UNFS

Upper North Farming Systems

2017

RESULTS

UPPER NORTH FARMING SYSTEMS ANNUAL RESEARCH AND EXTENSION COMPENDIUM

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DISCLAIMER

THANK YOU TO ALL OUR SPONSORS

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THANK YOU TO OUR FUNDING BODIES AND PROJECT PARTNERS

The Australian Government; Natural Resources Northern and Yorke; Grains Research and Development Corporation; South Australian Grains Industry Trust; Ag Excellence Alliance; University of Adelaide; Primary Industries and Regions SA; South Australian Research and Development Institute; Birchip Cropping Group; and Rufous & Co.

Without the support 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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Matt Nottle	**Vice Chairman**	0428 810 811	matt.nottle@hotmail.com	Booleroo Centre
Barry Mudge	**Board Member**	0417 826 790	theoaks5@bigpond.com	Nelshaby
Joe Koch	**Finance**	0428 672 161	breezyhillag@outlook.com	Booleroo Centre
Jim Kuerschner	**Strategic Board**	0427 516 038	jimkuerschner@bigpond.com	Orroroo/Black Rock
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Jess Koch	**Ladies on the Land Hub**	0419 982 125	Jessica.breezyhill@outlook.com	Booleroo Centre
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Kristina Mudge	**Admin Officer**	0438 840 369	admin@unfs.com.au	Nelshaby

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 in the 2017 season.

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, Susan Murray) for their excellent efforts in project leadership, group governance, finance and administration.

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 Projects and Grants 2017

(Including projects undertaken in the 2016-2017 FY)

UNFS Project #	Other Names/ References	Full Name	Funding Source	Project Manager
209	Yield Prophet	Yield Prophet in the Upper North	EPIC and GrainCorp Sponsorship/UNFS	Barry Mudge/ Hannah Mikajlo
211	GRDC Stubble Initiative	Maintaining Profitable farming systems with retained stubbles in Upper North SA	GRDC	Ruth Sommerville/ Hannah Mikajlo
214	Overdependence on agrochemicals	Overdependence on agrochemicals UN	SARDI/GRDC/ Central West Farming Systems	Barry Mudge/Naomi Scholz (SARDI)
216	Controlled Traffic	Application of CTF in the low rainfall zone	ACTFA	Matt McCallum
217	Post Pasture Stubble Demonstrations	Upper North SA - Increased Uptake of No-till in Post Pasture Cropping Phases (25ALG-507)	Landcare	Ruth Sommerville
219	Upskilling UNFS Women	Up-skilling the Women of the Upper North in Sustainable and Productive Farming Principles	SAGIT	Jess Koch
		Rural Business Management 101 - Up-skilling the Women of the Upper North in Sustainable and Productive Farming Principles *SGR1-0598*	Landcare	Jess Koch
220	Time of Sowing Trial	"Upper North Time of Sowing and Yield Loss from Frost / Heat Stress"	SAGIT	Hannah Mikajlo
221	Weed Seed Burning Project	Burning of weed seeds in low rainfall farming systems	SARDI/SAGIT	Ruth Sommerville/ Hannah Mikajlo
222	Production Wise	Production Wise in the Upper North	GrainGrowers	Hannah Mikajlo
223	Pasture Options Demonstrations	Demonstrating Improved Pasture Options for the Upper North	PIRSA/Ag Ex Alliance	Matt Nottle/ Hannah Mikajlo
224	Micronutrients in the Upper North	Increasing the knowledge and understanding of micronutrient deficiency in the UN - UNF117	SAGIT	Hannah Mikajlo
225	Soil Acidity in the Upper North	Investigating Soil Acidification in the Upper North	NYNRM	Hannah Mikajlo
226	UNFS pulse check group	GRDC southern pulse extension project	GRDC	Hannah Mikajlo/ Barry Mudge

Upper North Farming Systems

Event Summary

Date	Event	Location	Participants	Details/Topic
31/1/17	Ladies on the Land Workshop	Booleroo Centre		Communication
15/6/17	Ladies on the Land Workshop	Booleroo Centre	12	FarmSafe & Revegetation Workshop. Speakers - Anne Brown from Greening Australia and Caroline Graham from SafeAg Systems
22/6/17	Gladstone/Laura Post Sowing Bus Tour Hub Bus Trip	Laura - Hart - Lochiel - Crystal Brook	21	Controlled traffic, paired row seeding, Grainflow tour in Crystal Brook
10/8/17	Members Expo	Booleroo Centre	70	Alternatives for Profitable Crop Rotations in the Upper North Speakers: *Welcome - Barry Mudge *UNFS project update - Hannah Mikajlo *Growing high value crops in a low rainfall zone -Chris Crouch *Pulse marketing - Jamie Koch *Update on pesticide regulations and practical tips for farmers - Peter Cousins *Recent advances and trends in the wool industry - Adrian Dewell *Inspection of local SARDI break crop trial
30/8/17	UNFS Western Spring Crop Walk	Nelshaby/ Wandearah/Baroota	30	Crop walk
12/9/17	Ladies on the Land Workshop	Booleroo Centre	10	Farm business planning workshop. Speaker - Linda Eldredge from Eldredge and Associates Consulting and Training
13/9/17	SAGIT visit to Time of Sowing/ Micronutrient trial site	Fullerville	7	Visit by funding body
14/9/17	UNFS Eastern Spring Crop Walk	Booleroo Centre and Fullerville	33	Pasture options demonstration, Time of Sowing and Micronutrient trials, weather stations/temperature sensors
20/9/17	JAPS (Jamestown) cropping tour	Jamestown and Spalding	15	Cropping tour
21/9/17	JAPS livestock tour	Jamestown and Wirrabara	9	Livestock tour
21/9/17	Laura/Gladstone/ Booleroo Hub presentation and meeting	Laura	35	Controlled traffic and farm machinery investments, with speaker James Hagan
5/12/17	First pulse check group meeting	Napperby	28	Post-harvest discussion with advisors Daniel Hillebrand and Jamie Koch

UNFS 2016/17 Audited Financial Statements

UPPER NORTH FARMING SYSTEMS

INCOME STATEMENT
FOR THE YEAR ENDED 30 JUNE 2017

	Note	2017 $	2016 $
INCOME			
Group Income			
Interest		1,491	1,817
Machinery Hire		2,584	-
Membership		4,477	5,742
Merchandise		241	-
Project Administration		5,951	2,310
Field Days		7,731	5,722
Commercial Paddock		22,908	-
Sponsorship		1,500	-
		46,883	15,591
OTHER INCOME			
Project Income			
Crop Sequencing		-	30,000
Pasture Production Zoning		2,000	10,380
Lower Rainfall Bus Trip		167	3,630
Yield Prophet		11,250	2,000
Nitrous Oxide		-	10,900
GRDC Stubble Initiative		195,300	-
Controlled Traffic		3,084	1,100
Overdependence Agrochemicals		30,000	10,000
Ladies on the Land Workshop		2,700	6,600
Perennial Pasture Project		24,385	-
Weed Seed Burning		7,500	-
		276,386	74,610
		323,269	90,201

UPPER NORTH FARMING SYSTEMS

INCOME STATEMENT
FOR THE YEAR ENDED 30 JUNE 2017

	Note	2017 $	2016 $
EXPENDITURE			
Group Expenses			
Administration		38,401	12,331
Audit Fees		5,700	5,690
Minor Equipment & Maintenance		1,435	-
Insurance		205	-
Merchandise Expense		2,067	125
Publications		913	4,500
Field Days		12,077	2,295
Commercial Paddock		940	-
Bank Fees		120	-
Depreciation		1,274	-
		63,132	24,941
Project Costs			
Crop Sequencing		-	14,545
GRDC Stubble Initiative		63,709	64,729
Yield Prophet		12,161	-
Pasture Production Zoning		1,000	10,230
Nitrous Oxide		951	3,165
Onion Weed		-	3,505
Controlled Traffic		819	2,646
Overdependence Agrochemicals		37,422	710
Post Stubble Demo		5,280	5,326
Ladies on the Land		7,757	-
Time of Sowing Trial		10,766	-
Production Wise		116	-
Pasture Options Demo		408	-
Weed Seed Burning		1,578	-
		141,967	104,856
		205,099	129,797
Profit (Loss) before income tax		118,170	(39,596)
Profit (Loss) for the year		118,170	(39,596)
Retained earnings at the beginning of the financial year		194,451	234,047
Retained earnings at the end of the financial year		312,621	194,451

UPPER NORTH FARMING SYSTEMS

BALANCE SHEET
AS AT 30 JUNE 2017

	Note	2017 $	2016 $
ASSETS			
Cash and cash equivalents	3	280,772	197,890
Trade and other receivables	4	4,357.00	-
TOTAL CURRENT ASSETS		285,129.00	197,890.00
NON-CURRENT ASSETS			
Property, plant and equipment	5	29,706	-
TOTAL NON-CURRENT ASSETS		29,706	-
TOTAL ASSETS		314,835.00	197,890.00
LIABILITIES			
CURRENT LIABILITIES			
Trade and Other Payables	6	2,214	3,439
TOTAL CURRENT LIABILITIES		2,214	3,439
TOTAL LIABILITIES		2,214	3,439
NET ASSETS		(312,621)	(194,451)
MEMBERS' FUNDS			
Retained earnings	7	312,621	194,451
TOTAL MEMBERS' FUNDS		312,621	194,451

NOTES TO THE FINANCIAL STATEMENTS
FOR THE YEAR ENDED 30 JUNE 2017

		2017 $	2016 $
3	**Cash and Cash Equivalents**		
	Freedom Bank Account 92540	14,121	30,730
	Business Bank Account 93340	266,651	167,160
		280,772	197,890
4	**Trade and Other Receivables**		
	Current		
	GST Account	4,357	-
		4,357	-
5	**Property, Plant and Equipment**		
	Plant & Equipment - at Cost	31,232	-
	Less Prov'n for Depreciation	(1,526)	-
		29,706	-
	Total Plant and Equipment	29,706	-
	Total Property, Plant and Equipment	29,706	-
6	**Accounts Payable and Other Payables**		
	Current		
	PAYG Withheld	1,439	-
	Superannuation Liability	775	-
	GST Account	-	3,439
		2,214	3,439
7	**Retained Earnings**		
	Retained earnings at the beginning of the financial year	194,451	234,047
	Net profit (Net loss) attributable to the association	118,170	(39,596)
	Retained earnings at the end of the financial year	312,621	194,451

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 2017, and the income and expenditure statement for the year then ended, and notes to the financial statements including a summary of significant accounting policies and other explanatory information, and management's assertion statement.

In my opinion, the accompanying financial report of the association for the year ended 30 June 2017 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.

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

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 9th day of August 2017

Upper North Farming Systems
Draft Cashflow 1/7/17 to 30/06/18
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	214 Overdependence on agrochemicals	217 Post Stubble Demo	219 Ladies on the Land Workshops	220 Time of Sowing Trial	221 Weed Seed Burning	222 Production Wise	223 Pasture Options Demo	224 Micronutrients	225 Soil Acidity in UN	226 Pulse Check	OVERALL TOTAL
INFLOWS																
Interest	1760															1,760
Machinery Hire_Vehicle Use	3142															3,142
Membership	5182															5,182
Merchandise	27															27
Project Administration	58047															58,047
Project Income	5000	4,120	7,389	3,200	130,200			800	24,385			5,000	23,500	17,000	13,086	233,680
Sale of Capital Items	5000															5,000
Sponsorship	18182	900		3,000							1,150					23,232
Sundry Income	70300															
TOTAL INFLOWS	166639	5,020	7,389	6,200	130,200	-	-	800	24,385	-	1,150	5,000	23,500	17,000	13,086	400,369
OUTFLOWS																
Administration	-6358	- 4,583														- 10,941
Audit Fees	-2450															- 2,450
Bank Fees	120															120
Event Expenses																
Event Catering		547						125								672
Event Expense		1,406						220						3,631		5,257
Presenter		1,200														1,200
Hub Expenses		1,026														1,026
Insurance	2002															2,002
Minor Equipment & Maintenance	1648															1,648
Project Expenses																
Communications													900	2,000		2,900
Consultants													3,750	7,019		10,769
Project Management					2,468									2,000		4,468
Travel				564	3,566				2,085	149			32	238	224	6,856
Other Project Expenses	-24792		1,715	7,925	328,349	1,121	3,498	89	10,721	5,744		1,182	4,503	561	3,126	343,742
Publications	2390				220											2,610
Wages																
Computer_Data Allowance	305				700											1,005
Superannuation	242				6,135											6,376
Wages Administration Officer	3148															3,148
Wages Project Officer				2,081	49,072	508		384	6,527	29	785	174	2,291	1,552	1,175	64,577
TOTAL OUTFLOWS	-23746	- 404	1,715	10,569	390,509	1,628	3,498	818	19,333	5,922	785	1,356	11,475	17,000	4,525	444,984
OVERALL TOTAL	190385	5,424	5,675	- 4,369	- 260,309	- 1,628	- 3,498	- 18	5,052	- 5,922	365	3,644	12,025	-	8,561	- 44,615
OPENING BALANCE as at 1/7/17	51,832	14,195	16,470	9,229	195,209.25	1,628	3,498	1,543	13,619	5,922	- 116	- 408	-	-	-	312,621
MOVEMENT	190,385	5,424	5,675	- 4,369	- 260,309.25	- 1,628	- 3,498	- 18	5,052	- 5,922	365	3,644	12,025	-	8,561	- 44,615
CLOSING BALANCE as at 30/06/18	**242,217**	**19,619**	**22,144**	**4,860**	**- 65,100.00**	**-**	**-**	**1,526**	**18,671**	**-**	**249**	**3,235**	**12,025**	**-**	**8,561**	**268,006**

UNFS Yield Prophet in 2017

Author: Hannah Mikajlo

Funded by: GRDC Stubble Initiative, GrainCorp, EPIC and participating landowners

Project title: UNFS Yield Prophet

Project duration: 2017 cropping season

Project Delivery Organisations: Barry Mudge Consulting and UNFS

Key points:

- **UNFS ran Yield Prophet on 10 sites throughout the Upper North in 2017.**
- **Although the programme accurately predicted the yield in some situations, on many sites it significantly underestimated the yield potential.**
- **Yield Prophet can be useful in assisting in-crop input decision making, particularly in-season applications of nitrogen.**

Background:

In 2017, UNFS operated 10 Yield Prophet sites across the Upper North region. Funding for the project was obtained from our valued sponsors GrainCorp, E.P.I.C., and GRDC (through the Stubble Initiative), as well as from participating farmers. Deep soil sampling was conducted in May, with the samples being analysed for various parameters including moisture and nitrogen content. The soil characteristics were then entered into the Yield Prophet program for each of the sites. Reports were regularly generated and emailed to UNFS members.

How Yield Prophet works

Yield Prophet is a web-based interface that provides estimates of crop yield. The program operates by using the APSIM model, developed and maintained by the APSIM Initiative and the CSIRO. APSIM simulates agricultural systems, taking into consideration a range of plant, soil, climate, and management interactions. Yield Prophet uses the model to provide a web-based decision-support tool for grain growers. After inputting data relating to the specific soil characteristics, further information relating to the crop (e.g. sowing date, fertiliser applications, crop variety) and daily rainfall data are entered, providing updated estimates of yield expectations.

The predictions generated by Yield Prophet can be used to inform management decisions. For instance, the program's ongoing estimation of the nitrogen status of the crop can be useful in assessing the value of applying additional nitrogen. The yield predictions may also provide greater confidence in forward marketing of grain.

The accuracy of Yield Prophet's predictions relies on historical rainfall patterns being repeated (see **Figure 1**). The results are also very specifically location based, although they can be extrapolated to other sites based on knowledge of the particular characteristics of each location.

In 2017, the cost to run Yield Prophet was an annual subscription of $180 (or $120 for members of Birchip Cropping Group), plus the cost of the initial soil sampling. Once subscribed, there is no limit to the number of times the information can be updated throughout the year, and the number of reports generated.

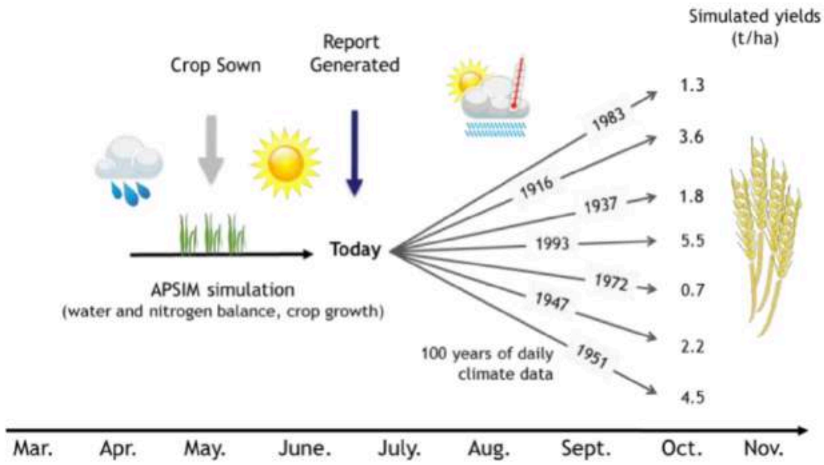

Figure 1. Diagram of the Yield Prophet simulation process.

Yield Prophet performance in 2017

During the previous years of the project, Yield Prophet has been for the most part relatively good at predicting crop yields. Despite some instances where the model's accuracy was compromised by factors such as frost, Yield Prophet remains a useful decision support tool.

Much of the Upper North experienced below average rainfall throughout the 2017 growing season, as well as a dry finish. Wet conditions during the previous spring and summer, however, meant that many sites had significant subsoil moisture reserves. Many areas also benefited from above average rainfall in April. Seeding at the project sites occurred from late April to mid-May. Yield limiting factors at some locations included minor frost damage, pest issues and a hot, dry finish.

The site locations for the UNFS Yield Prophet project in 2017 are shown in **Figure 2**. Summaries of the Yield Prophet reports are included below. Also included are graphs for each site, showing the 10^{th}, 50^{th}, and 90^{th} percentile of predicted yield for each date that the model was run, as well as the actual yield. To interpret the results, and as an example, the 90^{th} percentile yield represents the yield which is expected to be equaled or exceeded in 90 years out of 100. The three lines showing the different percentiles in the graphs eventually converge at the end of the season. The point at which they meet is the final yield prediction.

Note that the predictions given by Yield Prophet are water and nitrogen limited estimates. As the season progresses and more information (e.g. rainfall data or nitrogen applications) is entered into the model the estimates are adjusted accordingly.

Figure 2. Yield Prophet site locations in 2017.

Barrie (9 km south-west of Morchard)

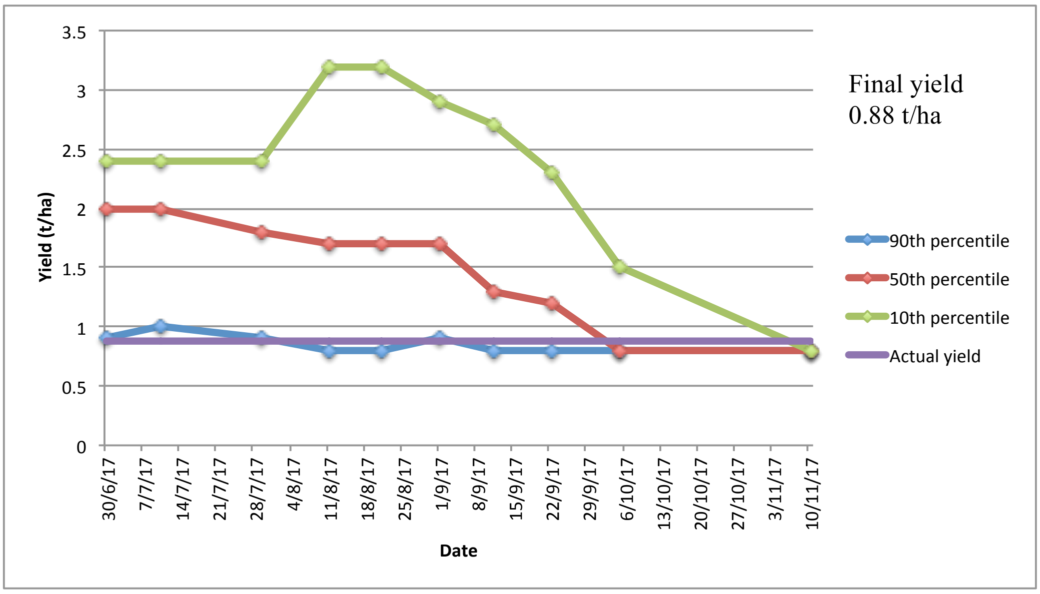

Figure 3. Yield potential (as measured by the 10th, 50th, and 90th percentiles) over the 2017 season for the Barrie site. The final yield is also shown.

The model performed very well at this site, with the final predicted yield being 0.8 t/ha, against the actual yield of 0.88 t/ha. Yield potential was limited by low levels of stored soil moisture at the time of sowing, and dry conditions throughout the season.

Berryman (4.5 km south-east of Murray Town)

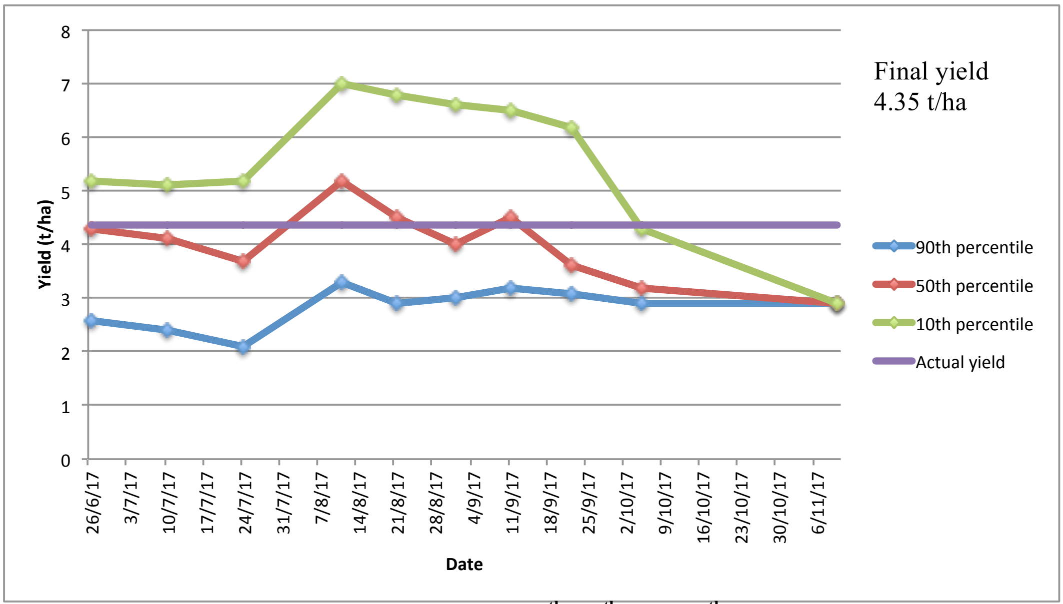

Figure 4. Yield potential (as measured by the 10th, 50th, and 90th percentiles) over the 2017 season for the Berryman site. The final yield is also shown.

The model significantly underestimated the yield at this site. The most likely reason for the disecrepancy was the difficulty of picking an accurate soil type for the area. The model also had to be adjusted part way through the season because the crop had developed at a much faster rate than Yield Prophet had predicted.

Bottrall (5 km south-east of Appila)

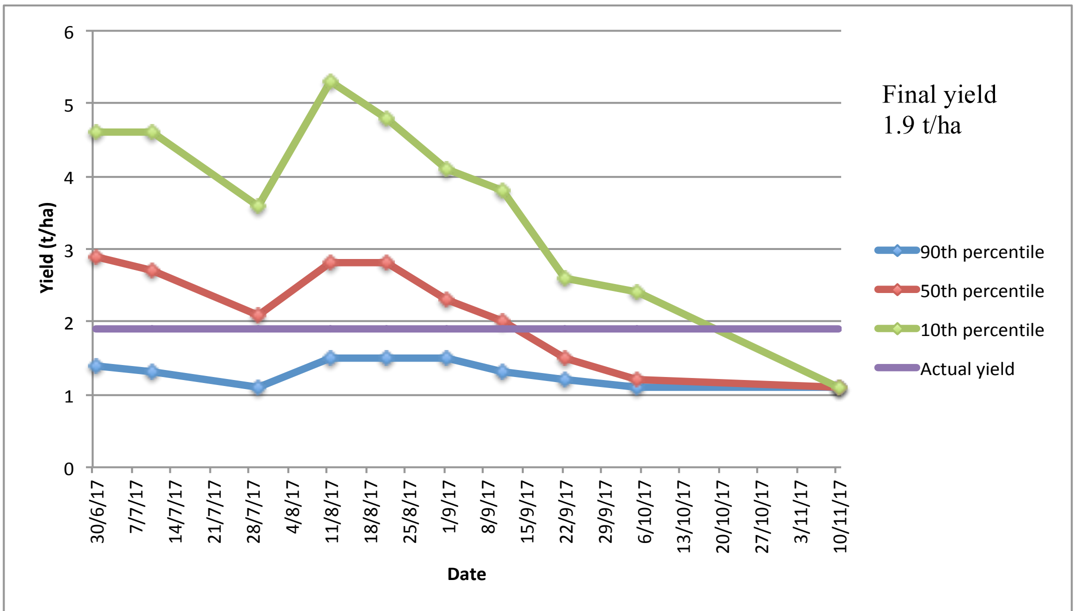

Figure 5. Yield potential (as measured by the 10th, 50th, and 90th percentiles) over the 2017 season for the Bottrall site. The final yield is also shown.

Yield Prophet performed reasonably well at this site although it did underestimate the yield somewhat. Possibly the crop was able to access soil moisture which was not detected during the set up of the model.

Clark (10 km south of Jamestown)

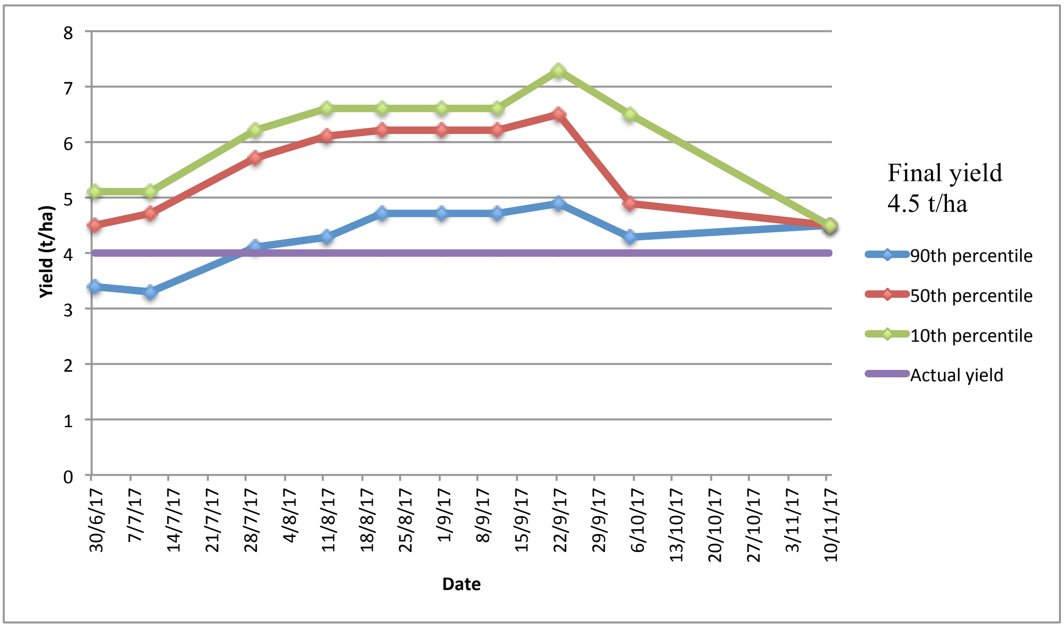

Figure 6. Yield potential (as measured by the 10th, 50th, and 90th percentiles) over the 2017 season for the Clark site. The final yield is also shown.

The model performed quite well at this site.

Crouch (Wandearah, 25 km south of Port Pirie)

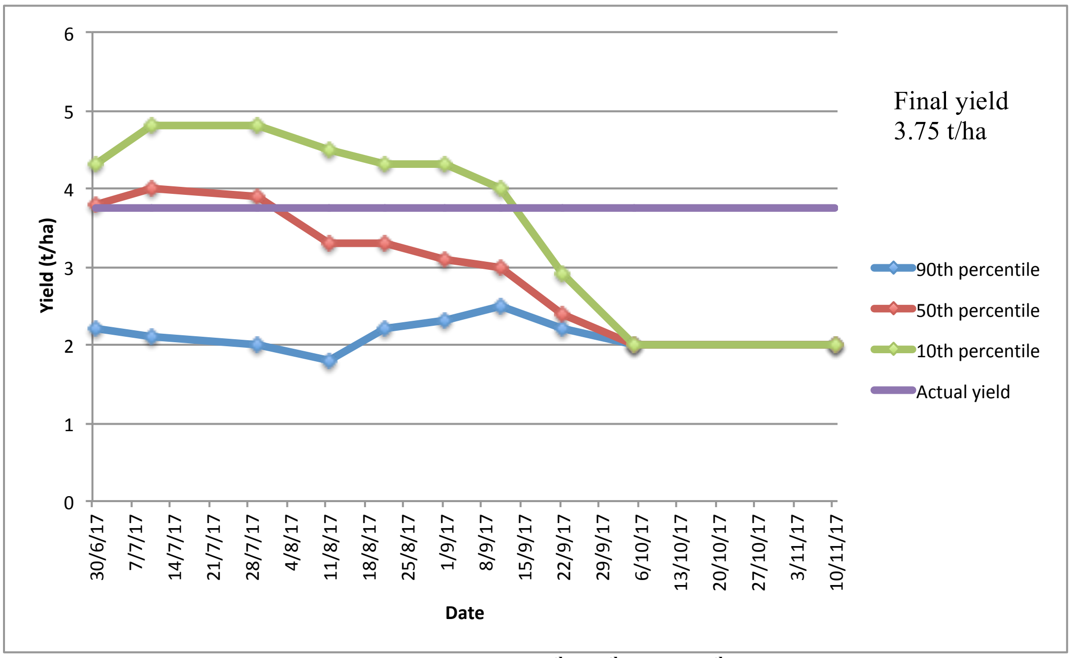

Figure 7. Yield potential (as measured by the 10th, 50th, and 90th percentiles) over the 2017 season for the Crouch site. The final yield is also shown.

The model did not perform well at this site, significantly underestimating the final yield. Chris suspects that the soil moisture at sowing might have been undervalued, and that late in the season the plants were able to access deeper soil moisture not picked up by Yield Prophet.

Kitto (8km north of Gladstone)

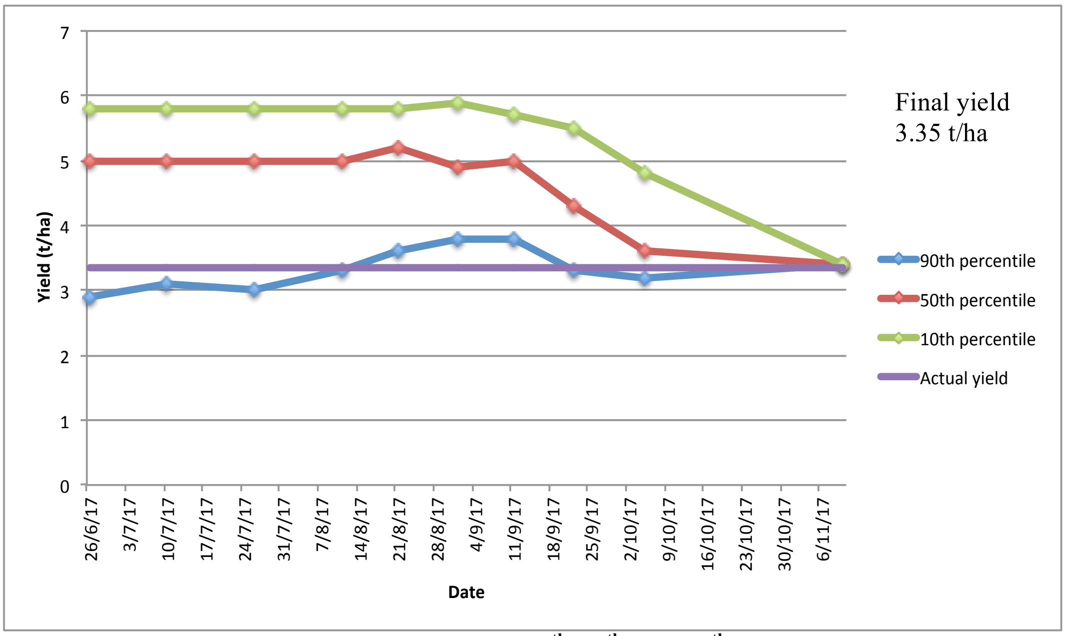

Figure 8. Yield potential (as measured by the 10th, 50th, and 90th percentiles) over the 2017 season for the Kitto site. The final yield is also shown.

Yield Prophet performed very well at this site.

Kuerschner (Black Rock)

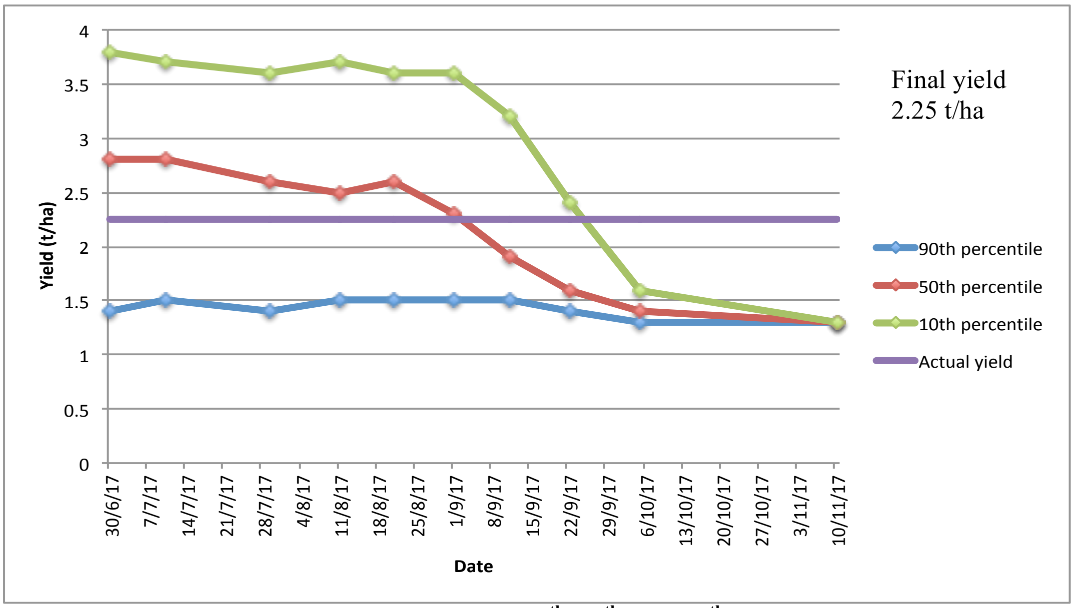

Figure 9. Yield potential (as measured by the 10th, 50th, and 90th percentiles) over the 2017 season for the Kuerschner site. The final yield is also shown.

Yield Prophet significantly underestimated the yield potential at this site. Again, this may have been due to the crop accessing deeper water reserves not picked up by Yield Prophet.

Mudge (Telowie, 6 km south east of Port Germein)

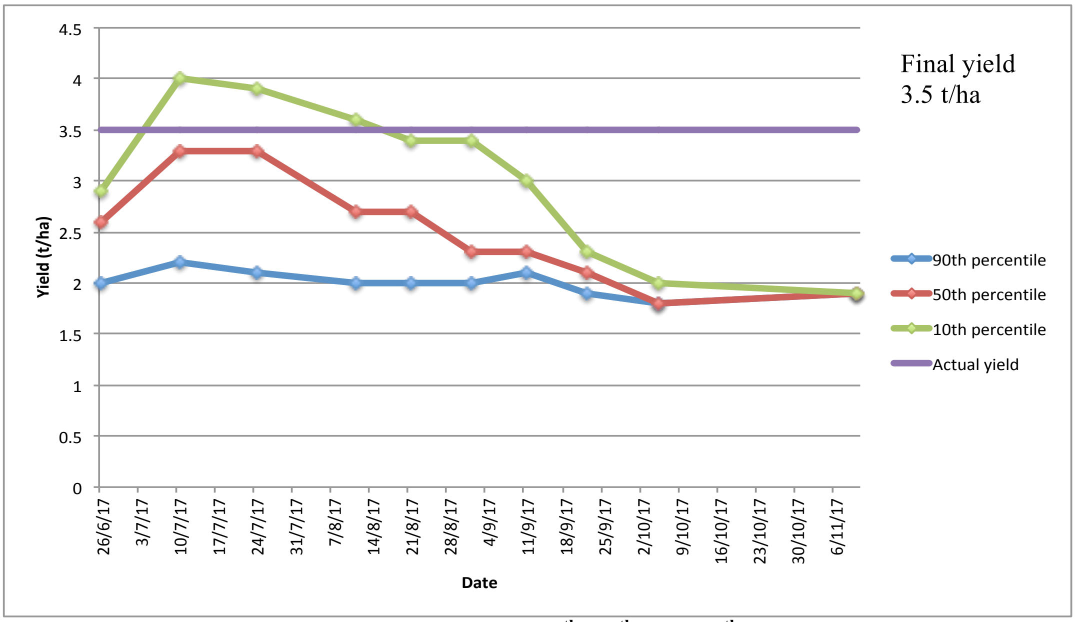

Figure 10. Yield potential (as measured by the 10th, 50th, and 90th percentiles) over the 2017 season for the Mudge site. The final yield is also shown.

Again, Yield Prophet significantly underestimated the yield, possibly because of unforseen soil moisture reserves.

Rodgers (Richman Valley, 9.5 km south of Quorn)

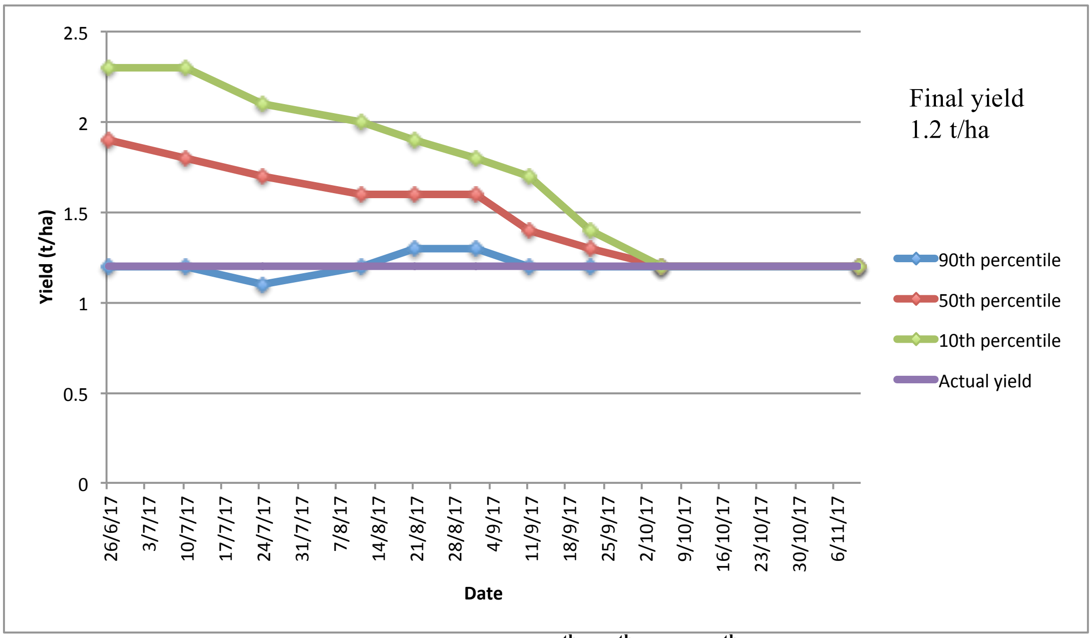

Figure 10. Yield potential (as measured by the 10th, 50th, and 90th percentiles) over the 2017 season for the Rodgers site. The final yield is also shown.

The model performed very well at this site.

UNFS Time of Sowing trial site (Fullerville, 5km west of Booleroo Centre)

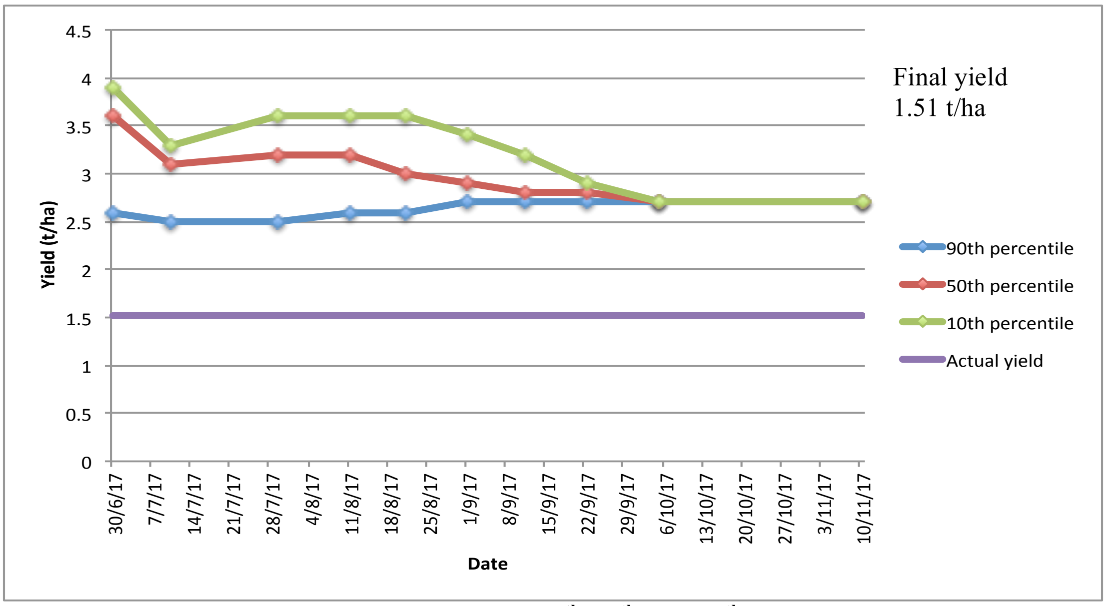

Figure 11. Yield potential (as measured by the 10th, 50th, and 90th percentiles) over the 2017 season for the UNFS TOS trial site. The final yield is also shown.

At the 2017 UNFS Time of Sowing trial site, Yield Prophet was run for the plots sown to Mace wheat in mid-April. This was the only situation in 2017 where the model significantly overestimated the final yield. The most likely reason for this was the model's inability to account for the severe frost damage that affected the trial.

Summary and conclusions:

Yield Prophet did not perform as well in 2017 as it has in previous years. Although it accurately predicted the final yield at some sites, more frequently it significantly underestimated the yield potential. The most likely explanations for the model being compromised are the difficulty in selecting an appropriate soil type for each site, and deep soil moisture reserves that were undervalued at the start of the season, but which the crop was later able to access. Despite its faults, Yield Prophet remains a useful tool for assessing water and nitrogen limited yield potential as the season progresses, and can assist with in-crop input decision making.

Acknowledgements:
Participating farmers – Peter Barrie, Dustin Berryman, Don Bottrall, Luke Clark, Chris Crouch, Andrew Kitto, Jim Kuerschner, Barry Mudge, Paul Rodgers, and Todd Orrock.
GRDC for funding the UNFS Stubble Initiative.
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Time of Sowing Trial at Fullerville, 2017:
Frost and Heat Effects on Crop Development and Yield

Author: *Hannah Mikajlo (UNFS)*

Funding body: *South Australian Grains Industry Trust*

Project title: *Upper North time of sowing and yield loss from frost/heat stress*

Project duration: *2016-2018*

Delivery organisation: *Upper North Farming Systems*

Key messages:

- **The fast-maturing Hatchet was afflicted by severe frost damage when sown early in April.**
- **Later-maturing varieties Longsword and Cutlass suffered a yield penalty when sown in late May.**
- **Yield and quality were heavily affected by frost and the dry finish in 2017.**
- **Understanding the development factors and requirements of the different wheat cultivars being sown is crucial to minimising frost and heat effects.**

Background:

Wheat is particularly susceptible to frost and heat damage during its flowering period, and this can have a significant effect on yield. Timing sowing to optimise the flowering window is complicated by varying maturity speeds for different wheat varieties. In South Australia's Upper North, manipulation of flowering time is made even more difficult by the highly variable climate across the region. Both frost and heat events also commonly occur during the spring period, further complicating matters.

Time of sowing can also be used to take advantage of seasonal conditions. Retained soil moisture and early breaking rains allow for earlier sowing, while fast maturing wheat varieties can be sown much later to compensate for late breaking rains.

2017 was the second year of this SAGIT-funded Time of Sowing trial. The results from 2016 clearly showed differences in performance for different wheat varieties when sown at different times. This highlighted the importance of having a clear understanding of the optimum sowing window for each variety, and the subsequent implications regarding nitrogen requirements and yield potential.

Methodology:

The trial was sown at Fullerville, approximately 5km west of Booleroo Centre on White Well Road. The paddock has a uniform red clay.

The trial was arranged in a split-plot design, with five different varieties of wheat (see **Table 1**), three times of sowing (TOS 1 – mid-April (18/4/17), TOS 2 – early-May (8/5/17) and TOS 3 – late-May (26/5/17)), and four replicates. Buffers were sown to Trojan at TOS 1. There was soil moisture sufficient for establishment at each time of sowing, so the plots did not need to be watered.

All plots were sown with 30 kg/ha urea and 80 kg/ha Granulock® SS, and at 70 kg/ha of seed. Sowing was conducted using a Primary Sales Plot Seeder loaned to UNFS by the South Australian Research and Development Institute (SARDI). An additional 80 kg/ha of urea was applied on the 18th of June. The plots were sprayed on the 20th of June with 700 mL/ha Amine Advance and 100 mL/ha of Lontrel™.

Soil temperature was recorded at each time of sowing (21°C at TOS 1, 15.4°C at TOS 2, 14°C at TOS 3). A canopy-height temperature sensor was also set up at the site and recorded temperatures from the 26th of July onwards. The temperature extremes from the 26th of July until the harvest date (6th of December) are shown in **Figure 5**. Throughout the trial the plots were examined for visual frost damage to the wheat heads.

The trial plots were harvested on 6/12/17 by SARDI. Grain quality analysis was carried out by Viterra at the Jamestown silos.

Results and Discussion:

Table 1. Commercial wheat varieties used in the 2017 UNFS Time of Sowing trial.

Variety	Maturity	Comments
Trojan	Mid-fast maturing spring wheat.	Relatively high yielding. Has a photoperiod gene that may allow it to be sown in late April and flower during the optimum time window.
Mace	Early-mid maturing spring wheat.	Often considered the benchmark variety in the Upper North. Has broad adaptation, and consistently high relative yield in a wide range of conditions.
Cutlass	Mid to late maturing spring wheat.	Similar maturity to Yitpi.
Hatchet CL Plus	Very fast-maturing spring wheat.	Developed from axe. Lacks a photoperiod requirement.
Longsword (previously known as RAC2341)	Fast-maturing winter wheat.	Developed from Mace. Requires a cold period (vernalisation) to initiate its reproductive phase, enabling early sowing whilst still aiming for the correct flowering period.

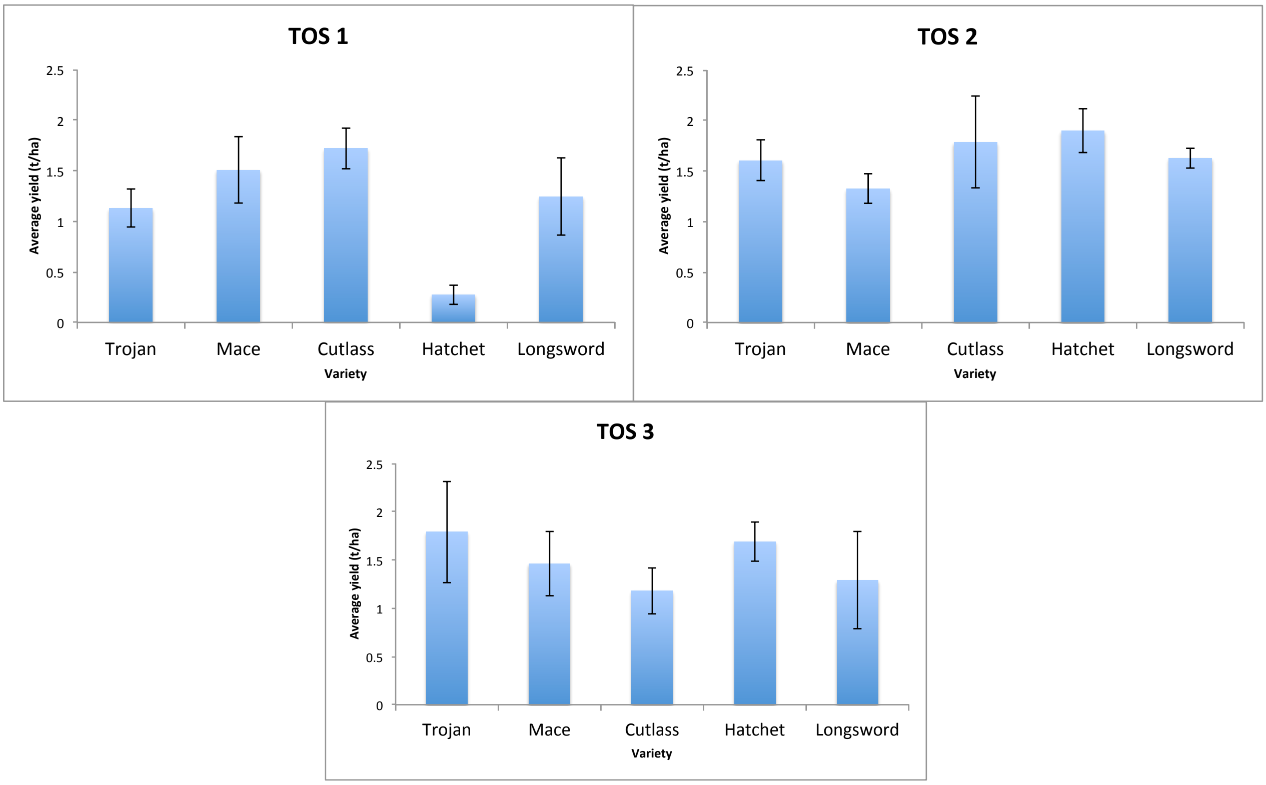
Yield

Yield results from the trial are presented in **Figures 1-4** and **Table 2**. As shown in **Figure 4**, the influence of sowing time varied between varieties. Some varieties experienced a yield penalty when sown later, while others performed better. The trial data were analysed using ANOVA and Least Significant Difference (LSD) tests. The analyses indicated statistically significant differences between the varieties when compared at each time of sowing. For TOS 1, Cutlass performed the best, followed by Mace. There was no significant difference in yield between Longsword and Trojan, which yielded less than Mace but more than Hatchet. Hatchet had a significantly lower yield than all other varieties at the first time of sowing. 2017 was a particularly cold year, with numerous frost events occurring during the growing season. This undoubtedly influenced the yield results. In particular, the early-sown and fast-maturing Hatchet was observed to suffer severe frost damage, something that was reflected in its significantly lower yield.

For TOS 2, there was no significant difference between the two highest yielding varieties, Hatchet and Cutlass. Again, there was no significant difference between the yields of Longsword and Trojan, which had lower yields than Hatchet and Cutlass, but performed better than Mace.

Hatchet and Trojan were the highest yielding varieties at TOS 3. There was no significant difference between them. Mace was the next best performing variety. Longsword and Cutlass had similar yields to each other, and the lowest of all varieties at TOS 3.

Grain quality was also analysed using ANOVA and LSD tests. The results are shown in **Table 2.** Protein content for each variety remained relatively consistent regardless of the time of sowing. The exception was the earliest sown Hatchet, which had a significantly higher protein content, probably due to the substantial frost damage it suffered. All varieties had test weight scores greater than 71 kg/hL, the minimum test weight requirement for the AUH2 grade. Screenings for all varieties at all times of sowing were below 1 per cent, and well below maximum limits for all grades.



Figures 1-3. Yield comparisons between the five wheat varieties at each time of sowing. Error bars show standard deviation.

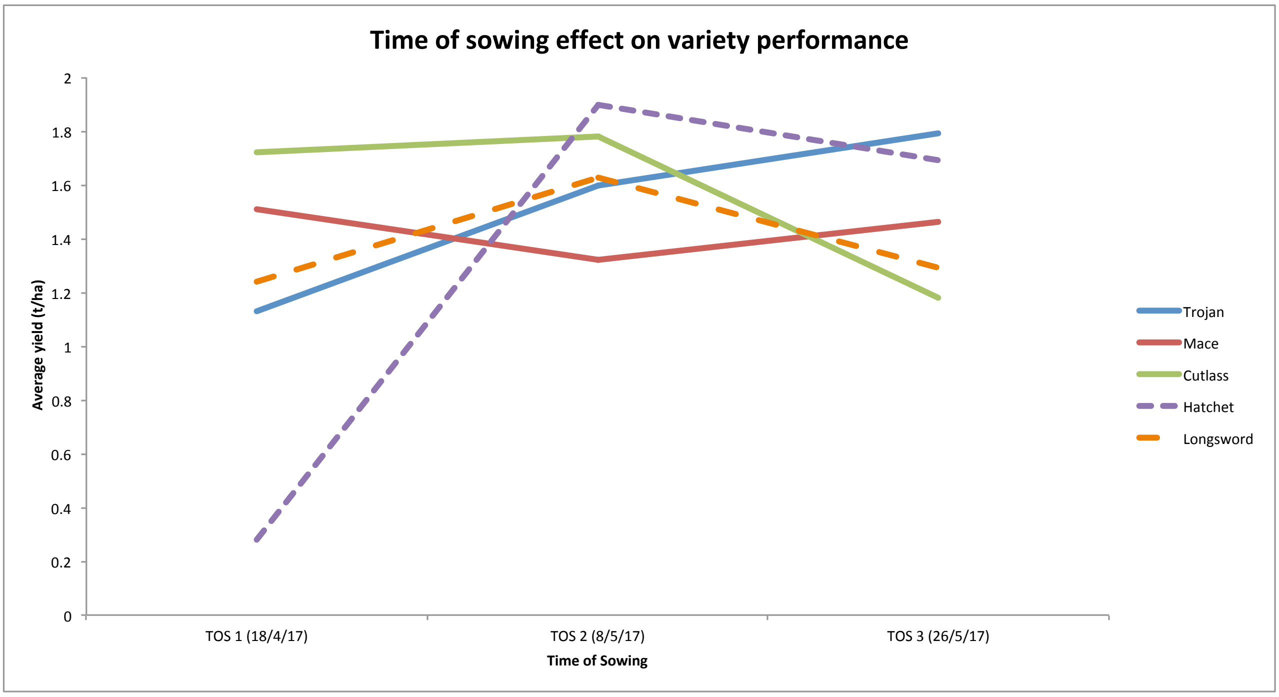


Figure 4. Average yield (t/ha) for the five wheat varieties against each time of sowing.

Table 2. Grain quality and grade for each wheat variety at each time of sowing.

	Yield (t/ha)		**Protein (%)**		**Test weight (kg/hL)**		**Screenings (%)**		**Grade**
TOS 1 (18/4/17)									
Cutlass	1.720	a	11.675	c	74.124	a	0.175	b	AUH2
Mace	1.507	b	11.800	c	74.184	a	0.263	b	AUH2
Longsword	1.244	c	12.925	b c	74.883	a	0.203	b	AUH2
Trojan	1.129	c	13.325	b	74.088	a	0.223	b	AUH2
Hatchet	0.276	d	15.600	a	71.621	b	0.52	a	AUH2
S.D.	0.553		1.585		1.250		0.140		
TOS 2 (8/5/17)									
Hatchet	1.898	a	12.400	a b	74.479	c	0.130	a	AUH2
Cutlass	1.783	a	10.975	b	77.019	a	0.138	a	APW1
Longsword	1.627	b	12.475	a	75.543	b	0.205	a	AUH2
Trojan	1.604	b	12.430	a	75.252	b c	0.183	a	AUH2
Mace	1.324	c	13.350	a	74.590	b c	0.180	a	AUH2
S.D.	0.217		0.853		1.020		0.032		
TOS 3 (26/5/17)									
Trojan	1.791	a	11.800	b	75.607	b	0.520	a b	AUH2
Hatchet	1.691	a	12.325	a b	73.614	c	0.435	a b	AUH2
Mace	1.460	b	13.450	a	75.319	b	0.485	a b	AUH2
Longsword	1.291	c	13.375	a	74.829	b	0.560	a	AUH2
Cutlass	1.180	c	12.950	a b	77.091	a	0.375	b	H2
S.D.	0.259		0.707		1.262		0.072		
F pr. values									
Sowing time	0.049		0.648		0.011		<0.001		
Variety	0.093		0.007		<0.001		0.156		
Interaction effect	<0.001		<0.001		0.002		0.035		

Seasonal conditions

Booleroo Centre had lower than average rainfall in 2017, particularly during the growing season (see **Table 3**). The crops relied heavily on stored subsoil moisture from the wet spring and summer the previous year. A soil test conducted just prior to sowing showed that the moisture content was 13 per cent in the top 10cm, 18 per cent in the 10-40cm depth interval, 21 per cent in the 40-70cm depth interval, and 16 per cent below 70cm. Maximum daily temperatures throughout the growing season were on average slightly higher than normal, while the minimum daily temperatures were on average slightly lower, particularly during the winter months. Records from the canopy-height temperature sensor located in the trial paddock are shown in **Figure 5**. Between 26/07/17 and 10/10/17 there were 46 days where the minimum temperature reached below 1°C. In that same period, the maximum temperature reached at least 30°C on 10 days.

The large number of days where the canopy temperature fell below 1°C resulted in significant frost damage to some of the plots (see **Figure 6**). All wheat varieties at all times of sowing showed some damage. The Hatchet sown in mid-April was by far the worst affected, both in terms of the percentage of heads with visible frost damage as well as the extent of damage to each head. Hatchet was the fastest maturing variety used in the trial, so this result was expected given that it reached its reproductive phase so early into the colder period. The slowest maturing varieties sown at TOS 3, Cutlass and Longsword, also suffered yield penalties, though due to the drier and warmer conditions rather than frost.

Table 3. Booleroo Centre rainfall measurements for 2017, and averages for all years (from http://www.bom.gov.au/)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
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
Annual average	22.1	21.7	17.6	27.2	39.1	46.9	42.2	45.4	41.3	36.1	28.5	24.8	392.9

Table 4. Anthesis windows for the different wheat varieties

	Anthesis window
Time of Sowing 1	
Hatchet	early-mid August
Trojan	mid-late August
Mace	mid-late August
Cutlass	early September
Longsword	mid-September
Time of Sowing 2	
Hatchet	early-mid September
Trojan	mid September
Mace	mid September
Cutlass	mid September
Longsword	mid-late September
Time of Sowing 3	
Hatchet	late September
Trojan	late September to early October
Mace	late September to early October
Longsword	late September to early October
Cutlass	early October

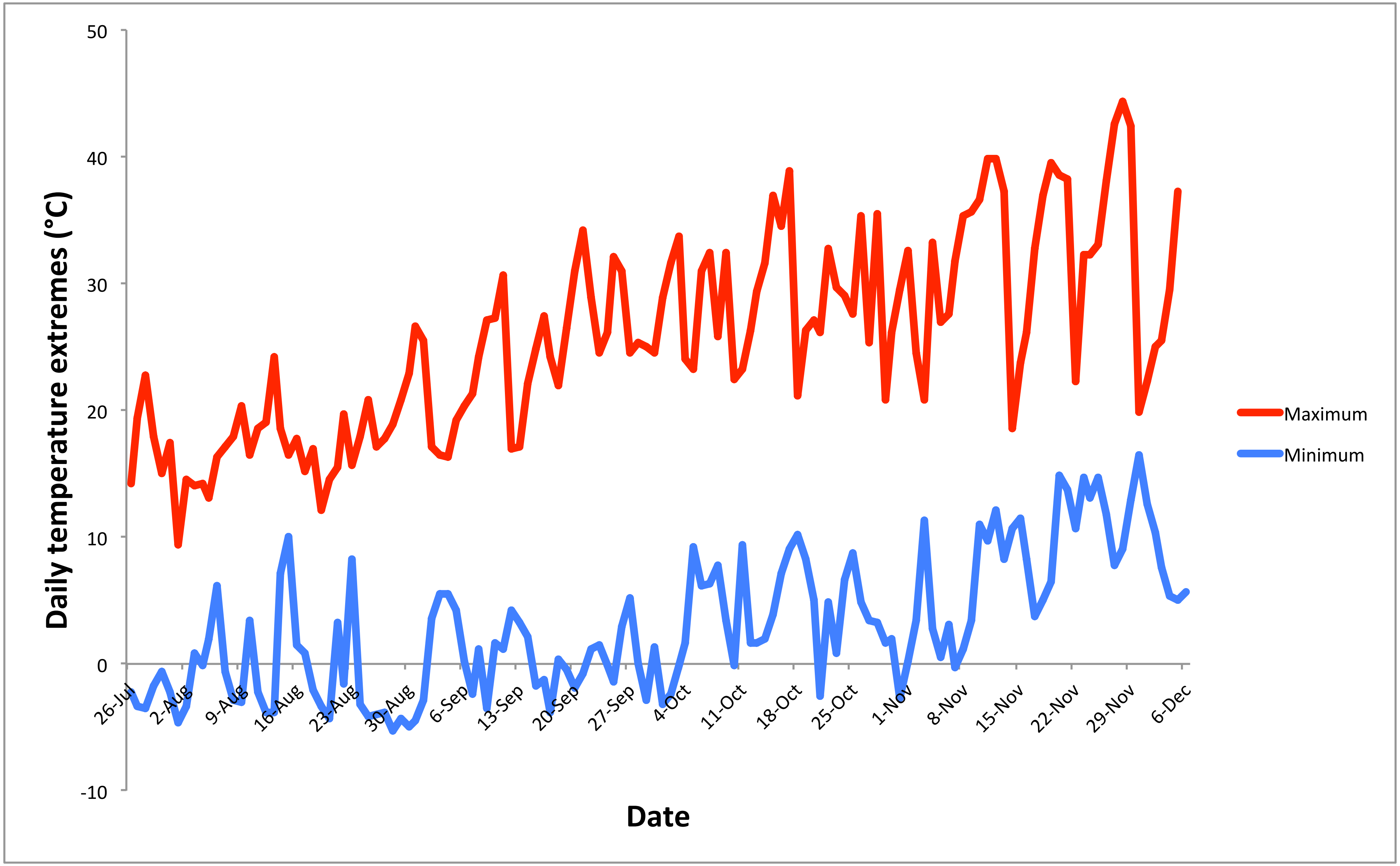


Figure 5. Daily minimum and maximum temperature recordings by the canopy-height temperature sensor located at the trial site.

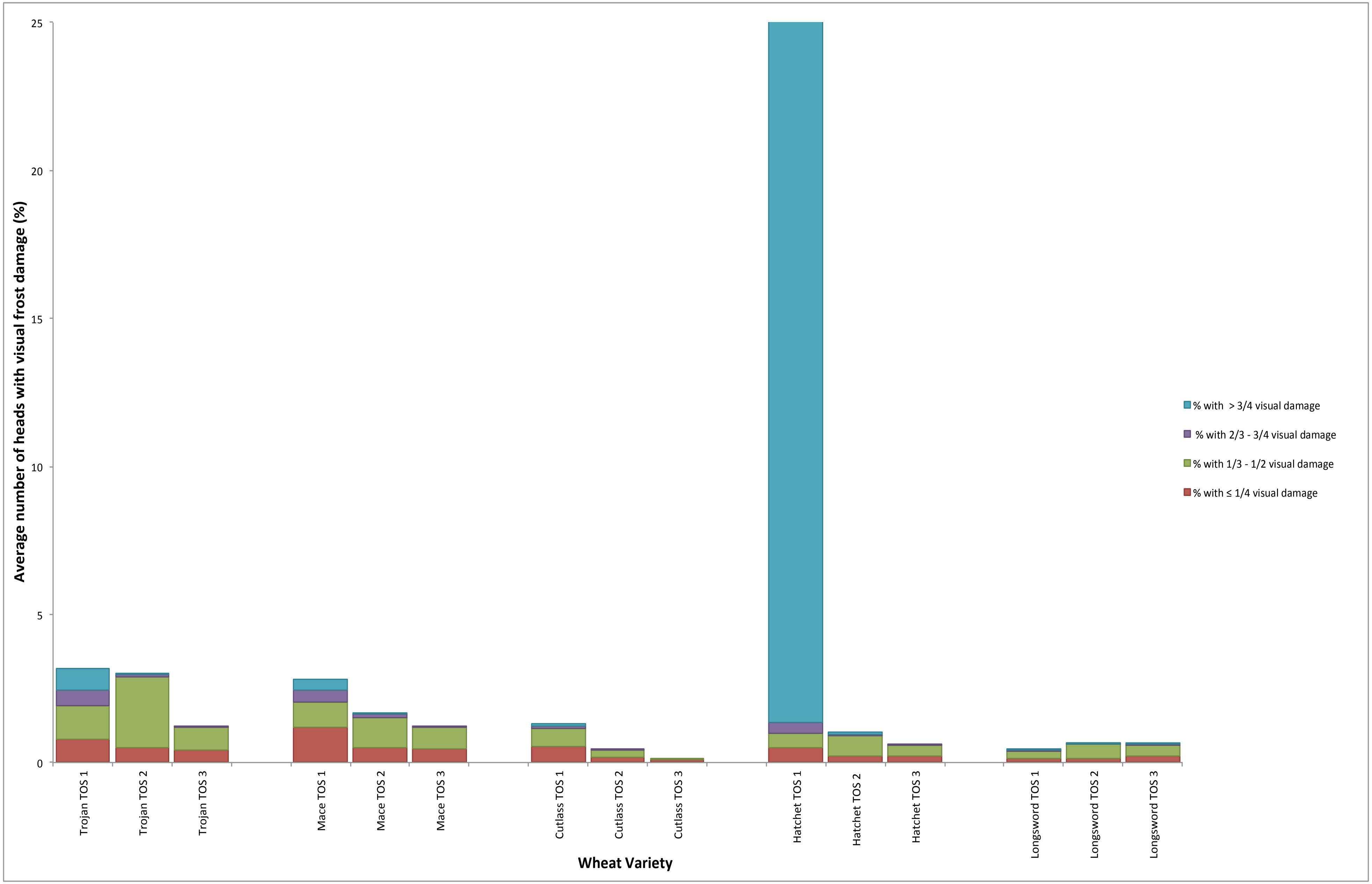


Figure 6. The average number of heads with any visual frost damage (%), for each wheat variety and at each time of sowing.

Summary:

2017 was a relatively difficult season. Rainfall in the months prior to seeding was below average, although stored sub-soil moisture and wet conditions in April, May, and August helped the plants to establish and develop. The frosty conditions throughout winter and spring had a significant impact on the trial, with all plots showing visible signs of damage. The fast-maturing Hatchet variety was the most severely affected, especially when sown early, with approximately a quarter of heads displaying at least some visual damage. The dry finish and warm conditions resulted in a yield penalty for some of the later sown and slower maturing varieties, namely Cutlass and Longsword.

Each wheat variety developed as expected. Cutlass had the highest yield for the first two times of sowing, although it suffered a yield penalty when sown later. Despite suffering such severe frost damage when sown early, Hatchet was among the highest yielding varieties for TOS 2 and TOS 3. Yield for Mace, Trojan, and Longsword was more variable.

As with the results from 2016, the results from the 2017 trial showed the importance of clearly understanding the appropriate sowing window for each wheat variety, with the subsequent implications for yield and quality. As was highlighted in the 2016 report, growers with larger wheat sowing programmes will benefit from using a combination of different wheat cultivars with different maturity times and developmental requirements in order to spread out their sowing schedule and optimise yield.

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Orrock Farming, Todd and Brooke Orrock, and Toby Fisher for the use of the land, supplying fertiliser and some seed, and the many hours of work put into setting up the seeder and looking after the trial.
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Micronutrients in the Upper North – Literature Review

Author: *Hannah Mikajlo (UNFS)*

Funding body: *South Australian Grains Industry Trust*

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

Project duration: *2017-2019*

Delivery organisation: *Upper North Farming Systems*

Introduction:

The objective of this review is to analyse the literature pertaining to micronutrients in South Australia's Upper North region. Part of a project funded by the South Australian Grains Industry Trust, this review will explore some of the questions around the role of micronutrients as an input in profitable farming operations in the Upper North. The first part of this review is an overview of micronutrients that are of most interest in the region, followed by an examination of soil types in the area and the implications for micronutrient status. The review then discusses some of the factors that have the potential to exacerbate local micronutrient deficiencies, then compares different methods of testing micronutrient levels. Finally the review examines some of the ways in which micronutrient deficiencies in the Upper North may be ameliorated.

Micronutrients of interest in the Upper North:

Discussions with Dr Nigel Wilhelm (South Australian Research and Development Institute) and various agronomists who work in the Upper North have indicated that copper and zinc are the micronutrients most likely to be deficient in the region. In fact, low levels of copper and zinc are often contiguous (Norton 2012). Matthew Foulis (2018), a Northern Ag agronomist working in the Upper North region, has identified several cases where micronutrients were deficient, and that there have been visual improvements in crop growth when applications of zinc, copper and molybdenum were made. Foulis analysed a range of tissue and soil data collected by Northern Ag between 2014 and 2018, focusing particularly on zinc, copper, and manganese. While acknowledging the weaknesses of soil testing for micronutrients, Foulis noted that the data collected indicated that over one third of soil samples taken demonstrated deficiency in zinc, more than half had copper levels insufficient for growing grain crops, and approximately 15 per cent of soils had toxic levels of manganese. Foulis's report has been included as an appendix. Matthew McCallum (McAg Consulting, 2018) conducted tissue testing in 15 Upper North paddocks between 2008 and 2010. The test results showed that 7 paddocks had marginal zinc levels while 1 had zinc deficiency, 6 paddocks had marginal sulphur levels and 1 was deficient, 2 paddocks had potassium deficiency and 3 had marginal boron levels.

Unfortunately there has only been limited research into micronutrients in the Upper North, but in some cases research from outside the region is still relevant, for instance the Grains Research and Development Corporation's investigations into the relationship between soil cultivation and micronutrient availability. Copper and zinc deficiencies in the Upper North are probably in part due to the adoption of reduced tillage practices within the region. The GRDC

(2013) and Norton (2012) note that since both copper and zinc are relatively immobile in the soil, the shift away from tillage means these micronutrients are not being spread through the topsoil, making them less accessible to crops. Other literature by the GRDC and the International Plant Nutrition Institute (IPNI) are also still useful for highlighting the importance of both nutrients, and the situations in which each are likely to be either sufficient or deficient;

Copper: used by plants in chlorophyll formation and pollen production. Copper levels in grains also influence the quality of baked products. Like other metallic cations, it is not easily leached from the soil. Copper has long residual activity, with evidence suggesting applied copper can remain plant-accessible after fifteen or more years. Deficiency is most common in alkaline sandy soils with high organic matter levels. Early season deficiency may only be temporary, and can be caused by dry conditions or large nitrogen applications. Symptoms of deficiency include rolling and curling of leaves, white leaf tips and poor seed set. Prolonged deficiency can cause the heads to darken in colour.

Zinc: required by plants for its role in shaping protein structures and for enzyme functions. Zinc is most likely to be deficient in alkaline sandy soils with high phosphorus concentrations. Use of group A or B herbicides can inhibit zinc uptake, while applications of lime or gypsum can lessen its availability. Early visual symptoms of deficiency include stunted or irregular growth and two-toning of leaves, starting as oily grey-green patches in the centre of the leaves and later developing into lesions. Like copper, zinc is not readily leached from the soil. There is evidence of applied zinc having residual activity in excess of fifteen years on acid, low organic matter sandy soils, but only three to five years on alkaline soils.

Although not as likely to be a problem as copper or zinc in the Upper North, there has recently been some local interest in molybdenum. Essential for nitrate reductase activity in plants, molybdenum is most likely to be deficient on acid sandy soils. Iron and aluminium also complex with molybdenum, reducing its availability. Symptoms of deficiency can appear similar to those of nitrogen deficiency. Local interest in molybdenum is driven in part by its importance for legumes. Legumes require molybdenum for the breakdown of nitrates acquired from soil, as well as for the fixation of nitrogen by root nodules.

Manganese: plays a role in several physiological processes, including chlorophyll synthesis. Manganese is most likely to be deficient in neutral or alkaline soils, particularly sands. Liming may induce deficiency. Visual symptoms of manganese deficiency include wilting, particularly of younger leaves. Leaves can also become yellow, starting in between the veins, and white or grey flecks may develop on the leaf base.

Boron: required by plants for cell development and the translocation, boron is also required for the development of reproductive structures and in pollination. Boron deficiency commonly occurs in dry conditions and in leached, sandy soils or soils with low organic matter. Both alkaline and acid soils can have boron deficiency. Symptoms of deficiency include chlorosis, distortion of stems, excessive branching, irregular root growth and poor seed development.

Soils and micronutrient availability in the Upper North:

Soil type plays a key role in determining micronutrient availability, so understanding it can be a useful tool for gauging the risk of deficiencies. Even if there is a high micronutrient content in a particular soil, this is no guarantee that it is either available or accessible. As Norton

(2012) points out in his survey and scoping study, the amounts of plant-available micronutrients in a soil are essentially dependent on that soil's chemistry and other properties. The pH and organic carbon content in particular are crucial, as they influence micronutrient solubility and the formation of organic ligand complexes. Norton's research notes that by analysing soil properties, including texture, pH, organic carbon concentration, structure, phosphorus content and incidence of waterlogging or drought, inherent micronutrient availability can be estimated from a soil (Table 1).

Table 1. An overview of soil and climatic factors and their effects on micronutrient availability. + indicates increased availability, while - indicates reduced availability. From Norton (2012).

	Boron	Copper	Manganese	Molybdenum	Zinc
pH > 7.5	+++	---	--	++	---
pH < 5.5	--	++	+++	--	+
Sand content	--	---	--	-	---
High organic carbon content	++	---	++	-	++
High phosphorus content	-	-	-	+++	---
Water-logged soil		+	++		+
Drought	---	---	---	-	-
Compaction	+	+	+	+	+

The Australian Soil Resource Information System (ASRIS) provides maps that allow identification of soil orders, which can be a useful starting reference for farmers and advisors considering micronutrients in their particular situation (Figure 1).

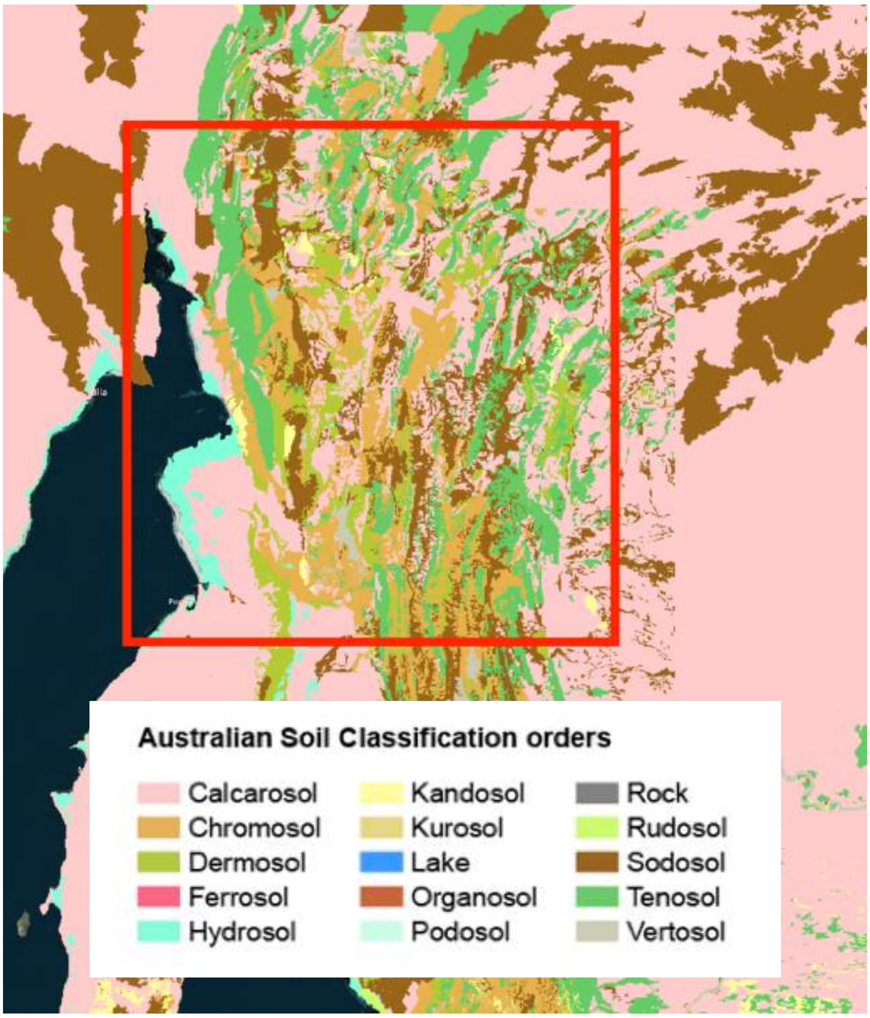

Figure 1: A map of South Australia's Upper North region, showing the areas of different soil orders. From http://www.asris.csiro.au/themes/Atlas.html and the CSIRO's SoilMapp.

In the Upper North region, most soils are classed as either Chromosols or Sodosols, although there are also smaller areas of Calcarosols and Tenosols. The Australian Soil Club (c. 2017) provides useful notes on each order, which may assist with micronutrient assessments and management decisions;

Chromosols: brown and red Chromosols, such as those found in the Upper North, are typically found in well-drained areas with annual rainfall between 350 and 600 mm. Chromosols tend to have moderate chemical fertility and water-holding capacity, giving them moderate agricultural potential. Chromosols can be susceptible to soil acidification and structural degradation.

Sodosols: this order has highly sodic subsoil, but is not highly acidic (pH >5.5). Sodosols are only found in poorly drained sites. They generally have very low agricultural potential, due to their high sodicity, poor structure, high erosion risk, low permeability, and low to moderate chemical fertility. Sodosols can also have problems with salinity.

Calcarosols: characterised by their calcium carbonate content, particularly in the subsoil. Calcarosols are found in either imperfectly drained sites where annual rainfall is up to 400 mm, or in well-drained sites where annual rainfall is between 250 and 500 mm. Calcarosols typically have low to moderate agricultural potential due to their low chemical fertility and water-holding capacity. Frequently, they can also have problems with salinity, alkalinity and boron toxicity.

Tenosols: typically very sandy and without clear horizons, Tenosols have weakly developed profiles. Usually Tenosols have low agricultural potential due to their low chemical fertility, poor structure and low water-holding capacity.

Each soil order has its own implications in terms of micronutrients, as frequently noted in literature (Norton 2012, GRDC 2013). In what the GRDC defines as the 'southern region,' which includes South Australia's Upper North, Calcarosols and Sodosols have a high risk of zinc deficiency, and if they contain more than 50 per cent free calcium carbonate, they may also have severe problems with manganese deficiency. Norton's (2012) micronutrient survey and scoping study assessed the risk of micronutrient deficiency for each soil order against other reports and literature as well as surveys of soil test data and grain nutrient concentration. A summary of the risks is presented below in Table 2. While useful as a starting point of reference, the data used were collected from the entirety of the GRDC Southern Region, so in some cases may not accurately reflect the situation in the Upper North.

Exacerbation of micronutrient deficiencies:

While inherent soil properties are significant determinants of micronutrient availability in the Upper North, farming practices can also be important. Particularly, there is evidence that reduced tillage and use of certain herbicides can exacerbate micronutrient deficiencies. While this research has not taken place in the Upper North region specifically, the findings are probably still applicable.

The adoption of minimum tillage is especially likely to be one such practice with implications for the Upper North. In the past, cultivation disturbed soil and distributed micronutrients throughout the topsoil. By comparison, the changeover to minimum or zero-tillage and one-pass seeding leaves the topsoil largely undisturbed, reducing opportunities for root-micronutrient interactions (GRDC 2013). This is particularly important for the Upper North because the main micronutrients of concern are zinc and copper. Both of these trace elements are immobile in soil, so must be directly in the pathway of plant roots in order to be accessed by the crop.

As with reduced tillage, there is evidence of herbicide use affecting root-micronutrient interactions. A paper by Wheal (1996) details how chlorsulfuron curtails root growth and therefore inhibits zinc uptake. Similarly, a series of experiments by SARDI (O'Keeffe and Wilhelm 1991) on the Eyre Peninsula during the 1990s found that applications of the group B herbicides chlorsulfuron and metsulfuron-methyl exacerbated pre-existing micronutrient deficiencies to the extent where there were yield penalties. By comparison, the experiments showed that on sites where micronutrients were in adequate supply, the herbicides could create micronutrient deficiencies in tissue concentrations but did not ultimately reduce yield. Ally® (metsulfuron methyl) is a commonly used chemical in the Upper North region.

Table 2. The risk of micronutrient deficiency for the soil orders most commonly found in the Upper North region. Table from Norton (2012).

Soil Order	Boron	Copper	Manganese	Molybdenum	Zinc
Calcarosol	Low	Moderate	High*	Low	High
Chromosol	Moderate	Uncertain	Low	Moderate	Moderate
Sodosol	Moderate	Moderate	Low	Low	Moderate
Tenosol	High	Low	Low	High	Moderate

** where free calcium carbonate is present*

There is strong evidence in the literature that tissue tests are the most reliable way to diagnose micronutrient status. This is further confirmed by discussions with agronomists and researchers such as Nigel Wilhelm.

<u>Testing for micronutrient concentrations:</u>

Tissue testing:
Given that plant nutrient status varies depending on weather conditions as well as the plant's age and variety, it is crucial to sample at the right time. The correct tissue also needs to be collected, as micronutrient distribution is often different in leaves compared to stems or whole plants. For copper, the GRDC (2013) recommends testing the youngest material at the flag leaf stage. Foliar applications of copper (copper sulphate, copperoxychloride or chelated copper) prior to anthesis can then be used if necessary. Results below 1.6 mg/kg indicate mild copper deficiency, while anything below 1.3 mg/kg is either moderately or severely deficient (GRDC 2013). For zinc, IPNI (2014) recommends testing the youngest expanded leaf blade, with test results of less than 10 mg/kg considered to indicate deficiency (GRDC 2013). Wilhelm et al. (1993) suggested a critical level of 18 mg/kg in the youngest emerged leaf blades.

Despite being more reliable than either grain or soil testing, some literature makes note that even tissue testing has its complications. Norton (2012) notes that tissues can have transient deficiencies due to soil conditions, or earlier in the season before plant roots have the chance to access micronutrient reserves deeper in the soil profile. Aside from complications with the actual sampling, another paper (Norton, Laycock and Walker 2012) points out that interpretation of the results can also pose challenges. For example, when more copper is added, rapid plant growth can mean that while the overall level of copper in the plant increases, the concentration within the tissue is diluted (i.e. the Piper-Steenbjerg effect). Micronutrient concentration can also vary between cultivars (GRDC 2013).

Soil testing:
Unlike tissue tests, soil tests only have low reliability for detecting micronutrient deficiencies. This is firstly because the predictions depend on soil type, pH, clay content, organic matter content, the crop in question, environmental conditions and the paddock management history (Norton 2012, Norton et al. 2012, GRDC 2013). If using a DTPA soil test, the critical levels for copper are <0.2 to 0.4 mg/kg (GRDC 2013). Critical levels for zinc are far more variable depending on the circumstances. Soil tests are also complicated by the fact that the micronutrients being tested are in such low quantities in the soil. As the GRDC (2012) notes,

there is only a small difference between a low reading that indicates adequate supply and one that indicates toxicity.

Despite their problems, soil tests can be used alongside other tests and visual assessments in order to diagnose potential micronutrient problems. In terms of resources available, the Department of Environment, Water and Natural Resources (DEWNR) has collected data from a series of soil pits dug throughout South Australia from 1992 to 2013, approximately 52 of which were in the Upper North and included analyses of micronutrients. From many of the sites, the trace elements copper, iron, manganese and zinc were tested for using DTPA extraction methods. These results can be analysed alongside other information contained in each report, including general site assessments, soil classifications and soil property analyses. Test results for other soil characteristics, such as pH, contained in the reports may also be useful for determining if micronutrient deficiencies are likely to be an issue.

Grain testing:
In addition to soil and tissue tests, micronutrient status can also be tested in grains. While these tests can only occur post-harvest, Norton (2012) suggests they may still be worthwhile, although their reliability depends on the cultivar, the yield and the mobility of the nutrient in question. Norton cites earlier research by McDonald (2006) that found strong correlation between grain copper concentrations and whole shoot nutrient concentrations at tillering for wheat and barley. Norton suggests that since applied copper often has long residual activity, monitoring grain for copper levels may actually be a more reliable method to assess paddock nutrient status rather than relying on soil tests.

Amelioration of micronutrient deficiencies:

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

While unfortunately there has only been limited research into micronutrients in the Upper North, there have been some trials conducted in the region. In 2002 SARDI was contracted by the Central North-East Farm Assistance Program to assess the effectiveness of fluid versus granular phosphorus fertilisers on wheat yield in the Upper North (Wilhelm 2002). The trials were run in Orroroo, on two soil types common to the district, the first being a grey mallee sand and the other a heavy red clay. As part of the trials, the researchers examined the effect of zinc nutrition on the response of wheat to the different phosphorus fertilisers. Zinc chelate was applied to all plots at a rate 0f 0.75 kg/ha. When the shoots and tillers were tested for nutrient concentrations, zinc levels were higher for plants treated with fluid rather than granular phosphorus. The researchers concluded that fluid nitrogen-phosphorus fertilisers seemed to be a more effective method for supplying broadacre crops with trace elements. Given the cost of applying liquid fertilisers, however, this may not be a viable option for growers in the Upper North region.

In 2003, SARDI ran two follow-up trials in the Orroroo district to confirm that fluid phosphorus fertilisers had good potential to improve wheat yields in Upper North conditions (Wilhelm 2003). Again, a rate of 0.75 g/ha Zinc chelate was applied either in solution with fluid phosphorus fertiliser, or below each seed row where granular rather than fluid phosphorus was used. When the plants were tested for micronutrient concentrations during tillering, the results once again found that fluid fertilisers were more effective at supplying the crops with zinc.

Although not conducted in the Upper North, there has been other research into how best to treat micronutrient deficiencies, the results of which may still be applicable in the region. For instance, the GRDC (2012) has published reports explaining that for immobile nutrients such as copper and zinc, it is more effective to apply smaller granules of fertiliser in larger amounts rather than larger, more concentrated granules. This provides a better chance for roots to come into contact with the micronutrients, especially if the topsoil is not being disturbed with cultivation. For immobile nutrients, the GRDC also notes that even where annual applications are not required, it is always better to apply them to the most responsive crop. In the case of copper and zinc, wheat is more responsive than canola.

In regards to foliar sprays, research by the GRDC (2012) has shown that multiple applications may be required if the plants are seedlings, as they only have a small leaf area. The GRDC also recommends leaving an untreated strip in order to determine whether the micronutrients really are the limiting factor.

<u>Conclusion:</u>

In conclusion, zinc and copper are the micronutrients of most interest in the Upper North. Deficiencies are primarily caused by soil characteristics, but farming practices may also be having an influence. There is strong evidence in the literature that tissue testing is the most reliable method for detecting micronutrient status. There are still gaps in the knowledge surrounding the exact extent of micronutrient deficiencies in the region, and there is a genuine need to identify whether it is ultimately cost effective to ameliorate them.

UNFS

Upper North Farming Systems

SAGIT

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Nigel Wilhelm (SARDI) and agronomists from Jamestown Elders, Jamestown Landmark, and Crystal Brook Platinum Ag Services were also consulted.

Appendix:

MICRONUTRIENT DEFICIENCIES IN THE UPPER NORTH REGION

MATT FOULIS B.Sc (Ag)

(Northern Ag)

Working as an agronomist in the upper north district for the past 9 years I have identified several cases of micronutrient deficiencies in both cereal and pulse crops. Crop visual growth improvement has been observed in response to applied Zinc, Copper, and Molybdenum throughout the region. Several growers have also trialled Manganese applications, in which we are yet to pick up a clear response. The idea of the Upper North Farming Systems (UNFS) running responsiveness trials to some of these products is certainly of great interest to myself, and the direct benefit to growers will likely be significant.

Through extensive soil and tissue testing we have been able to identify areas likely to respond to applied micronutrients in our region. The difficulty with soil tests is that they are not highly accurate in the case of micronutrients. This is often why we follow up with tissue tests – although these face issues of their own. Mainly being that we can only take a "snapshot" of the plant at a particular time of its growth. To effectively diagnose deficiencies of these nutrients we really need to be tissue sampling once per week; which can become very expensive and time consuming.

After analysing the entire range of soil and tissue data that we have sampled over the past five seasons, I have been able to display with the following results on the three micronutrients sampled for; being Zinc, Copper, and Manganese. I have decided not to display the tissue sample data in the results for a number of reasons. These being; reduced sample size, varying crop types and growth stages that samples were taken from (from Z22 through to Z39), and samples have been generally only performed we have noticed a visual issue in the crop, meaning that data is heavily biased.

SOIL DATA COLLATED FROM THE UPPER NORTH REGION:

Zinc:

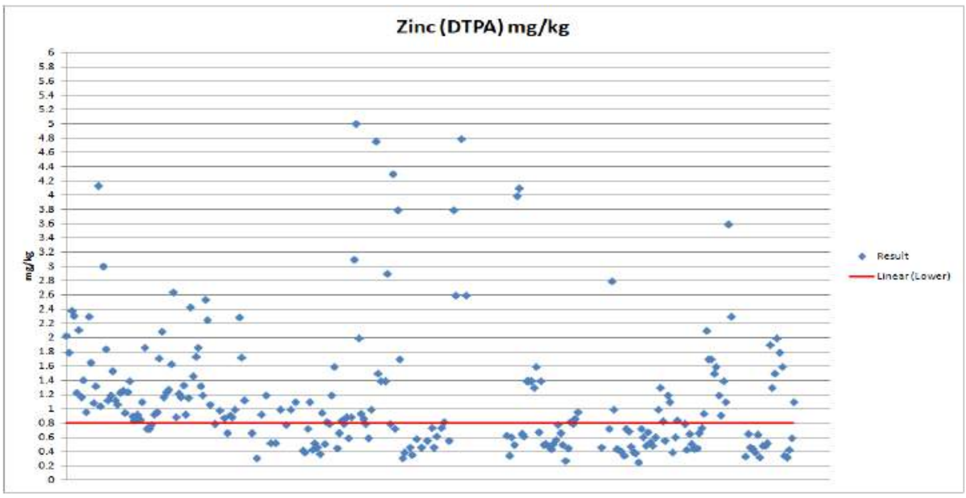

Figure 1: Soil zinc levels (top 10cm) in the Upper North region from Jan 2014 - Jan 2018. (Source of Critical Value: Back Paddock Co.)

All points below the red trend line (0.8mg/kg) are considered low to very-low in zinc. Over one third of soil samples taken are in this range, indicating that there is potential for good responses to applied zinc within the region. The data points to the right of the chart are samples that have been taken in the past two seasons, which we have seen a reasonable adoption of seeding fertilizer applied zinc across the Upper North. Suggesting that the increase in Zn levels are quite possibly a direct result of these applications.

Copper:

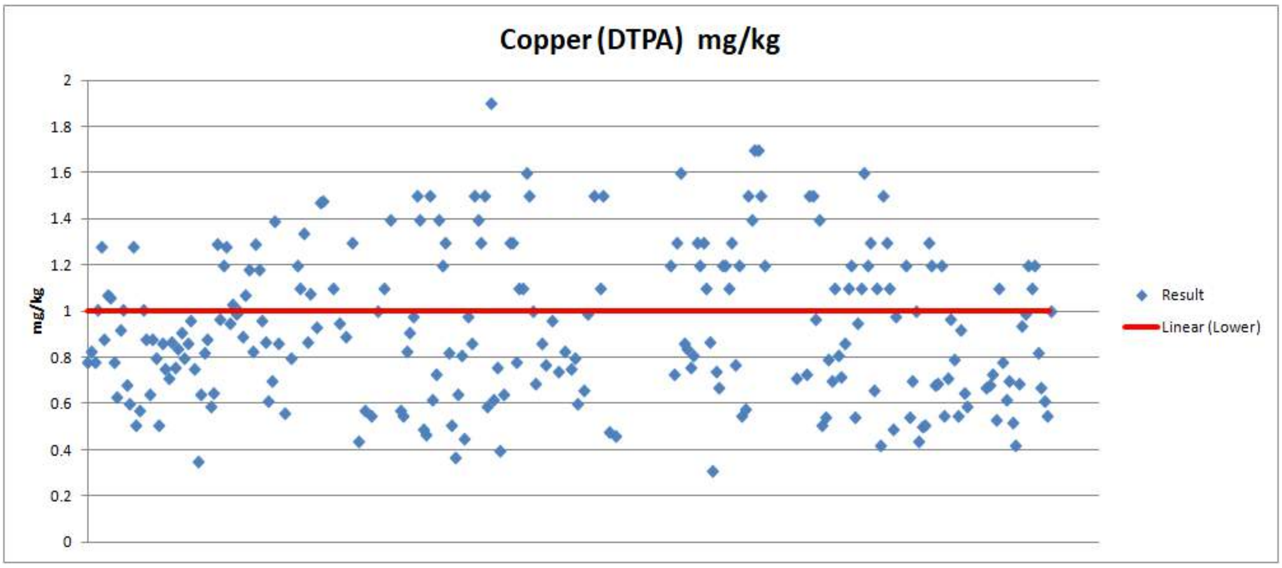

Figure 2: Soil copper levels (top 10cm) in the Upper North region from Jan 2014 - Jan 2018. (Source of Critical Value: Back Paddock Co.)

The chart indicates that over 50% of soils sampled in the district are below the acceptable range for growing grain crops (1mg/Kg). Copper is a nutrient that several growers in the district have claimed to be getting good responses to, and this data helps support these claims.

Manganese:

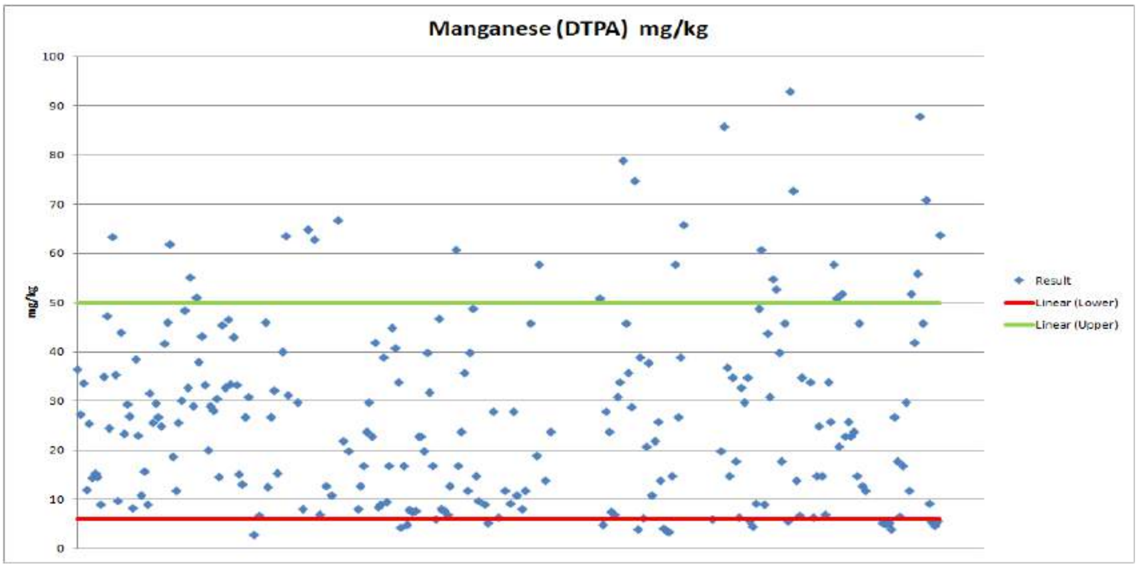

Figure 3: Soil Manganese levels (top 10cm) in the Upper North region from Jan 2014-Jan 2018. (Source of Critical Values: Back Paddock Co.)

Manganese is a micronutrient that we are not prone to deficiency issues with in the Upper North region. The chart does indicate that the odd soil is lacking, although by far the majority are well within the sufficiency range. We have noted an occasional Mn toxicity issue in the district, and the soil data collated does show that approximately 15% of soils tested are in the excessive range (above 50 mg/kg).

The results above help validate concerns in regard to widespread malnutrition of zinc and copper in the region. As explained earlier, we understand that these sample results are not 100% reliable, but these, along with tissue samples are the only method of testing that we have currently available, and are at the very least a informed guide. Manganese deficiency, as expected, is less of an issue in the region. I believe that information that could be gained by trialling a range of zinc and copper products, application methods, and timings would be of great benefit to growers in the Upper North.

NORTHERN AG

GRDC Southern Extension Project

Funding body: *GRDC*

Project title: *GRDC Southern Pulse Extension Project*

Project duration: *2017-2019*

Delivery organisation: *Upper North Farming Systems*

Grain growers are being supported to diversify into pulse crops in non-traditional production areas of Victoria and South Australia through a new 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 maximise 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 will meet at least four times a year over the coming 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.

Since the commencement of the project, UNFS has hosted three pulse check group workshops, each attended by between 19 and 25 people. 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 everyone together from across the district to share ideas and knowledge.

So far the meetings have covered a range of topics, including a post-harvest review for the previous season, paddock selection and other sowing considerations, different types of pulse crops and different varieties, pests, weeds, diseases, and pulse markets, including the recent Indian tariffs. The recent post-emergence meeting also took the opportunity to look at a UNFS pulse trial being run on farmer Brendon Johns’ property in Warnertown. The trial is investigating the effects of time of sowing, moisture levels, stubble architecture, and pulse variety.

Feedback from the meetings has been highly positive, with attendees praising the speakers and topics, and those new to pulse crops saying that it was great to attend meetings so that they were not “starting blind.”

UNFS has welcomed the opportunity to be involved in the project. Pulse crops are of significant interest in the area, with many local farmers also considering shifting away from peas and faba beans towards lentils. The pulse check groups are proving to be a great way to help local farmers gain the confidence and skills necessary to adopt new pulse varieties, or to improve on their current practices.

Pulse Check groups will not only provide growers with a competent understanding of best management practice for these crops, but advisers with limited knowledge of pulse crop agronomy will also acquire the skills and knowledge to support pulse crop expansion into new areas.

Much of the information to be delivered to growers and advisers through the Pulse Check groups initiative has been generated out of the GRDC's Southern Pulse Agronomy program. Southern Pulse Agronomy, led by Agriculture Victoria pulse agronomist Dr Jason Brand, has made a significant contribution to the rise in pulse production across the southern region. Southern Pulse Agronomy has trial sites spread throughout SA and Victoria, but most of these are located in established pulse production areas. From 2018 new sites will be incorporated in new pulse growing regions and will be incorporated into Pulse Check group activities.

Other groups are facilitated by representatives from farming systems organisations Riverine Plains Inc, Mallee Sustainable Farming, MacKillop Farm Management Group, Birchip Cropping Group, Lower Eyre Agricultural Development Association, and Eyre Peninsula Agricultural Research Foundation, as well as Rural Directions and Ag Excellence Alliance.

A Southern Pulse Extension steering committee, comprising representatives from the GRDC, Pulse Australia, Southern Pulse Agronomy, agribusiness and the adviser community, has been established to guide the initiative.

Steering committee chairman Bill Long, an agricultural consultant and former GRDC Southern Regional Panel member, says the Pulse Check initiative has already been well received by growers considering production of high-value pulse crops.

"Attendances at meetings have been very pleasing, reflecting the demand and need for GRDC investment in a program such as this," Mr Long said.

"The concept is not a new one – previous Lentil Check programs for example have been very successful in transferring knowledge to growers moving into new crop types – so it's a formula that we know works.

"I'm confident that the Southern Pulse Extension project will over the next two years deliver tangible results for growers and advisers who are keen to build their knowledge and understanding of the key aspects of lentil and chickpea production."

Other activities involved in the project include a regional workshop program, leveraging SPA and Validation trials and focusing on areas not currently being serviced by a Pulse Check Group, an agribusiness consultation process, engagement at industry events, review of existing and development of pulse resources available to industry and ongoing communication activities.

Any general enquiries about the Southern Extension Project can be directed to the Project Manager, Pru Cook on 0438 923 258 or at pru.cook@bcg.org.au.

Image 1. The third pulse check group meeting, held in Warnertown. Photo: UNFS

Maintaining profitable farming systems with retained stubble
"The Stubble Initiative"

Funded by: GRDC

Project title: Maintaining profitable farming systems with retained stubble

Project duration: 2013-2018

From 2013 to 2018, Upper North Farming Systems has been involved in the GRDC-funded initiative *Maintaining profitable farming systems with retained stubbles*. Based in the southern cropping region, the initiative involves many farming systems groups, research organisations, and agribusinesses. Aside from UNFS, these include Eyre Peninsula Agricultural Research Foundation; Mallee Sustainable Farming Systems Inc; MacKillop Farm Management Group; Birchip Cropping Group, on behalf of Southern Farming Systems; Victorian No Till Farming Association and Irrigated Cropping Council; Riverine Plains Inc; Central West Farming Systems; Farmlink Research Limited; Lower Eyre Agricultural Development Association; Yeruga Crop Research, on behalf of the Mid North High Rainfall Farming Systems Group and the Yorke Peninsula Alkaline Soils Group; Hart Field Site Group; and the South Australian Grains Industry Trust. CSIRO and SARDI have provided research support and assistance with coordination and communication. While each grower group has its own locally specific project requirements, there has also been collaboration between the groups.

UNFS's key project objective has been to improve the profitability and sustainability of farming systems throughout the Upper North through increased stubble retention. Benefits may include better erosion control, improved crop water-use efficiency, provision of feed for grazing animals, and the potential for more adaptive land management.

As part of the project, UNFS has run a series of trials, field days, demonstrations, and crop walks. UNFS has also developed a collection of locally specific guidelines to encourage and assist Upper North farmers to retain more stubble residues. Topics covered by the guidelines and project reports include reviews of the benefits and costs of stubble retention, stubble monitoring and management, seeding equipment and operations, break-crop options, weeds, diseases, pests, crop nutrition, and grazing management.

UNFS would like to sincerely thank all the growers, speakers, and researchers who have assisted in the delivery of the Stubble Initiative project. The numerous events UNFS has held over the course of the project would not have been possible without assistance from all the farmers and members and their valued contribution. We would also like to thank the Grains Research & Development Corporation for funding the project.

Funding body: Grains Research & Development Corporation (GRDC). Project code: UNF00002

For further information, contact the project coordinator Naomi Scholz (SARDI) at naomi.scholz@sa.gov.au or see http://unfs.com.au/

Burning of weed seeds in low rainfall farming systems

Authors: Ben Fleet, Samuel Kleemann and Gurjeet Gill (University of Adelaide, School of Agriculture, Food and Wine)

Funding body: *SAGIT*

Project title: S416 – Burning of weed seeds in low rainfall farming systems

Key messages

- **Seeds of all species could be killed with heat, however there were differences in tolerance to heat.**
- **Duration of heat treatments had a significant impact on the efficacy on weed seeds in all species.**
- **Seeds of most weed species could be killed by simulating conditions similar to burning narrow harvest windrows.**
- **The efficacy of narrow windrow burning in the field is largely determined by the proportion of weed seeds that can be collected by the header and placed into harvest windrows.**

Why do the trial?

Weeds are one of the largest costs to grain producers and a primary driver in how cropping systems are managed. Weeds are estimated to cost Australian grain growers $3,318 million annually (Llewellyn *et al*. 2016). Weeds will continue to drive crop management systems as weed challenges evolve, particularly from herbicide resistance. This will increase the importance of cultural control methods as part of any integrated weed management (IWM) strategy. Burning crop residues to destroy weed seeds is one of the oldest cultural weed control measures in agriculture. While information exists on annual ryegrass and wild radish efficacy from burning crop residues (Gill and Holmes, 1997; Walsh and Newman, 2007), little is known about other weed species. This study aims to investigate the potential of crop residue burning to control weeds that are problematic for low rainfall cropping systems in southern Australia. A method similar to Walsh and Newman (2007) was used to simulate different levels of heat (temperature) and duration experienced during crop residue burning on weed seeds.

How was it done?

Seed collection

Seeds of 10 different weed species were collected from cropping fields at weed maturity (Table 1). Seed was cleaned and removed from associated structures for all species except Mallow that was left in individual seed pod segments. This was done to achieve consistency with the state of weed seeds shedding and at the time of stubble burning. Seeds were counted and placed into packets of 100 seeds.

Table 1. Weed seeds and district of origin.

Weed species	**Region**
Barley grass *Hordeum glaucum*	Upper Eyre Peninsula
Brome grass *Bromus diandrus*	*Northern Yorke Peninsula & Mallee
Wild Oats *Avena fatua - (1)*	Lower North
Wild Oats *Avena fatua – (2)*	Upper Eyre Peninsula
Annual ryegrass *Lolium rigidum*	# 'safeguard ARG' control species
Onion weed *Asphodelus fistulosus*	Upper Eyre Peninsula
Statice *Limonium lobatum*	Upper North
Mallow *Malva parviflora*	Upper North
Indian Hedge Mustard *Sisymbrium orientale*	Lower North
Lincoln weed *Diplotaxis tenuifolia*	Upper Eyre Peninsula
Wild Turnip *Brassica tournefortii*	*Mallee & Upper North

** composite population, Mallow was treated in individual seed pod segments*

Heat treatment

A kiln (Woodrow GK63TL top loading glass kiln) was used to apply heat treatments to seeds. The kiln was preheated to the desired temperature. Seed of each species were placed in a ceramic dish, held in a rack and swiftly placed into the kiln for the desired duration. Seed was allowed to cool in the dishes and placed back into their packets for later germination assessment. Temperature readings from the kiln were calibrated against a laboratory infrared thermometer (MIKRON IR-MAN model 15t) shown below in Table 2.

Table 2. Kiln temperature calibration against laboratory infrared thermometer (IRT).

Kiln temp	200^{o}C	250^{o}C	300^{o}C	350^{o}C	400^{o}C	450^{o}C
IRT temp	200.1^{o}C	246^{o}C*	300^{o}C	355.3^{o}C	400.6^{o}C	451^{o}C

*IRT temp mean of multiple readings, * kiln set to 255^{o}C to achieve correct temperature*

Germination assessment

Treated seed packets were placed in petri-dishes with 2 filter paper discs on the base. 10 mm of 0.001M Gibberellic acid (GA) solution was applied to the seed, brome grass and barley grass requiring 12.5 mm and wild oats requiring 15 mm GA solution. Dishes were then sealed with parafilm and then all 19 dishes (single replicate of each weed species) was wrapped in two layers of aluminium foil and placed into a controlled environment growth room (Phoenix systems) at 20^{o}C/12^{o}C day/night temperature for approximately 14 days, at which time both germinated and non-germinated seeds were counted. At 14 days mallow seeds were counted and individual seeds were removed from seed pod segments. Mallow seeds that were deemed to be potentially viable (still hard), but not germinated were knicked with a scalpel and placed back onto dishes with fresh GA solution and returned to growth room for a further seven days when germination was again assessed. Wild oat populations were given extended time in the growth room, but failed to germinate and were excluded from the trial.

Trial details and analysis

The trial was replicated three times with 100 seeds in each sample. Germination in each dish was compared back to the relevant untreated control. This was then statistically analysed using an analysis of variance using GENSTAT 15th Edition statistical computer program.

What happened?
The ability of weed seeds to tolerate heat varied considerably between species with Lincoln weed seed being the most susceptible and mallow seed being the most tolerant to heat (Table 2). Germination data was plotted against a heat index (HI = temperature ^{o}C x duration seconds), and a sigmoidal logistic 3 parameter model was fitted using SigmaPlot 12.5 v002 statistical program. Parameter X_0 from the fitted model represents the HI units required to suppress seed germination by 50%. X_0 values were used to rank weed species for tolerance to heat. Tolerance of weed seeds to heat was not closely related to seed size or weed type. Brassica seeds with their smaller size and high oil content would be expected to be more sensitive to heat. This was the case for both Lincoln weed and Indian hedge mustard (IHM) which were the two most susceptible weed species to heat. However wild turnip, another brassica weed, was the second most tolerant species studied. Larger seed size did not correlate with tolerance to heat, with smaller seeded ryegrass showing greater tolerance to heat than larger brome or barley grass seeds.

Table 3. Ranking of weed seed tolerance to heat from least to the most tolerant.

Rank	Weed	X_0 for HI *(SEM)*	HI R^2	P
1	Lincoln weed	6231 *(325)*	0.78	*P<0.0001*
2	Indian Hedge Mustard	10021 *(929)*	0.70	*P<0.0001*
3	Onion weed	15028 *(391)*	0.77	*P<0.0001*
4	Barley grass	16043 *(373)*	0.82	*P<0.0001*
5	Brome grass	16070 *(562)*	0.73	*P<0.0001*
6	Statice	16618 *(298)*	0.88	*P<0.0001*
7	Annual ryegrass	17505 *(474)*	0.78	*P<0.0001*
8	Wild Turnip	18405 *(484)*	0.74	*P<0.0001*
9	Mallow	21197 *(1413)*	0.44	*P<0.0001*

SEM - Standard error mean

Grass weeds
Barley grass has become a serious weed of many low rainfall cropping systems due to increased seed dormancy and incidence of herbicide resistance (Fleet *et al.* 2012; Shergill *et al*. 2015). The effect of heat, like that produced from burning crop residues, on barley grass was found to be strongly influenced by both temperature and duration (Table 4). Barley grass seed was completely killed at 350^{o}C, but only at a duration ≥60 seconds. However, barley grass seed kill was significantly reduced at shorter durations. Exposure of barley grass seeds to 300^{o}C for a duration of 60 seconds could halve barley grass seed viability. However, the same level of control could be achieved by exposure to >450^{o}C for 20 seconds. Based on the results of stubble burn temperatures from Walsh and Newman (2007), effective control of barley grass seed is only expected in heavy windrows or narrow windrows. Burning a standing stubble is unlikely to be effective in killing barley grass seed. Unfortunately, most barley grass seed has shed well before crop harvest and is unlikely to end up in the windrow for burning or captured by harvest weed seed capture (HWSC) systems. In a field trial in the UN, Fleet *et al.* (2014) found that when wheat was harvest-ready, <1% of barley grass had the potential of being collected, with the remainder either being shed onto the ground or below 10 cm in height. Similar results were found in plot studies where <6% of barley grass seed remained on the panicles when wheat was harvest-ready (Kleemann *et al*. 2016). Therefore, the effectiveness of windrow burning against barley grass is expected to be rather low.

Table 4. Effect of heat on Barley grass seed viability (% survival).

	Temperature (^{o}C)					
Duration (s)	**200**	**250**	**300**	**350**	**400**	**450**
20	97 *a*	100 *a*	97 *a*	97 *a*	94 *a*	57 *bc*
40	96 *a*	100 *a*	100 *a*	62 *b*	**19 *d***	**0 *e***
60	97 *a*	96 *a*	51 *c*	**0 *e***	**0 *e***	**0 *e***

P<0.001, LSD=9.666, cv rep=5.6%, >80% reduction ***bolded***

The response of brome grass to high temperature exposure was very similar to barley grass (Table 5). Effective kill of brome grass seed is also likely to require crop stubble to be burnt in either a heavy row or narrow windrow to achieve required temperatures and duration of heat. Contrary to barley grass, brome grass is capable of retaining 75% of its seed on the panicle by earliest crop harvest. However brome grass plants can often lodge and fall below the harvest cutting height. In a field trial at Roseworthy, depending on weed density, 30-80% of brome grass panicles were below the height of crop harvest at earliest crop harvest (Kleemann *et al.* 2016). Despite this, HWSC followed by burning of windrows could provide some level of control of brome grass.

Table 5. Effect of heat on Brome grass seed viability (% survival).

	Temperature (^{o}C)					
Duration (s)	**200**	**250**	**300**	**350**	**400**	**450**
20	100 *a*	98 *a*	100 *a*	91 *a*	71 *b*	68 *b*
40	97 *a*	93 *a*	98 *a*	59 *b*	**7 *c***	**0 *c***
60	98 *a*	89 *a*	72 *b*	**2 *c***	**0 *c***	**0 *c***

P<0.001, LSD=16.07, cv rep=5.8%, >80% reduction ***bolded***

While ARG seed was found to be the most heat tolerant of the grass weeds trialled (Table 3), it followed a similar trend to brome and barley grass (Table 6). ARG required approximately 100^{o}C more heat at equivalent duration than either brome or barley grass to achieve a high level of weed seed control. These results show ARG to be more tolerant to heat than previously reported by Walsh and Newman (2007). Given the temperatures required to control ARG seeds, HWSC tactics where harvest residue is placed in heavy rows or preferably narrow windrows for burning would be required. A South Australian study of the potential of HSWC tactics found that between 26-73% of annual ryegrass seed could potentially be captured and then placed in narrow windrows for burning (Fleet *et al.* 2014). While still highly variable, depending on the timing and seasonal conditionals, ARG has the potential for significant seed control with HWSC tactics and narrow windrow burning. Ranking of these grass species would be barley grass: unviable < brome grass some control < annual ryegrass moderate control.

Table 6. Effect of heat on Annual Ryegrass seed viability (% survival).

	Temperature (^{o}C)					
Duration (s)	**200**	**250**	**300**	**350**	**400**	**450**
20	93 *ab*	98 *a*	98 *a*	98 *a*	93 *ab*	70 *b*
40	98 *a*	97 *a*	99 *a*	73 *b*	54 *c*	**0 *e***
60	99 *a*	95 *ab*	82 *b*	21 *d*	**1 *e***	**0 *e***

P<0.001, LSD=14.44, cv rep=3.2%, >80% reduction ***bolded***

Broad-leaved weeds

Onion weed seed was more sensitive to heat than the grass species studied (Table 7.). Onion weed is usually found in areas of poor competition in crops and pastures (Pitt *et al.* 2006). Despite the potential of heat to control onion weed seeds it could be difficult to have enough crop or pasture biomass to achieve enough heat and duration for effective control, particularly if burning pasture residues or standing stubble. Such paddocks are also prone to wind erosion so the implications of burning need to be considered carefully.

Table 7. Effect of heat on Onion weed seed viability (% survival).

	Temperature (^oC)					
Duration (s)	**200**	**250**	**300**	**350**	**400**	**450**
20	94 *ab*	93 *ab*	88 *ab*	90 *ab*	82 *b*	38 *c*
40	91 *ab*	89 *ab*	91 *ab*	31 *c*	**1 *d***	**0 *d***
60	87 *ab*	86 *ab*	**11 *d***	**0 *d***	**0 *d***	**0 *d***

P<0.001, LSD=15.31, cv rep=7.9%, >80% reduction ***bolded***

Statice seed was significantly more tolerant of heat than onion weed (Table 3). It required temperatures ≥400^oC for 60 s duration to achieve effective control of statice seeds. From the stubble burning temperatures reported in Walsh & Newman (2007), HWSC and narrow windrow burning would be required to possibly achieve effective control of statice seed. This species shows potential of HWSC techniques as it appears to retain seed pods and is often a grain contaminant in problem paddocks, however will require very hot and prolonged stubble burning conditions. As statice is often found in paddocks affected by some level of salinity, the level of crop residue present may be inadequate for achieving prolonged hot burn.

Table 8. Effect of heat on Statice seed viability (% survival).

	Temperature (^oC)					
Duration (s)	**200**	**250**	**300**	**350**	**400**	**450**
20	96 *ab*	95 *ab*	96 *ab*	100 *a*	99 *a*	83 *b*
40	98 *ab*	92 *ab*	97 *ab*	76 *b*	46 *c*	**4 *e***
60	94 *ab*	91 *ab*	48 *c*	24 *d*	**2 *e***	**4 *e***

P<0.001, LSD=14.50, cv rep=3.3%, >80% reduction ***bolded***

Mallow seed was treated in small pod segments as by autumn when crop residues are burnt the primary mallow pods have broken up and individual pod sections remain. Mallow was found to be extremely heat tolerant and would likely prove very difficult to control in many stubble burning situations. It was found to require ≥450^oC for ≥40 seconds to obtain effective control of seeds (Table 9). At 450^oC there was no seed kill at 20 seconds duration, but high levels of control at 40 seconds duration, indicating a critical heat duration time between 20-40 seconds at this temperature. Mallow was the most heat tolerant weed species in this study (Table 3).

Table 9. Effect of heat on Mallow seed viability (% survival).

	Temperature (^oC)					
Duration (s)	**200**	**250**	**300**	**350**	**400**	**450**
20	100 *a*	92 *ab*	95 *ab*	100 *a*	100 *a*	100 *a*
40	97 *ab*	75 *ab*	100 *a*	100 *a*	92 *ab*	**3 *c***
60	92 *ab*	88 *ab*	95 *ab*	44 *b*	66 *b*	**9 *c***

P<0.001, LSD=32.26, cv rep=3.1%, >80% reduction ***bolded***

Brassica weeds

Lincoln weed seed was found to be the most sensitive weed species to high temperature exposure in this study (Table 3). Like other species, Lincoln weed seed control was dependent on both temperature and duration. However once temperature was ≥350°C, effective control could be achieved even with 20 s exposure (Table 10.). This indicates that there would be some potential to control Lincoln weed in standing stubble situations. An additional complication would be that such a small seed could fall between soil clods or cracks and be insulated from any heat caused by burning. Walsh and Newman (2007) reported that as little as 1 cm of soil cover could effectively insulate seed from heat produced from residue burning. Lincoln weed would not be suited for HWSC and narrow windrow burning as it is generally a weed of summer fallows where it grows after crop harvest.

Table 10. Effect of heat on Lincoln weed seed viability (% survival).

	Temperature (°C)					
Duration (s)	**200**	**250**	**300**	**350**	**400**	**450**
20	97 *a*	92 *a*	62 *b*	**11 *c***	**0 *c***	**0 *c***
40	49 *b*	**18 *c***	**0 *c***	**0 *c***	**0 *c***	**0 *c***
60	**18 *c***	**3 *c***	**0 *c***	**0 *c***	**0 *c***	**0 *c***

P<0.001, LSD=28.87, cv rep=17.1%, >80% reduction ***bolded***

IHM seed was found to be more tolerant of heat than Lincoln weed (Table 3). While temperatures ≥450°C could completely control IHM seed at the shorter duration times, duration times of ≥60 seconds were required to achieve effective control at 250-300°C (Table 11). According to the temperature and duration results reported by Walsh and Newman (2007), potentially enough heat would be generated for long enough to effectively control IHM seed when either burning heavy conventional or narrow harvest windrows. IHM is also well suited for HWSC followed by windrow burning as it has high pod and seed retention (Fleet *et al.* 2016).

Table 11. Effect of heat on Indian Hedge Mustard seed viability (% survival).

	Temperature (°C)					
Duration (s)	**200**	**250**	**300**	**350**	**400**	**450**
20	71 *b*	66 *bc*	88 *a*	54 *c*	69 *b*	**0 *e***
40	73 *b*	53 *c*	47 *c*	**0 *e***	**0 *e***	**0 *e***
60	69 *b*	**19 *d***	**1 *e***	**0 *e***	**1 *e***	**0 *e***

P<0.001, LSD=12.55, cv rep=4.2%, >80% reduction ***bolded***

Wild turnip seed was found to be one of the most heat tolerant of the weed species studied, particularly when compared to other brassica weeds. Wild turnip was nearly 2 and 3 fold more tolerant than IHM and Lincoln weed, respectively (Table 3). Wild turnip required ≥400°C for 60 seconds to effectively kill seeds; a 40 second duration achieved the same results when temperature was increased to 450°C. However at 450°C, 20 second heat duration had no effect on seed viability (Table 12). Narrow windrow burning of stubble would be the only way to potentially achieve the temperatures and durations required to effectively control wild turnip seed (Walsh and Newman, 2007). Wild turnip is unlikely to be well suited to HWSC and narrow windrow burning as it is prone to shed seeds early before crop harvest.

Table 12. Effect of heat on Wild Turnip seed viability (% survival).

	Temperature (°C)					
Duration (s)	**200**	**250**	**300**	**350**	**400**	**450**
20	98 *a*	98 *a*	98 *a*	100 *a*	100 *a*	99 *a*
40	99 *a*	99 *a*	98 *a*	99 *a*	92 *a*	**0 *c***
60	100 *a*	99 *a*	98 *a*	32 *b*	**0 *c***	**0 *c***

P<0.001, LSD=21.40, cv rep=3.7%, >80% reduction ***bolded***

What does this mean?

All weed species investigated showed that exposure to heat could provide control of seeds, but there were large differences between weeds in their tolerance to heat. Combinations of high temperature and exposure time investigated could provide complete kill of all species except marshmallow. High temperature and duration of burn expected from burning narrow windrows should provide effective seed kill of most of these species. However, the performance of this method is completely dependent on how much of the weed seeds can be collected at harvest (HWSC) and placed into narrow harvest windrows. Grass weeds all showed similar patterns of tolerance to heat with ARG being the most tolerant. Despite the higher tolerance to heat, high pre-harvest seed retention in ARG makes it more suited to effective control from residue burning (narrow windrows) than barley grass, which sheds most of its seeds well before harvest. Among brassica weeds, IHM showed good potential for control by burning harvest windrows as it is sensitive to both heat and HWSC methods.

Acknowledgements

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Location: South Australia

Burning temperatures of harvest windrows and standing stubbles in low rainfall farming systems

Authors: Amanda Cook[1], Ben Fleet[2] and Naomi Scholz[1]
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Funding body: SAGIT

Project title: S416 – Burning of weed seeds in low rainfall farming systems project

Key messages

- **Cereal windrow burning achieved temperatures in excess of those required to achieve high levels of weed seed mortality, except in paddocks which had 11 mm of rainfall the week before.**
- **The open paddock burn with a high stubble load had a quicker, faster burn but still achieved the necessary temperatures of 450^{O}C for longer than 60 seconds.**

Why do the trial?

Farmers and advisers list weeds as one of the major constraints to improving the productivity and sustainability of southern Australian farming systems. Narrow windrow burning has been rapidly adopted across southern Australia as a weed management tool. The technique has been found to be very effective for controlling annual ryegrass and wild radish in WA. These weed species retain much of their seed by the time of crop harvest and a significant amount of weed seeds can be collected by the harvester and then concentrated into rows with the chaff and straw. High weed seed kill efficacy is generally achieved for annual ryegrass and wild radish at temperatures often achieved by burning narrow windrows.

Knowledge of both the threshold temperatures to kill weed seeds, and the temperatures achieved when burning crop residues in various formats are required to provide a guide to expected weed seed control of problematic weeds in low rainfall cropping systems. Unlike a whole paddock burn, this information will only relate to the fate of seed that enters the harvest windrow. The total efficacy of this method will be largely controlled by the proportion of weed seeds that can be collected by the harvester. Threshold temperatures to kill weed seeds are reported in the article *'Burning of weed seeds in low rainfall farming systems'*.

How was it done?

SARDI staff on upper EP and the staff of the Upper North Farming Systems (UNFS) group measured temperatures during burning (windrows or whole paddock) of different crops in their region. The UNFS group located farmers in their region who were narrow windrow burning or burning whole paddocks, and the EP paddocks were monitored on the Minnipa Agricultural Centre (MAC).

Over the late summer/autumn of 2016-17, temperatures were measured when burning crops by using a hand held laser type thermometer (Kestrel delta T instrument) by holding the temperature gun at full arms-length pointing at the middle of the windrow. Temperatures were recorded every 10 seconds for 240 seconds, then recorded at 300 and 360 seconds.

Wind speed, direction and air temperature (either from BOM site or using a Kestrel delta T instrument) and the height of the standing stubble were also recorded. For the whole paddock burn the same protocol was used, measurements were taken in a stationary position and due to preserving personal safety, only one set of data were recorded until 210 seconds.

What happened?

Nine paddocks were monitored for burning temperatures, most were cereal stubbles in windrows (Table 1).

Table 1. Paddock details, crop type, stubble and weather conditions at burning in autumn 2017.

Burning date	Crop	Crop yield (t/ha)	Paddock	Burn type	Stubble height (cm)	Stubble load (t/ha)	Relative humidity (%)	Wind speed and direction (km/h)	Temperature (°C)
20-Mar	Mace wheat	3	MAC S1	windrows	18	2-Mar	16	10 WNW	30
28-Apr	Mace wheat	3.1	MAC S7	windrows	19	2-Mar	17	9 SSE	19
26-Apr	Compass barley*	4	MAC Airport	windrows	22	2.5-3.5	38	28 SSW	16
26-Apr	Mace wheat*	2.8	MAC Airport	windrows	19	2-Mar	38	28 SSW	16
17-Mar	Trojan wheat	2.6	MAC S4	windrows	17	2-Mar	17	9 S	29
17-Mar	Mace wheat	3.6	MAC N5S	windrows	15	2-Mar	17	9 S	29
10-May	Medic and barley grass	3.7 DM hay cut	MAC N1	large plots - paddock burn (9 m x 9 m)	17	3-Apr	23	15 NNE	19
10-May	Mace wheat	2.9	MAC N1	windrows	17	2-Mar	23	15 NNE	19
9-May	UNFS Canola	2.3	Nottle Paddock 1	windrows	40	1-Feb	36	7 NNE	20
9-May	UNFS Canola	2.1	Nottle Paddock 2	windrows	40	3-Apr	27	4 NNE	21
5-May	UNFS Wheat	NA as leased	Hazels	windrows	40	5-Jun	36	8 NE	19
5-May	UNFS Wheat	NA as leased	Hazels	paddock burn	40	5-Jun	36	8 NE	19

**11 mm received between 20-27 April*

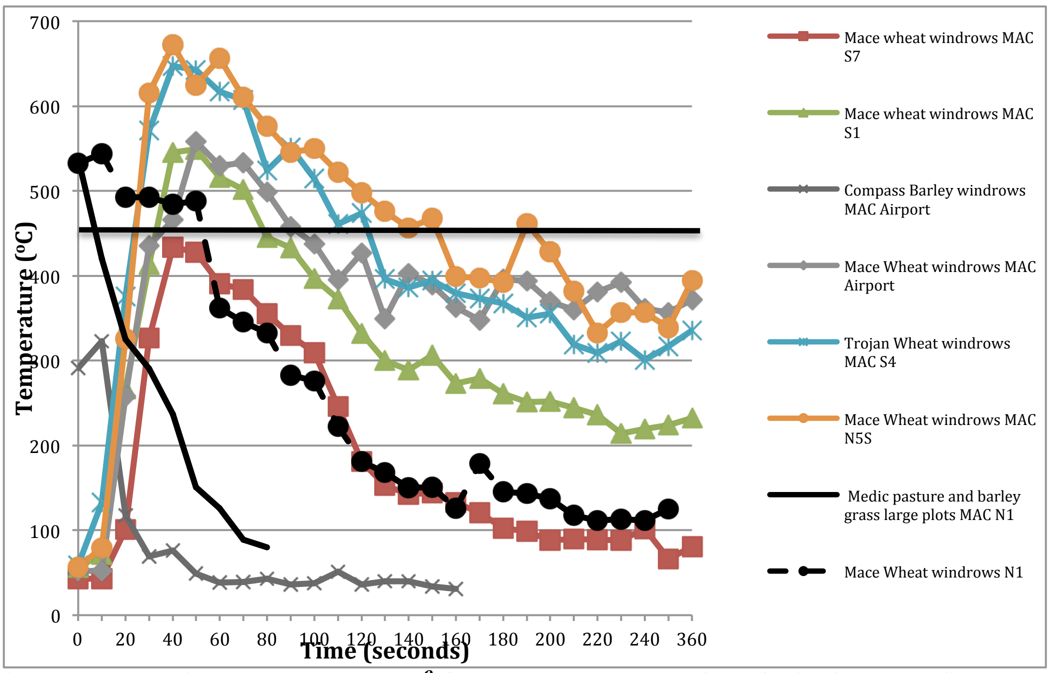

Figure 1. Burning temperatures (°C) over time (seconds) of windrows (wheat and canola) prior to seeding in 2017 at Minnipa Agricultural Centre.

Most paddocks with cereal windrows at MAC achieved temperatures greater than 450°C for longer than 60 seconds (Figure 1). The Compass barley in windrows in the airport paddock received 11 mm of rainfall in the week before, with 0.2 mm the day before burning, so despite having the highest stubble load at Minnipa, it did not achieve the target temperatures of higher than 450°C for greater than 60 seconds. Likewise, the S7 paddock burn was conducted 8 days after receiving 11 mm of rainfall at MAC and did not achieve the temperatures required for weed seed kill.

The medic pasture and barley grass plots (9 m x 9 m) were burnt as a whole paddock burn situation (replicated 8 times). The medic and grass plots did not achieve the high temperatures required for weed seed kill, however further measurements in other medic paddocks and at different dry matter levels are required to make more robust conclusions.

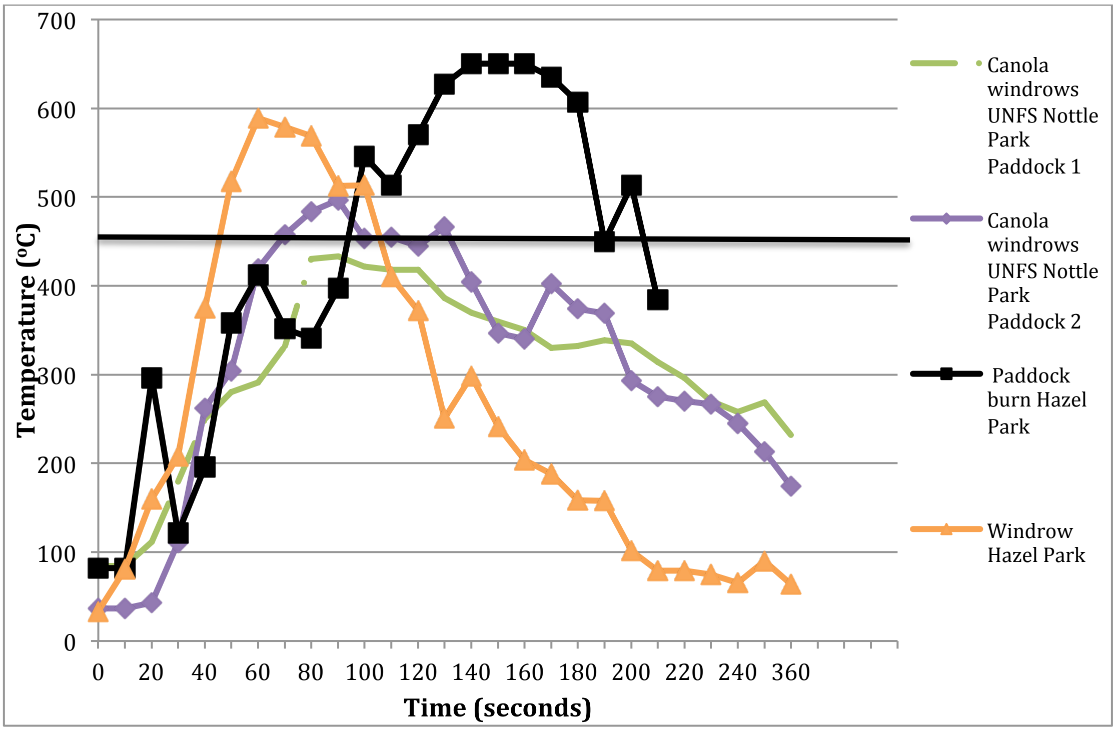

Figure 2. Burning temperatures (°C) over time (seconds) of windrows (wheat and canola) prior to seeding in 2017 in the Upper North, SA.

The UNFS canola paddock (Nottle) had been raked twice, so the windrows were low and scattered with very little standing stubble around the windrows, and these windrows didn't achieve the temperatures of greater than 450°C for longer than 60 seconds needed for weed seed kill (Figure 2).

Hazel's paddock was heavy wheat stubble with high numbers of grass weeds, especially ryegrass. The open paddock burn had flames that travelled fast and immediately behind the fire front cooled off relatively quickly; therefore any weed seeds on the soil surface that did not burn directly were not likely to suffer any damage.

Previous burning measurements in windrows at MAC taken in 2015 and 2016 show that with higher stubble loads after a good growing season, temperatures of 450°C for 60 seconds or greater are being achieved. A time interval of 40 seconds with temperatures of 450°C or greater would result in some mortality of seeds, but not a total weed seed kill.

What does this mean?

Recent research under controlled conditions (using a kiln) on the temperatures required to kill weed seed species commonly found in SA cropping regions showed temperatures greater than $450^{O}C$ for 60 seconds of exposure resulted in high mortality for most weed species (*Burning of weed seeds in low rainfall farming systems*, Fleet et al. EPFS Summary 2017).

The results from the paddock burning measurements, using hand held temperature gun, showed that, when dry, in most situtations temperatures achieved when burning narrow harvest windrows were likely to achieve good control of the weed seeds collected in the harvest row. Total control of weed seeds across the paddock using these methods will depend on the proportion of the weed seeds that can be collected by the harvest operation.

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Location
Minnipa Agricultural Centre
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2017 Total: 281 mm
2017 GSR: 155 mm
Yield
Potential: 1.7 t/ha (W)
Actual: 1.0 t/ha average
Soil type
Red loam

Break Crop Options for the Southern Low Rainfall Zone

Author: Sarah Day, SARDI Clare

Funded By: GRDC – DAS00162-A

Project Title: Validating recent research on break crop options in the low rainfall zone to determine the best options for different climate, soil type and biotic stress situations.

Project Duration: 2017 - 2019

Project Delivery Organisation: SARDI

Key Messages:

- **Break crop performance was variable across the southern low rainfall zone in 2017, due to high variation in seasonal rainfall.**
- **Break crop trials indicated significant interactions between variety and grain yield across the four sites in 2017.**
- **Lentil were the most profitable break crop species at Willowie in 2017, while lupin were the least profitable.**

Background:

Current farming systems in the southern low rainfall zone (LRZ) are dominated by cereal production, with cereal cropping intensities of 60-70% common. Break crops continue to occupy a very small percentage of arable area despite recent research demonstrating the value and profitability of including them in the rotation. This is generally thought to be due to the perception that break crops have an increased risk and production cost compared to cereals. Once a grower has decided that a paddock is due for a break from cereals, there is still a lack of confidence about choosing the break crop that is best suited, and the correct management approach required to reduce production risk and minimise inputs. There is currently little information around both of these topics for low rainfall environments, as break crop development has largely occurred in medium and high rainfall zones, with these strategies often being inappropriate for low rainfall cropping systems.

This project builds on GRDC funded projects DAS00119 (Profitable crop sequencing in the low rainfall areas of South Eastern Australia), DAV00113 (Southern region pulse agronomy), CSP00187 (Southern region canola agronomy), and SAGIT funded project MSF115 (Adopting profitable crop sequences in the SA Mallee). The long-term aim of this project is to improve production and profit of low rainfall farming systems through the adoption of break crop management packages specifically developed for low rainfall farming systems.

Methodology:

To meet the project aim, four randomized break crop trials were established in 2017 at strategically located sites in the major cropping regions in the southern LRZ (Upper Eyre Peninsula, SA, Upper North, SA and the Mallee region of SA and Victoria). The break crop trials include 3-6 varieties (to represent the major options with potential in the low rainfall zone) of canola, lupin (where appropriate), field pea, vetch, lentil, chickpea and faba bean. Specific agronomic management trials addressing break crop production in the LRZ were established in the Upper North, SA (Willowie), in 2017, and will be strategically expanded to other sites in 2018 and 2019. Agronomic management trials in 2017 were focused on chickpea ascochyta blight fungicide management, field pea blackspot fungicide management, canola nitrogen management, lentil group B and C herbicide management, and lentil plant sowing density. Soil characteristics, soil moisture, grain yield and biomass yield were measured at each site.

Trials were managed so that each crop species received appropriate and optimum management requirements, including sowing time, inoculum, sowing depth, herbicide treatments, fertiliser and harvest timing. Soil moisture and nutrients were measured prior to sowing, while soil moisture was also measured for each crop species post-harvest.

For the purpose of this report, the focus will be on trials located at Willowie. Canola, faba bean, vetch and lupin were sown on May 1, while field pea, lentil and chickpea were sown on May 18. Field pea, lentil, faba bean, vetch and lupin were harvested on October 26, while the canola and chickpea were harvested on November 9.

Gross margins were calculated for each crop species using the Rural Solutions 'Farm Gross Margin and Enterprise Planning Guide'. The costs were calculated using the actual inputs in the trial and the values provided in the gross margin guide.

Results:

The grain yield by variety response was significant for break crop variety trials at all four sites, in 2017. At Willowie, there were varieties within each species that showed adaptation to the local and seasonal conditions (figure 1).

PBA Samira faba bean (1.5 t/ha) was the highest yielding break crop variety at Willowie in 2017, but not significantly higher than field pea varieties PBA Percy (1.49 t/ha), PBA Wharton (1.48 t/ha), vetch variety Timok (1.48 t/ha) and lentil variety PBA Jumbo2 (1.38 t/ha) (figure 1). ATR Stingray, PBA Monarch, Genesis^{TM}090, ATR Bonito and PBA Striker were the lowest yielding varieties, with grain yield of 0.8-0.89 t/ha.

Grain yield of Nuseed Diamond (1.31 t/ha) was higher than all other canola varieties by 0.26 – 0.51 t/ha. Timok and PBA Bateman were higher yielding than other vetch and lupin varieties by 0.18 t/ha and 0.14 t/ha respectively, indicating better adaptation. Kaspa grain yield was lower than all other field pea varieties, by 0.14 – 0.37 t/ha, indicating progress in the breeding program in developing higher yielding field pea varieties with broader adaptation. PBA Jumbo2 (1.38 t/ha) was higher yielding than PBA Blitz and PBA Hurricane XT by 0.2 t/ha.

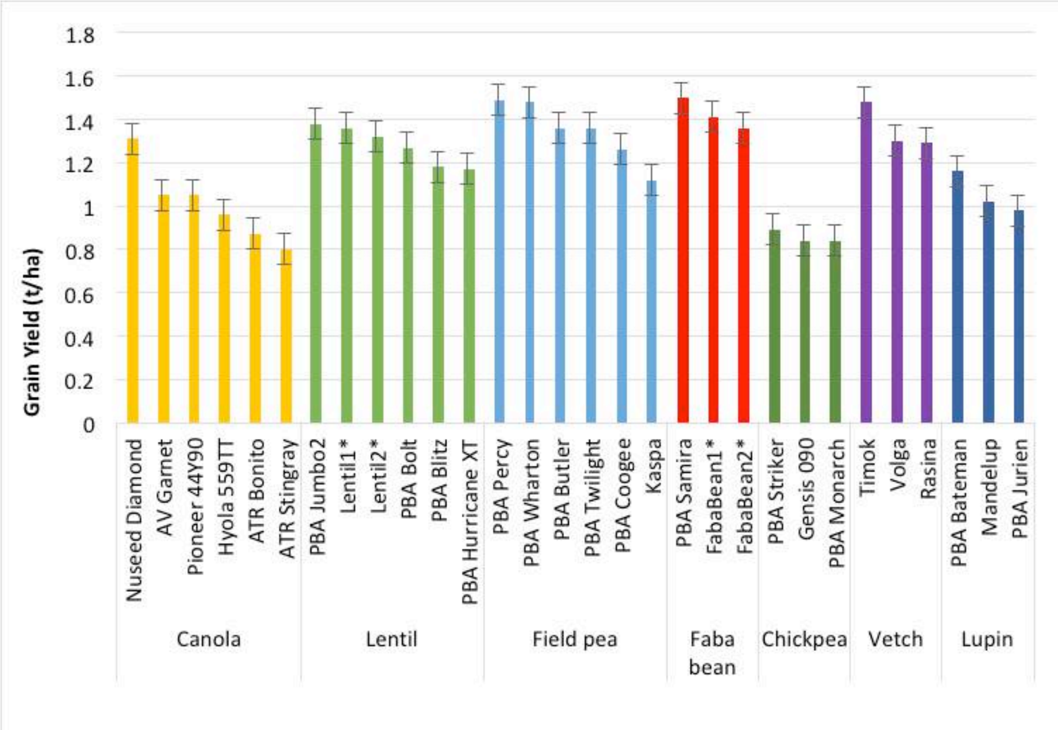

Figure 1. Grain yield of break crop varieties at Willowie, 2017.
Error bars = least significant difference (LSD).
***Advanced breeding lines not yet commercially available at time of publication**

All break crop species were profitable for grain production at Willowie in 2017 (figure 2). Lentil were the most profitable break crop species with a gross margin (GM) of >$400/ha, for both conventional and herbicide tolerant lentil. Vetch and conventional canola had gross margins of >$200/ha, while lupin were the least profitable break crop with a gross margin <$50/ha.

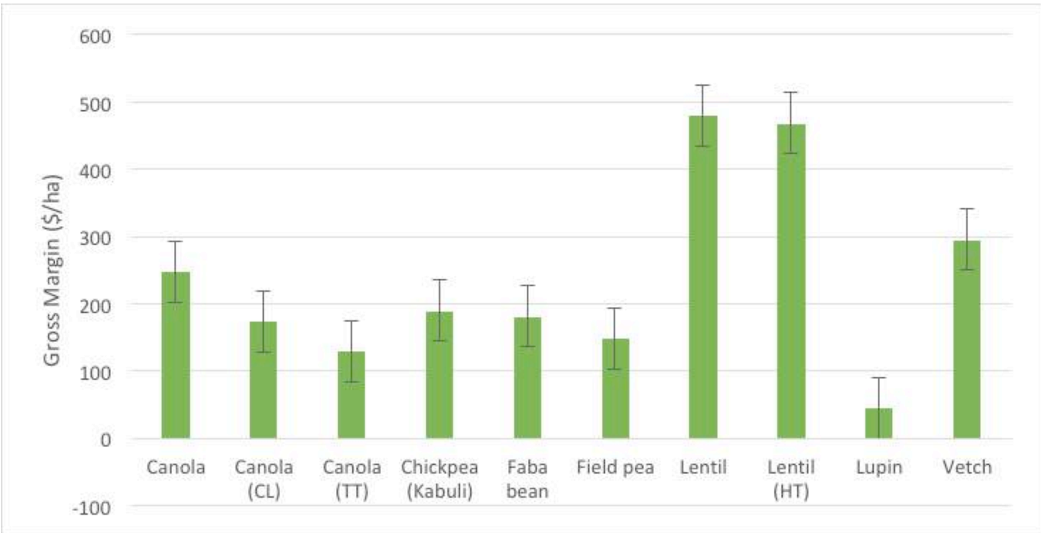

Figure 2. Gross margin of break crop species at Willowie, 2017. Error bars = standard error.
Note: calculated GM's represent an average case scenario and are to be used as a base guide only.

The lentil sowing density management trial had a significant grain yield response to different plant sowing densities for both PBA Bolt and PBA Hurricane XT at Willowie, in 2017. No significant difference in grain yield was seen when PBA Bolt was sown at plant densities of 60-140 plants/m^2 (figure 3). These preliminary results indicate a seeding rate as low as 60 plants/m^2 did not compromise yield at this site in 2017.

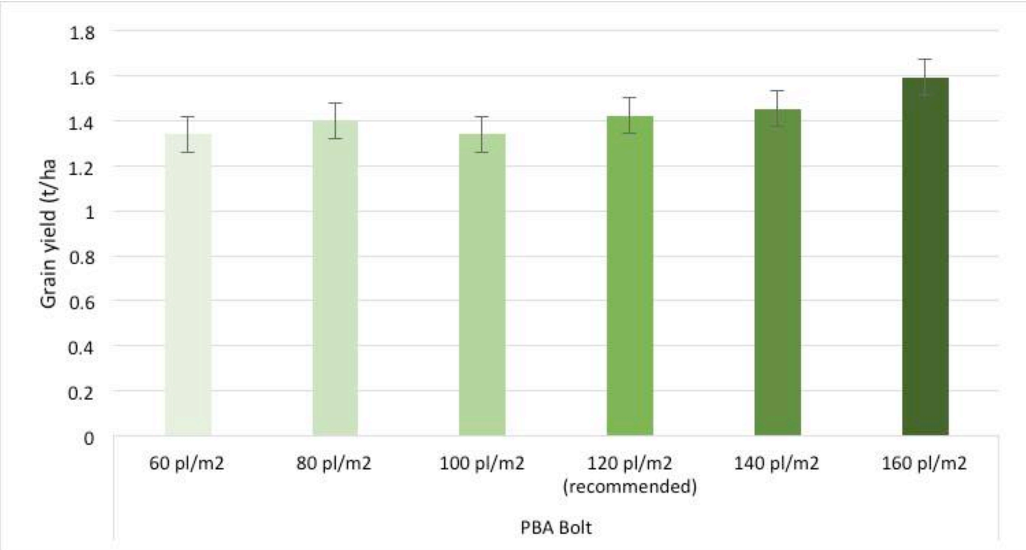

Figure 3. Grain yield response of PBA Bolt sown at multiple plant densities at Willowie, 2017.
Error bars = least significant difference (LSD).

Grain yield of PBA Hurricane XT sown at plant densities of 120 plant/m^2 and 100 plants/m^2 were not significantly different at Willowie, 2017 (figure 4). These preliminary results indicate that a reduction of seeding rate by 20 plants/m^2 did not compromise yield at this site in this year. Grain yield of PBA Hurricane XT sown at 60 and 80 plants/m^2 was lower than all other plant densities.

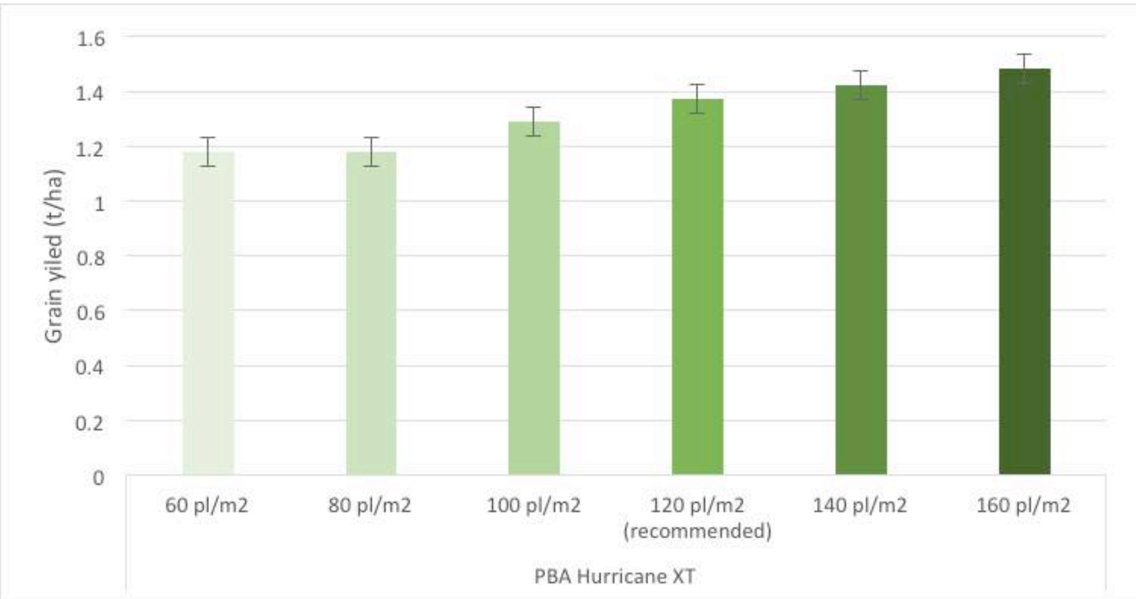

Figure 4. Grain yield response of PBA Hurricane XT sown at multiple plant densities at Willowie, 2017. Error bars = least significant difference (LSD).

Conclusion:

Significant grain yield differences were observed for break crop varieties at all four trial locations in 2017, although results were variable across the regions due to variable rainfall. GM calculations using actual trial inputs indicated lentil were the most profitable grain break crop at Willowie in 2017, while lupin were the least profitable.

The lentil sowing density management trial had a significant grain yield response to multiple plant sowing densities in 2017. The trial indicated the potential for reducing sowing density without compromising grain yield in the LRZ. No disease infection or herbicide damage occurred in management trials in 2017 and therefore no significant interactions were seen for grain or biomass yield.

Break crop variety trials and specific management trials will continue over the next two seasons, as additional data is required to allow accurate conclusions to be drawn and the development of break crop management packages for the southern LRZ.

Acknowledgements:

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Managing the Risk of Canola Production in Low Rainfall Environments

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Funded by: GRDC Optimised Canola Productivity

Peer review: Elizabeth Meier

Project title: GRDC Optimised Canola Productivity (CSP00187)

Key words: time of sowing, cultivar, nitrogen

Key Messages

- **Sowing at the earliest opportunity (which requires rainfall) is an important component of reducing the risk of canola production in low rainfall environments.**
- **The amount of N available to the crop is critical to productivity in a canola crop that has established well.**
- **Applying adequate doses of fertiliser N at seeding or early in the crop's development have produced the highest grain yields but this was less important in a wet spring like 2016.**
- **Legumes can provide N to a subsequent canola crop, but in many cases, canola growing on legume residue will still respond to fertiliser N inputs.**
- **Analysis of the profit-risk context for optimal N inputs for canola produced in low rainfall environments is underway.**

Background

In 2015 a co-ordinated series of trials at three low rainfall locations (Mildura, Minnipa and Loxton) were established to evaluate options to manage risk in canola crops without yield penalty. The treatments included a range of sowing dates, hybrid (Hyola 450) vs TT (Stingray) cultivar comparisons, N fertiliser timings and N fertiliser rates with the aim to improve the reliability of canola establishment, optimise sowing date (while keeping canola at the very beginning of the sowing program), quantify the cost/benefit of hybrid varieties and identify optimal timing for N inputs. Experiments in 2015 indicated that sowing at the earliest opportunity, in this case a break of season sowing in April, offered the best yield outcome. Yield gains from hybrid canola were small and not economic compared with open pollinated canola. Canola productivity was best with early N application, and in the case of the Mildura site waiting until stem elongation for N application resulted in a 10 – 20% yield penalty (Ware et al. 2017, Moodie et al. 2016). Experiments in 2016 focussed on N management, given the increased confidence in the key messages around time of sowing and the lack of varietal options obtained from the 2015 experiments. Experiments were established at Ouyen, Minnipa and Karoonda to explore the opportunity and risk associated with N management in low rainfall canola. The treatments included a range of N fertiliser timing, N fertiliser rate, soil type and sowing date to assess whether: different soil types and N management history require different N management, the application of N can be delayed without penalty to yield, higher rates of N provide an economic response and the optimal management of fertilizer N differs depending on sowing date. In 2016 the best sowing date was with a break of season rainfall event in May, and establishment issues associated with dry sowing in April caused a yield penalty. At Karoonda there was a response to N fertiliser on all soil types (at 10 kg grain/kg fertiliser N for all soils at the 80 kg N/ha rate) and the highest yielding treatments were those that received most of their N fertiliser later at stem elongation in a season with a dry start and wet spring. However, consistent across all sites and seasons, time of nitrogen application was not as important as the quantity available to the plant (McBeath et al. 2017). Yield gains from increased N application did not impose an oil content penalty.

In 2017, we established experiments at Minnipa, Mildura and Karoonda 2017 to explore whether sowing canola into legume stubble can reduce N fertiliser requirement and provide a risk management strategy. This approach was taken following the demonstrated importance in 2016 of N supply to canola productivity in low rainfall environments and evidence of an N driven yield gap despite relatively high fertiliser N. The treatments included a range of N fertiliser rates (Karoonda), legume residue types (Mildura and Minnipa) and soil types (Karoonda) to assess whether:

- Legume N reduces fertiliser N requirement in canola
- Soil type affects legume and fertiliser N supply and requirement in canola
- Legume type affects N supply in canola

About the 2017 trials

The experiments included assessments of pre-sowing soil water and mineral N, crop establishment, NDVI, date of 50% start of flowering and biomass and maturity biomass, grain yield and quality. Minnipa Canola plots were sown into medic, field pea and wheat residue in May but conditions were extremely dry and the crop did not establish until August. As a result no fertiliser N was applied. Ouyen In 2016 plots of barley, field pea, field pea/ barley, vetch/ barley, vetch/ field pea, vetch/ field pea/ barley and vetch were established. Barley and vetch were spraytopped in the Spring in order to brown manure while field peas were grown to maturity. Stingray canola was sown on the 15th May 2017 (resown after failed establishment for April sowing) with 100 kg/ha of single superphosphate. On the 13th July 32 kg N/ha was applied as urea to one half of each plot. There was no follow up rain to incorporate the urea application until the 3rd of August. At Karoonda plots of lupin and wheat were established in 2016. All plots were sown on the 3rd May 2017 with Stingray canola and received 11 kg P/ha, 11 kg S/ha, 27 kg K/ha and foliar Zn, Cu and Mn to ensure other nutrients were non- limiting. Fertiliser was applied as 50 kg/ha MAP + 1% Zn at sowing (5kg N) and any additional fertiliser was applied after the crop emerged at 2-4 leaves by top dressing with Urea (at 30 or 80 kg N/ha) on the 21st of June.

2017 Trials Results & Discussion

Minnipa

Given the very late establishment it was surprising that canola yielded 0.3-0.4 t/ha across the residue types, but due to the season there was no significant response to treatments despite a difference in starting N conditions (Table 1).

Table 1. Pre-sowing Soil Mineral N in response to 2016 crop type at Minnipa.

2016 crop	Pre-sow soil Mineral N (kg N/ha/m)
Wheat	145
Field Pea	140
Medic	197

Ouyen

Crop residue from the previous crop had a significant effect on canola grain yield (Table 2). The pre-sowing mineral N derived from the crop residue (Table 2) was found to be a primary driver of the canola yield response with a relationship of 13.3 kg grain/ kg pre-sowing Mineral N (R^2=0.9, Figure 1). Canola grain yield also responded to fertiliser N input, but this response was independent of the crop residue type and had a lower efficiency (5.3 kg grain/ kg fertiliser N). There was a 2.5 week gap between the urea application and a rainfall event which may have affected the efficacy. Pre-sowing soil water was not found to affect grain yield (data not shown).

Table 2. Pre-sowing soil mineral N and canola grain yield (t/ha) in response to 2016 crop type and fertiliser N (32 kg N/ha) addition at Ouyen in 2017.

	Pre-sow soil Mineral N (kg N/ha/m)	**Grain Yield (t/ha)**
2016 crop		
Barley	39.1	0.79
Field Pea	52.3	1.07
Field Pea/Barley	42.4	0.87
Vetch/Barley	78.5	1.35
Vetch/Field Pea	75.3	1.24
Vetch/Field Pea/Barley	40.3	0.89
Vetch	85.1	1.49
SED (P=0.05)		0.18
Fertiliser	59	
Minus		1.05
Plus		1.22
SED (P=0.05)		0.08

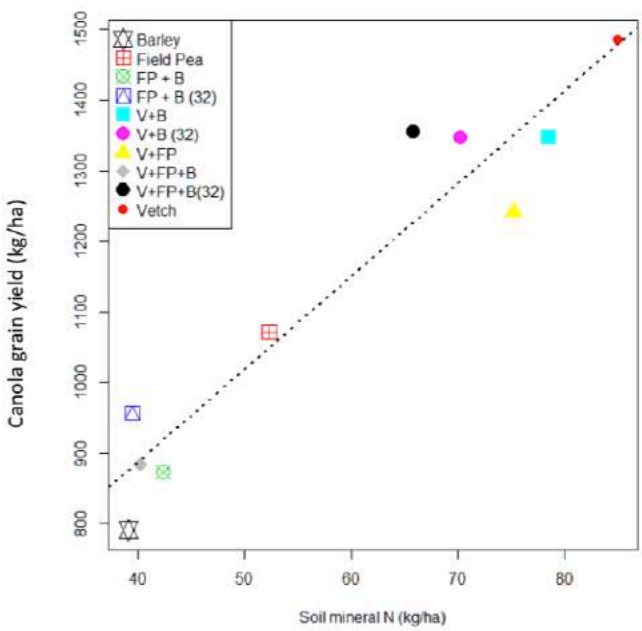

Figure 1. Relationship between pre-sowing soil mineral N (kg/ha) and grain yield (kg/ha) **Karoonda**

The 2016 lupin crop provided an additional 19-62 kg pre-sowing mineral N/ha depending on the soil type with the greatest benefit on the swale. However, there was only a grain yield response to lupin residue compared with wheat on the sandy dune and mid-slope soils with a 40-60% yield benefit and as a result soil mineral N and canola grain yield were not directly related at the Karoonda site (Table 3). The grain yield benefit did not directly relate to pre-sowing mineral N or the change in mineral N provided by the legume (e.g. the canola on the swale had the highest mineral N boost from the legume but there was no yield benefit of legume vs wheat). Residue type did not interact with fertiliser N input for grain yield response. Both of the sands showed significant yield benefit at the 80kg N/ha input level compared with 5 kg N/ha. There was a wide variation in the extra grain produced from this 75 kg N/ha supplied as fertiliser with 4.4-10.6 kg grain/ kg fertiliser N. Canola oil content was not affected by treatment and varied from 44.12-47.62%. There was a tendency for oil content to be higher in higher yielding plots.

Table 3. Canola grain yield*(t/ha) on Karoonda dune, mid-slope and swale soils in response to residue type (wheat and lupins) and N fertiliser input (5,30 and 80 kg N/ha).

	Soil Type		
	Dune	Mid-slope	Swale
Residue Type			
Wheat	0.79	0.70	**0.78**
Lupins	1.29	0.98	0.86
LSD, P=0.05	0.11	0.09	NSD
Fertiliser N rate (kg N/ha)			
5	0.70	0.74	0.79
30	0.92	0.71	0.79
80	**1.50**	**1.07**	0.88
LSD, P=0.05	0.24	0.11	NSD

** Note that there was a significant hailstorm two days before the plots were hand-harvested. Assessments indicated that different treatments did not have different levels of hail damage within a soil type, canola on sands had approximately 60% pod loss while canola on the swale had approximately 38% pod loss.*

Implications for commercial practice

For crops that had sufficient surface soil water to establish in 2017, N availability was a key driver of yield on the sandy soil types. Extra pre-sowing mineral N derived from legume residues proved directly beneficial to canola yield. In addition fertiliser N provided yield gains. The lack of interaction between residue and fertiliser N demonstrates the responsiveness of canola on sands to extra N in the system because even with extra N from residue, canola responded to fertiliser N inputs. This is consistent with our findings on wheat crops produced on Mallee sands. Further work to explore the profit-risk trade-offs is needed to arrive at the optimal level of N input for canola in the low rainfall environment. Recent data suggests that there are new varieties that may prove higher yielding than Stingray in low rainfall environments and testing their fit and N requirement together is likely beneficial.

Acknowledgements

Thanks to the Loller family for their generous support in hosting the trial, and to Jeff Braun and Lou Flohr for discussions around trial design and management. This work is a component of the 'Optimised Canola Profitability' project (CSP00187), a collaboration between NSW DPI, CSIRO and GRDC, in partnership with SARDI, CSU, MSF and BCG.

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GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

CSIRO

Mallee Sustainable Farming

SARDI SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

Virtual fencing as a future tool for Mallee farmers

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Funding body: Department of Agriculture and Water Resources

Project title: Targeted sheep grazing technology

Key Messages:

- **The first on-farm field trial applying virtual fencing to sheep showed that grazing can be successfully managed using virtual fencing methods, with the sheep showing promising learning ability.**
- **Based just on the benefits from avoiding the need to remove livestock from an entire paddock when just one soil or zone incurs excessive groundcover loss and erosion risk, spatial grazing in a typical Mallee crop-livestock system has the potential to increase the relative profitability of livestock and increase Mallee farm profit by 15% (excluding the cost of the technology). Other potential benefits include improved general improvements in feed utilisation, labour saving, targeted grazing for weed management purposes, and managing pasture establishment.**
- **The results offer encouragement for the ongoing pursuit of cost-effective virtual fencing technology for sheep.**
- **Due to wool and animal size differences with sheep, the use of collars may not be a long-term solution for commercial devices so technical development of other platforms such as ear tags is likely to be required.**

Why was the trial/project undertaken?

Virtual fencing technology that allows livestock to be managed using GPS-based technology offers the potential for major grazing productivity, labour and NRM benefits. A virtual fencing system based on CSIRO technology using collars for cattle is expected to become commercially available for use with cattle in 2018 (www.agersens.com). There has been major interest from mixed farmers regarding the potential use of virtual fencing although very little work had been done with sheep.

How was the trial/project undertaken?

Over the past 2 years we have been conducting field trials in collaboration with MSF to test the potential to manage sheep with virtual fencing methods. Trials were initially conducted at the CSIRO research station near Armidale NSW to test the ability of individual sheep to be trained to respond to an audio cue on test collars. The first on-farm trial was conducted near Gol Gol NSW in 2017 to test whether a small number of sheep can be excluded from an erodible area of a small paddock over a 2 day period. In 2018 a trial at Waikerie is being conducted to test how effectively sheep grazing can be managed when not all sheep are wearing a virtual fencing device. The potential economic benefits of spatial grazing on a mallee mixed farm has also been evaluated using the MIDAS whole-farm model.

Acknowledgements The contributions of Bill Barnfield, Allen Buckley, Dave Henry and the Chiswick and Moodie Agronomy teams are gratefully acknowledged.

Summer weeds survey of South Australian cropping districts

Authors: Ben Fleet, Christopher Preston and Gurjeet Gill (University of Adelaide, School of Agriculture, Food & Wine)

Key messages

- **Heliotrope was the most frequent summer weed surveyed.**
- **Frequency ranking of summer weed species varied greatly between districts.**
- **Dry summer fallow conditions in 2014/15 is likely to have reduced summer weed pressure, but not species composition.**

Why do the trial?

Effective management of summer weeds can greatly improve subsequent crops by preserving stored soil moisture and nitrogen, improving crop establishment and reducing levels of weed vectored insects pests and disease (Cameron & Storrie, 2014). Information on summer weed species will both direct growers into targeted management of problem summer weeds in their cropping region and help direct future research into summer weeds.

How was it done?

A random paddock survey was conducted on summer weeds across South Australian (SA) cropping regions during February to March in 2015 and 2016. The Lower North (LN), Mid North (MN), Upper North (UN), Yorke Peninsula (YP), Mallee, Upper South East (USE), and Lower South East (LSE) cropping districts were surveyed in 2015. The Upper Eyre Peninsula (UEP) and Lower Eyre Peninsula (LEP) were surveyed in 2016. In total 298 paddocks were surveyed and a breakdown of total surveyed paddocks in each region is displayed in Table 1. Sites were selected at approximately 10 km intervals. At each site, weed species were identified along an 80-100 m long transect. Weed density was assessed visually and rated as either low (0-10 plants/ m^2), medium (11-50 plants/m^2) or high (>50 plants/m^2). Details of crop residue, soil type, NDVI (most sites) and comments on growth stage were recorded at each site. Any species that could not be identified on site had photos taken for later identification. Analysis of weed frequency was done using Microsoft Excel 2013.

What happened?

The frequency ranking of different summer weeds varied significantly across SA cropping regions. Heliotrope was the most prevalent summer weed species across all surveyed regions of SA and in eight of the nine individual cropping districts surveyed (Tables 1 and 2).

Roly poly, Afghan melon and Clammy goosefoot were common summer weeds across most of the cropping regions. Whereas some weeds appear to be more localised in their distribution such as Tares (LN); Cutleaf mignonette (YP); Tar vine (UN); Skeleton weed, Small burr grass and Innocent weed (Mallee); Afghan thistle (UEP) and Wild radish (USE).

Sowthistle had the highest frequency of occurrence in the LSE region and it was also quite common in the LN and MN. Sowthistle was found at <10% of survey sites on the YP, which maybe a surprise given the increasing prevalence of this weed in lentil crops.
Panic grass was a regular occurrence in LN, MN, UN, and LSE districts where it has now established itself as a consistent summer weed.

While mallow was a regular occurrence in many cropping regions, it had a higher frequency in LN, MN and LEP cropping districts. Caltrop was only found at a regular frequency (>10%) in three regions (UN, Mallee and USE). Lincoln weed was only found to occur on the YP, UEP and LEP. Some areas had a much lower diversity of weed species (e.g. YP) than other others (e.g. USE and UN).

What does this mean?

The 2014/15 summer fallow period was quite dry for many cropping regions surveyed, which could have reduced summer weed pressure (density) and plant size, but weed species composition is still likely to be representative of the general trend.

Table 1. The frequency of summer fallow weed species for each South Australian cropping region (for all species found at more than 10% of sites). Frequency of sites given as a percentage and the number of paddocks surveyed for each district is in brackets.

Lower North (25)	Mid North (33)	Yorke Peninsula (34)	Upper North (22)	Mallee (48)	Upper Eyre Peninsula (58)	Lower Eyre Peninsula (37)	Upper South East (14)	Lower South East (19)
Heliotrope 84%	Heliotrope 68%	Heliotrope 47%	Heliotrope 68%	Heliotrope 67%	Heliotrope 48%	Heliotrope 51%	Heliotrope 71%	Sowthistle 21%
Sowthistle 44%	Panic grass 35%	Cutleaf Mignonette 24%	Stinking Love Grass 27%	Afghan Melon 46%	Afghan Melon 38%	Lincoln Weed 27%	Afghan Melon 36%	Clammy Goosefoot 16%
Panic grass 32%	Clammy Goosefoot 32%	Prickly lettuce 21%	Rolypoly 27%	Rolypoly 29%	Lincoln Weed 34%	Afghan Melon 24%	Clammy Goosefoot 36%	Heliotrope 16%
Mallow 28%	Mallow 26%	Lincoln Weed 15%	Panic grass 23%	Caltrop 27%	Rolypoly 29%	Medic 24%	Panic grass 29%	Panic grass 16%
Goosefoot 24%	Sowthistle 26%	Afghan Melon 12%	Caltrop 18%	Skeleton Weed 23%	Fleabane 28%	Mallow 22%	Stinking Love Grass 21%	Spear Thistle 16%
Rolypoly 20%	Wireweed 26%	Rolypoly 12%	Clammy Goosefoot 18%	Small burr Grass 19%	Caustic Creeper 16%	Onion Weed 19%	Caltrop 21%	Couch Grass 11%
Afghan Melon 16%	Salvation Jane 18%		Tar Vine 18%	Prickly Paddy Melon 17%	Prickly Paddy Melon 16%	Stinking Love Grass 14%	Lincoln Weed 21%	Mallow 11%
Wireweed 16%	Caustic Creeper 15%		Salvation Jane 18%	Wild Turnip 17%	Stinking Love Grass 14%	Fleabane 14%	Wild Radish 21%	Ox Tongue 11%
Prickly lettuce 12%	Afghan Melon 12%		Afghan Melon 14%	Onion Weed 15%	Onion Weed 14%	Sowthistle 14%	Capeweed 21%	Fathen 11%
Tares 12%	Stemless thistle 12%		Couch Grass 14%	Stinking Love Grass 13%	Prickly lettuce 14%	Wireweed 14%	Couch Grass 14%	
Salvation Jane 12%			Caustic Creeper 14%	Innocent Weed 10%	Silverleaf Nightshade 12%	Capeweed 14%	Caustic Creeper 14%	
Medic 12%			Mallow 14%		Afghan Thistle 12%	Clammy Goosefoot 11%	Fleabane 14%	
			Wireweed 14%		False Sow Thistle 10%	Rolypoly 11%	Mallow 14%	
			Salt bush 14%				Prickly lettuce 14%	
			Storksbill 14%				Stinkwort 14%	
							Salvation Jane 14%	
							Saffron Thistle 14%	
							Salt Bush 14%	

Table 2. The frequency of summer fallow weed species across South Australian cropping re survey sites (for all species found at more than 5% of sites). Note that weed species are arra order of decreasing frequency.

Common name	Scientific name	Occurrence all SA (% of fields)
Heliotrope	*Heliotropium europaeum*	57%
Afghan melon	*Citrullus lanatus*	25%
Roly poly	*Salsola australis*	18%
Lincoln weed	*Diplotaxis tenuifolia*	14%
Sowthistle	*Sonchus oleraceus*	14%
Clammy goosefoot	*Chenopodium pumilio*	13%
Panic grass	*Panicum spp*	13%
Stinking love grass	*Eragrostis cilianensis*	11%
Fleabane	*Conyza bonariensis*	11%
Mallow	*Malva parviflora*	11%
Caltrop	*Tribullus terrestris*	10%
Prickly paddy melon	*Cucumis myriocarpus*	9%
Onion weed	*Asphodelus fistulosus*	9%
Prickly lettuce	*Lactuca serriola*	9%
Wireweed	*Polygonum aviculare*	8%
Caustic creeper	*Chamaesyce drummondii*	8%
Medic	*Medicago polymorpha*	7%
Salvation jane	*Echium plantagineum*	7%
Silverleaf nightshade	*Solanum elaeagnifolium*	6%
Skeleton weed	*Chondrilla juncea*	6%
Couch	*Cynodon dactylon*	5%

Acknowledgements:

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Early sown winter wheats - Booleroo

Author: Dylan Bruce[1], Sarah Noack[1], Kenton Porker[2], James Hunt[3]
Hart Field-Site Group[1], SARDI[2], La Trobe University[3]

Funding body: GRDC

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

Key Findings:

- **The highest yielding spring wheat was Scepter sown on the 4th of May and 16th of March at 1.98 t/ha and 1.82 t/ha, respectively.**
- **The winter wheat varieties yielded between 0.82 – 1.33 t/ha, with no variety consistently outperforming another.**
- **2017 conditions at Booleroo were unfavourable for winter wheats, further data across seasons and locations will be continued in 2018 and 2019.**

How was it done?

Plot size	1.75 m x 10.0 m	**Fertiliser**	DAP (18:20) + 2% Zn @ 75 kg/ha
Seeding date	ToS 1 – 16th March		UAN (42:0) @ 60 L/ha on 13th July
	ToS 2 – 3rd April		
	ToS 3 – 19th April		
	ToS 4 – 4th May		

The trial was a split block design with four replicates of nine varieties (Table 1) at four times of sowing (ToS). Fungicides and herbicides were applied as necessary to keep the crop canopy free of disease (i.e. stripe rust and net blotch) and weeds. All plots were assessed for grain yield, protein, test weight and screenings with a 2.0 mm screen.

Table 1. Different categories of wheat varieties based on their development habits (and speed) selected for the trial at Booleroo.

Spring	Facultative	Winter
Cutlass (slow)	LPB14-0392 (intermediate	ADV08.0008 (slow)
Scepter (fast)	winter – fast spring)	ADV11.9419 (slow)
Trojan (fast-medium)		Kittyhawk (medium)
		Longsword (fast)
		V09150-01 (medium)

Results and discussion

After receiving above average rainfall over the summer months of 2016/2017 (86 mm above long-term average) opening rains for the 2017 growing season were minimal during the March

ToS, with only 2.6 mm falling for the month. A significant rainfall event did not arrive until the 20th of April wher 32 mm fell at the Booleroo site. To ensure plant emergence would occur, the first two ToS (16th March and 3rd April) were irrigated with the equivalent of 10 mm of rainfall post-sowing. The last two ToS did not require irrigation for emergence.

Emergence & Establishment

Plant establishment differed between ToS with the lowest average plant density recorded at ToS 1 (16th March) with 33 plant/m², while the highest average plant density was recorded at ToS 3 (19th April) with 149 plant/m² (Table 2). The reduced emergence and establishment during the earlier ToS was due to the combination of a lack of initial soil moisture and higher soil temperatures in the first 10 cm of top soil, therefore leading to faster evaporation and soil crusting. For the latter two ToS however, conditions were more suitable for germination with adequate seed bed moisture and cooler soil temperatures, allowing plant densities to reach the targeted 150 plants/m². The slower maturing winter types ADV08.0008 and ADV11.9419, and the facultative type LBP14-0392 on average emerged poorly when compared to the other varieties.

Table 2. Average plant densities across all four ToS at Booleroo (target 150 plants/m²).

Time of Sowing	Average plants/m²	Average air temperature (°C) two weeks post sowing
1	33	23.0
2	81	17.2
3	154	15.4
4	149	12.6
LSD (P≤0.05)	**23.5**	

Grain Yield

Overall grain yields at Booleroo ranged from 0.82 t/ha to 1.98 t/ha (Table 3). The yield and flowering date results for the spring varieties in ToS 1 at Booleroo were inconsistent, flowering later and yielding higher compared to ToS 2 (Figure 1 and 2). This was a result of the variable and staggered germination in ToS 1, causing the development of plants in individual plots to be inconsistent and initiate flowering at different times.

The highest yielding treatment at Booleroo was Scepter sown on 4th May at 1.98 t/ha (Table 3). Both Cutlass and Trojan were also high yielding at the early May sowing. The winter varieties yielded between 0.82 t/ha and 1.33 t/ha, with no one variety consistently outperforming another. In general the yield of the winter varieties was consistent across all ToS. The exception was Longsword at ToS 3 where the yield dropped due to a high level of sterility (57%).

Overall the selected spring varieties and facultative variety outperformed the winter varieties, even when sown well before their optimal sowing window. These results have been caused by the combination of drought, frost, heat and disease (crown rot) stress observed at Booleroo in a season which favoured varieties that develop quickly.

Environmental conditions at Booleroo made it difficult for any varieties to flower during periods of low frost or heat/drought risk as the optimal flowering window is narrow. This is primarily due to a lack of in-season rainfall and temperatures dipping below 0°C on ten occasions and exceeding 30°C on two occasions between August and September. Due to the nature of the season yields and grain quality were generally low. This can be attributed to high levels of sterility which resulted from drought, frost and heat stress during critical growth phases such as flowering and grain filling, which affected grain development.

Grain Quality

Grain protein content was generally high across the trial and differed between variety and ToS (Table 3). The majority of variety and ToS treatments contained protein levels well above 13% (minimum required for maximum grade). The highest protein contents were observed in Kittyhawk (ToS 4) at 18.0%, closely followed by V09150-01 (ToS 4), Longsword (ToS 4) and Kittyhawk (ToS 3). This is likely due to the extreme drought and heat experienced during grain-fill with later sowing, where accumulated nitrogen has been distributed amongst fewer grains or within smaller grains, increasing the protein concentrations in each grain.

Test weights differed between variety and ToS across the trial (Table 3). In general test weight increased with ToS from 74.5 kg/hL at ToS 1 up to 76.9 kg/hL at ToS 4. Overall the spring varieties outperformed the winter varieties in test weight. Trojan had the highest average test weight with 78.1 kg/hL, followed by Scepter and Cutlass with 76.5 kg/hL and 76.4 kg/hL, respectively.

Overall there were few treatments to exceed the 5% screening level at Booleroo (Table 3). The lowest performing ToS was ToS 1 with screenings levels at 3.9%, however this improved with later ToS. Overall the spring varieties had lower screenings on average when compared to the winter varieties with Trojan, Cutlass and Scepter recording average screenings of 1.9%, 2.2% and 2.3%, respectively.

Table 3. Grain yield and quality for all wheat varieties at different times of sowing at Booleroo in 2017 (LSD P≤0.05 is for the interaction between variety and time of sowing). Treatments shaded grey are not significantly different from the highest yielding treatment.

	Yield (t/ha)				Protein %			
	16th March	3rd April	19th April	4th May	16th March	3rd April	19th April	4th May
ADV08.0008	0.83	1.03	1.14	1.09	15.7	14.6	14.7	16.0
ADV11.9419	1.15	1.21	1.21	1.33	15.1	13.9	13.9	15.7
Cutlass	1.32	1.03	0.99	1.61	13.5	13.1	13.9	14.1
Kittyhawk	1.13	1.10	0.97	0.99	14.6	13.8	16.5	18.0
LPB14-0392	1.22	1.31	1.17	1.28	14.5	14.9	15.3	16.2
Longsword	1.11	0.91	0.82	1.22	16.2	16.2	16.1	16.6
Scepter	1.82	1.70	1.56	1.98	11.9	12.0	12.9	12.8
Trojan	1.53	1.59	1.42	1.57	12.6	13.2	13.4	14.1
V09150-01	1.10	1.12	1.11	1.30	15.3	15.1	15.2	16.7
LSD (P≤0.05)	**0.29**				**1.25**			

	Test weight (kg/hL)				Screenings %			
	16th March	3rd April	19th April	4th May	16th March	3rd April	19th April	4th May
ADV08.0008	72.0	73.4	76.4	76.5	5.2	6.0	4.7	4.2
ADV11.9419	73.4	74.5	75.6	76.0	7.6	7.3	4.3	4.9
Cutlass	76.0	76.2	75.6	77.7	2.3	1.2	2.5	2.8
Kittyhawk	75.3	75.8	76.4	77.5	4.6	4.8	5.1	2.1
LPB14-0392	74.0	74.2	75.2	77.5	7.0	5.2	5.6	3.2
Longsword	72.8	73.2	69.8	74.1	2.0	2.0	4.3	2.6
Scepter	76.8	76.3	74.4	78.5	2.3	1.5	2.5	3.0
Trojan	78.1	76.2	78.0	80.1	1.6	2.1	2.0	1.7
V09150-01	71.9	74.5	74.5	74.4	2.0	3.3	2.2	3.3
LSD (P≤0.05)	**2.83**				**2.44**			

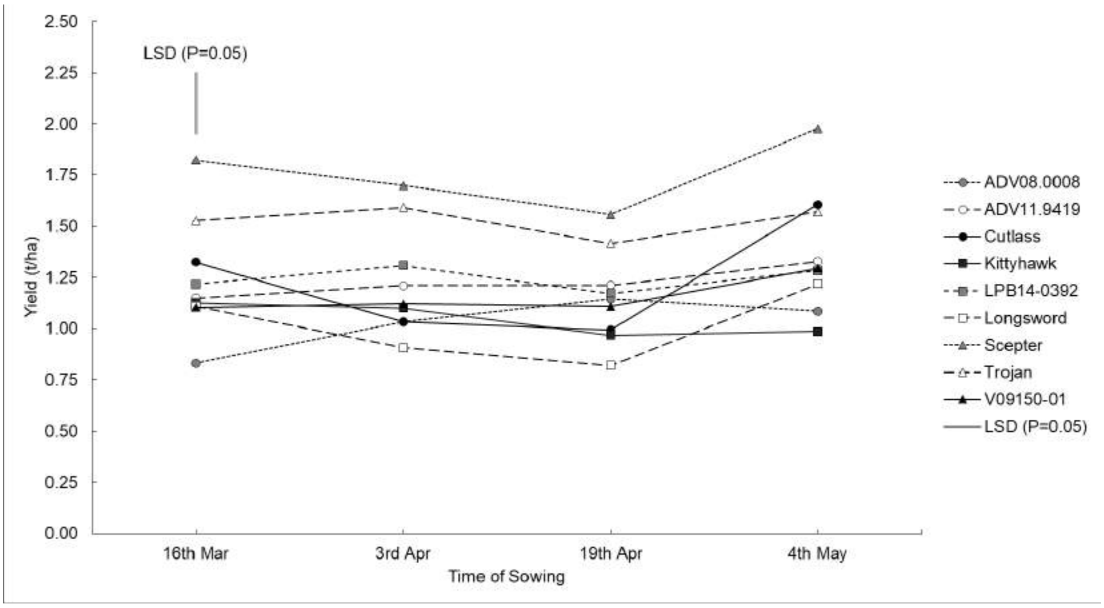

Figure 1. Average yield for all varieties and times of sowing at Booleroo in 2017.

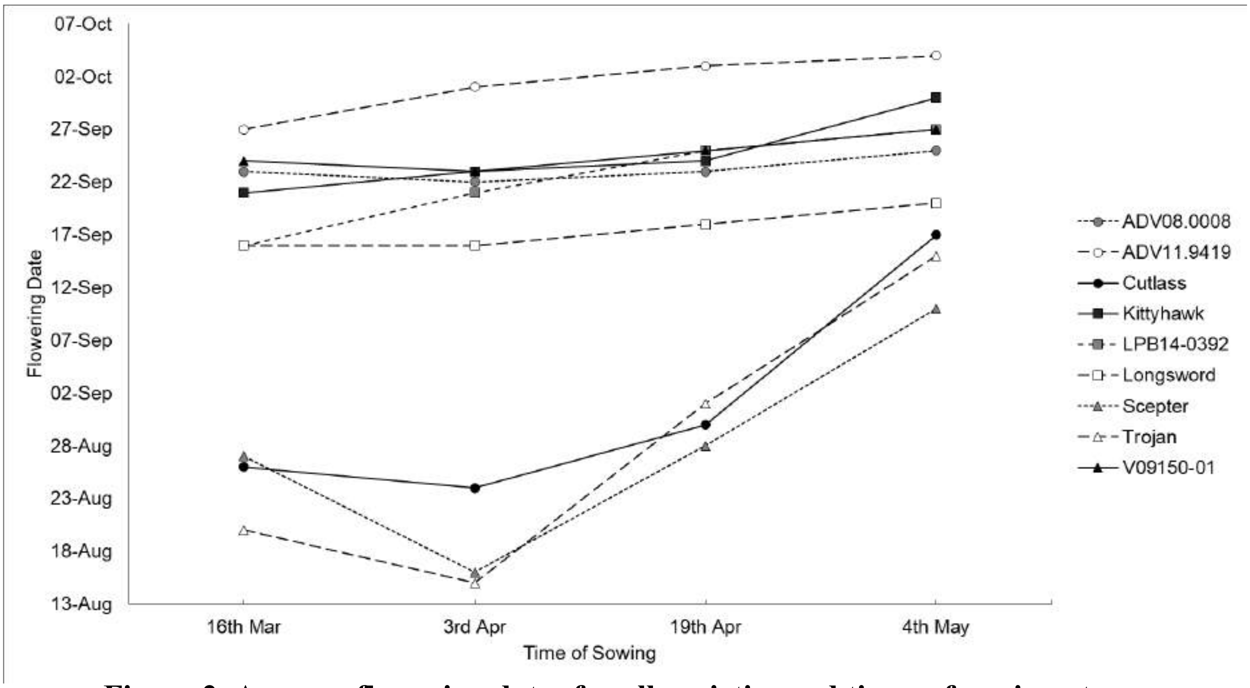

Figure 2. Average flowering dates for all varieties and times of sowing at Booleroo in 2017.

Summary / implications

Overall the 2017 season at Booleroo was a challenging one with only 165 mm falling during the growing season compared to the long-term average of 274 mm. Achieving good emergence and establishment was difficult due to dry top soil and lack of opening rainfall, until a significant rainfall event arrived in late April.

The use of different ToS and short and long season varieties resulted in a wide range of flowering dates, yields and overall crop performance. Due to low rainfall, hot and frosty conditions, quicker developing spring varieties such as Scepter, Trojan and Cutlass were favoured at Booleroo compared to the longer season winter wheats. The winter wheats however, had greater stability in flowering time and yield even though they were consistently lower than the spring varieties. It would be interesting to see how these varieties would perform in this environment under more favourable conditions, but further investigation and consecutive years of data collection and analysis is required.

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 Clare, SARDI team for their assistance with trial management.

2017 National Variety Trials

In 2017 a series of National Variety Trials were conducted in the Upper North region, investigating wheat, field peas, lentils, faba beans, oats, barley, and lupin.

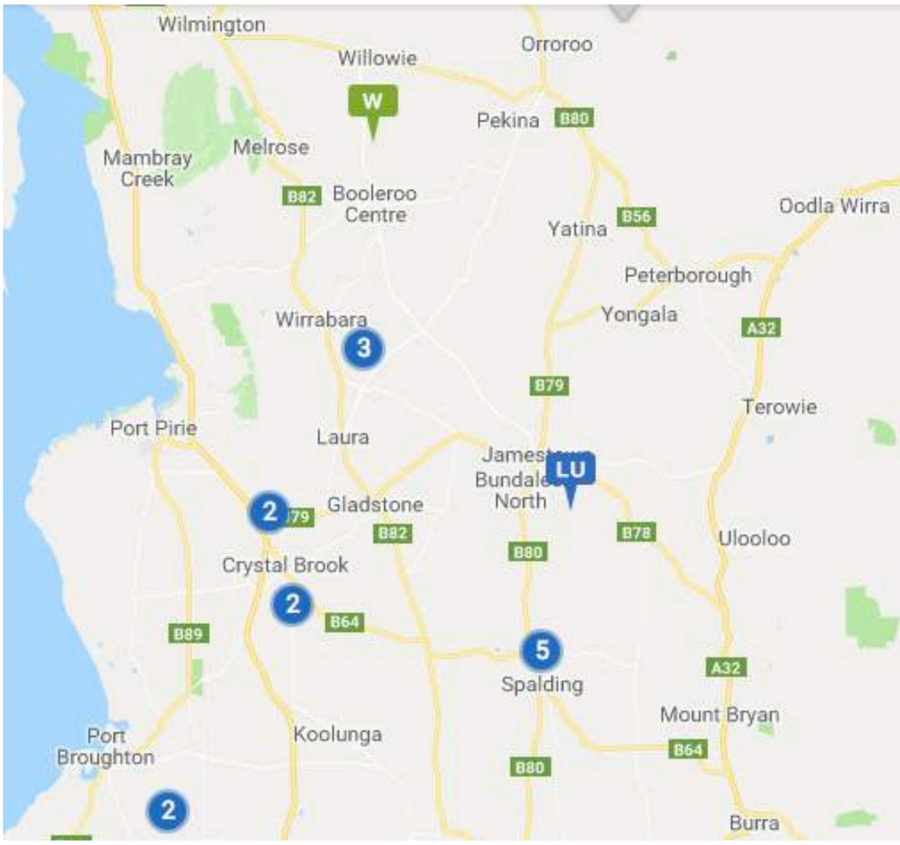

Figure 1. NVT locations in 2017. Numbers indicate how many trials were run in each location.

Crop varieties were analysed for their predicted yield and receival standards.

To view the results of the trials, please visit http://www.nvtonline.com.au/

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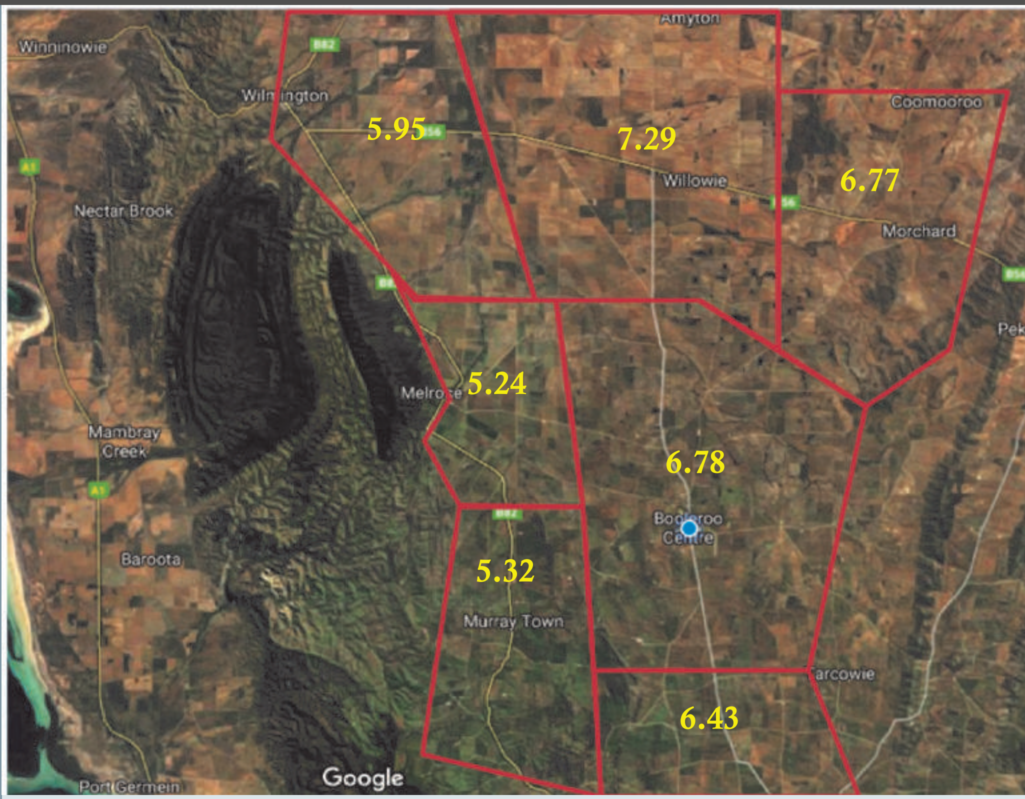
SOIL ACIDIFICATION IN THE UPPER NORTH



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Australian Government

Government of South Australia

Northern and Yorke Natural Resources Management Board

Google Maps image of the Upper North district split into seven geographical regions. The average pH (measured in calcium chloride) in the top 10cm has been displayed for each region. The higher rainfall regions are clearly the more acidic. Map developed by Matt Foulis, Northern Ag.

What is happening – prevalence of declining soil pH

Soil acidification is emerging as an issue in South Australia's Upper North. Although acid soils have not traditionally been a widespread problem in region, some local farmers have recently noticed the pH in some of their paddocks is dropping. NYNRM estimates that around 35 per cent of soils in the Northern and Yorke region, which encompasses the Upper North, are considered to have a moderate to high risk of acidification. While soil acidification is a naturally occurring process, it is being accelerated by more intensive and productive farming systems. Acid soils may also be becoming more noticeable due to farmers growing more acid-sensitive crops, such as lentils.

UNFS

Upper North Farming Systems

What is soil acidity?

Soils become acidic when they have excess levels of hydrogen ions. Acidity often starts in the topsoil, but if left untreated can also affect the subsoil.

Acidity and alkalinity are expressed using the logarithmic pH scale, which ranges from 0 to 14. A pH reading of 7 is considered to be neutral, while everything below 7 is acidic, and everything above is alkaline.

The optimum pH range for most plants is 6-8, when measured in calcium chloride. The lower the pH reading, the more acidic the soil. While mildly acidic soils can cause problems for sensitive crops, soil acidity become a much more serious threat when the pH falls below 5. At this level, even tolerant crops and pastures are affected.

Soil pH is either measured in water or calcium chloride. Using calcium chloride generally gives more accurate results, and so is the preferred method.

Canola is particularly sensitive to acid soils.
Photo: Ruth Sommerville.

Why is it happening – causes of acidification

Areas with lower rainfall, such as the Upper North, tend to have alkaline soils. Soil acidification is, however, a naturally occurring process and is quickly accelerated by certain agricultural practices. Systems with higher inputs and higher production are most susceptible. Major contributors to soil acidification in the Upper North include;

- **Addition of nitrogen**: inefficient use of nitrogen fertilisers is the main cause of soil acidification. Ammonium-based fertilisers in particular lower soil pH because once in the soil ammonium is easily converted to nitrate and hydrogen ions. If not quickly taken up by plants, nitrate leaches down through the soil profile, leaving behind a high concentration of hydrogen ions in the plant root zone. Nitrogen added to the soil by legume crops can also lead to this problem.

- **Product removal**: most plant products are alkaline, and removing them from the paddock leaves behind a higher residual concentration hydrogen ions. Product removal includes the harvest of grain and hay, as well as grazing by stock. Removal of animal products can also acidify soil. While this usually occurs at a slower rate, the effects can build up over time. Uneven deposition of animal waste in set stocking systems can also contribute.

- **Leaching**: when nitrate is leached it is accompanied by other positively charged ions, including calcium, magnesium, sodium and potassium. In the process, hydrogen ions are left behind, acidifying the root zone. Because of their low cation exchange capacity (CEC) and low water holding capacity, sandy soils are particularly susceptible to acidification. Water does not drain as quickly through clay soils, which also have a greater ability to buffer acidification by releasing other ions.

- **Organic matter accumulation**: organic matter is inherently acidic, so its accumulation in soil will acidify it.

Consequences of soil acidification

Acid soils have a range of negative outcomes for productivity and sustainability. Primary effects of acid soils include;

- Greater nutrient leaching,
- Tie-up of phosphorus, magnesium, molybdenum and calcium,
- Release of toxic levels of aluminium and manganese into the soil solution,
- A decline in microbial activity,
- Degradation of clay soil structure.

Further consequences of these effects include;

- Declining production,
- Poor and uneven plant establishment,
- Stunted root growth and declining water-use efficiency,
- Poor plant vigour and competitiveness,
- Inhibition of legume nodulation,
- Grass tetany (hypomagnesaemia) and milk fever (hypocalcaemia) in livestock.

Remember that symptoms associated with acid soils can also be characteristic of various other problems. Soil pH should be tested before remedial actions are taken.

Monitoring and checking soil pH

Soil pH can be checked using field pH kits, available from most agricultural suppliers. Ideally, soil samples should also be sent to an accredited laboratory every 5-10 years. The best time to collect samples is during summer, when the soil is dry.

When sending soil to a laboratory for testing;

- Try to sample from uniform areas of the paddock to ensure consistency in the results. Avoid sheep camps, headlands, tracks etc.
- Use a soil corer to take 10cm deep samples from along a fixed transect.
- Collect at least 30 cores, then thoroughly mix them together. Remove a smaller-sub sample from the bulked soil to send for testing.

Make sure to keep records of where samples were collected and the pH measurements so that any changes over time can be identified.

Lime is costly and pH can vary greatly across a paddock. Precision soil pH mapping, for example using Veris machines, can significantly reduce input costs by allowing more targeted lime applications.

Table 1. Crops grown in the Upper North region and their sensitivity to acid soils.

Crop type	Tolerance to acidity
Faba beans, canola, annual medics, lucerne	Very sensitive
Some wheat varieties, barley, field pea, phalaris	Sensitive
Some wheat varieties, sub-clover, cocksfoot, vetch, fescue, perennial ryegrass	Tolerant
Oats, triticale, serradella	Very tolerant

How to manage decreasing soil pH

Soil pH is raised by adding lime or other liming materials. How much lime needs to be applied will depend on a range of factors, including the current pH, the desired pH, the soil texture and the lime source being used. Lime's effectiveness at improving soil pH will also depend on its quality, defined by its 'neutralising value, and its particle size. The neutralizing value is determined by the lime's calcium carbonate content. Good lime or liming material should have a neutralizing value of 80 per cent or greater. Finer material with a smaller particle size will neutralize the acid in soils much faster than coarser material, but is harder to spread and can block up spreaders. For this reason, it may be better to have a mixture of fine and coarse liming material. Ideally, 60 per cent of the lime will also pass though a 0.3 mm sieve. Incorporating lime into the soil will have the quickest results. Lime moves very slowly down the soil profile, so if just spreading on the soil surface, it is better to do so well before sowing.

Equation for working out lime requirement:

Lime requirement (t/ha) = (target pH – current pH) x soil texture factor

Texture factor and lime required to raise the soil pH by 1 unit:

Loam to clay loam: 4
Sandy loam: 3
Sand: 2

Example: to raise the pH of a clay loam with a pH of 4.9 to pH 5.5;

(5.5 – 4.9) x 4 = 2.4 t/ha lime required

Cautions:

- Be careful not to over-apply lime, as this can result in trace-element deficiencies in plants and stock, and may increase the risk of some plant diseases such as take-all.
- Do not try to raise the pH level by more than one unit per lime application.
- If organic matter levels are low, reduce the lime rate by 25 per cent.

Many farmers in the Upper north have traditionally relied on Nutrilime®, a byproduct from the soda ash manufacturing plant in Adelaide, however the plant has now closed. Alternative forms of lime for the region include Clare Quarry lime, Kulpara dolomite, and Angaston Penlime®.

Other resources:

Soil Quality Pty Ltd (2018) 'Soil pH fact sheet,' http://soilquality.org.au/factsheets/soil-ph-south-austral

Ag Excellence Alliance (2018) 'Soil acidity,' https://agex.org.au/project/soil-acidity/

Upper North Farming Systems

Stubble Management Guidelines

Stubble grazing

Monitor and manage weeds in stubble paddocks to prevent toxicity issues in livestock. Photo: Hamish Dickson, AgriPartner Consulting

Key facts

- Crop stubble offers a valuable source of feed for livestock during summer providing careful feed budgeting, monitoring and grazing management is in place.
- Grazing stubble in a mixed farming enterprise can be an effective way to manage stubble loads and summer weeds.
- A sound understanding of livestock nutritional requirements and stubble quality and quantity is essential to support both livestock and paddock condition.
- Monitor feed on offer and livestock condition carefully to determine if and when supplementary feeding or use of a containment area needs to be implemented.

Grazing crop stubble presents an opportunity for mixed farming enterprise managers to more closely integrate livestock and cropping systems. When managed well, grazing stubble can provide benefits to and maximise the profit of both cropping and livestock enterprises.

Crop stubble provides a valuable feed resource for livestock and can often allow pastures a rest from grazing during summer and early autumn. Grazing stubble provides an additional stubble management strategy and integrated weed management tool for cropping enterprises.

As with any grazing system careful monitoring and management is required to ensure both livestock and paddock condition are maintained in optimal condition. Poor management can result in a drop in animal condition and productivity, and the loss of ground cover, which can lead to erosion, particularly on light soils.

Feed value of stubbles

Stubble can provide a significant amount of feed for livestock, however, it is important to fully assess both the quality and quantity of feed available when utilising this resource.

Assessing stubble feed quality involves evaluating the different components of stubble — residual stems, leaf, chaff and grain. Each component varies in terms of its nutritional value for livestock (Table 1). In general, most of the feed value in stubble comes from the residual grain in the paddock following harvest.

Project information

This *Stubble grazing* guideline has been developed for the Upper North Farming Systems Group (UNFS) as part of the Maintaining Profitable Farming Systems with Retained Stubble Initiative, funded by the Grains Research and Development Corporation (GRDC UNF00002).

The Stubble Initiative involves farming systems groups in Victoria, South Australia and southern and central New South Wales, collaborating with research organisations and agribusiness, to address challenges associated with stubble retention.

The GRDC, on behalf of growers and the Australian Government, is investing $17.5 million in the initiative that has been instigated by the GRDC Southern Regional Panel and the four Regional Cropping Solutions Networks that support the panel.

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

TABLE 1. Typical range in feed quality of different cereal stubble components

Component	Metabolisable energy (MJ/kg DM)	Crude protein (%)
Straw	5.5 – 7.5	2.0 – 5.0
Leaf / chaff	6.5 – 9.0	5.0 – 8.5
Grain	12.0 – 13.5	9.0 – 15.0
Green feed / re-growth	9.5 – 11.5	15.0 – 25.0

Cereal stubble showing stem, chaff and grain components.
Photo: Hamish Dickson, AgriPartner Consulting

When evaluating stubble quality, it is important to determine what value it can provide to livestock in terms of energy and protein. Table 2 shows the average and range in nutritional quality of different types of crop stubble (straw-only) and indicates that stubble quality is generally low and below maintenance requirements of livestock if the residual grain portion is unavailable. Nutritional requirements of sheep are outlined on page 4.

Availability of grain in the stubble typically dictates the potential grazing duration more often than the quantity of stem material on offer. Assessing the amount of grain available in the stubble requires counting the number of grains in a sample quadrat for each paddock. Table 3 shows the number of grains required in a 0.1m^2 quadrat to provide 100kg/ha of grain for livestock. This assessment assumes an even distribution of grain across the paddock. Using a single header row as the only measured area will lead to an inaccurate estimation for the paddock. Randomly assess 10 locations across a paddock and use the average of these results to gain a more reliable assessment of total grain availability.

TABLE 2. Range and average (shown in brackets) in nutritive value of different stubble straw

Straw/stubble	Dry matter (%)	Metabolisable energy (MJ/kg DM)	Crude protein (%)
Oats	89	6.0 – 7.7 (6.8)	4.0 – 6.5 (5.0)
Barley	89	6.0 – 7.5 (6.7)	4.0 – 6.5 (5.0)
Wheat	91	5.8 – 7.0 (6.5)	2.5 – 6.5 (3.5)
Triticale	89	5.5 – 7.0 (6.3)	2.5 – 6.0 (3.5)
Lupins	92	5.5 – 9.5 (8.0)	6.0 – 10.0 (8.0)
Peas	90	6.5 – 7.8 (7.2)	6.0 – 8.5 (7.5)
Canola	92	5.5 – 7.5 (6.5)	4.0 – 7.5 (6.0)

Source: Independent Lab Services

TABLE 3. Number of grains per 0.1m^2 quadrat to provide 100kg/ha of grain in stubble

Grain	Number of grains
Wheat and oats	28
Barley	25
Lupins	8
Field peas	5
Faba beans	2

High stocking rates for short periods of time will optimise feed utilisation when grazing stubble and maintain paddock condition. Photo: Hamish Dickson, AgriPartner Consulting

Grazing management

Management of livestock grazing stubble is just as important as managing livestock on pastures. Grazing stubble with high stocking rates, for short periods of time, results in the best utilisation of feed resources, and helps to conserve paddock ground cover and condition.

A rotational grazing style of management is preferable to set stocking for longer periods. Set stocking typically results in uneven utilisation of the paddock and overgrazing around water points and camp areas, leading to erosion and soil degradation.

There is a range of methods available to predict the number of grazing days available from stubble paddocks, however as most of the feed value is derived from the grain within the stubble, monitoring of this component should be the driver of when stubble quality has declined and stock should be removed or supplementary fed.

Research from the GRDC's ***Grain and Graze*** project has shown livestock typically lose weight when less than 40kg/ha of grain is available. Livestock require approximately 0.7kg/day/DSE to maintain condition.

Example of 50 per cent ground cover for cereal stubble. Source: *Stubble Management: A Guide for Mallee Farmers* (2013), Mallee Sustainable Farming Inc

When grain availability has declined to the point it will not meet animal requirements (i.e. less than 40kg/ha), stock should be removed from the paddock, or if ground cover permits, supplementary fed to maintain animal performance.

A minimum of 50 per cent ground cover is required to prevent wind erosion and consider allowing higher amounts of ground cover where stubble is not well anchored, or on particularly light soil types.

The following calculation can be used to determine the number of available grazing days:

STEP		EXAMPLE
1	Determine grain availability	100kg/ha present (60kg/ha available to stock and 40kg/ha unutilised)
2	Assess animal DSE rating	1.3DSE (e.g. 65kg dry ewe)
3	Determine stocking rate	5 ewes per hectare (i.e. 6.5DSE/ha)
4	Calculate grain consumption per hectare	0.7kg x 6.5 = 4.55kg/ha/day
5	Calculate available grazing days	60kg/ha / 4.55kg/ha/day = 13 days

Stubble components (straw, leaf, chaff, grain) can rapidly change in quality and availability depending on grazing management and summer rainfall. Livestock performance will vary with overall quality and availability, so closely monitor animal condition when grazing stubble. Monitor livestock by condition scoring or weighing a sample of 50 animals from the group on a regular (ideally monthly) basis. This will quickly identify any issues and allow for management strategies, such as supplementary feeding, to be implemented before flock performance is affected.

Supplementary feeding

To assess whether supplementary feeding is required first requires an understanding of the nutritional requirements of the animal.

The primary nutritional requirements of livestock are for energy and protein. Table 4 shows the nutritional requirements of a range of different classes of sheep. Use this information to compare the nutritional quality available from stubble to the requirements of the animal and determine whether supplementary feeding is necessary.

TABLE 4. Energy and protein requirements of sheep

Animal type	Metabolisable energy (MJ/kg DM)	Crude protein (%)
Ewes — dry (maintenance)	8.9	8.0
Ewes — late pregnancy (single)	13.7	8.7
Ewes — late pregnancy (twins)	17.4	10.5
Ewes — early lactation (single)	14.9	11.8
Ewes — early lactation (twin)	18.9	15.5
Weaner lambs	15.4	16
Replacement ewe lambs	13.5	14

Note: Assumes 65kg mature weight of ewes. Requirements will vary depending on the liveweight and target growth rates or condition score of animals

For further information on animal requirements see **www.makingmorefromsheep.com.au** or **http://mbfp.mla.com.au/** (for cattle information)

Using the earlier example of a 65kg dry ewe (maintenance), the following process can be used to calculate whether the stubble is adequate to meet the energy requirements of the animal, until grain availability declines.

If summer rainfall events generate significant amounts of green feed in stubble, account for this in the diet of livestock. This feed can contribute both energy and protein (Table 1), however its high moisture content can limit the amount consumed.

Mineral supplementation can also be important while grazing stubble. In general, cereal stubbles are deficient in calcium and for this reason a mix of lime and salt (80 per cent lime, 20 per cent salt) is recommended for stock grazing these stubbles to meet calcium demands. Other minerals, such as cobalt, selenium and copper, can also be deficient in stubble, however mineral profiles vary depending on location and season. Seek professional local advice before supplementing with these minerals.

Other considerations

Water

Water is the most critical requirement of livestock and both the quality and positioning of water points can affect animal performance and stubble utilisation. Ensure water is clean and readily available so stock do not have to wait at a water trough for access. Water points are ideally located in the middle of the paddock to encourage even grazing, however where this is impractical, troughs can be located on the paddock perimeter and should not be located more than 500m apart.

Animal health

Grazing stubbles can present several animal health issues. While residual grain provides a valuable feed resource for livestock, it can also present an acidosis risk, particularly for stock not adapted to eating grain. Acidosis occurs when sheep or cattle are rapidly introduced to grain and the rumen has not had adequate time to adapt. Always introduce livestock to grain by gradually increasing the amount available, particularly for high-starch grains, such as barley or wheat. Where large amounts of grain are available in the stubble this may be best achieved by trail feeding stock before introducing them to the stubble paddock.

Some summer weeds, such as heliotrope, can also present a toxicity problem for sheep and cattle. Manage weeds to ensure livestock do not consume large amounts of any toxic plant.

Lupin stubbles can present a risk of lupinosis, which is a liver disease caused by a mycotoxin present in the lupin stalks, mostly commonly occurring after summer rain.

STEP		EXAMPLE
1	Determine grain requirement	8.9 MJ ME/day (from Table 4)
2	Estimate grain intake from stubble	0.7kg/DSE x 1.3DSE rating = 0.9kg/head/day as fed, or 0.8kg/head/day dry matter (DM)*
3	Determine energy content of grain available	Barley = 12.8MJ ME/kg DM
4	Calculate energy intake per day	0.8kg DM x 12.8MJ ME/kg DM = 10.2MJ ME/day
5	Calculate whether supplementation is required	Requirement = 8.9MJ ME/day Stubble supply = 10.2MJ ME/day Balance = +1.3 MJ ME/day No supplementation required

Rations are typically formulated on a dry matter (DM) basis (i.e. moisture content is removed). For this grain example 0.9kg x 89% DM = 0.8kg on a DM basis).

Containment areas

When stubble quality and quantity has declined to the point where stock need to be removed, one option for managing livestock is to place them into a containment area. Containment areas are simply a small area where stock can be contained and are provided their entire diet. These facilities help to prevent overgrazing of stubbles and are also often used to defer grazing of pastures at the break of the season to allow an adequate feed wedge in front of stock.

Containment areas can be used to prevent overgrazing when stubble quality and quantity is insufficient to support the nutritional needs of livestock. Photo: Jim Kuerschner

Stubble offers complementary feed source

Don Bottrall, *Heathdon*, Appila, SA

Don Bottrall owns and runs a mixed farming enterprise about 7km south-east of Appila in the Upper North region of South Australia. Crop stubbles provide feed for livestock after pasture paddocks have finished. Don usually complements stubble with supplementary feeds to get sheep, particularly pregnant ewes, through the autumn 'feed gap'.

From 2014–17, PIRSA ran a stubble-grazing trial on Don's property as part of the Upper North Farming Systems' GRDC-funded 'Stubble Initiative'. The trial compared set-stocking with rotational grazing to see if the grazing value of the stubble could be maximised without losing too much ground cover. Ground cover is important to Don for protecting his soils against erosion. It was also thought the greater grazing pressure under rotational grazing might result in more even cover and less areas bared out by stock tracks and camps.

Overall, there were no consistent differences between set-stocking and rotational grazing in ground cover measurements. In the final trial year, grazing intensity was lighter on both treatments compared with other years, and stock tracks were more evident on the set-stocked area than on the rotationally-grazed area. The stubbles on the rotationally grazed areas tended to be more flattened and more evenly distributed whereas the set-stocked stubbles appeared more upright and in clumps after grazing. This was assumed to be due to the greater stocking density in the rotationally-grazed areas.

The trial on Don's property was carried out in a 7ha paddock and he believes that in larger paddocks, there would be more uneven grazing under set-stocking. However, subdividing larger paddocks into smaller ones on a permanent basis to get more intensive grazing would significantly affect cropping activities.

Don Bottrall uses stubble to provide a source of feed when pastures have finished. Photo: Mary-Anne Young

Don found rotationally grazing stubbles probably had more advantages from a stubble management perspective than the feed value of the stubbles. More even trampling and flattening of stubbles makes it easier for machinery to work through at sowing, and flattened stubble is less favourable for snails than upright stubble.

Feed quality was analysed each year before stock went into the trial paddock and the tests consistently showed the stubble had low nutritional value.

Since carrying out the on-farm grazing comparison, Don has introduced supplementary lick feeders to sheep grazing stubbles and has found that by paying attention to flock size and type, and carefully monitoring residue levels in paddocks, he can get good utilisation of crop stubble through grazing.

Stubble boosts stocking rates

Jim Kuerschner, Black Rock Ag, Orroroo SA

Jim Kuerschner estimates that grazing stubbles in his family's mixed farming operation increases carrying capacity by 20–30 per cent, as well as utilising a valuable feed resource that would otherwise be wasted and providing an additional stubble management and weed control tool during summer.

Jim and his family operate a mixed cropping and livestock enterprise about 15km south of Orroroo in the Upper North region of South Australia. Their sheep enterprise consists of a 1400 head self-replacing Merino flock, lambing during July–August. Wether lambs are typically finished in an on-farm feedlot. Jim also runs cattle, but runs them on pastures only, and does not use cattle to graze stubbles. About 40 per cent of farm is cropped, providing a large area of stubble, which is utilised by the sheep enterprise following harvest.

To maximise the feed value from stubbles, Jim grazes them with ewes as quickly as possible following harvest. He determines the feed quality available predominantly from the amount of grain on the ground and the presence of any green feed from weeds or volunteer growth.

Jim regularly monitors the proportion of each component of stubble (i.e. straw, chaff and grain) as well as the level of grazing in unarable areas of the paddock, such as creek lines or shrubs. This allows him to assess whether he needs to implement supplementary feeding to ensure sheep maintain condition. When supplementary feeding grain, Jim prefers to use oats as it is a 'safer grain' to feed than barley or wheat.

Jim has been able to increase stocking rates by utilising crop stubble as a valuable feed source. Photos: Hamish Dickson, AgriPartner Consulting

While Jim does not have a set target for factors such as ground cover, to dictate when to destock paddocks, visual monitoring of ground cover, available feed and the amount of dust in the wool of sheep, support his decision as to when to remove stock from stubble paddocks.

Several years ago the Kuerschners built a multi-purpose feedlot for finishing lambs and containing ewes when stubbles or pastures need to be destocked. The containment area is often also used at the break of the season to defer grazing pastures and develop a feed wedge in front of stock.

Overall, Jim sees grazing stubbles as a valuable way to integrate cropping and livestock enterprises. Grazing can assist the control summer weeds and stubble breakdown before sowing the following season.

Grazing stubble optimises integration

Matthew Nottle, Lambruk and Gillawarra, Booleroo Centre SA

Matthew Nottle believes grazing stubble is a great way to integrate his cropping and livestock enterprises. Stubble provides a valuable feed resource for sheep throughout summer and autumn when pastures require rest, while livestock assist the cropping enterprise by reducing crop residue for sowing, providing some control of summer weeds, and assisting with mice and snail control.

Matthew and his family operate a mixed cropping and livestock enterprise east of Booleroo Centre in the Upper North region of South Australia.

Their livestock enterprise comprises a self-replacing Merino flock of 370 ewes, plus a further 130 Merino ewes joined to a white Suffolk terminal sire for first-cross lamb production. Lambing occurs during June–July, with weaning taking place around harvest time for lambs to go onto the best stubbles. The Nottles' cropping enterprise typically start their cropping rotation with wheat then barley, followed by a break crop or pasture. More than 90 per cent of the property is cropped, providing 1200ha of stubble for grazing.

As soon as harvest is underway, sheep start grazing stubble. Crossbred and Merino lambs preferentially graze the higher-quality legume stubbles, such as peas or vetch. Hoggets followed by mature ewes graze the lower-quality cereal stubbles, which better suit the nutritional demands of these classes of stock.

Matthew condition scores livestock and closely monitors their grazing behaviour to help determine when supplementation is required. He has been using lick feeders to provide grain to stock grazing stubbles for many years and finds they minimise the wastage and contamination that can occur when trail feeding. Lick feeders also reduce the labour cost of feeding grain and provide better control over the amount of grain fed compared with trail feeding grain.

Utilising crop stubble as a feed source is just one way Matthew Nottle integrates his livestock and cropping operations. Photos: Hamish Dickson, AgriPartner Consulting

Legume stubbles boost bottom line

Lachlan Smart, Avonmore, Wirrabara SA

Legume stubbles used to finish crossbred lambs have delivered a profit of $400/ha on top of the cropping margin, while cereal stubbles provide a place for stock to go during summer, giving pastures a well-earned rest on Lachlan Smart's mixed farming enterprise about 8km west of Wirrabara in the Upper North region of South Australia.

Lachlan's livestock enterprise comprises a self-replacing Merino flock of 1200 ewes, plus a further 600 Merino ewes joined to a terminal sire for first-cross lamb production. Ewes lamb during May and June.

'Avonmore' has 600ha of arable land with an additional 1000ha of unarable hill country. The cropping enterprise is largely driven by the needs of the livestock enterprise, in that it provides sown pastures and grain to feed sheep. The arable land is sown to about 200ha of pasture, 200ha of legume/pulse crops and 200ha of cereal crops.

Lachlan starts grazing stubbles as soon as harvest is underway and calculates the amount of residual grain in stubble to assess the quality available. He uses a minimum threshold of 30 grains per $0.1 m^2$ to determine whether supplementary feeding is required.

Most commonly Lachlan supplements with either barley and lupins, or lupins on their own, and he liaises with his consultant to determine suitable supplementation rates. Lachlan does not feed hay to stock grazing stubbles, however during recent years he has started providing lime and salt to help manage calcium nutrition.

Crop stubble offers multiple livestock benefits in Lachlan smart's mixed farming operation. Photos: Hamish Dickson, AgriPartner Consulting

Grazing management

Lachlan has moved away from traditional set stocking and towards a high-density rotational grazing strategy. This has not only assisted in better utilisation of stubbles, but also provided improved weed management for the cropping program, typically saving one chemical application per year.

Overall, Lachlan sees grazing stubbles as a great way to integrate his livestock and cropping enterprises. Grazing can assist the control of summer weeds and breaks down stubbles for sowing the following season.

References and further information

» GRDC's Grain and Graze website. Click

» Stock containment areas — More than a drought measure, Government of South Australia and Natural Resources, Adelaide and Mt Lofty Ranges. Click

Acknowledgements

This guideline was prepared by Hamish Dickson — AgriPartner Consulting. Don Bottrall's case study was prepared by Mary-Anne Young — PIRSA Rural Solutions.

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Stubble Management Guidelines

Crop nutrition

Heavy stubble loads can result in nitrogen tie-up, impacting on early crop growth, yield and grain quality. Photo: UNFS

Key facts

- » Heavy stubble loads can tie up nitrogen (N), but stubble retention is unlikely to affect the availability of other nutrients, such as phosphorus (P).
- Additional nitrogen at sowing can be beneficial in paddocks with heavy stubble loads, particularly on lighter, low-organic-carbon soils.
- Stubble retention only has a minimal impact on maintaining soil organic carbon (C) levels in low-rainfall farming systems.
- Deep soil sampling and soil moisture probes can provide useful information to support nitrogen fertiliser decisions.

In the lower-rainfall areas of the Upper North growers traditionally apply low levels of nitrogen fertiliser due to the area's lower yield potential, inherent medium-to-high soil fertility and the use of legume-based pastures in crop rotations.

With increased cropping intensity, and some poor seasons, the legume content of pastures has declined on many farms, lowering soil nitrogen levels. As a result, during recent years nitrogen fertiliser application in the Upper North has increased.

The Upper North contains a small proportion of highly-productive loamy sand and sandy loam soils (about 10 per cent or 25,000 hectares) with low organic carbon levels (<0.5 per cent). With improved agronomy and management, heavy stubble loads (>5t/ha) are becoming more frequent on these soils and resulting in nitrogen 'tie-up', and subsequent nitrogen deficiency during early crop growth, lower grain yields and reduced grain quality.

Impact of stubble on soil nitrogen

Lighter-textured soils with low organic carbon levels pose a particular management challenge when dealing with high stubble loads. As soil microbes break down stubble, they extract available nitrogen from the soil as a source of energy to fuel the stubble decomposition process. This temporary 'tie-up' of nitrogen limits the amount available to growing crops, often resulting in nitrogen deficiency.

Project information

This *Crop nutrition* guideline has been developed for the Upper North Farming Systems Group (UNFS) as part of the Maintaining Profitable Farming Systems with Retained Stubble Initiative, funded by the Grains Research and Development Corporation (GRDC UNF00002).

The Stubble Initiative involves farming systems groups in Victoria, South Australia and southern and central New South Wales, collaborating with research organisations and agribusiness, to address challenges associated with stubble retention.

The GRDC, on behalf of growers and the Australian Government, is investing $17.5 million in the initiative that has been instigated by the GRDC Southern Regional Panel and the four Regional Cropping Solutions Networks that support the panel.

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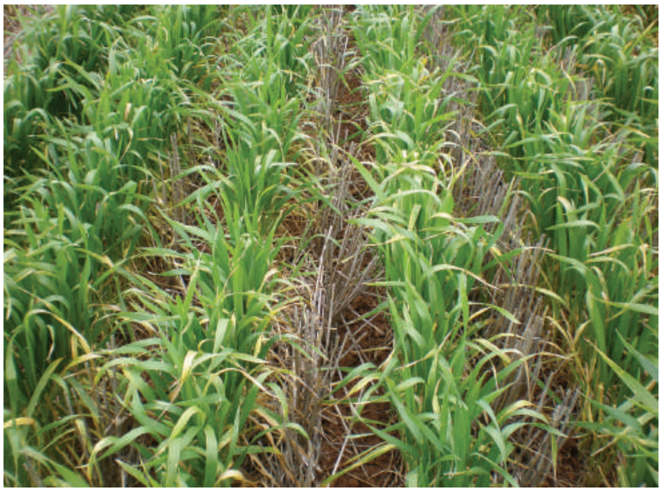


Standing stubble (left) immobilises less nitrogen than incorporated stubble (right). Photos: UNFS

The type of stubble, in addition to the amount of stubble (stubble load), also influences the extent and duration of nitrogen tie-up.

The carbon:nitrogen (C:N) ratio of decomposing stubble is the main factor determining whether nitrogen is immobilised (made unavailable to the crop) or mineralised (made available to the crop). Crop residues with a large C:N ratio (more than 22:1) will result in immobilisation, while lower ratios will result in mineralisation.

Wheat stubbles tend to have C:N ratios of around 85:1, whereas legume stubbles are more commonly around 35:1. Nitrogen in stubble will continue to be immobilised until the C:N ratio drops sufficiently as the stubble decomposes, returning crop-available nitrogen to the system.

Stubble treatment

Stubble treatment is another factor affecting the rate of nitrogen immobilisation and mineralisation.

Incorporated wheat stubble can immobilise 5–13kg/ha of nitrogen for each tonne of stubble. However, where stubble remains standing, immobilisation figures are significantly lower (<5kg/ha N/t stubble) due to the slower rate of stubble decomposition.

Significant yield penalties may occur if insufficient nitrogen is applied when sowing into heavy cereal stubbles that have been incorporated into the soil.

The white arrow indicates low nitrogen availability and reduced crop growth

Yellow arrow indicates high soil nitrogen availability and increased crop growth

Visible nitrogen tie-up 'strips' in an oat crop in the Upper North following a 5t/ha barley crop. These low-nitrogen strips are the result of high surface stubble loads being spread unevenly by the harvester in the previous season. Photo: Matt Foulis

Burning heavy stubble loads can reduce nitrogen tie-up, but burning increases the risk of wind erosion, lowers soil fertility and can exacerbate moisture loss through increased soil evaporation. While burning will make some nitrogen immediately available for plant uptake, up to 80 per cent of the total nitrogen and a significant amount of carbon, sulphur (S), phosphorus and potassium (K) contained in the stubble is lost as a result of the burn.

Impact of stubble on other nutrients

Retaining stubble is unlikely to have a major effect on the availability of other nutrients (phosphorus, sulphur, potassium etc.) in the short term, with a positive effect in the longer term as these stubbles decompose. These nutrients will generally become available at the same rate at which the stubble decomposes.

Organic carbon levels can act as an indicator of the amount of nutrients, particularly nitrogen, available to be mineralised. Although stubble retention is unlikely to lead to instant increases in soil organic carbon levels (research indicates this may take decades in a lower-rainfall environment), there is often an immediate increase in microbial biomass carbon. This increase in microbial carbon aids in biological fertility of the soil, influencing the rate at which microbes cycle nutrients.

! Soil sampling and analysis

When sampling soil for testing, collect samples according to soil type rather than on a whole-paddock basis. Avoid headlands, waterways and stock camps.

1. **Standard 0–10 cm samples** — A standard 0–10cm sample is appropriate when testing for phosphorus, organic carbon, pH, and trace elements.

   In paddocks where you plan to inter-row sow, take soil samples in the inter-row space rather than randomly across the paddock, as the fertility in the inter-row may be lower.
2. **Deep soil testing (0–60cm) pre-sowing** — Carry out deep soil testing to measure nitrogen, sulphur and stored soil moisture levels at the start of the season.
3. **Deep soil testing (0–60cm) in-crop** — An increasing number of samples are now collected in-crop to take into account soil mineralisation following harvest, nitrogen tie-up and sowing-applied nitrogen. This approach is likely to be a more reliable tool than pre-sowing testing for post-sowing applications. Take care when handling moist soil samples to avoid poor results. Keep samples cool and express post them to an accredited laboratory for quick analysis.

The deep soil nitrogen level can be used in a range of nitrogen decision models to help determine if additional nitrogen may be required to achieve target yields and grain quality.

Note: Use an ASPAC-or NATA accredited laboratory for all soil tests to take advantage of the quality control this accreditation represents.

Timing of nitrogen applications

Pre-sowing or at sowing

The amount of nitrogen applied at sowing may be increased where:

- the crop is following a non-legume (e.g. cereal or canola)
- soil organic carbon levels are low (<0.8 per cent)
- stored soil moisture is above average
- stubble loads are high (>3t/ha)
- the target yield is high.

Post-sowing (in-crop)

Delaying nitrogen fertiliser application for as long as possible is an effective risk management strategy in lower-rainfall areas, however the longer it is delayed the greater the risk of poor nitrogen use efficiency.

Applications at late tillering to early stem elongation (GS30–31) tend to give the best results in low-rainfall areas, with increased yield and a low risk of higher screenings. Later applications tend to increase protein without boosting grain yield.

Split application (pre-sowing and post-sowing)

Splitting applications is perhaps the most common and sensible technique. This involves an application of 30–70 per cent of nitrogen at sowing, followed by an in-crop 'top-dress' of 30–70 per cent. This technique allows the option to increase or decrease the in-crop nitrogen rate based on seasonal conditions, without compromising plant health in the early growth stages.

During late winter to early spring — when crop growth is greatest — a plant's daily nitrogen demand can be four to five times the rate of soil nitrogen mineralisation. Peak mineralisation is 1kgN/ha/day for an average loam soil with one per cent organic carbon and lower for sandy soils. A fast-growing crop may require 4–5kgN/ha/day during this time.

! Variable rate nitrogen applications

Aside from carefully choosing the timing, the efficiency of fertiliser applications may also be improved through variable rate applications. Soil variation within a field can sometimes make blanket nitrogen applications difficult. Improvements in precision agriculture technology have given growers the option to segregate fields into different production/management zones. This technique has been widely adopted for varying phosphate fertilisers at sowing, and can similarly be used to vary nitrogen rates either at sowing, in-crop or both.

Nitrogen fertiliser decision tools

There is a range of different nitrogen fertiliser decision tools available. The Upper North Farming Systems (UNFS) group has been using Yield Prophet® for a number of seasons with growers generally reporting success after using it as a nitrogen fertiliser decision tool.

An increasing number of growers have installed soil moisture probes during recent years as they become more affordable and reliable. Stored soil moisture levels can be used to estimate yield potential and nitrogen demand to help better understand plant available water and root growth. This information can be used to improve Yield Prophet® results.

There is a range of other nitrogen budgeting tools that growers, agronomists and advisers use to aid nitrogen fertiliser management, such as the CSIRO-developed 'Yield and N Calculator' (also referred to as the Mallee Calculator) or the Better Fertiliser Decisions for Cropping tool (**www.bfdc.com.au/interrogator/frontpage.vm**).

Nitrogen supply and demand is relatively complex. Seek professional advice for your individual situation.

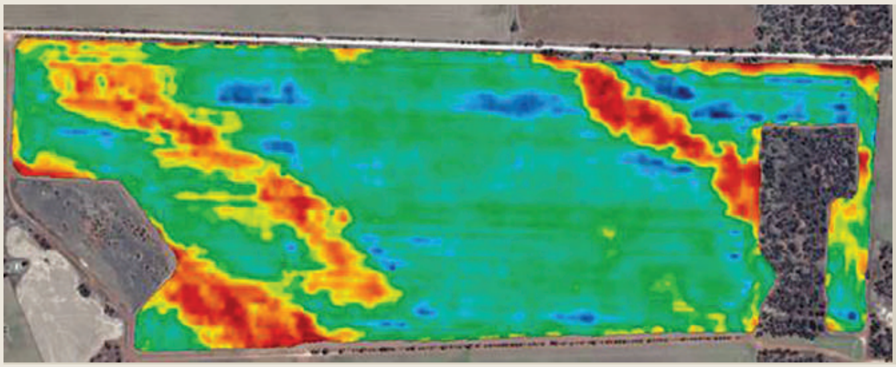
Growers have access to a wide range of support tools that can help guide nitrogen fertiliser decisions. Photo: UNFS

Variable rate technology offers economic advantage

David Kumnick, Booleroo Whim

David farms in the Booleroo and Willowie area of the Upper North, with soils ranging from deep sands to medium clays. There is often a big variation in wheat yields from the different soil types and the potential to manage these soil types differently to reduce risk and improve profitability.

During 2014 the Upper North Farming Systems (UNFS) group established a large-scale demonstration on one of David's highly-variable paddocks to evaluate the use of a variable rate nitrogen application approach.



2013 yield map of David Kumnick's paddock

The previous wheat crop yielded an average of 3t/ha across the paddock, with stubble loads of 3–3.5t/ha at sowing the following season. Four production zones (sand, sandy loam, clay loam and clay) were developed using a combination of EM38 and yield maps. Each of the production zones was soil tested to 60cm with low nitrate and sulphur recorded in the deep sand. Both the clay loam and clay soils had moderate salinity levels and high levels of boron at depth, which can limit yield, particularly in dry seasons. Three nitrogen rates (0, 50 and 100kg/ha urea) were applied in strips across the four production zones.

TABLE 1. Whole field benefit if optimal treatment applied over each soil zone

Soil zone	Optimal treatment (kg/ha)	Area (ha)	Benefit ($/ha)	Total benefit ($/ha)
(Sand) 40.7	100	14.85	92.60	1,375.11
(Sandy loam) 72.9	100	27.68	138.60	3,836.45
(Clay loam)103.8	50*	24.38	–	–
(Clay)145.3	50*	14.34	–	–

**No benefit gained for 50kg/ha treatment as this is considered standard application rate.*

The results indicated an economic benefit in varying the nitrogen application rate across these zones. The sand and sandy loam soils were most profitable at the 100kg/ha urea rate, whereas the clay loam and clay soils were most profitable at the 50kg/ha urea rate (Table 1).

Continued following page.... »

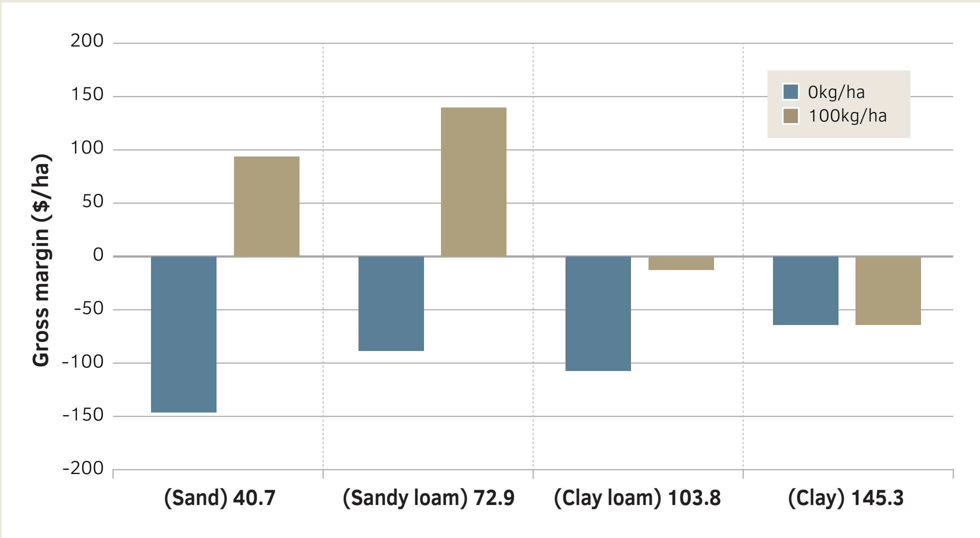
Variable rate technology offers economic advantage (continued)

The most economical nitrogen rate will vary from season to season, however results from this trial suggest sandy soils are likely to respond to higher rates of nitrogen in most seasons.

David is yet to adopt a variable rate fertiliser program over his entire farm due to the apparent lack of significant variability across many of his paddocks. He is, however, managing his sandy rises on paddocks such as the one containing the demonstration separately to the rest of the paddock. This includes applying additional sulphate of ammonia fertiliser on these soil types to account for leaching and nitrogen tie-up.

David has not ruled out adopting a full variable rate system in the future.

Figure 1. Gross margin returns across the four different soil zones, using 50kg/urea/ha as the base treatment and assuming Hind1 barley at $230/t and cost of urea at $500/t



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Acknowledgements

This guideline was developed by Matt Foulis (Northern Ag).

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Stubble Management Guidelines

Managing stubble at harvest

Retaining stubble has a range of benefits, provided it is managed well. Photo: UNFS.

Key facts

- » It is important to plan ahead to manage both high and low stubble loads.
- » Managing high stubble loads starts at harvest, with adequate chopping and spreading of stubble residues.
- » Heavy stubble loads decompose slowly, while lighter stubble loads decompose more rapidly, which can make management more difficult.
- » It is important to maintain adequate groundcover, stubble anchorage and stubble height to minimise wind and water erosion.
- » Standing stubble reduces wind speed and soil evaporation, and improves pre-emergent herbicide efficacy.

In mixed farming systems stubble retention has been demonstrated to improve soil health by maintaining or improving soil organic carbon levels and soil stability (reducing the risk and impact of wind and water erosion, and minimising the loss of soil nutrients through such erosion). Over time retaining stubble will improve crop yields and quality, and can reduce inputs to the farming system.

In average and low-stubble years management is often focused on maintaining adequate groundcover to protect soil from wind and water erosion, and to maintain soil structure and health. Photo: UNFS

As these benefits have become better understood, the adoption of conservation farming practices has increased. At the same time the proportion of pastures (and livestock) in these farming systems has reduced, with associated impacts on stubble management.

Project information

This *Managing stubble at harvest* guideline has been developed for the Upper North Farming Systems Group (UNFS) as part of the Maintaining Profitable Farming Systems with Retained Stubble Initiative, funded by the Grains Research and Development Corporation (GRDC UNF00002).

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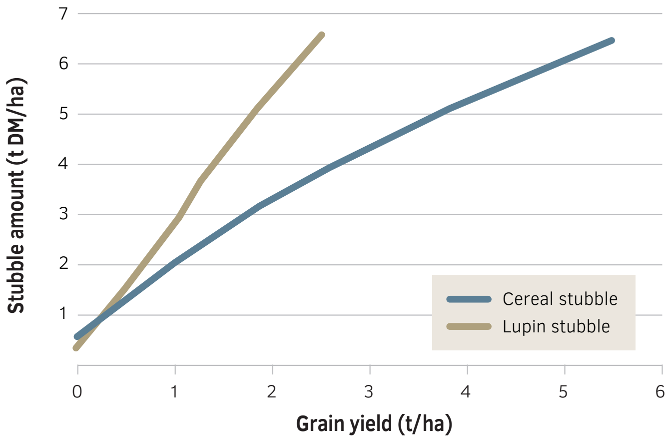
The GRDC, on behalf of growers and the Australian Government, is investing $17.5 million in the initiative that has been instigated by the GRDC Southern Regional Panel and the four Regional Cropping Solutions Networks that support the panel.

Figure 1. Relationship between the amount of grain and amount of stubble immediately after harvest (adapted from Perry, 1992)



How much stubble will I have at sowing?

The ratio of grain to straw varies and depends on a range of factors, including the crop type, variety and seasonal conditions. As a general guide, for every 1t/ha of grain yield there will be 1.5–2t/ha of cereal stubble remaining immediately after harvest (see Figure 1). Legume and canola stubbles will have even more variability in stubble levels relative to grain yields, with higher stubble ratios at harvest. Due to higher nitrogen content these are either grazed or break down quicker with often less stubble remaining at sowing.

Harvest management

In years with high stubble loads at harvest it is important to plan ahead. Stubble management needs to start at harvest to avoid blockages during sowing.

The amount of stubble that can be handled during sowing varies with the machinery type and the type of crop sown. Most new sowing equipment can handle significant stubble loads, but in the past many growers modified or upgraded their machinery to deal with high stubble loads.

Stubble spread

During harvest, ensure straw from thick stubble is evenly distributed across the header width (this is becoming more difficult as header fronts become wider). Many standard straw choppers and spreaders tend to concentrate chaff and straw directly behind the header, which can result in sowing equipment blockages, reduced crop establishment and poor herbicide efficacy.

The amount of stubble that can be handled during sowing varies with the machinery type and the type of crop sown. Photo: UNFS.

Vetch on crop lifters. Stubble management needs to start at harvest to avoid blockages during sowing. Photo: Andrew Kitto.

The newer-model headers often have an improved residue spreading pattern and there are several residue spreading units that can be retro-fitted to older model headers (for example Redekop MAV® straw chopper or PowerCast® tailboard). Despite these improvements, most straw spreaders currently have the capacity to spread residue evenly across the width of a 9–10.5m front (30–35 feet), although some manufacturers claim they can evenly spread up to 15m.

During harvest, ensure straw from thick stubble is evenly distributed across the header width. Photo: UNFS.

Chopped vetch stubble spread across a paddock. Chopping stubble into short pieces requires more power and can be difficult to distribute, but has benefits including faster decomposition and nutrient cycling. Photo: Andrew Kitto.

Spreading across wider fronts (12m or more) can be achieved by increasing the cutting height to reduce the amount of residue to be spread, or by adjusting rotor speed and vane settings to suit windy conditions or sloping paddocks.

Chopping the stubble into short pieces will speed up residue decomposition and nutrient cycling, but it requires more power and is more difficult to distribute the lighter residue pieces across the header width.

Mixing the straw and chaff together (such as can be achieved with Case 2388/8010/John Deere STS/Claas Lexion) and spreading it as one mass of material helps convey the lighter material and chaff, resulting in a greater spread of residue.

Light crops harvested on windy days present the biggest challenge for all brands of harvesters, so any chopper/spreader combination positioned closer to the ground is generally more effective, because the wind does not affect the material as much. Any chopper/spreader system that incorporates an air distribution principle is even better as it is easier to blow residue, rather than trying to throw it, especially during dry harvest conditions.

Other options to improve the spread of residue:

- Double spreaders distribute chaff much more evenly than the single spinning spreader.
- When wind speeds are high, try to harvest back and forward on the downwind side of the crop if possible, rather than into the wind. This will usually produce the best residue spread pattern.
- Keep knife blades on the chopper sharp to ensure even residue sizing and minimise power losses.
- A stripper front is an excellent option to increase harvester capacity, improve residue management and reduce fuel costs. Stripper fronts work well in high-yielding cereals, with only a small amount of the crop going into the harvester. The remaining stubble is relatively tall and requires further management or inter-row sowing the following season (Refer to the *Inter-row sowing stubble management guidelines*).

Stubble decomposition and grazing

In seasons with high stubble loads, cereal grain yields are usually well above average and the nitrogen content of stubble stem is low. This low nutritive value impacts on both livestock and the decomposition of stubble by microbes and other organisms. Under a heavy stubble load (more than 5t/ha), if left untreated, only about 20 per cent of the stubble will have decomposed by sowing.

In these seasons only the grain, chaff and leaf material (20–25 per cent of total stubble) provide any nutritive value, with the stem having very low nutritional value to livestock.

In comparison, following poor seasons with a hot dry finish, grain yields are low and a higher proportion of nutrients remain in the stubble (including the stem). Stubbles with higher nitrogen levels are more attractive to livestock and are also more readily broken down by micro-organisms.

In these seasons 40 per cent or more of the stubble can decompose by sowing and, when combined with grazing, stubble levels can quickly fall below desired levels for groundcover and protection from erosion (Table 1).

Legume stubbles and pasture residues also tend to contain more nitrogen and will be more readily grazed and broken down by micro-organisms. Carefully manage the grazing of legume residues to maintain adequate groundcover. Avoid grazing pea stubbles on sandy soils, or only graze after heavy summer rains, which germinate summer weeds, as stock graze and dislodge any attached residues, which break up and blow away leaving the soil bare. Ungrazed pea stubbles that are chopped and spread at harvest have a far lower risk of wind erosion.

Calculating grazing days on stubble

Grazing sheep eat or trample about 2kg of stubble per DSE per day. Use the following equation to calculate the total number of grazing days, to ensure sufficient stubble remains for adequate ground cover.

$$\frac{\text{stubble level (kg/ha)} - \text{critical ground cover level (kg/ha)}}{\text{removal rate (2kg/ha/day) x stocking rate (DSE/ha)}}$$

Grazing sheep eat or trample about 2 kg of stubble per DSE per day. Ensure that sufficient stubble remains for adequate ground cover. Photo: UNFS

How much stubble should I aim to keep?

In average and low-stubble years management is focussed on maintaining stubble to ensure there is adequate groundcover to protect soil from wind and water erosion and maintaining soil structure and health.

Retaining adequate stubble cover will:

- return nutrients to the soil (each tonne of stubble contains approximately $9 of nitrogen, phosphorus and sulphur) plus potassium and trace elements
- improve long-term soil fertility
- reduce the risk of wind and water erosion
- reduce evaporation from the soil
- protect the surface soil structure from the impact of raindrops.

Protection from wind and water erosion

The degree to which plant residues protect the soil from wind erosion depends on a combination of the:

- percentage of total residue on the soil surface
- percentage of cover anchored to the soil surface
- residue height.

Adequate surface cover is required to protect the soil against water erosion with the amount required varying with paddock slope (Table 1).

There are a number of benefits in leaving standing stubbles including:

- reduced risk of wind erosion and protection of emerging crops — standing stubble reduces the wind speed at or near ground level. For example 5cm high stubble will reduce wind speeds 20cm above the ground by 35 per cent, but 35 cm high stubble will reduce wind speeds by 75–80 per cent. Lowering wind speed at the soil surface can also reduce evaporation of moisture from the soil
- reduced soil moisture evaporation and soil temperatures
- improved pre-emergent herbicide efficacy
- improved trash/stubble flow through the sowing equipment
- the ability to inter-row sow between the standing stubble — in heavy stubbles inter-row sowing is the key to effectively sowing into these stubbles without causing significant stubble clumping.

Benefits of retaining crop or pasture residues on the soil surface include:

- improvement in fallow efficiency by minimising the physical impact of raindrops on the surface soil
- maintaining structural integrity of soil
- improved water infiltration rates
- reduced water run-off and soil erosion
- slowing the flow of water on the soil surface, allowing more time for infiltration and slowing soil evaporation following rainfall events. However if conditions remain dry for an extended period (6–8 weeks), total evaporation will not be affected by residues.

It is important to note stubble architecture (standing or slashed) has negligible effect on soil moisture conservation.

TABLE 1. Minimum and desirable cover levels to protect soils from erosion

Erosion type	Soil characteristics	Minimum cover		Desirable cover	
		%	t/ha	%	t/ha
Wind	Loam	15	0.5	35	1.0
	Sandy loam	20	0.6	50	1.5
	Sand	50	1.5	70	2.5
Water	Level land	60	2.0	75	3.0
	Sloping land	75	3.0	85	4.0

Source: DWLBC 'Surface cover for protection against wind and water erosion' factsheet, 2008

Stubble architecture (standing – shown on left, or slashed – shown on right) has negligible effect on soil moisture conservation. Photos: UNFS.

Implementing changes improves stubble handling

Barry Mudge, Port Germein

Barry Mudge, who farms around Port Germein, harvested a 5t/ha barley crop in November, 2013 with a NH89 harvester, which had relatively poor straw spread. This resulted in high stubble loads directly behind the harvester, and Barry was unable to penetrate these heavy stubbles at sowing.

In response Barry purchased John Deere Conservapak, with greater stubble handling capability and upgraded his harvester by fitting a Redekop MAV® straw chopper. The straw chopper smashes the straw into small pieces and spreads it relatively evenly to a width of 9.5m, slightly short of the 10.5m comb width.

Barry has also improved his inter-row sowing capacity with the help of guidelines identified as part of the UNFS Stubble Initiative (See *Inter-row sowing stubble management guidelines*).

By implementing better stubble management and purchasing higher-capacity sowing equipment Barry can now manage high stubble loads at harvest and has improved his sowing efficiency, crop emergence and herbicide efficacy.

Upgrading his harvesting set-up with a straw chopper has allowed Barry to improve his stubble handing at harvest.

References and further information

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Acknowledgements

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UNFS Upper North Farming Systems

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Upper North Farming Systems

Stubble Management Guidelines

Weed control at sowing

UNFS
Upper North Farming Systems

The amount and condition of stubble residues on the soil surface affects the efficacy of herbicides, particularly pre-emergent herbicides. Photo: Damien Sommerville

Key facts

- High stubble loads can prevent herbicides from reaching the soil and also tie up some herbicides, making them unavailable for weed control.
- Many pre-emergent herbicides can be used effectively with up to 50 per cent stubble cover.
- At harvest ensure residue is spread evenly across the header width and harvest as high as possible to maximise standing stubble.
- When applying herbicides, use high water rates (80L/ha or more) with larger non-air-inducted droplets.
- Consider using herbicides that will wash off stubbles more easily.

The weed spectrum is changing as fewer paddocks are being routinely cultivated — certain species are no longer being controlled by tillage. As a result, growers are increasingly relying on herbicides to control weeds.

Effective weed management in retained-stubble systems is important to take advantage of the many benefits of retained stubble and residue cover, without suffering losses associated with poor weed control.

Emerging weeds develop quickly within the retained-stubble system — keep on top of them before they get out of control. Photo: Matt McCallum

Project information

This *Weed control at sowing* guideline has been developed for the Upper North Farming Systems Group (UNFS) as part of the Maintaining Profitable Farming Systems with Retained Stubble Initiative, funded by the Grains Research and Development Corporation (GRDC UNF00002).

The Stubble Initiative involves farming systems groups in Victoria, South Australia and southern and central New South Wales, collaborating with research organisations and agribusiness, to address challenges associated with stubble retention.

The GRDC, on behalf of growers and the Australian Government, is investing $17.5 million in the initiative that has been instigated by the GRDC Southern Regional Panel and the four Regional Cropping Solutions Networks that support the panel.

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Stubble provides a physical barrier, impeding herbicides from reaching weeds and soil, and it can also bind to and tie up some herbicides. Photo: UNFS

Impact of stubble residues on herbicide efficacy

The amount and condition of stubble residues on the soil surface affects the efficacy of herbicides, particularly pre-emergent herbicides, in two ways. Stubble provides a physical barrier, impeding herbicide from reaching the target weed or soil, and it can also bind to and tie up some herbicides making them unavailable for weed control.

When spraying into stubble it is important to consider:

- herbicide type and mode of action
- timing of application and seasonal conditions
- appropriate water rates
- nozzle type, boom height and spray unit speed.

How pre-emergent herbicides work

Pre-emergent herbicides work in a number of ways. They are generally applied to the soil and taken up by either the emerging root or shoot, or a combination of both. Some (e.g. Logran® and Boxer Gold®) also have some leaf activity, but this activity is not usually as important for efficacy as the root and shoot uptake.

The specific site of 'root' or 'shoot' uptake varies between herbicides and their mode of action, giving each herbicide group its unique weed control attributes. Regardless of the mode of action, for a herbicide to interact with either the root or the shoot, it must first come into contact with the soil.

Stubble can prevent herbicides from reaching the soil, intercepting the droplets on their way to the ground. For some herbicides, such as trifluralin or triallate, this interception can be permanent, as the herbicide binds strongly to the stubble and is unlikely to remain active. Others, such as metolachlor, bind less strongly to stubble and can be washed off stubble and onto the soil surface with adequate rainfall.

When on the soil surface, all pre-emergent herbicides require either physical incorporation or incorporation by rainfall to be effective. Incorporation enables the chemical to access the target part of the weed, by being at the right depth in the soil, as well as protecting it from volatilisation and UV degradation. The amount of rainfall or physical incorporation required varies according to the herbicide chemistry, rate and prevailing conditions.

As well as incorporation, pre-emergent herbicides also need at least some moisture following application to become 'activated' and available to be taken up by germinating weeds.

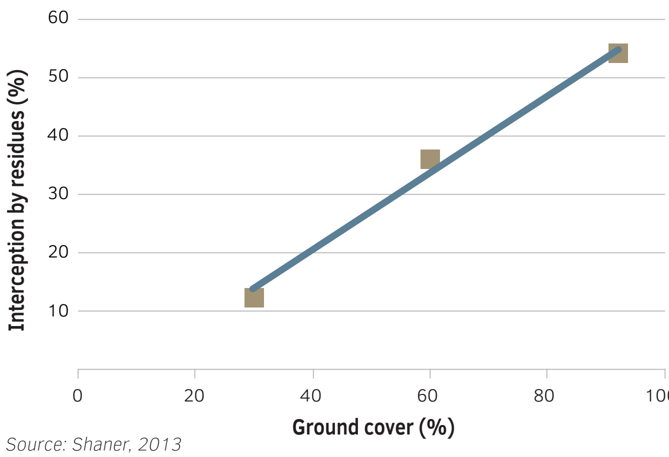
Estimating stubble loads

Up to 50–70 per cent of the stubble from harvest can still be present at sowing and with a high-yielding crop the stubble load could be well above 3t/ha. As the groundcover percentage increases, the amount of herbicide intercepted by the stubble residue also increases (see Figure 1).

Many pre-emergent herbicides can be used effectively with up to 50 per cent stubble cover (1.7–2.5 t/ha stubble, depending on the amount lying on the soil surface) across a paddock. Pre-emergent herbicide efficacy starts to be significantly impacted when stubble exceeds 50 per cent cover.

Estimate the stubble load by looking onto stubble from above and assessing the area of soil/stubble ratio (see the UNFS guideline *Monitoring stubble*).

Figure 1. Relationship between groundcover and herbicide interception by crop residue



Source: Shaner, 2013

Standing stubble offers greater opportunities for herbicides to reach the soil. Photo: Matt McCallum

Thick layers of chaff and straw on the ground are difficult for herbicides to penetrate. Photo: Matt McCallum

Optimising herbicide efficacy in heavy stubble

Although high levels of stubble can compromise the efficacy of pre-emergents, there are ways to improve results.

Herbicides can penetrate standing stubble is more easily than lying stubble, which can form a thatch on the ground.

Managing stubble height at harvest and grazing stubble during summer both influence stubble loads and physical attributes at sowing.

To optimise herbicide penetration in standing stubble, keep water rates up, travel slowly so droplets have a more vertical trajectory, and keep spray quality coarse.

It is important to set up the spray rig correctly. Set the height so the double overlap is occurring at the height of the stubble, rather than the ground. This helps to ensure even application.

Some level of interception can't be avoided, but there are differences in the way various chemicals behave when in contact with stubble. As a general rule the more water-soluble herbicides cope better with crop residues. For example, trifluralin is one of the least water-soluble herbicides, whereas Boxer Gold (containing prosulfocarb and S-metolachlor) is one of the most soluble (see Table 1). As such, Boxer Gold is likely to be more effective than trifluralin in high-stubble situations, where it can wash off. Table 1 highlights some of the properties of common pre-emergent herbicides and their influence on the suitability for use in stubble.

Adjusting herbicide rates in light of different stubble conditions can improve efficacy. Trifluralin products have label recommendations that allow for higher rates to be used in high-stubble situations to account for the active ingredient that remains tied up on stubble.

Stubble can also affect the evenness of application, particularly when a sowing system struggles to adequately penetrate the stubble. In these situations stubble can bunch up and drag with the sowing equipment, bulldozing soil. This moves previously-applied herbicide with it, and can result in uneven final placement of the herbicide across a paddock.

Planning ahead for optimal efficacy

Some planning is required when using pre-emergents in heavy stubble, starting at harvest, to ensure a trouble-free sowing.

A last resort is always to burn the stubble, which will remove any trash clearance issues at sowing, but if a herbicide has been applied, followed by burning, the herbicide is lost unless it has already been washed into the soil.

In paddocks where burning is the best option, defer herbicide application until you are confident the sowing equipment can handle the stubble load.

Table 2 demonstrates how various stubble management options can influence the performance of pre-emergent herbicides in the paddock.

Burning is a last resort. In paddocks where burning is the best option, defer herbicide application until you are confident the sowing equipment can handle the stubble load. Photo: Hannah Mikajlo (UNFS)

TABLE 1. Key characteristic of common pre-emergent herbicides, which influence their efficacy in high-stubble-load situations

Herbicide group	Herbicide product	Mode of uptake	Water solubility#	Binding to soil organic matter ##	Suitability to be used in high stubble loads (50% cover)
B Sulfonyl ureas	Triasulfuron (Logran)	Roots and leaves — quickly translocated to growing points preventing further growth.	High	Low	Yes
B Sulfonyl ureas	Chlorsulfuron (Glean®)	Roots and leaves — quickly translocated to growing points preventing further growth.	Very high	Low	Yes
C Triazines	Atrazine	Roots and leaves — quickly translocated inhibiting photosynthesis.	Medium	Medium	Yes
	Simazine	Roots and leave — quickly translocated inhibiting photosynthesis.	Low	High	Yes
C Ureas	Diuron	Roots and leaves — quickly translocated inhibiting photosynthesis.	Medium	High	Yes
D Dinitroanilines	Trifluralin (TriflurX®)	Roots — inhibits microtubule assembly.	Very low	Very high	Maybe
	Pendimethalin (Stomp®)		Very low	Very high	Maybe
J Thiocarbamates	Triallate (Avadex® Xtra)	Shoots (predominately) — inhibits fat synthesis.	Low	High	Maybe
	Prosulfocarb (Boxer Gold)	Shoots, roots and leaves — inhibits cell division. Also contains Group K.	Low	High	Yes
K Chloroacetyamides	S-metolachlor (Dual Gold®)	Roots and leaves — inhibits cell division and enlargement.	High	Medium	Yes
K Isoxazolines	Pyroxasulfone (Sakura®)	Roots and shoots — inhibits very long chain fatty acid biosysthesis, causing the growing point and coleoptile to be interrupted.	Low	Medium	Yes

 # At 20°C and neutral pH
In pH neutral soils

Source: Haskins, 2012

TABLE 2. The impact of stubble management and herbicide options on annual ryegrass control at Sandilands, Yorke Peninsula, 2006

Stubble treatment	Trifluralin (% control)	Metolachlor (% control)	Triallate (% control)
Burnt	89.3	66.7	38.3
Slashed	29.3	37.3	16.3
Standing	84.3	78.3	51.7
LSD (5%)	17.3	35.5	20.2

Note: *The trial was sprayed with a hand boom using 02 Flat Fan, 3 bar, 80L/ha and an estimated speed of 8km/hr.*

Benefits of stubble

Stubble also provides some benefits when using pre-emergent herbicides. It can add a margin of crop safety to products prone to leaching into the seed bed, by slowing infiltration rates and pooling of water into furrows. It can also reduce soil throw and provide a buffer from chemical-treated soil being thrown into an adjacent row, acting as a physical fence to reduce soil movement.

Stubble paddocks retain more moisture under marginal conditions than bare paddocks, helping pre-emergents stay active in the soil for longer, thereby improving weed control.

Stubble can aid in summer weed spraying by slowing moisture loss from the soil, and keeping weeds fresher for longer. This can lengthen the window for effective summer weed spraying, when moisture stress often limits the effectiveness of herbicides.

The impact of stubble on knockdown herbicides

The same issues with stubble interception and pre-emergent herbicides apply to knockdown herbicides, both when spraying summer weeds and at sowing.

In the case of knockdowns, shading from stubble and stubble residue can significantly reduce efficacy, particularly when using contact herbicides, such as paraquat. Translocated herbicides, such as glyphosate and 2,4-D can both remain effective when coverage is compromised, and may provide better results when stubble cover is high and weeds are hidden.

To improve coverage when using a double knock before sowing, spraying in alternate directions can be useful, ensuring weeds that may be hidden in one spray direction are covered in the second spray.

Tips for more effective weed management in stubble-retained systems

Although using herbicides in stubble has its challenges, there ways to maximise the success of weed control:

Start managing stubble at harvest — Ensure trash is spread evenly across the header width. Trash concentrations in the header row can bind to herbicides impacting weed control. Remember, the header row is also where many weed seeds concentrate. Consider tools to reduce chaff and control weed seeds at harvest, such as windrow burning or chaff carts.

Leave stubble standing — Straw choppers on headers mulch and pulverize stubble into chaff, which breaks down faster. This is much better than slashing, chaining or harrowing, which leaves stubble in long lengths acting as an impenetrable thatch, limiting herbicide access to the soil surface.

Increase water rates — Use high water rates (>80L/ha) with larger non-air-inducted droplets (coarse at a minimum) to deliver more herbicide to the soil. Even the more water-soluble herbicides (Boxer Gold, Sakura) control annual ryegrass better when applied at higher water rates.

Use the right spray nozzles — Non-air-inducted nozzles produce droplets with more capacity to 'bounce' off stubble, and still reach the ground. Air-inducted droplets do not bounce as readily and are more likely to stay on the stubble they hit.

Match spacings — Matching row spacing and nozzle spacing on real time kinetic (RTK) guidance allows precise positioning of nozzles between stubble rows, minimising stubble shadowing of herbicide.

Choose a suitable product — Select herbicides that are more suited to high-stubble-load situations (see Table 1). Most herbicides are washed off stubble residues with 5mm of rainfall, with more herbicide being washed off with increasing rainfall and following rainfall events.

Understand your product — Some pre-emergent herbicides are sensitive to sunlight and need to be incorporated or covered by soil to minimise losses. Herbicides like trifluralin only need a light cover of soil to reduce photodegradation. Some herbicides are volatile and can be lost to evaporation, especially from wet soil.

Up the rate — Use higher herbicide rates, particularly for products like trifluralin, which has label recommendations that support higher rates of product for use in higher-stubble-load situations.

Manage inter-row soil throw — In most no-till sowing systems the soil from the sowing row is thrown to the inter-row space, reducing the rate of application of soil-applied herbicide near the seed and increasing the effective application rate in the inter-row. Pay attention to detail during sowing and ensure soil throw on the inter-row while maintaining a seed furrow free from herbicide. Concentrated chemical soil in the furrow can damage crops and reduce plant vigour.

Close the furrow — Ensure the seed furrow is closed to prevent herbicide washing onto the seed. Sowing systems vary in their ability to 'close the slot'.

Monitor sowing depth — Ensure even seed depth placement (typically 3–5cm of loose soil on top of the seed in cereals for optimal crop safety). This is a key safety mechanism. Whatever else you do, keep the seed more than 3cm deep if in marginal moisture conditions, or in crops sensitive to particular herbicides. If you can't – wait for better conditions!

Consider spraying conditions — If applying herbicide onto dry sandy soil where there is a risk of significant rainfall (more than 25mm) the chemical can move rapidly through the soil profile and damage the crop. Stubble cover will slow infiltration rates and act as a buffer to improve crop safety.

Consider herbicide timing — Incorporate by sowing (IBS) rather than post sowing pre-emergent (PSPE) to improve crop establishment and early vigour.

Take a toolbox approach — Establish a toolbox approach to weed management in retained-stubble systems. Stubble interferes with herbicide target contact, reducing efficacy. Plan to tackle escape weeds with tools such as crop rotations, windrow burning, chaff carts, seed destructors and targeted in-season and at-harvest spray applications. Emerging weeds develop within the retained-stubble system — keep on top of them before they get out of control.


Start managing stubble at harvest to make weed management easier later on. Photo: UNFS

Incorporation at sowing offers efficacy and flexibility

Brendon Johns, Warnertown

In order to get better soil contact with his pre-emergent herbicides Warnertown farmer Brendon Johns has been using a spray bar mounted on the front of his seeder for the past 15 years. The system works with a Dosatron unit direct injecting the herbicide into the mix as water is pumped through from a 7000 litre liquid tank following the air cart.

Brendon uses a pre-emergent mix of trifluralin and triallate extensively with this system. He finds these two particular chemicals work well, as they are getting incorporated 'within a second' of application. The slow sowing speed (10km/hr) versus a typical spraying speed also means droplets can penetrate through stubble to the soil surface and Brendon estimates he is getting around 70 per cent spray coverage with this method.

The combination of herbicides and the incorporation during the sowing process improves the efficacy of the mix, meaning Brendon achieves effective weed control from relatively moderate application rates.

Another advantage of Brendon's system is the flexibility of the boomspray during sowing. The timing of the knockdown is no longer compromised by the need to have the pre-emergent incorporated, and good spraying conditions for knockdowns can be exploited. There is also less risk of loss with the pre-emergents due to a breakdown — they are only going out when the seeder is actually running, rather than being exposed to a seeder breakdown, which leaves them on the surface and subject to loss.

Brendon uses a spray bar mounted on the front of his seeder to get better soil contact with his pre-emergent herbicides. Photo: Diesel Performance Solutions

As a further innovation to his system Brendon is now developing some modifications that will enable full 'inter-row spraying' to occur. He is already inter-row sowing, and by positioning a nozzle in front of each sowing tyne, with a drop tube to lower the nozzle height, he expects there to be a further benefit in coverage and efficacy, rather than the current nozzle height, which still provides some interception with stubble. This additional innovation will help concentrate the chemical on the exposed soil rather than interacting with the stubble, further enhancing coverage.

Planning allows for targeted weed control before sowing

Chris Crouch, Wandearah

Wandearah farmer Chris Crouch considers each paddock's stubble loads carefully when applying knockdown herbicides during summer and before sowing.

In paddocks with heavier stubble, Chris uses higher water rates (up to 100L/ha), coarse droplets and sprays in the direction of the stubble row to enhance penetration and get better coverage. To keep droplets angled downwards Chris operates at a maximum travel speed of 15km/hr.

Chris also considers stubble load when choosing his herbicides. He prefers to use a translocated herbicide, such glyphosate, when spraying in heavy stubble, to ensure an effective result even if droplet coverage is not complete. Barer paddocks following a pulse crop open up more options for contact herbicides, as spray coverage is generally better.

Chris also considers stubble levels when determining spraying priorities and urgency. He sprays barer paddocks or pulse stubbles first, as weeds are more visible when they are small. These paddocks also tend to dry out the fastest during summer, meaning a shorter window for herbicide uptake before weeds become stressed. For paddocks with taller cereal stubbles, Chris prefers to wait until weeds are slightly larger before spraying. This gives a better chance of getting effective coverage among the stubble and the delay does not affect efficacy as the cover maintains soil moisture and keeps the weeds fresher for longer than on the bare paddocks.

Chris Crouch carefully considers stubble loads before selecting his herbicide options Photo: Iris Crouch

By retaining soil moisture, stubble can lengthen the window for effective summer weed spraying. Photo: Damien Sommerville

References and further information

- *Understanding pre-emergent herbicides*, GRDC Updates (GRDC). Click
- *Balancing crop safety and effectiveness when using pre-emergent herbicides*, Grain and Graze 2 (GRDC). Click
- *Using pre-emergent herbicides in conservation farming systems* (NSW DPI). Click
- *Achieving good pre-emergent spray results*, GRDC Fact Sheet (GRDC). Click

Acknowledgements

This guideline was developed by Michael Wurst (Rural Solutions) and Ruth Sommerville (Rufous and Co).

Upper North Farming Systems

Stubble Management Guidelines

Monitoring stubble

Stubble — if you don't measure it you can't manage it. Photo: UNFS

Key facts

- Monitoring stubble loads before and at harvest allows informed decisions to be made about how to best manage stubble loads post-harvest.
- Stubble loads can impact on feed budgets, sowing operations and subsequent crop establishment and early vigour.
- Assess both stubble loads and ground cover when monitoring stubble.
- Assessments can be carried out using a harvest index, photo standards or in-field measurements.

Measuring stubble loads in the field is the first step in managing the impacts of stubble loads following harvest.

A clear understanding of how much stubble remains in the paddock post harvest enables appropriate and economical stubble management practices to be implemented.

Monitoring stubble loads can be a useful tool to determine:

- summer feed budgets for livestock
- impacts on sowing, including machinery blockages, nitrogen tie-up, herbicide efficacy and plant establishment
- potential soil erosion risk post-harvest —"No till with no stubble is no good."

Stubble loads vary from season to season and from crop to crop. The treatment at harvest, volume of breakdown over summer and amount grazed by livestock also affects total stubble loads and condition.

Field monitoring leading up to harvest provides guidance on the strategies to employ for effective stubble management, while still leaving adequate soil cover to prevent erosion. This proactive approach also will limit the negative impacts of stubble retention on the following season's sowing operations and early crop establishment and vigour.

Project information

This *Monitoring stubble* guideline has been developed for the Upper North Farming Systems Group (UNFS) as part of the Maintaining Profitable Farming Systems with Retained Stubble Initiative, funded by the Grains Research and Development Corporation (GRDC UNF00002).

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What to look for when monitoring stubble

There are two primary elements to stubble monitoring:

- stubble load (volume of dry matter)
- ground cover (volume of material covering the soil surface).

The distribution and condition of stubble residues are also important factors to consider.

Stubble load is the total kilograms per hectare of stubble matter or crop residue remaining in the paddock.

Stubble load affects sowing operations and nutrient availability to the subsequent crop. The condition, (i.e. standing, rolled) and the amount of chaff or chopped stubble and its distribution behind the header also affects livestock accessibility to stubble nutrients, speed of breakdown and ease of sowing operations.

Ground cover is the amount of plant material (dead or alive) covering the soil surface. It is usually expressed in percentage terms — 100 per cent ground cover means the soil cannot be seen and 0% ground cover is bare soil. Ground cover is particularly important when assessing risk of soil erosion.

How do I monitor stubble?

There are three primary methods to monitor stubble loads (and assess ground cover):

- harvest index (HI) estimates
- photo standards
- in-field measurements

Harvest index (HI) estimates

Stubble management starts at harvest. An HI can be used to estimate stubble loads from estimated grain yield. This index is the ratio of grain yield to total above-ground biomass. For wheat the HI generally ranges from 0.3–0.5.

There can be large variations in HI depending on factors such as seasonal conditions, crop variety, soil type and fertility, fertiliser and lime use, disease levels and weed competition.

Research carried out by the Agricultural Machinery Research and Design Centre at the University of South Australia, showed wheat stubble levels amount to 1.3–2.8 times the grain yield, and start to create handling problems from stubble levels of 3–4 t/ha.

Photo standards

Photo standards can be used to compare actual stubble residues with a photo standard to estimate stubble loads.

After harvest, walk across the paddock looking at the stubble, estimate stubble loads at 10 or more random points, comparing the actual stubble with the photo standards shown in Figure 1 (do not avoid bare area or areas with uneven levels of stubble). Average the 10 estimates to gain an estimate of the stubble load in the paddock.

Stubble loads can be difficult to estimate where row spacings, harvest heights and crop types vary.

In-field measurements — stubble load

Using a 0.1m^2 quadrat (30cm x 30cm square), cut stubble to ground level and collect loose straw and chaff off the ground. Repeat this 10 times along a path or transect across the paddock to enhance accuracy of the calculations. Combine all cuts and weigh the material. This will give stubble loads from 1m^2.

A subsample (e.g. 100g) can be dried to calculate dry matter percentage (DM%), but stubbles are generally 95% DM. If the measurements are taken after rain or dew this may vary significantly.

Stubble load (kg DM/ha) = 1m^2 quadrat average wet weight (g) x DM% x 10 (convert to kg/ha)

EXAMPLE: average wet weight in a 1m^2 = 300g

Stubble load (kg DM/ha) = 300g x 95%

= 285g DM/m^2

= 285g DM/m^2 x 10,000 (m^2 to ha) ÷ 1000 (g to kg)

= 2850kg DM/ha

In-field measurements — ground cover

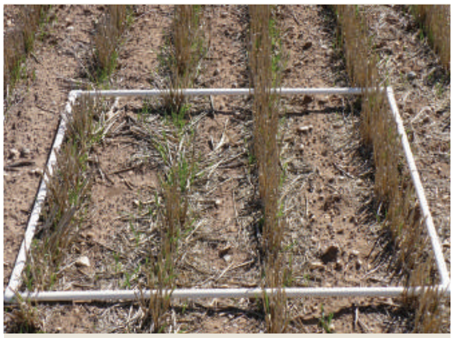
A handy method to estimate ground cover is to stand in a representative area of the paddock with feet 50cm apart. Imagine a square quadrat (50cm x 50cm) in front of your feet, look down and estimate the percentage of area covered by plant material. Do this 10 times across the paddock and average the results. Alternatively use a quadrat as described above.

It is often easier to estimate the percentage of bare soil and convert this to percentage ground cover than it is to estimate the ground cover itself.

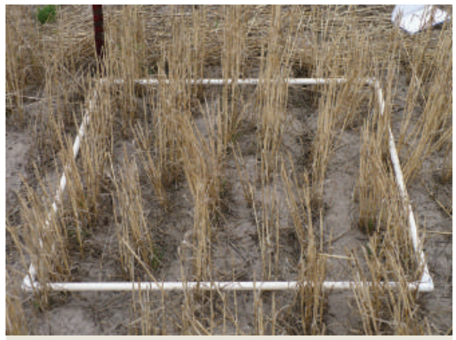
There are a number of smartphone applications in development to assist in assessing ground cover. An easy-to-use option is the Ground Cover App produced by the Local Land Services North West. Using the Basic Assessment Tool users walk a transect and record what they see at their toes with each step. This then gives a percentage ground cover. It is important if using a tool like this to ensure you go across the stubble rows and not along the rows!

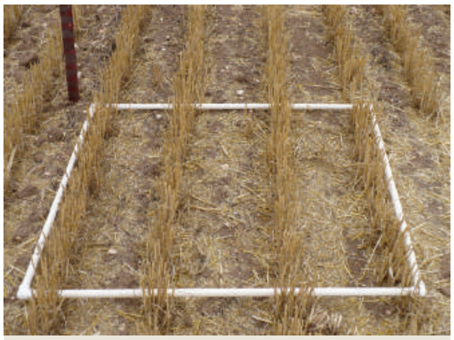
Stubble loads can be difficult to estimate where row spacings vary. Photo: UNFS

Figure 1. Photo standards for estimating stubble load in wheat and barley


Wheat stubble 30cm row spacing 0.9t/ha


Wheat stubble 18cm row spacing 2.2t/ha


Wheat stubble 23cm row spacing 2.3t/ha


Wheat stubble 30cm row spacing 2.2t/ha


Barley stubble 18cm row spacing 3.2t/ha


Barley stubble 25cm row spacing 3.3t/ha


Barley stubble 30cm row spacing 3.3t/ha


Wheat stubble 30cm row spacing 4.4t/ha


Barley stubble 30cm row spacing 5.1t/ha

Photos: Brett Masters (PIRSA Rural Solutions SA)


Barley stubble 25cm row spacing 5.5t/ha


Wheat stubble 18cm row spacing 6.0t/ha

Photo standards can also be used to assess ground cover. Make a 30cm x 30cm quadrat (square) out of sturdy cardboard or wire (this quadrat is used to help focus the eye on a defined area for assessment.)

Along a pre-determined transect line, throw the quadrats out at random and visually assess the groundcover in the quadrant, comparing it with the photo standards shown in Figure 2).

Figure 2. Photo standards for estimating ground cover

Pea stubble 25% ground cover

Pea stubble 50% ground cover

Pea stubble 75% ground cover
Photos: Brett Masters (PIRSA Rural Solutions SA)

Pea stubble 100% ground cover

When should I monitor my stubble?

The amount of stubble and its condition will vary throughout the fallow period depending on the management of the paddock. It is important to monitor the stubble load, ground cover and its condition before implementing any stubble management and, in the case of grazing, regularly throughout the treatment. The condition and amount of stubble can deteriorate rapidly under certain climatic and management conditions.

Have a clear understanding of how much stubble is desired at sowing and in what condition it needs to be in to ensure sowing is hassle free, pre-emergent herbicide efficacy is optimised and the desired plant establishment can be achieved, all while protecting soils from erosion.

! What else do I need to consider when monitoring my stubble?

How stubble is managed affects the distribution and condition of the stubble. This can have a significant effect on the next season's growing conditions.

Not all stubble is the same. This is particularly the case when considering stubble as a feed source for livestock.

While undertaking stubble load and ground cover assessments keep an eye out for the following:

- Uneven chaff distribution by the header can lead to nitrogen (N) tie up, areas of increased weed seed bank and clumping in the sowing equipment.
- Lodged stubble and excessive stubble heights result in hair pinning during sowing and reduced plant establishment.
- Weeds may become tangled in the sowing equipment.
- Consider break down of the stubble during summer. Above average rainfall can result in higher rates of stubble breakdown, especially in legume crops. As a rule of thumb, 20 per cent breakdown can occur with low-quality dry feed and little summer rain. Average breakdown is 30–40 per cent. More than 50 per cent breakdown can occur with high-quality feed and above-average summer rains.
- Keep in mind that standing stubble has limited feed value for livestock. Although a paddock may still have sufficient cover and DM, the nutritional value will deteriorate in a stubble paddock rapidly after spilt grain and leaf and chaff matter has been consumed. Cereal stubbles vary in their nutritional content depending on seasonal conditions. In dry seasons with minimal stubble loads nitrogen content of the stubbles is often high, leading to high palatability and rapid break down. In high-production seasons, when grain yields are high, most nitrogen is moved out of the straw into the grain leaving low levels of nitrogen, making the stubbles relatively unpalatable and slow to break down. Understanding the feed quality of stubbles will improve the profitability of livestock enterprises.

A range of useful resources are available to guide accurate stubble monitoring calculations. Photo: UNFS.

Additional stubble monitoring resources

» Good stubble or bad stubble (CWFS). Click

» Ground Cover measuring tool (Agriculture Victoria). Click

» Hunt, N and Gilkes, B (1992) *Farm monitoring handbook*. University of Western Australia, Nedlands Western Australia.

» Primary Industries South Australia, 2003, Andrea Francis Rural Solutions SA, Richard Payne DWLBC, Fact sheet no: 8/01. *Field methods for measuring soil surface cover*.

» Primary Industries South Australia, 1996, *Pasture Pics: easy estimation of pasture dry matter levels*, Appila / Bundaleer Pasture Group, Appila, SA.

Acknowledgements

This guideline was developed by Michael Wurst (Rural Solutions) and Ruth Sommerville (Rufous & Co).

Disclaimer

Upper North Farming Systems

Stubble Management Guidelines

Maireana

Yanga bush (*Maireana brevifolia*). Photo: Hannah Mikajlo (UNFS).

Key facts

- Maireana species are well adapted to a range of soil types and low-rainfall environments.
- Maireana can be used as fodder shrubs but they have high salt and oxalate levels and their ability to spread quickly and form dense stands where there is no cultivation makes Maireana species a potential weed in no-till cropping systems.
- No herbicides are registered to control Maireana and these shrubs can tolerate heavy grazing. Mechanical disturbance, such as using prickle or disc chains, can be used to break up the shrubs.

Maireana are a genus within the Chenopodiaceae family, alongside other plants such as saltbushes, fissure weeds and samphires. There are about 20 Maireana species found throughout the Upper North region of South Australia, but by far the three most common are Yanga bush (*Maireana brevifolia*), black bluebush (*M. pyramidata*) and cotton bush (*M. aphylla*).

These small, evergreen perennial shrubs grow to roughly a metre high and up to 1.5m wide. The stems are often woody and the leaves are usually fleshy or succulent. The roots are shallow and spreading.

Maireana tend to flower and fruit during summer and autumn. Species such as Yanga bush are well adapted to lower-rainfall environments (250–450mm), can grow in a wide range of soil types and are moderately–highly salt tolerant. They can also tolerate hot conditions and some frost, but are sensitive to waterlogging.

Although Maireana will grow naturally on bare or uncultivated ground, they can also be sown or planted as fodder shrubs. Species such as Yanga bush have relatively high levels of crude protein, but are not a complete feed source on their own.

While not normally viewed as a problem in livestock situations, Maireana's ability to spread quickly and form dense stands makes it a potential weed in cropping systems, particularly where zero-tillage is practised.

Project information

This *Maireana* guideline has been developed for the Upper North Farming Systems Group (UNFS) as part of the Maintaining Profitable Farming Systems with Retained Stubble Initiative, funded by the Grains Research and Development Corporation (GRDC UNF00002).

The Stubble Initiative involves farming systems groups in Victoria, South Australia and southern and central New South Wales, collaborating with research organisations and agribusiness, to address challenges associated with stubble retention.

The GRDC, on behalf of growers and the Australian Government, is investing $17.5 million in the initiative that has been instigated by the GRDC Southern Regional Panel and the four Regional Cropping Solutions Networks that support the panel.

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Maireana spreads across undisturbed areas. Photo: Hannah Mikajlo (UNFS).

Maireana in the Upper North

Maireana shrubs will grow and spread over uncultivated ground, easily becoming weeds in no-till and stubble-retained systems, where ground is left undisturbed. Where Maireana does invade farmland, colonisation tends to occur in a series of waves, determined by how easily each variety spreads.

Commonly, Maireana will be accompanied by other colonising weeds, including thorny saltbush (*Rhagodia spinescens*), cannon-ball (*Dissocarpus paradoxa*) and Dillon bush (*Nitraria billardierei*).

Yanga bush (*Maireana brevifolia*)

Yanga bush is an early coloniser and will often be the first Maireana type to appear. It spreads easily due to its light-weight and fan-shaped fruiting bodies, which can disperse across wide distances.

Yanga bush has slender branches and fleshy oval-shaped leaves. Photo: Hannah Mikajlo (UNFS).

Yanga bush grows to roughly one metre. It has slender, red-tinged branches, which can have sparse, woolly patches. The oval-shaped leaves are 2–5mm long and fleshy.

Although drought resistant, in times of water-stress Yanga bushes will often only have green leaves on the tops of the branches, while the lower leaves are dry and brown.

Yanga bushes often have outer green leaves with dry brown leaves underneath. Photo: Hannah Mikajlo (UNFS).


Black bluebush (*Maireana pyramidata*).


Cotton bush (*Maireana aphylla*).


Black bluebush leaves are a characteristic blue-grey colour.


Spiny, leafless branches on a cotton bush. Photos: Hannah Mikajlo (UNFS).

Black bluebush (*Maireana pyramidata*)

Black bluebush often appears in the second phase of colonisation. This variety spreads more slowly due to its heavier fruiting bodies, which are not as easily dispersed as those of Yanga bush. Although this shrub is a prolific seed producer, supporting rapid infestation, the seeds lose viability after only a few months.

A long-lived perennial, black bluebush will grow to around 1.5m. The branches are rigid and often carry spikes. The fleshy, oval leaves are 2-4mm long and are a characteristic blue-grey colour.

Cotton bush (*Maireana aphylla*)

Cotton bush is the third most common variety of Maireana in the Upper North region and typically colonises undisturbed ground later than either Yanga bush or bluebush.

This variety of Maireana grows to roughly 1.5m and is characterised by its almost complete lack of leaves. For this reason, it is also known as 'leafless bluebush'. Where leaves are present they are usually 1–4mm long. The stems have spines.

Control options

Chemical

» At present, there are no herbicides registered to control Maireana

Grazing

» Although Maireana are sometimes used as fodder shrubs, many species are not particularly palatable and livestock can be reluctant to graze on them until they become more familiar with them. Maireana will tolerate heavy grazing, but contain high levels of oxalates (9–12 per cent in the leaves), which can prove toxic to livestock. These shrubs also contain potentially high salt levels.

Cultivation

» Cultivation can be used to control Maireana. Mechanical disturbance, such as using prickle or disc chains, can also be used to break up the shrubs.

Cropping clean-up control Maireana

Barry Mudge, Port Germein

Maireana grows as a weed on Barry Mudge's property near Port Germein. Early colonising varieties appear on land removed from the cropping phase for more than one year, growing first along the fence lines then spreading towards the middle of the paddock. Maireana can quickly colonise entire paddocks, depending on how many years the land is left uncropped.

Barry has found applying a mix of glyphosate and metsulfuron to clean up paddocks during spring, before they come back into the cropping program, offers a successful control option. This may need to be followed by cultivation with either a chisel plough or a blade plough.

For thicker and more-difficult-to-control infestations, Barry uses further mechanical disturbance with prickle or disc chains to break up the dead plants. This stops the residual woody stems from causing problems during sowing.

Maireana growing on Barry Mudge's property. Maireana, alongside species such as saltbush and cannon-ball, will colonise undisturbed soil. Photo: Hannah Mikajlo (UNFS).

References and further information

» Botanic Gardens of South Australia plant database (2007). Click

» G. M. Cunningham, W. E. Mulham, P. L. Milthorpe & J. H. Leigh (1992) *Plants of Western New South Wales*, Inkata Press.

» Department of Water, Land and Biodiversity Conservation (South Australia) Saltland Pastures for South Australia Manual (2007). Click

» Electronic Flora of South Australia *Maireana* genus fact sheet (2007). Click

» Jason Emms (SARDI) (2008), Small leaf bluebush factsheet, collaboration between AWI, GRDC, MLA, RIRDC and Dairy Australia. Click

» Florabank *Maireana brevifolia* fact sheet (c. 2010). Click

Acknowledgements

This guideline was developed with assistance from Geoff Axford and Barry Mudge.

Disclaimer

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Upper North Farming Systems

Stubble Management Guidelines

Statice

Statice (*Limonium lobatum*). Photo: Hannah Mikajlo (UNFS).

Key facts

- Statice (*Limonium* spp.) populations can quickly build up along roadsides, fence-lines and in depressions.
- Dense stands of statice have reduced crop yields by up to 30 per cent, while statice leaves can discolour and contaminate grain.
- Currently there are no herbicides registered for control of statice.
- Cultivation and crop competition are more effective control measures than grazing. Weed seed capture and destruction also can be effective options.

Statice (*Limonium* spp.) weeds are starting to emerge as a serious problem across low-rainfall cropping regions of southern Australia. Although statice has been present in the Upper North region for a number of years, it has recently become a more significant issue, likely due to increasing adoption of no-till practices and diminishing use of sulfonylurea and Diuron herbicides.

The most common statice species in the Upper North region is *L. lobatum*, commonly called winged sea lavender.

L. lobatum grows as either an annual or short-lived perennial. The seeds germinate during autumn and winter, with most growth occurring during winter and spring. At maturity, the plant is roughly 10–50cm tall, with a basal rosette of wavy leaves as well as erect, winged stems. In South Australia, flowering and seed set occur during spring and summer.

The small white or yellow flowers are enclosed in large, papery purple-blue calyx and bracts. *L. lobatum* has deep taproots, which enable it to compete against crops for nutrients and soil moisture. *L. sinuatum*, or perennial sea lavender, is also prevalent in the Upper North. The wings on its stems are narrower than those found on *L. lobatum*.

Statice often flourishes in paddocks where crops are rotated with pastures and is well adapted to a range of alkaline, sodic and moderately saline soils. Numbers can quickly build up along roadsides, paddock fence-lines and around creeks or in depressions, easily spreading into nearby paddocks.

Project information

This *Statice management* guideline has been developed for the Upper North Farming Systems Group (UNFS) as part of the Maintaining Profitable Farming Systems with Retained Stubble Initiative, funded by the Grains Research and Development Corporation (GRDC UNF00002).

The Stubble Initiative involves farming systems groups in Victoria, South Australia and southern and central New South Wales, collaborating with research organisations and agribusiness, to address challenges associated with stubble retention.

The GRDC, on behalf of growers and the Australian Government, is investing $17.5 million in the initiative that has been instigated by the GRDC Southern Regional Panel and the four Regional Cropping Solutions Networks that support the panel.

L. lobatum (winged sea lavender) growing near Booleroo Centre. Photo: Hannah Mikajlo (UNFS).

L. sinuatum (perennial sea lavender) growing along a roadside near Port Pirie. Photo: Hannah Mikajlo (UNFS).

Anecdotal evidence suggests statice populations increase rapidly in the wake of pulse crops, and can be extremely difficult to control during summer, before sowing, and particularly in-crop.

There is evidence of dense stands of statice reducing crop yields by up to 30 per cent while the leaves can discolour and contaminate harvested grain.

Statice weeds quickly multiply along paddock fencelines and undisturbed areas. Photo: Hannah Mikajlo (UNFS).

Statice is best controlled during the seedling stage. Photos: Fleet and Kleemann

Managing statice

Statice can be difficult to control, but researchers from the University of Adelaide recommend concentrating on reducing seed set and controlling the weed seedbank by killing seedlings.

Non-chemical control options

There is limited research into how to manage statice without herbicides.

Grazing

» Unfortunately, grazing has been shown to be a fairly ineffective control method because, although not toxic to livestock, statice is unpalatable. Livestock can also end up dispersing the weed over a larger area.

Increasing the competitiveness of the crop

» This technique, along with cultivation, has been shown to be more useful than grazing, potentially controlling up to 50 per cent of a statice population. This may involve increasing the sowing rate or growing a more competitive crop, such as barley. Delaying sowing so as to remove more weeds with herbicides can also help.

Cultivation

» Recent research by the University of Adelaide found exposure to sunlight was a key factor in stimulating statice germination, explaining why no-till systems, where weed seeds are left on the soil surface, support flourishing statice populations. Statice seeds left on the soil surface were found to decay at a significantly slower rate than seeds incorporated into the soil. After being buried 2cm deep for just two months, more than 95 per cent of the seeds in the study lost their viability. This also means 'green manuring' (i.e. where the crop and weeds are cultivated into the soil while still green) can be used as a control method.

Brown manuring

» Another potential control option involves spraying out a pulse crop, using knockdown herbicides, before seed set by weeds. This method provides nitrogen benefits, through fixation by the pulse crop, while controlling difficult weeds. The timing of spraying is determined by the growth stage of the statice, rather than the crop itself. Brown manuring may require more than one herbicide application.

Weed seed capture or destruction

» While statice seeds decay quite rapidly, each plant can produce more than 2000 seeds. Weed seed capture or destruction at harvest could prove effective in controlling the seedbank. Narrow windrow burning may be an option, however there has not yet been sufficient research to determine what temperature or duration of heat is required to render the statice seeds unviable.

Paddock use

» Herbiguide notes that statice numbers tend to decline under continuous cropping or continuous pasture.

Controlling statice in non-cropped areas

» Statice numbers can quickly build up along fencelines and other un-cropped areas, so keeping these areas clean is vital. Spray small plants, aiming for 100 per cent control of seed set. Avoid using herbicides during times of water stress.

BELOW: Statice seeds quickly lose viability in soil, so actions that incorporate the seeds into the soil can be effective control methods. Photo: Jim Kuerschner.

Early control offers greatest success

Leighton Johns, Port Pirie

Statice is a problem weed on Leighton Johns' family's mixed farming enterprise, south of Port Pirie.

According to Leighton statice has been an issue in the area for a number of years, but within the past decade it has become particularly challenging. The Johns have experimented with different ways to control the weed and have found some approaches that seem to work.

Leighton finds statice more difficult to kill after it flowers, so targets the weeds when they are young and small.

The Johns greatest success has been using a high rate of glyphosate (1.2–1.8l/ha) and Hammer® (18–20ml/ha) at seeding. When cropping cereals, the Johns use Diuron (250g/ha) + MCPA 750 (250ml/ha) and Ally® (5g/ha) post emergence. For peas, they use Terbyne post seeding and pre emergence, or Diuron (500g/ha) post seeding and pre emergence in vetch.

During pasture phases, Leighton waits until the clover has podded, then sprays the statice out with a mix of glyphosate and Hammer® and keeps spraying each time it germinates, until seeding.

Statice growing in one of Leighton Johns' paddocks.
Photo: Hannah Mikajlo (UNFS).

References and further information

- Benjamin Fleet (2014) Post emergent herbicide control of Statice (*Limonium lobatum*), unpublished research (University of Adelaide)
- Samuel Kleemann, Benjamin Fleet, Fleur Dolman and Gurjeet Gill (University of Adelaide) (2017) Statice (winged sea-lavender); biology, ecology & IWM Tactics factsheet Click
- Sam Kleemann, Benjamin Fleet and Gurjeet Gill (University of Adelaide) (2017), Latest research on emerging weeds – brome grass, statice and common sowthistle, GRDC Update Paper Click
- Cameron Taylor and Jarrod Brown (2014), Statice Control, Birchip Cropping Group Research Results Click
- GRDC Winged Sea Lavender Weed Ute Guide (2014) Click
- Guidelines to managing key weed species across low-rainfall regions of south-eastern Australia (2016), partnership between NRM Organisations and the Grains Industry, funded by GRDC and the Ag Excellence Alliance Click

Acknowledgements

This guideline was developed using research by Sam Kleemann, Benjamin Fleet, Fleur Dolman and Gurjeet Gill (University of Adelaide).

Upper North Farming Systems

Stubble Management Guidelines

Yellow Leaf Spot

Yellow leaf spot (YLS) occurs commonly in stubble-retained systems. Photo: Hugh Wallwork (SARDI).

Key facts

- Yellow leaf spot (YLS) disease primarily affects bread wheats and is most common in stubble-retained systems.
- Symptoms appear as tan-coloured spots with yellow edges along the leaves.
- The fungus kills plant tissue before feeding on it, preventing fungicides from travelling to the sites of infection.
- Yield losses are usually lower than 15 per cent, but can be considerably higher if conditions favour the disease.
- Avoid sowing susceptible wheat varieties into infected stubble.

Yellow leaf spot (YLS) is a disease caused by the fungal pathogen *Pyrenophora tritici-repentis*. In the Upper North region of South Australia, YLS primarily affects bread wheat varieties.

Initial symptoms of the disease appear on the leaves as small tan-coloured spots with discrete yellow halos surrounding them. As the lesions grow they can vary in size and shape and can join together. When a leaf is severely affected its tip will turn yellow and die.

Occasionally when infection occurs after flowering, because of wet conditions during spring, pink pigmentation can develop in plant stems and seeds. Affected seed can be downgraded.

Infection by YLS is a two-stage process and is heavily dependent on the weather. A primary infection of seedlings is quite common, but this does not always mean a secondary and more significant infection will occur later on. For YLS to transfer upwards through the canopy to affect the top leaves and impact significantly on yield, frequent, and often prolonged, rainfall events are required. If these conditions are present, however, the disease can rapidly spread through the canopy and become more difficult to manage due to the constant production of spores from the stubble and lower leaves.

Project information

This Yellow Leaf Spot management guideline has been developed for the Upper North Farming Systems Group (UNFS) as part of the Maintaining Profitable Farming Systems with Retained Stubble Initiative, funded by the Grains Research and Development Corporation (GRDC UNF00002).

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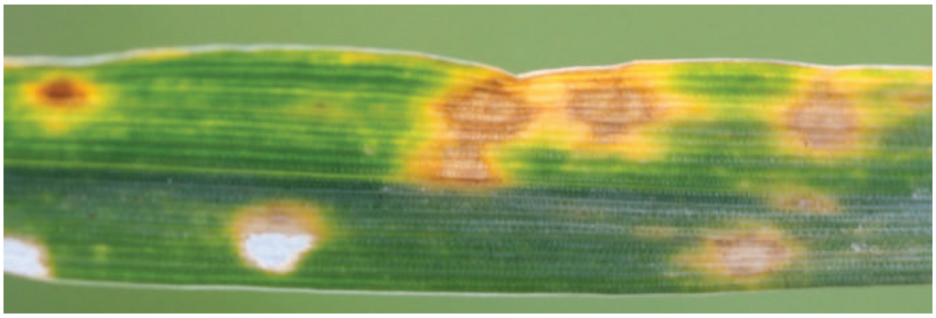


Disease symptoms appear on the leaves as tan-coloured spots with yellow halos.
Image courtesy of Frank Henry, Agriculture Victoria, DEDJTR.

LEFT: Black fruiting bodies on stubble. Image courtesy of Mark McLean, Agriculture Victoria, DEDJTR.

Tips of severely affected leaves die. Photo: Hugh Wallwork (SARDI).

Diagnosis

The yellow leaf colouring caused by YLS can be confused with symptoms caused by other issues, such as nitrogen deficiency, zinc deficiency or damage from herbicides, so it is important to diagnose the problem correctly.

Some wheat varieties, including those released by Australian Grain Technologies (AGT), can also demonstrate leaf yellowing in certain conditions, for example during wet and cold periods.

Biology

Because the fungal pathogen persists on crop stubble and plant residues, YLS is most commonly an issue in paddocks where minimum tillage and stubble retention are practiced. When conditions are particularly dry, the fungus can survive on stubble for up to two years, although its viability decreases after 18 months.

The fungus has a short life cycle, and after infecting a plant will take only 4–7 days to produce visible lesions on the leaves.

The spread of the infection can be a two-stage process, with two different types of inoculum being generated by the fungus.

Primary infection

During autumn and winter the fungal infection produces black, pinhead-sized, elevated fruiting bodies, with hairlike projections that cause them to feel rough when touched. Clusters often form on stem nodes. When wet, the fruiting bodies swell and expel microscopic spores over a distance of roughly 100mm. These spores cause lesions to develop on any seedlings they touch. This comprises the initial spread of the infection.

Secondary infection

The lesions that develop as a result of the primary spread of the fungus produce spores, called conidia. Conidia are dispersed by wind and can travel significant distances. Conditions are optimal for infection where leaves remain wet for six or more hours and the temperature falls in the range of 15-28°C. This secondary spread is the main cause of rapid disease development through the crop, leading to high yield losses. The secondary infection can also be exacerbated in the middle of the growing season by cold conditions, which slow plant development and prevent leaves from growing away from the infection sites.

The YLS fungus feeds on dead and decaying plant matter. During infection, the fungus secretes toxins into the cells of the host plant, causing them to die. This is why the lesions appear as a tan-coloured section of dead plant material surrounded by yellow rings of dying cells.

Because the fungus kills the plant cells, fungicides cannot move through the dead cells to protect the rest of the plant. This drastically reduces the efficacy of fungicides applied after infection has been initiated.

The fungus can also feed on already dead plant material. This increases the susceptibility of bread wheat varieties as they ‘dry off’, regardless of their resistance rating. It also means other crops and stubbles, such as barley and oats, can host and spread the fungus, even though they are immune from the disease while green.

Assessing the risk

When managing YLS, first assess the situation and gauge the risk. Management in-season is difficult, so pre-sowing management is critical.

Disease presence

YLS is most commonly a problem in paddocks where wheat is being sown into wheat stubble — particularly when the new crop is a susceptible variety. Infected stubble can continue to spread the disease throughout the growing season, so take care to choose a more resistant wheat variety when sowing into potentially infected stubble.

When assessing paddocks for risk of infection, bear in mind that YLS from infected stubble is unlikely to spread to adjacent paddocks without particularly wet and windy weather. Although the fungus can be spread by wind, it is not as mobile as other fungi, such as stripe rust. Since the fungus is usually located in the lower canopy of the crop, this can also trap it in that year's crop and help prevent its spread. Although it can quickly spread through a paddock, YLS is not so easily transferred to new paddocks.

Crop type and variety

Although cereals other than wheat can host YLS as they dry-off or are retained as stubble, the disease is really only a major threat to bread wheat varieties. As such, carefully consider a wheat variety's susceptibility before sowing, especially if it is being sown into potentially-infected stubble (see Table 1).

Reducing yield losses

Yield losses resulting from YLS are usually less than 15 per cent, but if conditions favour its spread, the losses can be significantly higher.

Crop rotation and variety choice are the main strategies to manage YLS in the Upper North.

Crop selection

Avoid sowing susceptible crop varieties into infected stubble, particularly if the existing inoculum load is moderate to high. Usually a one-year break from a non-host crop will reduce the inoculum load by as much as 95 per cent, provided the stubble is sufficiently broken down.

If sowing a wheat crop into infected stubble, select a variety with some degree of resistance to YLS (at a minimum it should have a rating of MR–MS). If the variety is susceptible, gauge how much inoculum is present in the paddock before sowing so the infected stubble can be managed accordingly (see Table 1).

Crop nutrition

Healthier, more vigorous crops cope better with infection. Soil tests before sowing and tissue tests during the growing season can support effective fertiliser decisions.

Under Upper North conditions, if a crop is infected, nitrogen and zinc applications are often a cost-effective method to manage YLS. Although this will not remove the fungus, nutrient applications can 'green up' the crop sufficiently to lessen the potential yield loss.

TABLE 1. Yellow leaf spot disease rating for a range of bread wheat varieties grown in South Australia*

Bread wheat variety	Yellow leaf spot disease rating in South Australia
AGT Katana	MS
Arrow	possibly MR
Axe	S
Chief	possibly R-MR
Cobra	MS
Corack	MR-MS
Cosmick	MR-MS
Cutlass	MS-S
DS Darwin	S
Emu Rock	MR-MS
Gladius	MS
Grenade	S
Hatchet	S
Justica	S-VS
Kord	MS-S
Mace	MR-MS
Scepter	possibly MR-MS
Scout	S-VS
Shield	MS
Trojan	MS-S
Yitpi	S-VS

S = susceptible, VS = very susceptible, MS = moderately susceptible, MR = moderately resistant.

Source: South Australian Crop Variety Sowing Guide (GRDC, 2017).

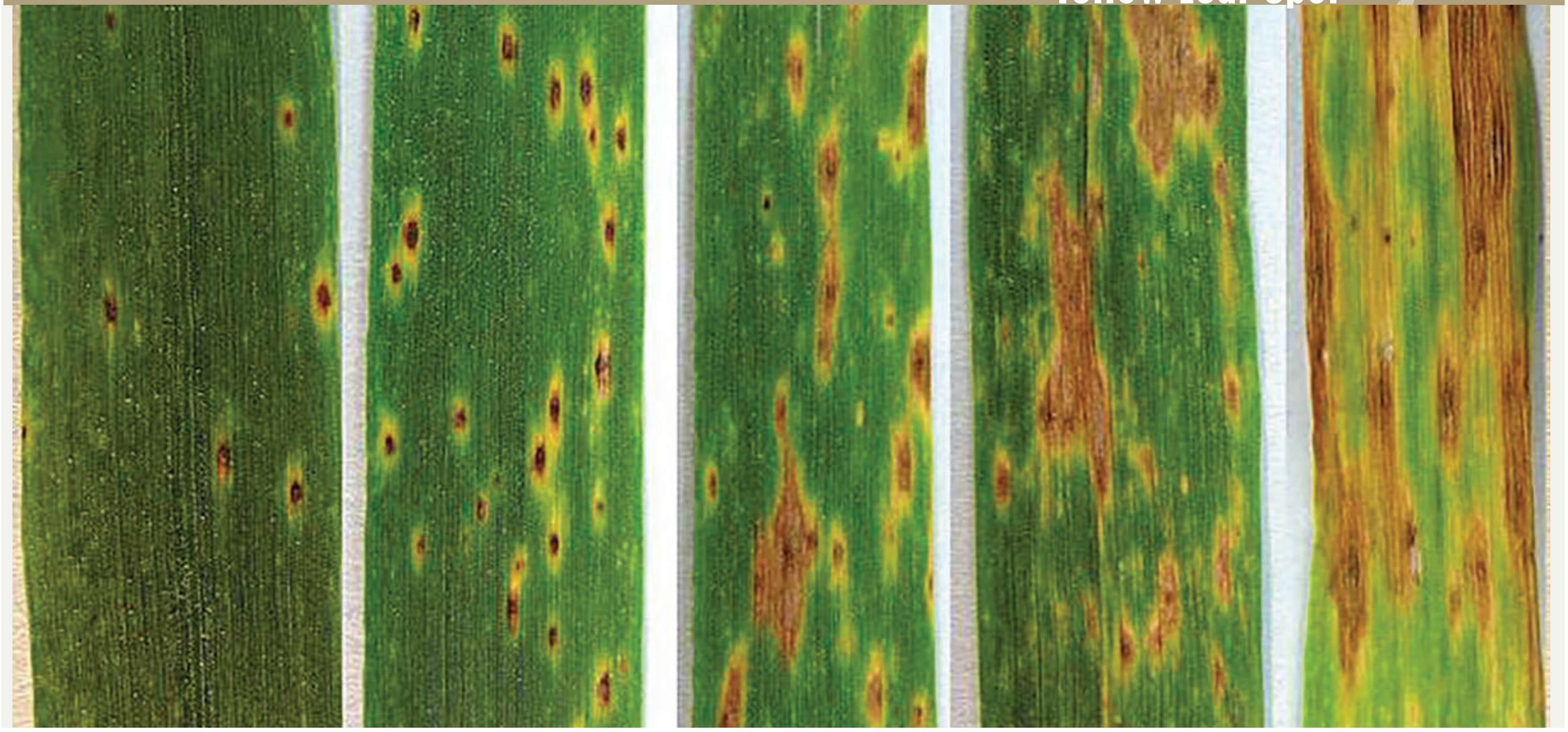
Stubble management

Burning and grazing can be effective control methods to remove infected stubbles, but need to be balanced against the other effects of removing stubble, including increased erosion risk.

Cultivation to incorporate stubble is another option, but any infected stubble remaining on the soil surface will generate fungal spores and infect the new crop. Cultivation can also spread other diseases associated with stubble, such as crown rot.

Fungicides

Prosaro®, Amistar Xtra® and fungicides containing the active ingredients propiconazole and tebuconazole are registered for YLS control, but often will have low efficacy because of the nature of the disease. Given typical Upper North yields, these fungicides are unlikely to be cost effective.



As YLS lesions grow, they can vary in size and shape and can join together. Photo: APS Press.

References and further information

- Herbiguide yellow leaf spot of wheat fact sheet (2014) Click
- Managing yellow leaf spot with fungicide and genetic resistance (2014) AGT guidelines Click
- Diagnosing yellow leaf spot of wheat (2016) WA Department of Agriculture and Food Click
- Yellow leaf spot of wheat (2014), Agriculture Victoria information note Click
- Yellow leaf spot (2011) GRDC Southern Region fact sheet Click
- Yellow leaf spot — is it worth spraying? (2013) GRDC Update paper Click
- Management of yellow spot in wheat: decide before you sow (2013) GRDC Update paper Click

Acknowledgements

This guideline was developed with assistance from Patrick Redden (Rural Directions).

Maintaining profitability in retained stubble systems on upper Eyre Peninsula

A joint EPARF and GRDC funded project.

Guideline 12: Economic and risk analysis of break crops compared to continuous wheat farming systems

Background

The Low Rainfall (LR) Crop Sequencing Project commenced in 2011 in field trials at 5 sites across the LR zone of southern eastern Australia.

The aim of this project was to test if one or two year well managed break phases in LR crop sequences would successfully address agronomic constraints, increase the productivity of subsequent cereal crops and most importantly improve the profitability and reduce risk when compared to continuous cereal.
There were 19 crop sequences in each trial site which included both one and two year break phases in 2011 and 2012 followed by three years of wheat from 2013 – 2015. A continuous wheat was also included.

The inclusion of legume crops, pastures and chemical fallow had a significant impact on increasing soil N levels. Rhizoctonia levels also reduced with the breaks, especially where canola was included. Weed seed banks were best controlled with the two-year break.

Cumulative break crop benefits were generally between 0.5–1.5 t/ha in the following wheat year.
One of the key issues with rotational trials is a one off year for a particular crop (either well above or well below average) can affect the outcome on a profit basis.

It was therefore important to take the key findings of the project and analyse the key crop sequences over a range (deciles) of seasons to give a better overall picture of profitability and risk.

Summary of low rainfall crop sequencing work

Including a one or two year break phase in low rainfall paddock rotations can increase profitability over maintaining a continuous wheat cropping sequence. The increase in profitability is due to an increase in yield of between 0.5 t to 1.5 t/ha for the cereal crop following the break. This yield increase is due to lower weed numbers, lower root disease and an increase in nitrogen nutrition.

Break phases that included stock (e.g. medic pastures or vetch) reduced the losses in below average deciles for both season and price.

Where stock was included in the break phases, the profit in the well above average seasons (decile 7-9) was reduced in comparison to continuous cropping.

For break phases that included a grain legume, the grain legume itself must be well suited to the soil types and environment, with profitability at least similar to continuous wheat.

For continuous wheat to maintain profitability, weed numbers and root disease levels need to be contained. To capture the higher profits in above average years requires higher nitrogen inputs at a level that challenges decision making for farmers.

Methodology

The economic analysis was undertaken for 5 of the 19 crop sequences trialled. These sequences were picked to represent different agronomic approaches:

1. Pasture, pasture, wheat, wheat, wheat – self-regenerating pasture, includes stock (PPWWW)
2. Peas, canola, wheat, wheat, wheat (FpCWWW)
3. Vetch, canola, wheat, wheat, wheat – includes stock (VCWWW)
4. Wheat, wheat, wheat, wheat, wheat (CW)
5. Wheat, wheat, wheat, wheat, wheat – reduced nitrogen input (CW (50 urea))

The economic analysis is based on a whole farm gross margin on a per hectare basis which captures income from grain and livestock sales and variable costs such as seed, herbicide and fertiliser inputs. We have also included Machinery ownership costs including depreciation and interest on monies borrowed. Machinery ownership is included due to differing investment requirements between different crop sequences, particularly less machinery investment when stock are included due to less hectares sown to crop. Also included in the analysis is the interest component on monies borrowed for some crop sequences that require more cash to run than others. This analysis has excluded all fixed costs including labour, which were deemed not to alter based on which crop sequence was selected.

The first analysis looked specifically at how each crop sequence performed on a $/ha basis over a range of 5 seasons (decile 1 – well below, decile 3 – below, decile 5 – average, decile 7 – above average and decile 9 – well above average). In this scenario, long term average grain prices were used: Wheat $255/t, Peas $280/t, Canola $490/t, Wool 981 cents clean, Lamb price $3.84/kg net on farm. The grain values were at Port so freight of $37/t was costed in. Important considerations of the analysis also included:

- The stock operation was based on a well-run, self-replacing merino flock running 2.5 DSE/ha.
- Additional feed was costed for the decile 1 & 3 scenarios.
- The yields were based on the loams to clay loams found at the Minnipa site.
- Peas were chosen because it is well suited to these soil types and has consistently been the highest yielding grain legume at Minnipa.

What happened?

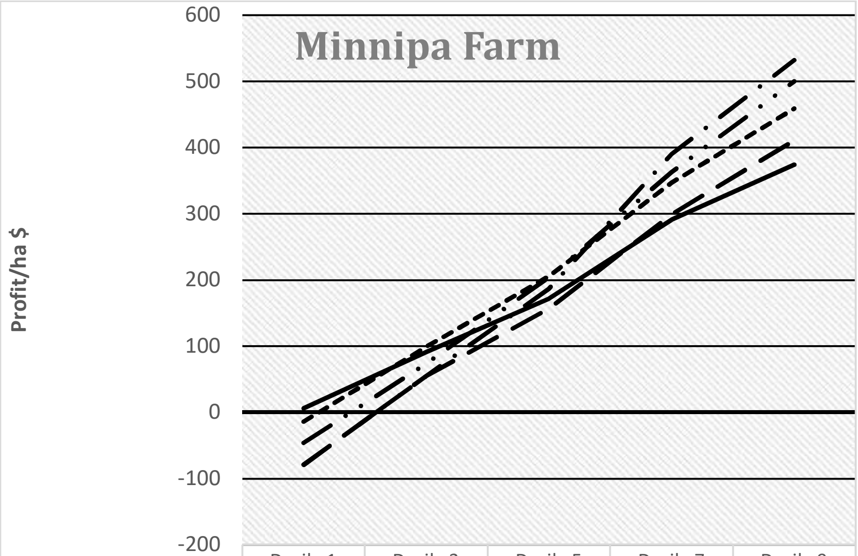
A comparison of profitability between crop sequences for each seasonal decile using a fixed average grain price are provided in Figure 1. The above outcomes are the profit on a $/ha basis for the 5 different scenarios.

The analysis confirms that including stock in the farming system can greatly increase farm resilience in below average seasons. For example, in the sequence with two years of pasture (PPWWW), the losses in the below average years (decile 1 & 3) were significantly reduced in comparison to the continuous cropping sequences with the continuous wheat having the greatest losses. This difference in a decile 1 year is $85/ha which over a 2000 hectare program equates to $170,000.

In the above average seasons, the continuous cropped sequences including the continuous wheat (CW) had greater profits than the stock operations, however, nitrogen inputs in the CW scenario were based on those required to drive the yields (i.e. in the decile 9 year the continuous wheat sequence has 90 kg urea applied). If nitrogen inputs are capped (i.e no more than 50 kg urea applied as in CW (50 urea)), then the continuous cropping system is not able to capture this profit advantage in favourable seasons.

Interestingly, the break crop rotation slightly reduced risk in below average years compared to continuous wheat. Provided that a well suited grain legume was grown (i.e. peas) the losses were half that of continuous wheat in the decile 1 year but maintained the upside in the decile 9 year. However, this well suited continuous cropping sequence still had higher losses than when sheep were included.

Where vetch was included and grazed the losses in the below average years were less than the continuous crop sequences but greater than the pasture scenario. It does indicate the higher cost of pasture establishment when compared with a self-regenerating pasture.



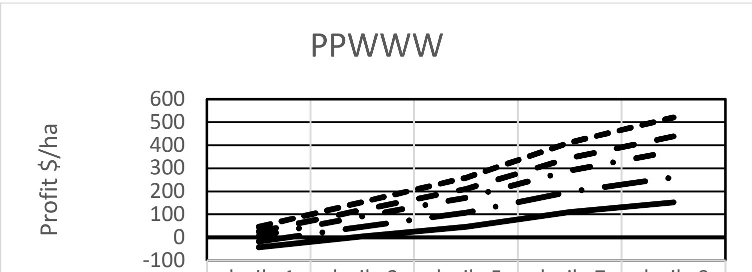
	Decile 1	Decile 3	Decile 5	Decile 7	Decile 9
p,p,w,w,w	6	91	172	291	374
pe,c,w,w,w	-46	74	204	363	500
v,c,w,w,w	-14	99	206	347	459
w,w,w,w,w	-79	55	187	390	532
cont w 50urea	-79	55	157	299	411

Figure 1. Comparison of profitability between each of five crop sequences for five seasonal decile scenarios (deciles 1,3,5,7,9) using a fixed average price.

Table 1. Commodity prices for different deciles.

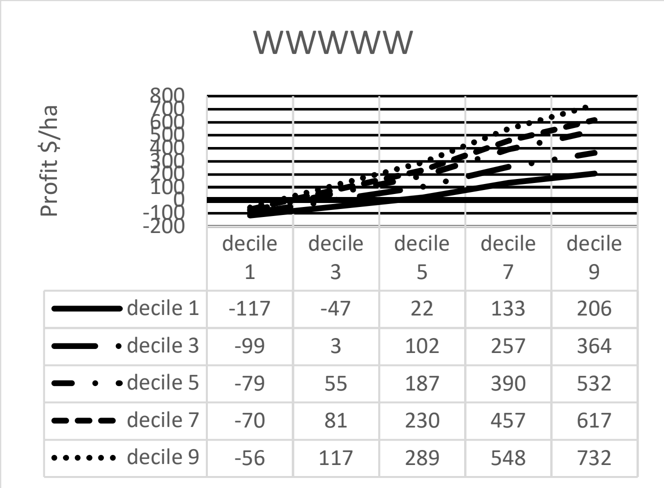
	Decile1	Decile 3	Decile 5	Decile 7	Decile 9
Wheat $/t	162	207	255	279	312
Peas $/t	220	240	300	360	450
Canola $/t	350	418	490	530	605
Wool cents/kg clean	734	846	981	1151	1315
Lambs $/kg	2.61	4.28	4.76	5.20	5.32

Two of the crop sequences (PPWWW Fig 2. and WWWWW Fig. 3) were evaluated for season and price.



	decile 1	decile 3	decile 5	decile 7	decile 9
decile 1	-43	4	46	110	152
decile 3	-18	47	108	198	260
decile 5	6	91	172	291	374
decile 7	25	119	211	344	438
decile 9	46	154	259	412	521

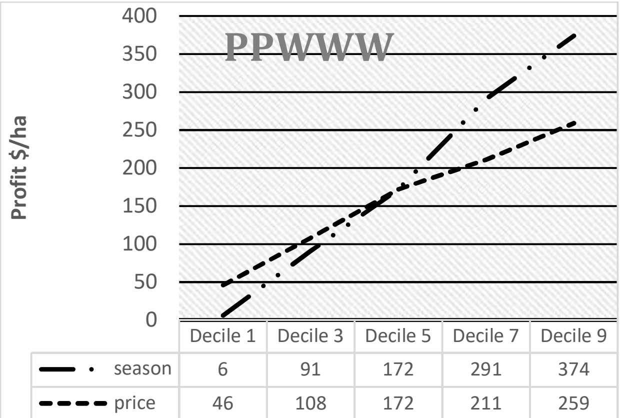
Figure 2. PPWWW season x price interaction.



	decile 1	decile 3	decile 5	decile 7	decile 9
decile 1	-117	-47	22	133	206
decile 3	-99	3	102	257	364
decile 5	-79	55	187	390	532
decile 7	-70	81	230	457	617
decile 9	-56	117	289	548	732

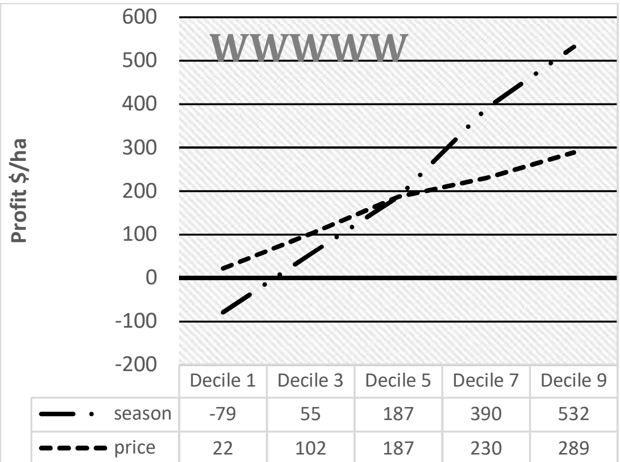
Figure 3. WWWWW season x price interaction.

With both season and price considered the WWWW is still showing more negative whole farm gross margins compared with the PPWWW. To further this analysis it is important to understand whether season or price has the greatest effect on profit. A comparison was then done for the two crop sequences (Figure 4. PPWWW and Figure 5. WWWWW).



	Decile 1	Decile 3	Decile 5	Decile 7	Decile 9
season	6	91	172	291	374
price	46	108	172	211	259

Figure 4. PPWWW decile season vs decile pricing.



	Decile 1	Decile 3	Decile 5	Decile 7	Decile 9
season	-79	55	187	390	532
price	22	102	187	230	289

Figure 5. WWWWW decile season vs decile pricing.

With both crop sequences the range of season (deciles) had a far greater effect on whole farm gross margin then a range of prices. For this example it is more important to be able to manage below average seasons.

Summary

Sheep included in a crop sequence will reduce losses in below average seasons but not capture all the upside in above average seasons. This is the least risky option.

Including a two year break with a well-adapted grain legume will reduce the losses in the below average seasons compared to the continuous wheat and also capture all the upside in the above average seasons. This is a reduced risk option.

Continuous wheat can generate good profits in above average seasons as long as appropriate nitrogen inputs are applied but has the greatest losses in the below average years. This is a risky option.

Continuous wheat with lower nitrogen input was also investigated. The maximum urea rate was 50 kg/ha. The outcome was the losses were the same as the normal continuous wheat in below average seasons but the profits in the above average seasons were reduced close to the pasture, pasture, wheat, wheat, wheat sequence because yields were limited by N.

The continuous wheat with less N input becomes the highest risk option.

Practical farmer decision making

Crop sequences that require more in season N decision making are more complex to operate than those that have less.

Where either pastures (pasture legumes) or grain legumes are included the natural N received from these will drive some of the yield without additional N applied. The 2-year pasture has greater residual N that a one-year pea which is greater than continuous wheat.

The inability to capture upside based on artificial N in the continuous wheat is a real issue. Consider the following:

1. Most N is applied before mid-August
2. Most N responses in the low rainfall environment are best when applied early
3. Many above average seasons are due to September/October rainfall, often outside the timing for post emergent N in the low rainfall areas.
4. If you overcome a production issue in the perceived above average scenario by applying higher rates early, there is a high chance you may not get a response if the season is only average or below. This approach increases costs and therefore increases risk in the below average years.

Practically, continuous wheat has had problems with grass weed issues and artificial N efficacy, especially on the lighter soil types as well as root disease issues. The sensitivity of this scenario is indicated by where urea input was capped at 50 kg/ha and its effect on both profit and risk.

A well-adapted grain legume in the rotation combined with a double break (canola) has given good profits and a reasonable risk position. The success of these breaks is critical for this outcome. Issues that need to be considered are; frost (especially for peas), soil type variation on the farm (affect consistency of yield), and disease.

The pasture scenario with stock gives the most consistent profit and the least risk.

Produced by Ed Hunt, February 2018

Acknowledgements

Michael Moodie, Moodie Agronomy

References

1. Ag Price Guide
   http://agprice.grainandgraze3.com.au/