall conditions. Several cohorts of improved medic material will be developed further, based on these findings.

Astragalus was one of the better performing alternative legumes, despite issues of poor nodulation. Zulu arrowleaf clover was an excellent performer in terms of plant establishment and seed set, however its peak DM production was in late spring and its flowering time may be too late for low rainfall SA conditions. Bartolo bladder

***Table 4** Seed assessment measurements at Minnipa 3 December 2018*

Pasture species	Average No. of seed pods/m2	Average No. of seeds/ pod	Average No. of seeds/m2
Santorini Yellow Serradella	691	5	3,404
PM250 Strand Medic	1,344	5	6,181
Studenica Common Vetch	41	4	147
Toreador Disc Medic	1,480	4	5,994
Bartolo Bladder Clover	740	32	24,032
Trigonella 5045	3,254	4	11,795
Herald Strand Medic	1,215	3	3,827
Casbah Biserrula	1,220	14	17,599
Pildappa Strand Medic	1,466	5	7,075
Astragalus Early	617	20	12,643
Minima Medic	2,154	4	7,915
Trigonella Early 37928	2,535	4	9,253
Margurita French Serradella	575	4	2,573
Scimitar Burr Medic	2,001	5	10,106
Boron Burr Medic	1,708	5	8,324
Lotus ornithopodiodies	2,425	4	10,246
EP Harbinger Strand Medic	1,256	5	5,873
Tammin SubterraneanClover	325	2	691
Prima Gland Clover	1,240	13	16,182
Lotus arenarius	1,241	11	13,219
Rose Clover Early 35623	474	9	4,465
SARDI Rose Clover	758	12	9,317
Volga Common Vetch	55	4	227
Cheetah Barrel Medic	1,053	6	6,526
Balansa Clover X nigrescens	643	6	3,935
Caliph Barrel Medic	1,229	6	6,850
Zulu Arrowleaf Clover	495	89	44,253
Sultan Barrel Medic	1,023	6	5,803
Jaguar Strand Medic	910	3	3,003

clover had good plant establishment and excellent seed production, however its DM production was very poor. Trigonella was slow to establish and had below average DM production, however it continued to grow vigorously into late spring and produced a large amount of seed.

Table 5 Summary of nodulation at Minnipa in 2018

Pasture species	Summary of observations
Bartolo Bladder Clover	Nodulation low, possibly limiting (only at MAC)
Margurita French Serradella	Low nodule number, possibly limiting
Casbah Biserrula	Nodulation satisfactory and not limiting
Lotus ornithopodiodies	Nodulation satisfactory and not limiting
Lotus arenarius	Nodulation satisfactory (but erratic at Lameroo)
Astragalus Early	Nodulation failure, but no signs of N deficiency

The potential benefit offered by some of the legume species, including improved ease of seed harvest, improved nutritive value and N-fixation may come at the expense of DM production. This trial will be allowed to regenerate in 2019. The growth of pasture lines that successfully regenerate will be monitored to determine how their performance differs from the establishment year.

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Commercial annual legume cultivars are produced by a range of companies and we appreciate them making their cultivars available for this work.

Table 6 Ranked performance of legume pasture species at Minnipa (seeding emergence, green seeker, plot vigour, dry matter and seed production)

Rank	Pasture species
1	Caliph Barrel Medic
2	Toreador Disc Medic
2	Scimitar Burr Medic
2	Cheetah Barrel Medic
5	EP Harbinger Strand Medic
6	Astragalus Early
7	Pildappa Strand Medic
8	PM250 Strand Medic
9	Zulu Arrowleaf Clover
10	Bartolo Bladder Clover
11	Studenica Common Vetch
12	SARDI Rose Clover
13	Trigonella 5045
14	Jaguar Strand Medic
14	Volga Common Vetch
16	Casbah Biserrula
17	Margurita French Serradella

Dryland Legume Pasture Systems: Quantifying benefits of novel legume pastures to livestock production systems

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Delivery Organisations: [1]SARDI, Minnipa Agricultural Centre; [2]SARDI, Waite

Location
Minnipa Agricultural Centre, paddock S8
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2018 Total: 269 mm
2018 GSR: 208 mm
Paddock History
2017: Scepter wheat
2016: Medic pasture
2015: Mace wheat
Soil Type
Red sandy loam
Soil Test
$pH_{(H20)}$ (0-10 cm) 8.4
Plot Size
6 treatments x 2 ha x 3 reps

Key messages

- Novel legume species and genotypes have the potential to reduce feed gaps and provide other farming systems and livestock benefits in low to medium rainfall regions of southern Australia.
- The five-year large scale grazing systems trial established at Minnipa in 2018 is the main livestock field site for the national Dryland Legume Pasture Systems project. Five annual legume species are being tested.
- The priority for this trial in 2018 was to optimise seed set given the poor seasonal conditions, and therefore no grazing was undertaken in the establishment year, but instead will commence with sufficient pasture growth in 2019 to determine the best legume option for livestock production.

Why do the trial?

In southern Australian mixed farming systems, there are many opportunities for pasture improvement, providing positive impacts to both cropping and livestock systems. Dryland legume pastures are necessary in low to medium rainfall zones to support productive and healthy livestock, along with optimal production in crops following these pastures. The majority of pasture species used in these mixed farming systems are short-lived annuals that complete their lifecycle from winter to early summer, with dry seasonal conditions resulting in a shorter growth window between germination and senescence. This is a major issue for livestock producers in these regions due to unreliable rainfall patterns leading to fluctuating legume growth, and the subsequent impact on feed supply and quality for grazing animals.

Innovative and improved legume species and pasture systems have the potential to fill existing nutrient gaps, thus reducing supplementary feed required for optimum ruminant performance, and maintain or improve livestock productivity through growth rates, fertility or product quality.

The Dryland Legume Pasture Systems (DLPS) project aims to boost profit and reduce risk in medium and low rainfall areas by developing recently discovered pasture legumes together with innovative management techniques that benefit animal and crop production and farm logistics. A theme of the DLPS project involves 'Quantifying the benefits of novel legume pastures to livestock production systems' and aims to maximise the advantages that pastures provide to livestock through increased animal growth and reproduction by extending the period of quality feed and reduced supplementary feeding. The animal systems research within the project will also assess areas of understanding anti-nutritional factors and 'duty of care' for new pasture species, providing opportunities for improved weed management and evaluate the main benefits of novel self-regenerating pasture legumes in crop rotations on animal production, health and welfare.

This theme is a component of a five year Rural R&D for Profit funded project supported by GRDC, MLA and AWI; and involving Murdoch University, CSIRO, SARDI, Department of Primary Industries and Regional Development; Charles Sturt University and grower groups.

A five-year grazing system trial was established at the Minnipa Agricultural Centre (MAC) in 2018 to examine this theme and is the main livestock field site for the DLPS trial in the southern region of Australia.

How was it done?

The large-scale (36 ha) grazing system experiment, measuring pasture production, legume seed bank dynamics and animal benefits from different pasture species was established in paddock South 8 at MAC and fenced in early 2018. The trial, which consists of six treatments arranged in a randomised block design with three replications, with each 'plot' 2 ha in size, was established to allow grazing during pasture phases and on stubbles after harvest in cropping years.

Soil borne disease tests were completed on soils collected on 26 June, with soil sampling for water content, basic nutrition and nitrogen undertaken on 2-3 July. Four permanent sampling points were marked out per treatment area (plot) for future measurements.

The planned rotational sequence for the five-year large-scale grazing trial aims to replicate current low to medium rainfall mixed farming practices, but also give novel pasture legumes the opportunity to successfully establish into the current system. For this reason, 2018 was intended to be the pasture establishment year with the aim to maximise seed set, followed by pasture regeneration in 2019, wheat in 2020, with options of another crop or pasture phase in 2021, depending on seasonal conditions.

Pasture species for the trial were selected after greenhouse tests of their adaptation to Minnipa soil. Twelve different legume species were tested prior to the 2018 growing season. Some clover, biserrula and serradella varieties were excluded from the trial after these experiments due to poor germination and/or growth. Treatments selected for the field trial were a continuous cereal (control 1, Scepter wheat in 2018), naturalised medic (control 2, sown Harbinger strand medic seed sourced locally), vetch (Volga), strand medic (new powdery mildew resistant and SU herbicide tolerant medic PM250), Trigonella balansae (a new aerial- seeded legume with expected good nodulation, closely related to medic) and clover (SARDI Rose, an aerial seeded variety). Table 1 presents the varieties chosen in addition to sowing information.

all inoculation treatments were applied with sticker @ 1.5%, lime and fungicide of 350 g/L Metalaxyl-M (ApronXL 350 ES) @ 1 ml/kg seed

Table 1 Sowing information for the large-scale grazing trial at MAC in 2018

Species	Germination (%)	Sowing rate (kg/ha)	Fertiliser DAP (kg/ha)	Inoculation*
Wheat	100	75.0	50	Nil
Naturalised medic	58	8.6	50	RRI128 peat @ 250 g/25 kg seed
Vetch	90	44.4	50	WSM1455 peat @ 250 g/100 kg seed
Strand medic	93	5.0	50	RRI128 peat @ 250 g/25 kg seed
Trigonella	90	4.4	50	RRI128 peat @ 250 g/20 kg seed
Clover	77	7.8	50	WSM1325 peat @ 250 g/50 kg seed

Sowing was delayed due to lack of rainfall, which was required to allow naturalised medic to germinate at the trial site. A pre- emergent herbicide was used two days prior to sowing (2 L/ ha Roundup DST + 40 ml/ha Hammer + 118 g/ha Sakura) to eradicate any naturalised medic plants already present, in order to reduce competition with the sown crop and pasture treatments. The 36 ha site was sown between 5 and 7 of July. Wheat and vetch (5 July) were sown first, followed by Harbinger medic (pasture control) and PM250 medic (6 July) and SARDI Rose Clover and Trigonella (7 July) using a discpasture seeder. Sowing rates were calculated based on recommended rates, % germinable seed and the amount of seed available for each variety, with an insufficient amount of seed available for the PM250 strand medic (sown @ -0.37 kg/ha of the recommended rate).

Plant emergence dates were recorded and counts were taken on 4 September at each permanent sampling point, recording grass and broadleaved weeds and assessing the density of naturalised medic that germinated. Flowering and pest infestation were both monitored during the growing season. Biomass cuts were undertaken on 29 October for later spring (maximum) dry matter production and pasture composition and estimates of the percentage ground cover were also recorded. The herbage was sub-sampled for both nutritive value and N fixation after processing (these samples will also be tested for N-fixation using the 15N natural abundance method), with both of these measures still being analysed. Soil sampling for water content and nitrogen was undertaken after legume senescence on 17 December. At this time, anthesis biomass and pasture composition was measured and samples were collected for pod count, pod weight and seed weight, and are still being processed.

Given the poor start to the season, late sowing time and aim to maximise seed set of the legumes, grazing was not undertaken on the trial in 2018, however baseline livestock measurements have been recorded on animals that will be used for grazing the trial in the 2019 season.

What happened?

Conditions were dry and dusty on the first day of sowing but improved with 4 mm of rainfall on the second and third days. In total, 12 mm of rainfall was received in the week of sowing, with another 5 mm the following week. The wheat (control) emerged 12 days after sowing, the vetch 14 days after sowing, the medics and clover 18 days after sowing and the Trigonella 20 days after sowing. Windy conditions caused some soil to blow into the sowing furrows, which slowed plant emergence and resulted in patchy germination, particularly with some of the smaller seeded species, including the trigonella and medics. A substantial rainfall total of 86 mm over August consolidated the establishment and supported some pasture growth.

Results of the plant emergence counts undertaken in early September are displayed in Table 2. The amount of naturalised medic that germinated in each treatment has also been recorded, with the amount in some treatments observed to affect the establishment and growth of sown legumes due to competition. The

Table 2 DLPS large-grazing trial sown legume plant counts, plant size, grass weed counts and naturalised regenerated medic plant counts in early September 2018

Species	Plants/m² average (range)	Plant size average (range)	Av. Grass weeds/m²	Av. Regenerated medic/m²
Scepter wheat	154 (142-164)	Z22 (Z16-23)	0	0.5
Harbinger medic	116 (80-144)	5 cm (3-6 cm)	1.5	6.0
Volga vetch	64 (54-80)	10 cm (4-12 cm)	1.8	8.0
PM250 strand medic	105 (82-146)	4 cm (2-6 cm)	1.0	8.7
Trigonella balansae	153 (122-202)	5 cm (2-10 cm)	0.5	14.7
SARDI Rose clover	152 (78-192)	4 cm (2-6 cm)	2.2	7.0

vetch had less plants but more early vigour than other legume species, with the smaller seeded species struggling to push through the soil that had covered the furrows after windy conditions. It was difficult to distinguish between the sown Harbinger medic and the naturalised medic regenerating form soil seed reserves.

A mixture of Targa Bolt @ 150 ml/ha, Uptake @ 0.35 L/ha and Clethodim @ 450 ml/ha was applied on 27 August to eradicate grasses. Over 80% of plants were flowering in the medic, vetch and trigonella treatments on the 29 September, with the majority of clover flowering on 2 October and most of the wheat was flowering by the 9 October. Aphids were observed on all species apart from the wheat at the end of September and were sprayed on 2 October with 500 g/ha Pirimicarb. All plots were also sprayed with 250 ml/ ha Alpha Scud Elite for native budworm on 10 October. These pests did somewhat supress plant growth, however plants recovered quickly after they were eradicated.

September rainfall was close to average with a total of 29 mm, conversely rainfall for October was well below average with only 7.2 mm received for the month (average 34.1 mm). Despite the low rainfall, all of the legume lines achieved satisfactory flowering and seed-set. The main October rainfall event during the middle of the month extended the growing season of some of the legumes and the wheat, however hot weather in the last week of October sped the anthesis process up rapidly. The natural medic began to senesce in early November with all other species growing until later into the month.

Table 3 presents the trial groundcover and peak legume biomass measurements undertaken in late October, and due to the substantial amount of both grass and broadleaved weeds growing within the treatments (many of which could not be controlled due to unavailability of information on the effect of typical chemicals on some of the legume species), the total weed biomass was sampled also. The percentage groundcover across the trial varied from 38- 84%, with plots being reasonably patchy due to early season wind (creating sandy areas) and poor germination in some parts of the 2 ha plots.
Biomass for the wheat control varied quite substantially with some areas of the trial having poorer results, with the slightly better yields from replicate 2 (1.5 t/ha) where the plot was located further down a minor slope than the other replicates (1.28 t/ha in both rep 1 and rep 3).

***Table 3** DLPS large grazing trial groundcover, peak legume biomass and grass/broadleaved weed biomass measurements in late October 2018*

Species	Groundcover (%)	Peak biomass (t/ha)	Weed biomass (t/ha)
Scepter wheat	59 (42-75)	5.7 (4.2-7)	0
Harbinger medic	61 (38-76)	0.8 (0.5-1.1)	0.2 (0.1-0.4)
Volga vetch	70 (52-84)	1.3 (0.7-2.2)	0.2 (0.1-0.2)
PM250 strand medic	63 (46-78)	0.5 (0.1-0.9)	0.4 (0.1-1.6)
Trigonella balansae	59 (41-71)	0.8 (0-1.4)	0.3 (0.1-0.8)
SARDI Rose clover	63 (49-79)	0.5 (0.1-0.9)	0.4 (0.2-0.7)

The sown Harbinger medic biomass again was difficult to separate from the regenerated medic biomass (the same and similar species) and is therefore likely to be an overestimate. The PM250 medic was observed to have a longer growing season, up to a month longer than the Harbinger medic, therefore 'peak' biomass may have increased after sampling in this variety, which may provide some advantage compared to current medic varieties.

As expected, the vetch had the greatest measured biomass, averaging 1.3 t/ha, however was still quite patchy. The trigonella performed reasonably well in a poor season with 0.8 t/ha of biomass, which had the potential to average higher, however had patchy areas within some sampling points where it failed to germinate, most likely due to the windy conditions and being located near a sandhill outside of the trial (where the sand had blown and covered in many furrows after sowing). The SARDI Rose clover had a similar issue in one of the replicates, averaging 0.5 t/ ha of biomass. Both the trigonella and clover had a similar growing season length to the PM250 medic.

What does this mean?

Patchy establishment and poor dry matter production of novel pasture legumes in the large grazing trial was predominantly caused by seasonal conditions in 2018, and meant that the potential benefits of **these cultivars have not yet been measured or observed in this study. Successful establishment when renovating pastures with new varieties is essential to maximise seed-set and therefore regeneration in the following year(s). Improved pasture establishment methods have considerable potential to reduce costs and labour requirements, and aid farm logistics, which are not being assessed in this trial, but will be evaluated over the next four years through other research and demonstration components of the DLPS project. The project will address key constraints to the adoption of pasture legumes, including concerns over cost effective and efficient establishment methods, through trials examining establishment techniques (such as summer sowing and twin sowing), cultivars with suitable patterns of hard-seededness breakdown and resilience, mixed species feedbases, the ability of new cultivars to produce seed that can be farmer harvested and pasture technologies that are simple and cheap to implement and manage. These improvements may have assisted in a more successful establishment year of the large grazing trial.**

It is likely that there are benefits to be had from some of the new legume varieties in terms of filling feed gaps in the low to medium rainfall zones of southern Australia. Improved nutrition and ruminant reproductive benefits are also possible. The later senescence of some of the novel legumes (e.g. PM250 medic and trigonella) may see them maintain higher nutritional value through senescence and reduce the need for supplementary feeding. Their nutritional value is presently being analysed. Farming systems benefits such as using livestock to remove weeds through selective grazing or nutrient cycling are difficult to quantify, and it is hoped that the DLPS project and this large-grazing trial may be able to provide some answers over the five-year period of study.

The priority for this trial in 2018 was to optimise seed set given the poor seasonal conditions, and therefore no grazing was undertaken on the large trial at Minnipa in 2018. Pastures will be allowed to regenerate in 2019 and livestock will be introduced once there is sufficient feed on offer to determine their performance on the different legume pastures. Wheat will be re-sown in the control plots with vetch planned to be re- sown on the same plots it was grown last season. The production of the legume treatments will be measured under grazing in 2019, with pasture regeneration, growth, composition, observed palatability and duty of care (ensuring that the plant type will not be problematic to livestock health, productivity or product quality) assessed in order to determine which legume species provide the best outcomes for livestock production and are able to persist in the farming system.

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The research partners include the South Australian Research and Development Institute, Murdoch University, the Commonwealth Scientific and Industrial Research Organisation, the WA Department of Primary Industries and Regional Development, and Charles Sturt University, as well as 10 grower groups.

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Mixed Cover Crops for Sustainable Farming

Author: Mark Stanley

Delivery Organisation: Ag Excellence Alliance

UNFS is a delivery partner in this project.

Key Messages

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

About the project

Crop intensive farming systems are running down soil carbon levels, requiring increased inputs to maintain or increase yield without necessarily improving profitability. Mixed species cover cropping offers a new approach in the Australian context. It is a key component of some farming systems overseas but is yet to be adopted widely in southern Australia. In the context of this project, mixed species cover crops refers to a diverse mix of plant species grown at the same time but often outside the main growing season to build fertile and resilient soils.

Benefits of cover crops include improving soil organic carbon, structure and health, while decreasing weed and disease levels for following crops, but these must be balanced against the cost of growing the cover crop and the water and nutrients it will use. Many potential cover crop options exist and while growers are beginning to investigate these, they lack the basic local knowledge to make informed decisions.

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

The project has three components:

1. ***Farm demonstration sites*** Cover cropping will be examined on 20 farms across south eastern Australia, including four sites on the Eyre Peninsula. On each farm, a replicated demonstration trial will be established from summer late 2018 (dependent on seasonal conditions) and will be monitored until harvest in summer late 2021. Paddocks will be sown with multiple species cover crop (Treatment 1), and will serve as a demonstration paddock. Replicated areas within in the paddock will have two further treatments: Treatment 2 no soil disturbance, no seed added (i.e. business as usual summer fallow) and Treatment 3 single cover crop species sown.

2. ***Cover crop evaluation field trials*** Two sets of field trials will be conducted. One will evaluate new and emerging summer and winter active plant species/varieties most suited to different environments across south eastern Australia. The other will evaluate the most effective strategies and timings to terminate a cover crop for achieving the optimum benefits for subsequent crops and soil health.

Extension and communications

Extension activities will include field days to be conducted at each of the demonstration sites over the course of the project, and inclusion of updates on project developments at grower group events. Progress on the project will be communicated on SANTFA Twitter, Facebook and Podcast sites, and a dedicated project web site will be hosted by the CSIRO to house project resources as they are produced.

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Mr	Tim	Arthur		Melrose
Mr	Peter	Barrie	Di	Orroroo
Mr	Howard	Bastian	Toni-Louise	Booleroo Centre
Mr	Michael & Braden	Battersby	Catherine & Emilie	Wilmington
Mr	Colin	Becker	Joy	Caltowie
Mr	William & Henry	Bennett		Orroroo
Mr	Shaun	Borgas	Marisa	Booleroo Centre
Mr	Donald	Bottrall	Heather	Jamestown
Mr	Brendon	Bradtke		Jamestown
Mr	Benjamin & Bevin	Bury		Wilmington
Mr	Neil, Emily & Malcolm	Byerlee		Orroroo
Mr	Todd	Carey	John	Wilmington
Mr	John (JP) & John (Snr)	Carey	Nicole	Booleroo Centre
Mr	Ben (Snr) & Ben (Jnr)	Carn	Susan	Quorn
Mr	David	Catford		Gladstone
Mr	Gilmore & Andrew	Catford	Michele	Orroroo
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Mr	Peter	Cousins	Pam	Crystal Brook
Mr	Trevor	Crawford	Christine	Jamestown
Mr	Ben & Bruce	Crawford	Beck	Georgetown
Mr	Mark & John	Crawford	Heidi	Georgetown
Mr	Chris	Crouch	Iris	Wandearah via Crystal
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Mr	Barry & Jonathon	Mudge	Kristina	Port Germein
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Mr	Todd & Mitch	Orrock	Brooke	Murray Town
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Mr	John	Polden		Booleroo Centre
Mr	Patrick	Redden		Clare
Mr	Mark	Reichstein		Appila
Mr	Jim	Richards		Crystal Brook
Mr	Steve	Richmond		Jamestown
Mr	Paul	Rodgers		Quorn
Mr	Gavin	Schwark	Alex (Son)	Booleroo Centre
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