Trial Results 2016

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Front cover photo: Sandy Kimber 2016

With thanks to Sandy Kimber, Sarah Noack and Gabrielle Hall for other photos used within this publication

Interpretation of statistical data from the trials

The least significant difference (LSD $P \leq 0.05$), seen at the bottom of data tables gives an indication of the treatment difference that could occur by chance. NS indicates that there is no difference between the treatments. The size of the LSD can be used to compare treatment results and values must differ by more than this value for the difference to be statistically significant.

So, it is more likely (95%) that the differences are due to the treatments, and not by chance (5%).

Of course, we may be prepared to accept a lower probability (80%) or chance that two treatments are different, and so in some cases a non-significant result may still be useful.

Disclaimer

Funding supporters

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Collaborators

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The success of the Hart Field-Site Group research program could not be achieved without the contribution of a large number of people and organisations.

Supporters

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Kathy Fischer, John Nairn, Phil Rundle, Sarah Day, Christine Walela, Dili Mao, Henk Venter, Tim Jenkins, Hayden Dreckow, Bowen Ralph-McIlroy, Ritchie Mould and Larn McMurray

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Andrew Ware

Hart Field-Site Group
Sarah Noack – Research and Extension Manager

Hart management

Our values

Independence, relevance, integrity, credibility, professionalism, value for money, generosity.

We have a clear purpose

To deliver value to growers and make agriculture better (in productivity, sustainability & community).

We are committed to delivering on our vision

To be SA's premier cropping field site, providing independent information and skills to the agricultural community.

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Chairman / Sponsorship
Damien Sommerville
chairperson@hartfieldsite.org.au
0417 850 587

Secretary
Sandy Kimber, PO Box 939, CLARE SA 5453
admin@hartfieldsite.org.au
0427 423 154

Research & Extension Manager
Sarah Noack
trials@hartfieldsite.org.au
0420 218 420

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Hart calendar of events 2017

Hart – rainfall & a summary of the 2016 season

Early seeded crops were sown into marginal soil moisture, with only 11 mm of rainfall recorded for April (Table 1). Time of sowing research trials required irrigation to achieve early sowing and establishment at Hart. Rainfall was patchy and lower than expected in May however, consistent rain in June, July and August was in line with the long-term average (Figure 1).

For those who attended the Hart Field day in September it was a muddy one. Overall 119 mm was recorded for the month, 75 mm more than the long-term average (Table 1). In late September wind gusts in excess of 110 km/hr were recorded in the Mid-North. Fortunately, a small windstorm which headed towards Blyth narrowly missed the trial site. Lodging and grain loss due to this weather however, was evident in many trial plots and has been noted in the interpretation of results.

Cooler evening temperatures caused minor frost damage at the trial site however, much greater damage was observed in neighbouring districts. Between August and October there were six events where temperatures fell below 1°C, ranging from 0.9°C to -0.4°C. Care should be taken when interpreting variety and time of sowing trials due to differences in varietal maturities and therefore possible frost incidence this season.

Overall the 2016 Spring was wetter and cooler compared to the two previous seasons. This resulted in well above average yields in many districts in the Mid-North (which were not affected by frost). Majority of Hart's trials were harvested prior to the first week of December and the 53 mm which fell that month. The 2016 growing season rainfall at Hart was 356 mm and annual was 485 mm, well above the long-term average of 300 mm and 400 mm, respectively.

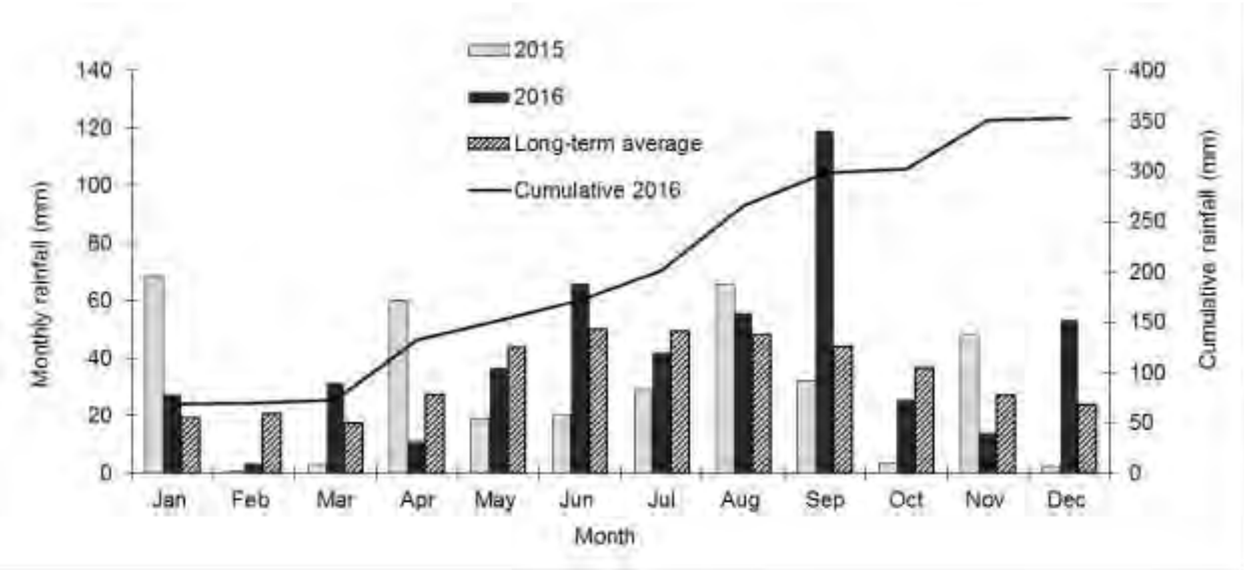

Figure 1. Hart rainfall graph for 2015, 2016 and long-term average. The black line indicates cumulative rainfall for 2016.

Table 1. Hart rainfall chart 2016

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	0	0	0	0	0	0	0.4	8.4	1.4	0	0	0
2	0	2.4	0	0	0	1	0	0.2	0	4.6	0	0
3	0	0.2	0	0	2.8	0	0	0.8	0.6	1	0	0
4	0	0	0	0	0.6	0	7.8	0	0	5.2	0	0.8
5	0	0	3	0.2	0	1.4	2	0	0.2	0	0	0
6	0	0	3.6	6.6	0	5	1.8	0	0	0	0	0
7	0	0	0.6	0	1.2	1	0	0	0	0	0	0
8	0	0	0.4	0	3.6	2.4	0	0	16.2	0	0	8.4
9	0	0	0.8	0	4.4	4.8	4.6	0	3.2	0.2	0	0
10	0	0	19.6	0	2.6	0.6	0.6	2.6	0	0.6	0	0
11	0.2	0	0	0	0	0.4	0.2	1.2	0	0	0	0
12	0	0	0	0	0	0	8	0	1.4	0	0	0
13	0	0	0	0	0	0	1	0	6.4	0	6.8	0
14	0	0	0	0	0	0	0	0	3.6	0	0	5.6
15	0	0	0	0	0	0	0	0	3.2	0	0	0.2
16	0	0	0	0	0.2	14.2	0	0.2	0.8	5.2	0	0
17	0	0	0.6	0	0	2.4	0	0	19.2	0.4	0	0
18	0	0	0.8	0	0	1.2	0	12.2	1.4	1.2	0	0
19	0	0	0	0	0	0	0	16.2	0	0	0	0
20	1	0	0	0.8	0	0	0	0	4.8	0	0	0
21	0.6	0	0	0.6	0	10.4	0	0	1.8	6	0.6	0
22	11	0	0	0	0	0.8	4.4	0	0	1	5.8	0
23	0	0	0	0	0	12.8	0.2	0	0	0	0	0
24	0	0	0	0	0	3.2	2.0	0	6	0	0	0
25	0	0.6	1.4	0	7.2	0.2	4.4	0	0	0	0	0
26	0	0	0	0	3.8	0	3.6	0	0	0.4	0	1.8
27	0	0	0	0	8.8	0.6	0.8	0	0	0	0	29.8
28	0	0	0	2	1.4	0	0	0	20.8	0	0	4
29	6.8	0	0.4	0.4	0	0	0	0.4	21.2	0	0	2.6
30	4.6		0	0.4	0	3.6	0	13.2	7	0	0.8	0
31	3.2		0		0		0.2	0.2		0		0
Montly total	27.4	3.2	31.2	11.0	36.6	66.0	42.0	55.6	119.2	25.8	14.0	53.2
GSR				11.0	47.6	113.6	155.6	211.2	330.4	356.2		
Total	27.4	30.6	61.8	72.8	109.4	175.4	217.4	273.0	392.2	418.0	432.0	485.2

Hart trial site – soil analysis

General soil physical and chemical properties for the Hart field site. Sampled on 14th April, 2015.

	Sampling depth (cm)				
	0-15	15-30	30 - 60	60 - 90	Total profile
Texture					sandy loam - loam
Gravel %	5	5	5	5	
Phosphorus Colwell mg/Kg	31	14	17	11	
Potassium Colwell mg/Kg	275	158	167	176	
Sulphur mg/Kg	2.5	2.3	5.5	26.5	
Organic Carbon %	1.0	0.8	0.6	0.3	
Conductivity dS/m	0.2	0.2	0.3	0.4	
pH Level ($CaCl_2$) pH	7.1	7.6	7.8	8	

Comparison of wheat varieties

Rochelle Wheaton, Hart Field-Site Group

Key Findings

- Phantom, Scepter, Cobra and Scout were the highest yielding commercially available AH varieties at Hart in 2016, yielding between 4.01 and 4.28 t/ha.
- Trojan and Cutlass were the highest yielding APW varieties at 4.6 t/ha.
- Test weight and screening levels across the trial averaged 81.2 kg/hL and 0.7%.

Why do the trial?

To compare the performance of new wheat varieties and lines against the current industry standards.

How was it done?

Plot size	1.75 m x 10 m	**Fertiliser**	DAP (18:20) + Zn 2% @ 100 kg/ha
Seeding date	10th May 2016		UAN (42:0) @ 95 L/ha, 4th July
		Fungicides	Systiva @ 150 mL/100 kg seed
			Amistar Xtra @ 400 mL/ha, 6th Aug
			Propiconazole (500 g/L) @ 250 mL/ha, 12th Sept

The trial was a randomised complete block design with three replicates and 21 varieties. Fungicides and herbicides were applied as necessary to keep the crop canopy free of disease and weeds. All plots were assessed for grain yield, protein, test weight and screening with a 2.0 mm screen.

Results and discussion

Wheat grain yields ranged from 3.24 t/ha for Axe up to 4.67 t/ha for Trojan (Table 1), with an average site yield of 3.87 t/ha. The highest yielding varieties were Trojan, Cutlass and Phantom, closely followed by Estoc, Scepter, Cobra and Scout, all yielding above 4.0 t/ha. Conditions throughout the growing season allowed later maturing varieties such as Trojan, Cutlass and Phantom, to grow for longer and achieve higher yields. Minor frost and hail damage occurred at the site during Spring. This should be taken into account when interpreting results. The long-term variety yield data shows that Trojan (111%) and Mace (107%) continue to perform well over a number of seasons (Table 1).

Wheat grain protein levels were generally low across the trial. No variety met the minimum protein level for Hard 1 or APW classification. Varieties that achieved protein levels of 10% or above were Axe, Arrow, Wallup, Emu Rock and Hatchet CL Plus.

Grain test weights across the trial averaged 81.2 kg/hL and all varieties exceeded 76 kg/hL, the minimum required for maximum grade (Table 1). Screening levels at the site averaged 0.7 % and all fell well below the maximum level of 5% for Hard and APW classification.

Table 1. Grain yield (t/ha), protein (%), test weight (kg/hL) and screenings (%) of wheat varieties at Hart in 2016. Mean grain yield (% of trial average) of Hart wheat variety trials (2010-2016) and number of trials.

Quality	Variety	Grain yield t/ha	% of site average	Protein %	% of site average	Test Weight kg/hL	% of site average	Screenings %	% of site average	Mean yield 2010-2016	No. of trials
AH	Arrow (LPB111728)	3.80	98	10.3	110	82.0	101	0.2	34	-	
	Axe	3.24	84	10.6	114	77.3	95	0.3	45	101	7
	Cobra	4.06	105	8.8	95	80.5	99	0.6	86	104	5
	Cosmick	3.92	101	8.4	90	81.9	101	1.0	137	104	3
	Emu Rock	3.82	99	10.1	109	82.1	101	1.2	171	106	6
	Gladius	3.82	99	9.6	103	80.6	99	0.7	94	100	7
	Grenade CL Plus	3.74	97	8.9	96	80.7	99	0.5	78	97	5
	Hatchet CL Plus	3.39	88	10.4	111	79.9	98	0.5	66	81	4
	AGT Katana	3.48	90	9.7	104	82.3	101	0.8	109	102	7
	Kord CL Plus	3.47	90	9.5	102	80.7	99	1.3	192	95	6
	Mace	3.65	94	9.1	98	79.3	98	0.5	74	107	7
	Phantom	4.28	111	8.4	91	82.8	102	0.8	115	102	6
	Scepter	4.09	106	8.9	95	81.4	100	0.8	110	-	
	Scout	4.01	104	8.6	92	83.4	103	0.9	133	105	7
	Shield	3.81	98	9.5	102	79.9	98	1.2	177	99	5
	Wallup	3.76	97	10.2	110	81.3	100	0.3	39	97	5
	H1 receival standard			*>13.0*		*>76*		*<5.0*			
APW	Corack	3.72	96	9.4	101	80.8	100	0.4	54	106	6
	Cutlass	4.60	119	8.5	91	81.2	100	0.6	80	-	
	Estoc	4.17	108	9.3	100	83.6	103	0.8	108	101	7
	Trojan	4.67	121	8.4	83	83.0	102	0.4	63	111	4
	APW1 receival standard			*>10.5*		*>76*		*<5.0*			
Unclassified	IGW6111	3.81	98	9.0	97	80.8	99	1.0	137	-	
	Site Average	3.87	100	9.3	100	81.2	100	0.7	100		
	LSD (P≤0.01)	0.52		0.89		0.88		0.28			

\- *Insufficient data (included in Hart wheat variety trials for less than three seasons)*

Comparison of barley varieties

Rochelle Wheaton, Hart Field-Site Group

Key Findings

- Oxford, Rosalind, Fathom and Fleet were the highest yielding feed barley varieties at Hart averaging 4.96 t/ha.
- Admiral, Charger and Navigator were the highest yielding commercially available malt varieties averaging 5.28 t/ha.
- Test weights, retention and screening levels were good across the trial with site averages of 65.8 kg/hL, 97.4% and 0.6% respectively.

Why do the trial?

To compare the performance of new barley varieties and lines against the current industry standards

How was it done?

Plot size	1.75 m x 10.0 m	**Fertiliser**	DAP (18:20) + Zn 2% @ 100 kg/ha
Seeding date	10th May 2016		UAN (42:0) @ 95 L/ha, 4th July
		Fungicide	Systiva @ 150 mL/100 kg seed
			Amistar Xtra @ 400 mL/ha, 6th Aug
			Propiconazole (500 g/L) @ 250 mL/ha, 12th Sept

The trial was a randomised complete block design with three replicates and 21 varieties. Fungicides and herbicides were applied as necessary to keep the crop canopy free of disease and weeds. All plots had the plot ends removed prior to harvest and were assessed for grain yield, protein, test weight, screenings with a 2.2 mm screen and retention with a 2.5 mm screen.

Results and discussion

The later maturing feed barley varieties, Oxford and Rosalind, were the highest yielding at Hart in 2016 at 5.63 and 4.83 t/ha, respectively (Table 1). Other high yielding feed varieties included Fathom and Fleet both yielding above 4.50 t/ha. The site average yield across all feed varieties was 4.60 t/ha. The lowest yielding feed varieties were Hindmarsh and Maritime both at 4.25 t/ha.

The highest yielding malt varieties were Admiral, Charger, Navigator, Bass and GrangeR ranging from 4.80 to 5.30 t/ha. Similarly, it was the later maturing varieties that were higher yielding. Explorer, was also high yielding at 5.25 t/ha. The average yield across all malt varieties at Hart was 4.61 t/ha. Long term yield results indicate that Charger, Navigator, La Trobe and GrangeR (>105%) continue to perform well in grain yield over a number of seasons.

Grain protein levels for all malt barley varieties averaged 9.5% across the trial. All malting varieties except for Navigator fell between the allowable protein range of 9-12% for malt classification.

Only two malting varieties fell below the minimum test weight specification of 65 kg/hL, which were Admiral and Charger. All feed varieties were above the minimum test weight specification for F1 feed barley of 62.5 kg/hL.

Screening levels across the trial averaged 0.6%, well below previous seasons. Retention levels across the whole trial were very high with a trial average of 97.4%. All commercially available malt varieties were well above the minimum retention specification for malt 1 (70%).

Table 1. Grain yield (t/ha), protein (%), test weight (kg/hL), screenings and retention (%) of barley varieties at Hart in 2016. Mean grain yield (% of trial average) of Hart barley variety trials (2010-2016) and number of trials.

Quality	Variety	Grain yield t/ha	% of site average	Protein %	% of site average	Test Weight kg/hL	% of site average	Screenings %	% of site average	Retention %	% of site average	Mean yield 2010-2016	No. of trials
Feed	Fathom	4.80	104	10.2	107	65.0	99	0.6	95	97.7	100	113	6
	Fleet	4.60	100	9.8	103	64.6	98	0.5	86	97.7	100	109	7
	Hindmarsh	4.25	92	9.7	102	66.9	102	1.0	157	95.2	98	107	7
	Keel	4.47	97	10.4	109	65.5	99	0.7	116	97.7	100	107	7
	Maritime	4.25	92	10.4	109	64.9	99	0.4	69	98.7	101	93	7
	Oxford	5.63	122	8.0	84	67.5	103	0.5	90	97.3	100	99	7
	Rosalind	4.83	104	8.9	93	64.7	98	0.5	89	97.1	100	-	
	F1 receival standard			*NA*		*>62.5*		*<15*		*NA*			
Malting	Admiral	5.31	115	9.0	94	63.8	97	0.5	80	97.9	101	-	
	Bass	4.91	106	10.0	105	66.8	102	0.5	80	98.5	101	100	5
	Buloke	4.61	100	9.8	103	66.1	100	0.6	106	96.0	99	102	7
	Charger	5.27	114	9.2	96	64.6	98	0.8	135	97.2	100	106	4
	Commander	4.25	92	9.5	100	66.6	101	0.6	94	97.7	100	105	7
	GrangeR	4.77	103	9.4	99	67.1	102	0.6	91	98.2	101	95	6
	La Trobe	4.33	94	9.5	99	67.4	102	0.9	141	95.7	98	105	5
	Navigator	5.24	113	8.7	91	66.1	100	0.5	80	98.1	101	105	7
	Schooner	3.36	73	10.4	109	67.0	102	0.7	119	96.6	99	91	7
	Scope	4.36	94	9.8	103	66.2	101	0.6	95	97.0	100	98	7
	SouthernStar	4.27	92	9.7	102	66.9	102	0.4	69	98.3	101	-	
	Malt 1 receival standard			*9-12%*		*>65.0*		*<7.0*		*>70*			
Unclassified	Explorer (EB1401)	5.25	114	8.9	93	63.4	96	0.8	137	97.0	100	-	
Pending malt accreditation	Spartacus CL	4.38	95	9.8	103	67.1	102	0.7	115	96.9	100	-	
	Compass	3.96	86	9.3	98	64.2	98	0.4	58	98.5	101	106	5
	Site Average	4.62	100	9.5	100	65.8	100	0.6	100	97.4	100		
	LSD (P≤0.01)	0.66		0.88		1.35		0.28		1.03			

- *Insufficient data (included in Hart barley variety trials for less than three seasons)*

Comparison of durum varieties

Sarah Noack, Hart Field-Site Group

Key findings

- The average grain yield for all durum varieties was 4.08 t/ha and the highest yielding variety was Yawa, closely followed by Tjilkuri.
- Grain protein levels were low however, test weight values were high and no varieties exceeded 5% screenings at Hart in 2016.

Why do the trial?

To compare the performance of new durum varieties and lines against current industry standards.

How was it done?

Plot size	1.75 m x 10 m	**Fertiliser**	DAP (18:20) + Zn 2% @ 100 kg/ha
Seeding date	10th May 2016		UAN (42:0) @ 87 L/ha, 4th July

The trial was a randomised complete block design with three replicates and seven varieties. Fungicides and herbicides were applied as necessary to keep the crop canopy free of disease and weeds.

All plots were assessed for grain yield, protein, test weight and screenings with a 2.0 mm screen.

Results and discussion

Durum grain yields ranged from 3.48 t/ha to 4.72 t/ha, with a site average yield of 4.08 t/ha (Table 1). This season the highest yielding variety was Yawa, closely followed by Tjilkuri. Long-term yields for durum varieties shows Yawa, Hyperno and DBA-Aurora are consistently high yielding at Hart.

Grain protein levels were low, with majority of varieties falling below 10% and into the feed grade. All varieties were well above the minimum test weight value of 76 kg/hL (minimum required for maximum grade), averaging 81 kg/hL. Screening levels across the trial were low and no varieties exceeded 5%.

Table 1. Grain yield (t/ha), protein (%), test weight (kg/hL) and screenings (%) for durum varieties at Hart, 2016. Average grain yield (% of trial average) of Hart durum variety trials (2012-2016) and number of trials.

Variety	Grain yield t/ha	% of site average	Protein %	% of site average	Test Weight kg/hL	% of site average	Screenings %	% of site average	Mean yield %	No. of trials
Caparoi	3.60	88	10.6	116	81.3	100	0.7	123	95	5
Tamaroi	4.01	98	9.4	103	80.9	100	0.7	122	92	5
Saintly	3.48	85	9.7	106	81.4	100	0.6	110	99	5
Hyperno	4.13	101	8.2	89	81.8	101	0.3	57	102	5
DBA-Aurora	4.16	102	8.6	94	80.5	99	0.7	119	102	3
Tjilkuri	4.47	109	9.0	98	81.2	100	0.4	78	97	5
Yawa	4.72	116	8.6	94	80.9	100	0.5	91	105	5
Site Average	**4.08**	**100**	**9.1**	**100**	**81.1**	**100**	**0.6**	**100**		
LSD (P≤0.05)	0.22		0.8		0.7		0.4			

Optimising cultivar and time of sowing in wheat

Rochelle Wheaton, Hart Field-Site Group

Key Findings

- The highest yielding treatment was Trojan sown on the 26th May at 5.96 t/ha.
- RAC2341 has shown good adaption to SA conditions as a Winter variety and its potential release could provide growers with an earlier sowing option.

Why do the trial?

The majority of current wheat varieties need to be sown in the first half of May to flower during the optimal period (mid-September for Hart) for grain yield. Recent work has validated that currently available Winter varieties (e.g. EGA Wedgetail and Rosella) bred for NSW, are not suited to SA conditions. This can be attributed to the fact that once these varieties meet their vernalisation requirement they still require a long period until they reach flowering (outside optimal flowering window).

Over the last two seasons (2014 and 2015) this trial work has been conducted over similar seasonal conditions in terms of dry and warm finishes. The trial was repeated in 2016 to see if results from cool and wet Spring conditions could be achieved. Cultivar selection was also modified to include RAC2341 which has shown potential as a long season wheat adapted to SA.

Another limitation in the current trial methodology is seeding rate (100 plants/m^2). It follows the traditional theory of 'sow early, sow light'. This seeding rate is well below the target seeding rates used in early May (180 plant/m^2). A seeding rate factor was added to the trial to identify the optimal time of sowing and seeding rate for each cultivar.

How was it done?

Plot size	1.75 m x 10.0 m	**Fertiliser**	DAP (18:20) + 2% Zn @ 100 kg/ha @ seeding
Seeding date	ToS 1 – 21st April ToS 2 – 10th May ToS 3 – 26th May		Urea (46:0) @ 120 kg/ha split application at GS30 and GS32 based on Mace at each ToS

The trial was a randomised block design with three replicates, two target plant densities (100 and 200 plants/m^2) and three varieties (Table 1). Fungicides were applied as necessary to keep the crop canopy free of disease (i.e. stripe rust). Crop growth stages were recorded between the 20th June and the 24th October to identify the flowering time for each treatment. All plots were assessed for grain yield, protein, test weight and screenings with a 2.0 mm screen.

Table 1. Wheat cultivar and maturity for varieties trialled at Hart, 2016.

Variety	Maturity	Comments
Mace	Early to mid-maturing Spring	High yielding AH quality variety SA main season benchmark for mid-late May sowing
Trojan	Mid to late maturing Spring	High yield potential in medium to high rainfall areas with early sowing situations
RAC2341	Fast maturing Winter	Fast to develop once its vernalisation requirement has been met

Results and discussion

The 2016 growing season started with minimal opening rains with only 11 mm of rainfall in April. To ensure even establishment of the earliest time of sowing treatments (21st April) irrigation was required. These plots were irrigated with the equivalent of 10 mm of rainfall (one day prior to sowing). The remaining time of sowing treatments did not require irrigation for establishment.

Hart is not generally considered a frost prone area however, minor frost damage was evident in some treatments (variety and ToS dependent). Minimum air temperature data collected from the site's weather station (Table 2) indicated mild frost events (≤ 1°C) may have occurred through August to October. This should be taken into account when interpreting results.

Table 2. Minimum air temperatures of 1°C or less recorded by the Hart weather station.

Date	2-Aug	25-Aug	26-Aug	27-Sep	23-Oct	31-Oct
Temperature (°C)	0.2	0.9	-0.4	0.7	0.1	0.7

Plant and tiller number

Plant establishment counts were carried out when plants had reached the 1-2 leaf stage to calculate plant densities. Actual plant densities were 103 plants/m^2 on average for the 100 plants/m^2 and 176 plants/m^2 for the 200 plants/m^2 treatment. Plant density did not differ significantly between varieties at any of the times of sowing. As RAC2341 is classified as a Winter type, it was expected that this variety would produce more tillers/m^2 than the Spring varieties. The tillering ability of RAC2341 was evident as it produced a higher amount of tillers/m^2. On average, for all times of sowing and seeding rates, RAC2341 produced 703 tillers/m^2 (Table 3). Spring varieties, Trojan and Mace averaged 443 and 449 tillers/m^2, respectively.

Table 3. Average plant and tiller numbers across both seeding rates and time of sowing for each variety used in this experiment.

Variety	Plants/m^2	Tillers/m^2
Mace	134	449
Trojan	141	443
RAC 2431	143	703
LSD (P≤0.01)	ns	55.7

Grain yield

The highest yielding treatment was Trojan sown in late-May at 5.96 t/ha (Table 4). Mace and RAC2341 also yielded highest when sown on the 26th May (ToS 3) at 5.37 and 5.10 t/ha, respectively. This is in contrast to 2014 and 2015 where varieties sown in mid-April and early May were favoured by the warm and dry finish. Interestingly, none of the highest yielding treatments in 2016 flowered during the optimal flowering time to maximise grain yield at Hart (considered to be mid-September). The wet and cool Spring provided favourable conditions for later sown crops to grain fill without heat stress which was evident in previous seasons.

Varieties sown on the 21st April (ToS 1) and 10th May (ToS 2) were generally 1.0 t/ha lower yielding compared to ToS 3. This can be attributed to greater exposure to mild frost temperatures and rain/hail damage which may have contributed to minor yield loss. For example, Mace sown on the 21st April (ToS 1) was at mid-flowering during mild frost events in August (Figure 1) and yielded 1.4 t/ha less than at ToS 3.

Grain yield did not differ significantly between seeding rates for any of the wheat varieties or times of sowing investigated. This shows that there was no yield penalty for sowing early at a lighter rate at Hart. However, this trial was managed to prevent weed and other pressures influencing grain yield. The results from this trial indicate that seeding rate could be lowered for earlier times of sowing provided that adequate early weed control could be achieved.

Grain quality

Protein varied across both ToS and variety with only two treatments consisting of a protein level above 10%. These treatments were RAC2341 sown on the 21st April (ToS 1) and Mace sown on the 10th May (ToS 2) with 10.3% and 10.1%, respectively. These two treatments were also the lowest yielding for each variety indicating a likely “dilution effect”. None of the commercially available varieties were able to achieve the minimum protein level required for Hard 1 or APW classification.

Test weight also differed between ToS and variety. All treatments were above 76 kg/hL the minimum required for maximum grade with an overall average of 81.8 kg/hL. Screening levels for all treatments were also well below the maximum level for of 5% for maximum grade.

Table 4. Grain yield and quality for all wheat varieties trialled at Hart, 2016 (LSD, P≤0.01 is for the interaction between variety and time of sowing).

	Yield (t/ha)			Protein (%)		
	21st April	10th May	26th May	21st April	10th May	26th May
Mace	4.03	3.98	5.37	9.6	10.1	9.1
Trojan	4.82	5.01	5.96	9.4	8.8	8.3
RAC 2341	4.03	4.89	5.10	10.3	9.3	9.5
LSD (P≤0.01)		0.29			0.6	
	Test weight (kg/hL)			Screenings (%)		
	21st April	10th May	26th May	21st April	10th May	26th May
Mace	79.1	80.8	81.9	0.4	0.4	0.9
Trojan	80.9	83.0	83.9	0.4	0.3	0.8
RAC 2341	81.0	82.6	82.9	0.2	0.4	0.2
LSD (P≤0.01)		0.6			0.1	

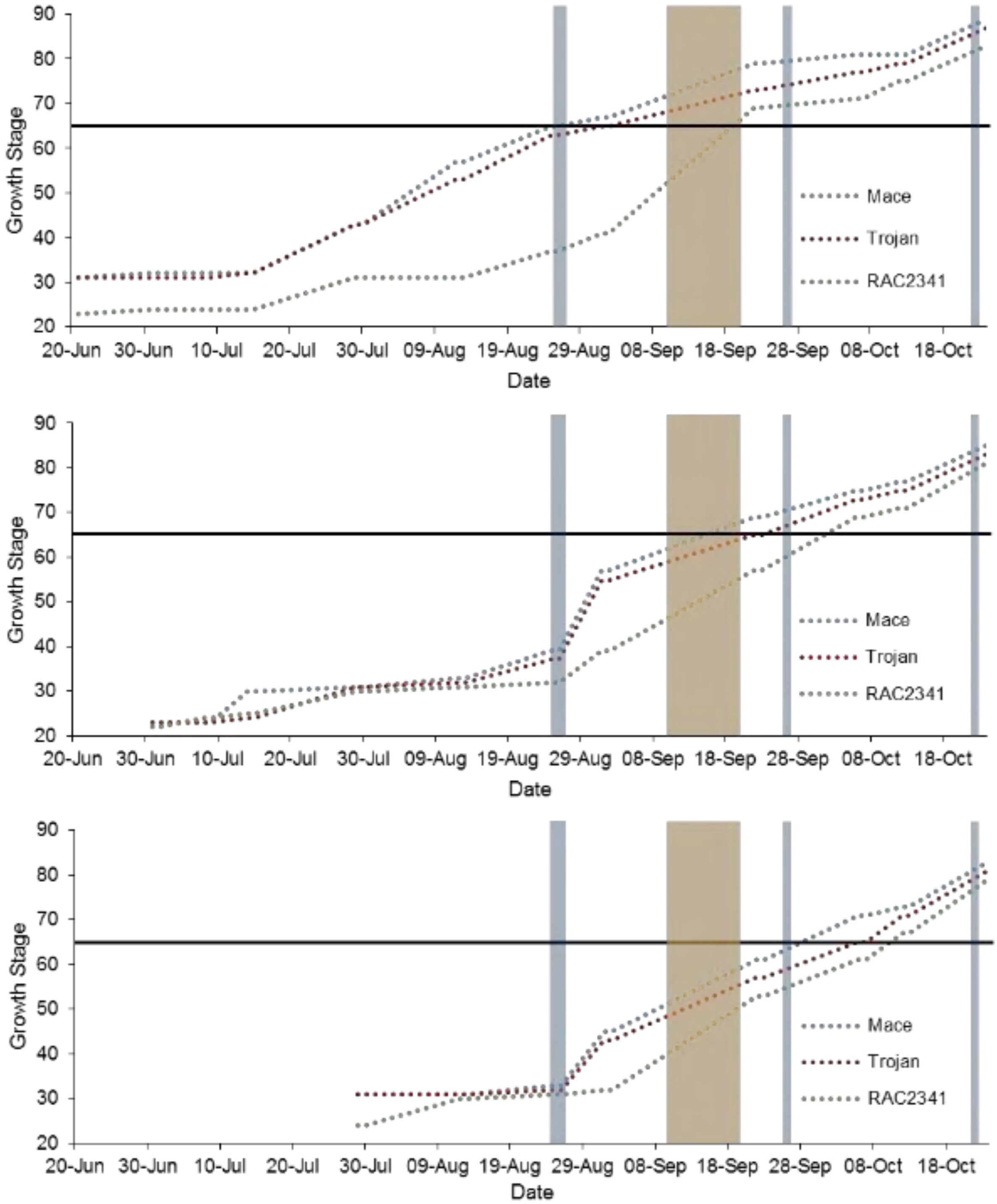

Figure 1. Growth stage assessment for all varieties and times of sowing 20th April (top), 10th May (middle) and 26th May (bottom) between 20th June and 24th October at Hart, 2016. The black horizontal black line represents mid-flowering (GS65) and the transparent yellow rectangle displays the optimal flowering window around the 15th September. The blue transparent rectangles indicate when minor frost events may have occurred.

Summary / implications

The 2016 season favoured later sowing due to favourable Spring conditions and above average rainfall in September. Overall Hart experienced above average rainfall for the 2016 growing season minimising stress from low water availability. Heat stress during flowering and grain fill was minimal due to the cooler Spring conditions. This is in contrast to 2014 and 2015 where the site experienced warm and dry finishes to the growing season. These seasons also consisted of below average rainfall which favoured varieties sown in mid-April and early May. Highest yielding treatments during these seasons were those that were able to flower at the optimal time.

Breeding new lines like RAC2341 will provide growers with better options for early sowing opportunities. However, continued evaluation of such lines will be required to better determine their fit in SA environments.

Left: Hart's regional intern Rochelle Wheaton taking plant establishment counts in this trial.

Below: looking over the wheat time of sowing trial at Hart.

Canola agronomy and phenology to optimise yield

Andrew Ware[1], Blake Gontar[1], Jacob Giles[1], Christine Walela[1], Ian Ludwig[1], Julianne Lilley[2], John Kirkegaard[2], Rohan Brill[3], Therese McBeath[2], Jeremy Whish[1], Michael Moodie[4]

[1]SARDI, New Variety Agronomy, [2]CSIRO, Food and Agriculture, [3]NSW DPI, Wagga Wagga, [4]Moodie Ag, Mildura

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Key findings

- Improved knowledge of how canola varieties develop in differing regions and the drivers behind development will assist growers in choosing the correct variety for a particular sowing opportunity.
- The development of site specific optimal flowering windows, where the balance between plant growth and frost and heat risks are accounted for, will allow growers and advisors to match canola variety selection with sowing opportunities.
- Nitrogen is an important driver of canola yields in above average seasons. Low risk techniques to ensure adequate nitrogen supply are critical to capitalise on above average rainfall in the low rainfall zone.

Background

Research to better understand yield drivers of canola in eastern Australia commenced in 2014 to 2016 focusing on improving the profitability of canola as part of the “Optimised Canola Profitability (OCP)” project. The research is targeted at low to medium rainfall zones of Eastern and Southern Australian cropping regions and is a collaboration between CSIRO, NSW DPI and GRDC, in partnership with SARDI, CSU, MSF and BCG. The project links closely with similar GRDC supported projects in Western Australia and high rainfall zones (HRZ).

2016 Season

The 2016 season in South Australia was typified by average to above average rainfall in most of the cropping region between April and August. Significantly higher than average rainfall fell in September and October. Average daily temperatures (daily maximum minus daily minimum divided by two) tended to be average to slightly warmer than normal between April and August and then considerably below average in September and October. Solar radiation was lower than normal (about 8% below average figures) placing 2016 as having one of the lowest cumulative totals of solar radiation for the growing season on record.

All of these factors had an effect on canola yields observed in 2016, challenging some of the results gathered by this project in previous years.

2016 Results

Similar to 2014 and 2015, in 2016 three time of sowing (ToS) x variety experiments were conducted at Yeelanna (Lower EP), Hart (Mid-North) and Lameroo (Murray Mallee). The grain yields show that the 2nd and 3rd sowing times at Yeelanna and Hart and the 1st and 2nd at Lameroo resulted in the highest yields in 2016. In general, these results are a reflection of the cooler and wetter finish to the 2016 season.

Table 1. Grain yields (t/ha) from time of sowing x variety experiments conducted at Yeelanna, Hart and Lameroo in 2016.

Variety	Yeelanna			Hart			Lameroo		
	8 April	20 April	6 May	15 April	2 May	16 May	13 April	28 April	12 April
44Y89CL	3.11	3.76	2.99	2.16*	2.67	2.83	2.11	2.41	1.83
45Y88CL	3.86	3.22	3.77	2.36*	2.81	3.08	2.01	2.19	1.53
Archer	3.72	3.87	3.43	2.80	3.17	3.05	2.14	1.86	1.27
ATR_Gem	2.72	2.78	3.40	1.69*	2.47	2.31	2.04	1.74	1.24
ATR_Stingray	2.11	2.89	2.42	2.00*	2.77	2.92	1.24	1.82	1.38
Hyola559TT	3.45	3.49	3.78	2.47*	3.03	3.05	2.18	2.31	1.61
Hyola575CL	2.91	4.04	4.45	1.98*	2.58	2.61	1.71	1.87	1.67
Hyola750TT	3.53	3.42	3.20	2.23*	2.81	2.39	2.09	1.65	1.17
Nuseed_Diamond	3.35	4.19	4.36	1.94*	2.08	3.26	1.80	2.74	1.76
Average	3.20	3.52	3.53	2.18*	2.71	2.83	1.92	2.06	1.50
lsd 5% (TOS)	0.16			0.18			0.17		
lsd 5% (variety x TOS)	0.47			0.53			0.52		
p (variety x TOS)	<.001			<.001			0.03		
GS Rainfall (Jan-Mar)	449 mm (71mm)			330mm (62mm)			300mm (47mm)		

* Yield adjusted to account for bird damage

The 2016 experiments showed that the short season variety Nuseed Diamond sown at ToS3 gave the highest grain yields at Yeelanna and Hart. The longer season variety, Archer yielded well in ToS1, but failed to match the yields of Nuseed Diamond sown late.

It should be noted that early flowering varieties sown early suffered from higher levels of upper canopy blackleg and sclerotinia infection compared to later sowings.

Given that experiments in previous years have demonstrated considerable benefits from sowing early, results from 2016 raise the question of how yields can be maximised in every season. The 2016 season was a usual year from a historical sense of the grain growing regions of South Australia. This season demonstrated how important it is to capitalise on the opportunities of late season rainfall.

How do canola varieties develop and why is it important?

The most common and easily recognised stages of canola development are emergence, green bud, flowering, podding and maturity. The development of canola crops is largely driven by temperature (thermal time), but is also affected by vernalisation and photoperiod to differing degrees in different varieties.

Thermal Time

Day degrees are the units of a plants biological clock. They are a way of combining time and temperature into a single number. To calculate the thermal time target for a plant's development stage you accumulate the day degrees until a specific target is reached, e.g. variety X accumulates 1000 degree days between emergence and flowering.

Vernalisation

Vernalisation can be described as a low temperature promotion of flowering. For canola if the average temperature is two degrees or below, then one vernal day is accumulated, no vernal days are accumulated if the average temperature is below zero or greater than 15. Between two degrees and 15 degrees only a proportion of a vernal day is accumulated.

There are two types of vernalisation; obligate and facultative.

Obligate vernalisation is the need for a plant to accumulate cold days before the day degree calculation can begin. This typically drives the development of Winter type canola varieties.

Facultative vernalisation occurs in both Spring and Winter type canola. It simply means the more cold days the plant accumulates between sowing and floral initiation (stage before green bud) the lower the thermal time target required.

Photoperiod (Day length)

Photoperiodism, is the response of plants to increasing or shortening day lengths. Long day plants (canola) respond to increasing day length. As you move from Winter to Summer the days lengthen and the crop requires fewer day degrees to move between growth stages so flowers earlier.

Once the drivers of phenological development for a particular variety are understood they can be used in models, such as APSIM, to determine how they will grow and develop in a particular environment. But to maximise yield, as discussed previously, an optimal flowering window for that environment needs to be developed and then an optimal sowing date for the variety extrapolated.

Optimal flowering period (OFP) for canola in South Australia

Crops which flower too early may have insufficient biomass or frost damage, while late flowering increases heat and water stress. Despite its importance, OFPs for canola have not been comprehensively defined for canola across eastern Australia's cropping zone, especially for crops sown prior to the traditional sowing window (late April to early May). Identifying the OFP is a first step to establish appropriate variety by sowing date combinations to optimise yields in different environments.

As seen in Figure 1, APSIM modelling can be used to develop an OFP for an example environment, where flowering ideally occurs when frost and heat stress risk are minimised. Once this is known the ideal sowing date can be generated for a variety based on historical meteorological data and knowledge of the drivers of the variety's phenological development.

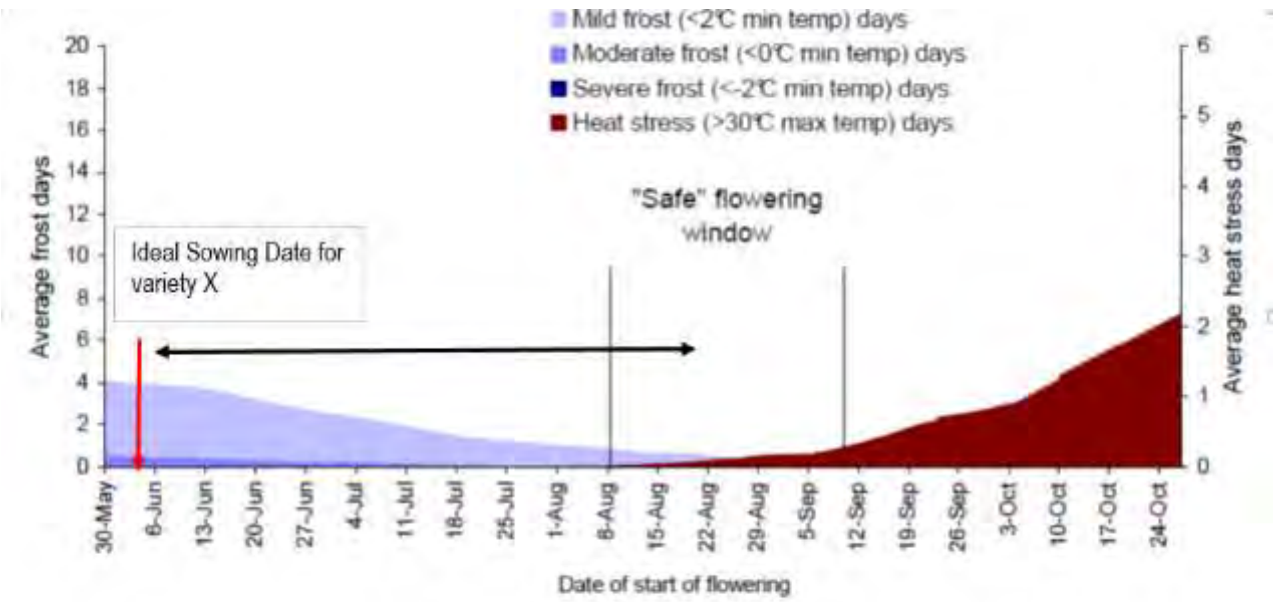

Figure 1. Example of how an optimal flowering period is generated and then an ideal sowing date is developed for an example environment.

Once an optimal sowing date for a particular variety is known then historical meteorological data can be used to determine how likely a sowing opportunity within the optimal window occurs for that location (Figure 2).

The development of OFP for South Australia is now well advanced and an increased understanding on the phenological drivers of recently released canola varieties is also being updated into crop models such as APSIM, meaning that growers and advisers will shortly have access to techniques that offer the potential improve canola productivity in their region.

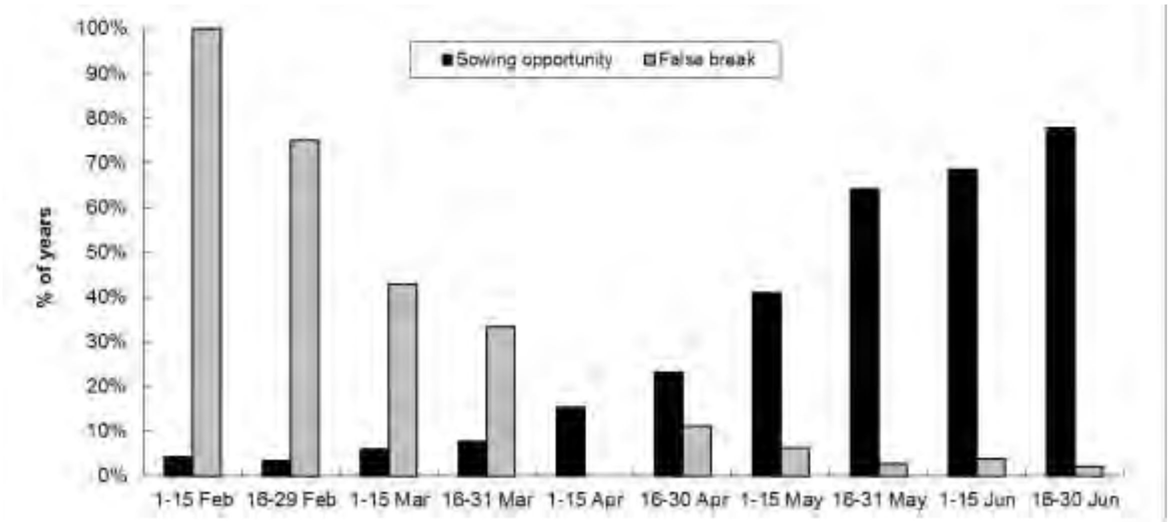

Figure 2. Hart sowing opportunities: for fortnightly periods the frequency of years with a sowing opportunity (i.e. rainfall > pan evaporation over 7 days) and the likelihood of a false break with no further effective rain (i.e. rainfall < pan evaporation over 7 days) in the subsequent 6 weeks.

Conclusion

The grain yields achieved in field experiments conducted at Yeelanna, Hart and Lameroo in 2016 showed that having the correct variety x ToS combination enabled yields to be maximised. An increased understanding of how a canola variety develops can be used in combination with the development of OFPs for a particular location so that optimal sowing times can be generated. Managing canola risk in low rainfall areas remains challenging if yields are to be maximised in above average rainfall seasons.

Acknowledgements

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Contact details

Andrew Ware
PO Box 1783 Port Lincoln, SA 5606
0427 884 272
andrew.ware@sa.gov.au

Faba bean agronomy and canopy management

Christine Walela[1], Jeff Paul[2], Amanda Pearce[3] Andrew Ware[4], Jason Brand[5], Larn McMurray[1]

[1]SARDI Clare, [2]University of Adelaide, [3]SARDI Struan, [4]SARDI Port Lincoln, [5]DEDJTR Victoria,
GRDC Project Code: GRDC project DAV00150 (Southern Pulse Agronomy)

Key findings

- Grain yields were increased by sowing early (mid-April to early-May) over later sowing (end of May) under the favourable growing seasons experienced at Hart in 2016, in contrast to similar climatic seasons in higher rainfall areas of SA such as Tarlee.
- Varieties with agronomic characteristics of early flowering and high biomass production optimised yields.
- There was no change in grain yields from application of plant growth regulators (PGRs) on early sown faba beans.
- Agronomic traits related to improved harvestability were observed from some PGRs, however further field testing will be required to better understand the best application timings and quantify benefits.

Why do the trial?

Choosing the optimum sowing time is key to managing and reducing abiotic stress and increasing yields of pulses. Pulses are particularly sensitive to abiotic stresses associated with cold/frosts and heat during the reproductive stages of podding and grain filling. Due to an expansion of faba bean production outside of traditional areas and the development of new varieties with improved agronomic traits, an understanding of optimum sowing time by variety will help to maximise yields in different environments.

Early sowing of faba beans, particularly in favourable environments and seasons, results in large bulky canopies potentially leading to issues with light and pollinator penetration, flower retention, pod-setting and disease management. Agronomic evaluation of canopy management strategies using plant growth regulator (PGR) hormones is needed to better understand the impact of modifying plant architectural traits such as height and stand ability on yields. Faba bean sowing date by variety and canopy management trials were sown at Hart in 2016 to improve the understanding of production in non-traditional areas along with providing a contrasting information source to similar experiments sown at Tarlee in a more traditional and favourable faba bean producing region.

How was it done?

The sowing date by variety trial was designed as a split plot randomised complete block design with sowing date as the main plot and faba bean varieties as the sub-plots replicated three times. Nine faba bean varieties, including, five commercial varieties (Farah, PBA Zahra, PBA Rana, Nura and PBA Samira), three advanced breeding lines (AF09167, AF09169 and AF1212) and one experimental determinant line (AF13250) were sown at three sowing dates, 14 April, 7 May and 26 May. The advanced breeding lines were chosen to evaluate their adaptation in high biomass producing environments and to explore their potential in low rainfall faba bean growing areas.

The determinate line has a growth type similar to lupins with characteristics of a terminal inflorescence that develops after the plants have developed flowers at about 4 or 5 nodes at which growth in plant height is restricted. This experimental line was included in our trials to help understand the potential of this trait in managing canopy growth where conventional plant types may produce too much vegetative growth at the expense of grain yield. Plots measured 10 m x 1.35 m. Sowing was direct drilled with a narrow point plot cone seeder at a depth of 5-7 cm with 22.5 cm (9 inches) row spacing.

Sowing occurred in relatively dry seed bed conditions, requiring an irrigation event of 20 mm of water immediately post sowing to enhance seed germination. MAP was applied at sowing at a rate of 100 kg/ha. Strategic fungicide and insecticide sprays were applied during the growing season to prevent disease and pests in line with the standard district practice for beans. Agronomic measurements and observations were taken including phenology, dry matter weight and grain yield.

The canopy management trial was sown on 14 April and standard trial design, layout and management, including an irrigation event to aid emergence, was done as for the sowing date trial. Treatments were a) nil; b) ethephon & trinexapac-ethyl - ethephon was applied at 8 node followed by trinexapac-ethyl at plant budding; c) paraquat & diquat herbicide – applied at a rate of 250 ml/ha at 8 node; d) Physical terminal bud removal (by hand pinching to simulate slashing/grazing) at 8 node. Faba bean variety PBA Samira, was used in the trial due to its suitability in medium and high rainfall faba bean districts. Agronomic measurements assessed included plant height, lodging, and grain yield. Plant heights were only taken at commencement of flowering as plants were lodged heavily at the time of harvest.

Results and discussion

Review of seasonal conditions, 2016

The Hart field site received a growing season rainfall of 356 mm in 2016, which was above the long term average of 305 mm. The last month of Autumn recorded a total of 36 mm marking the break to the season, which was followed by wet conditions in Winter and heavy rains in early to mid-Spring. Wet conditions favoured early crop vigour and provided conditions for beans to develop large canopies. Wet conditions also favoured development of disease and small outbreaks of ascochyta blight (AB) were observed in varieties such as Farah, PBA Rana and PBA Zahra. Strategic sprays during vegetative growth, at canopy closure and during podding were applied to control AB in the trials. Cool, wet conditions during Spring favoured pod filling and prolonged maturation of crops. As a result, significantly high yields above long term averages were recorded.

Sowing date by variety trial

Flowering and biomass production

The advanced breeding line AF09169, sown mid-April, flowered 25 days earlier than Farah, AF09167, AF11212 and AF13250 which all flowered at similar dates (Table 1). Commercial varieties Nura, PBA Rana and PBA Samira sown mid-April flowered less than 10 days from each other but one month after the advanced breeding line, AF09169. Differences in variety time to flower when sown in early and late May decreased considerably compared with the earlier sowing date. The early flowering varieties flowered between 10 and 17 days earlier than the later maturing varieties (Nura, PBA Rana and PBA Samira) at the May 7 sowing and the difference was even less at the last sowing date (27 May).

Table 1. Calendar date and number of days from sowing to commencement of flowering of nine faba bean varieties sown at three different dates at Hart field site, 2016.

Variety	Date of commencement of flowering			No. of days to commencement of flowering from sowing date		
	Time of sowing			Time of sowing		
	14-Apr	7-May	26-May	14-Apr	7-May	26-May
AF09167	26-Jul	5-Aug	22-Aug	103	90	88
AF09169	1-Jul	5-Aug	23-Aug	78	90	89
AF11212	26-Jul	8-Aug	22-Aug	103	93	88
AF13250	29-Jul	11-Aug	24-Aug	106	96	90
Farah	26-Jul	5-Aug	22-Aug	103	90	88
Nura	6-Aug	22-Aug	25-Aug	114	107	91
PBA Rana	5-Aug	15-Aug	25-Aug	113	100	91
PBA Samira	8-Aug	22-Aug	26-Aug	116	107	92
PBA Zahra	29-Jul	15-Aug	25-Aug	106	100	91

*Commencement of flowering was taken as 50% flowering and determined by 50% of plants within plot having one opened flower

Varieties differed in the amounts of biomass produced at commencement of flowering however, this was dependent on sowing date (Table 2). Most varieties recorded higher amounts of biomass from the earliest sowing date while the two later sowings recorded lower and more variable biomass between varieties. Early flowering varieties Farah, AF09167, AF11212 and AF13250 recorded lower amounts biomass at the mid and later sowing dates compared to the early sowing date. Similarly, later flowering varieties PBA Zahra and PBA Rana, had reduced dry matter weight with delayed sowing. In contrast, the biomass of Nura and PBA Samira was unaffected by sowing date. It is worth noting that beans produced higher amounts of biomass at flowering in 2016 compared with the previous year at this site.

Table 2. Dry matter production (t/ha) at commencement of flowering of nine faba bean varieties sown at three different dates at Hart, 2016.

Variety	Dry biomass weight (t/ha)		
	Time of sowing		
	14-Apr	7-May	26-May
AF09167	4.28	3.29	2.51
AF09169	3.58	3.11	3.07
AF11212	3.38	2.38	2.53
AF13250	4.72	2.89	3.19
Farah	5.31	2.48	2.75
Nura	3.91	3.69	3.04
PBA Rana	4.97	3.64	2.65
PBA Samira	4.03	4.93	3.69
PBA Zahra	5.14	4.63	3.05
LSD (P≤0.05)		**1.09**	

Grain yield

There was no sowing date by variety interaction for grain yields at this site. Sowing early in mid-April and early-May resulted in higher yields than late sowing at the end of May (Figure 1). Bean varieties yielded exceptionally well ranging from 5.5 to 6.3 t/ha (Figure 2), which was well above long term averages for this site. Two early flowering varieties, AF09169 and AF11212 had the highest yields, equal to the commercial variety PBA Zahra. All other varieties had lower yields with little to no differences between them.

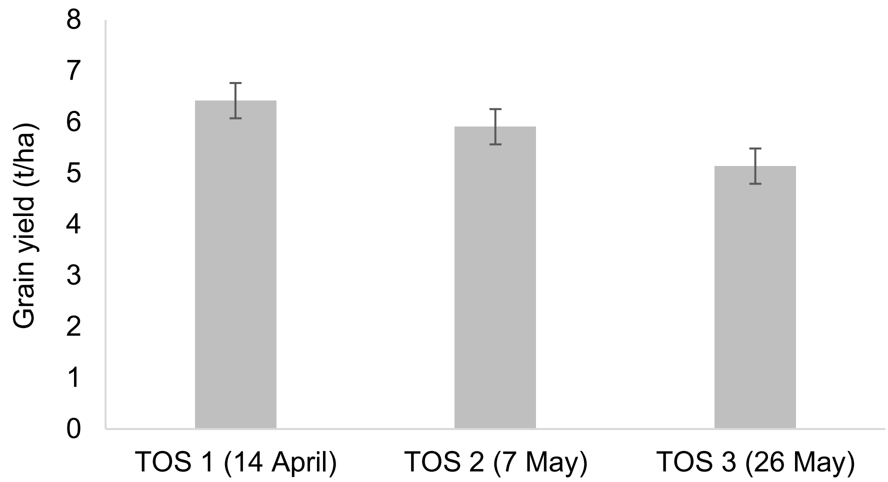

Figure 1. Grain yield (t/ha) across three sowing dates averaged across nine faba bean varieties at Hart, 2016.

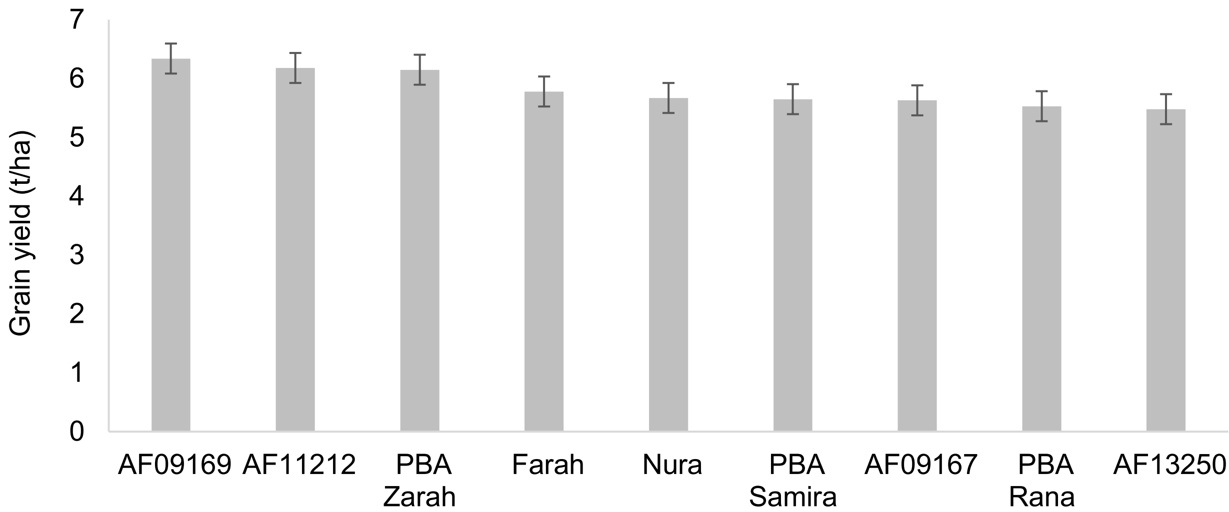

Figure 2. Grain yield (t/ha) of nine faba bean varieties averaged across three sowing dates at Hart, 2016.

Canopy management trial

A treatment response was found for plant height (cm) and lodging (1-9 scale). The treatments ethephon & trinexapac-ethyl and paraquat & diquat significantly reduced plant height compared to the nil and physical terminal bud removal. Lodging was reduced only by the application of ethephon & Terinexapac-Ethyl (Table 3). There was no grain yield response for any PGR treatments trialled, averaging 5.6 t/ha.

Table 3. Plant height (cm) and lodging (1-9 scale) in faba bean variety, PBA Samira as affected by application of four canopy management treatments, Hart, SA, 2016.

Treatment	Plant height (cm) at flowering	Lodging (1-9 scale)*
Nil	53	2
Physical terminal bud removal	48	2
Ethephon & trinexapac-ethyl	36	5
Paraquat & diquat	34	3
LSD (P = 0.05)	**11.60**	**1.13**

*Lodging scores 1-9 scale where 1 = flat and 9 = erect; numbers represent angle from ground as follows: 0-10° = 1, 11-20° = 2, 21-30° = 3, 31-40° = 4, 41-50° = 5, 51-60° = 6, 61-70° =7, 71-80° = 8, 81-90°=9

Summary / implications

Above average rainfall during the faba bean growing months favoured early crop vigour and provided ideal conditions for development of high biomass canopies. Further, cool and wet Spring conditions during pod-filling led to prolonged maturation contributing to significantly higher yields at this site. Pulse crop yields are strongly driven by environmental conditions in Spring, particularly the length of grain filling period which is largely influenced by availability of soil water and optimum temperature. The current results should therefore be interpreted in the context of the favourable season. It is also interesting to note that despite the extremely high yields and favourable growing season, early sowing was still beneficial in faba beans at Hart in 2016 in contrast to similar climatic seasons in higher rainfall areas of SA such as Tarlee.

The advanced breeding line AF09169 sown in mid-April, flowered 25 days earlier than varieties with similar flowering profile suggesting the existence of genotypic variation in sensitivity to environmental factors such as photoperiod and temperature. This variety was also equal to AF11212 and PBA Zahra, which indicates that the three varieties were responsive under favourable Spring conditions. The two highest yielding advanced breeding lines, AF09169 and AF11212 produced the least amount of biomass compared with other varieties at this site. Results from sowing date by variety trials over a number of seasons are now starting to show differences between varieties in biomass production at the early sowing date and these associations will be explored in our future trials. Compared to other commercial varieties, the newly released PBA Zahra is characterised by high biomass production and early canopy growth and it is more suited to favourable environments and seasons. The experimental determinate faba bean line AF13250 had low yields similar to Farah, which may be explained by susceptibility to disease (rust) and weather damage due to its determinate growth habit, where the inflorescence and pods are exposed at the top of the plants.

Trial results from various sites in SA over the last three years have shown that some PGRs, ethephon and trinexapac-ethyl, were consistently associated with a reduction in plant height together with resistance to lodging and necking without compromising grain yields in faba bean. Ethephon, which, breaks down in plants and releases ethylene which in turn inhibits the growth of the terminal shoot thereby enhancing lateral growth with a corresponding reduction in height. Application timing has been shown to be important for effectiveness of PGR with an early application timing at 8 node growth stage more responsive than later applications pre-flowering.

Acknowledgement

Funding for this work was provided through GRDC project DAV00150 (Southern Pulse Agronomy) and their support is greatly appreciated. We also acknowledge the support of research colleagues from the SARDI teams at Clare. Much gratitude also goes to Hart field site management for hosting the trials over the years.

Lucy (10 years old) standing in the first bean ToS treatment at Hart on Sept 3, 2016.

Managing Compass barley with nitrogen and PGRs

Rochelle Wheaton and Sarah Noack, Hart Field-Site Group

Key findings

- The application of a plant growth regulator (PGR) significantly reduced plant height for all nitrogen rates (0-80 kg N/ha).
- Grain yield increased with higher nitrogen rates, however PGR application had no effect.
- The highest yielding treatment was a combination of 80 kg N/ha + PGR at 4.66 t/ha.

Why do the trial?

Variety specific management has been investigated over the years with a particular focus on nitrogen rates and timing as part of the GRDC-funded 'Barley Agronomy for the Southern Region' project.

The barley variety Compass was chosen for this trial as it is a newer variety which has been rapidly adopted by growers in SA. Compass has similar traits to Commander and has also been associated with lodging problems in high yielding environments.

The aim of this trial was to investigate the effects of different rates of nitrogen +/- plant growth regulator (PGR) treatment on plant height, lodging, head loss and yield. Moddus Evo was used in this trial as is currently the only PGR registered for use in barley to reduce lodging and suppress head loss.

How was it done?

Plot size	1.75 m x 10.0 m	**Fertiliser**	No fertiliser at seeding
Seeding date	10th May 2016	**Variety**	Compass

The trial was a randomised block design with three replicates and six treatments made up of different combinations of nitrogen rates and PGR applications (Table 1). Nitrogen applications were spread on the 27th July at the beginning of stem elongation (GS31). The PGR treatment of Moddus Evo was applied during this time at a rate of 400 mL/ha.

Normalised difference vegetation index (NDVI) assessments were conducted using a Greenseeker® on the 7th July to measure plant "greenness". Plant height (base of the stem to the top of the grain head) was also measured during late October.

Fungicides and herbicides were applied as necessary to keep the crop canopy free of disease and weeds. All plots had the edge rows removed prior to harvest and were assessed for grain yield, protein, test weight, screening with a 2.2 mm screen and retention with a 2.5 mm screen.

Results and discussion

Plant height and NDVI

Nitrogen rate had a significant effect on plant height, with higher nitrogen rates associated with taller plants (Table 1). The application of a PGR also influenced plant height with an overall reduction of 9 cm or more. However, the interaction between plant height and PGR application was not statistically significant.

NDVI readings varied between the nitrogen rates applied. There was a step wise increase in NDVI with increasing nitrogen rate from 0, 40 to 80 kg N/ha (Figure 1). These lower readings indicate less crop nitrogen and biomass in these plots. The application of PGR did not affect the NDVI value for the respective nitrogen rate.

Despite differences in canopy height and biomass, significant lodging was not observed in the trial which is not reflective of many paddocks in 2016. The photos below show that the addition of PGR had little effect as the barley plants were upright in all treatments (Figure 2).

Table 1. Effect of nitrogen rate and application of a PGR on average Compass barley plant height (cm) at Hart, 2016.

	Plant height (cm)	
N rate	**- PGR**	**+ PGR**
0 kg N/ha	55.2	45.2
40 kg N/ha	70.5	59.3
80 kg N/ha	80.1	71.3
LSD (P≤0.05)		
PGR	3.4	
N rate	2.6	
PGR x N rate	ns	

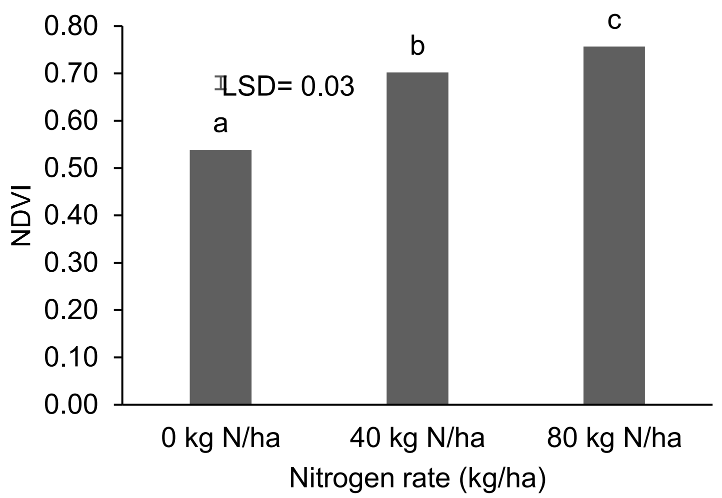

Figure 1. Effect of nitrogen rate on NDVI at Hart, 2016. Where present, different letters denote significant differences (P≤0.05) between treatments.

Figure 2. Compass barley plants treated with PGR (right) and control treatment (left) both treatments spread with urea at 0 kg N/ha, 40 kg N/ha and 80 kg N/ha (L-R in each photo).

Grain yield

As expected in 2016, higher nitrogen rates increased grain yield. The application of PGR did not increase or decrease grain yield (Table 2). The highest yielding treatment was the combination of 80 kg N/ha with a PGR application at 4.66 t/ha. Minimal lodging within the trial was observed in 2016, meaning the risk of grain yield losses due to lodging was low. Other studies have demonstrated PGR application can improve Compass grain yield (Porker *et al.* 2017). It should be noted, however, that these yield responses have generally been observed in high yielding environments. While Hart is a medium rainfall environment, the trial experienced rain and hail damage during the 2016 season.

Grain quality

Protein levels varied between treatments with a trial average of 9.4%. The varied protein levels did not reflect a clear relationship between treatments however, the application of a PGR did significantly reduce protein levels (Table 2). All treatments fell between the allowable protein range of 9-12% for malt classification.

Similarly, test weights did not indicate a particular trend between treatments. Significant differences between some nitrogen rates were present (Table 2). The combination of 80 kg N/ha + PGR resulted in the highest test weight of 63.9 kg/hL and the lowest was the 0 kg N/ha with a test weight of 62.4 kg/hL. All treatments were below the minimum test weight specification of 65 kg/hL for malt classification.

Screening levels were well below the maximum level of 7% for malt classification. The application of a PGR significantly increased screening levels (Table 2). Similarly, retention levels were well above specification with an overall trial average of 97.9% with an increasing effect as a result of higher nitrogen rates.

Table 2. Summary of average grain yield (t/ha), protein (%), test weight (kg/hL), screenings (%) and retention (%) for each treatment at Hart in 2016.

	Grain yield (t/ha)		**Protein (%)**		**Test weight (kg/hL)**		**Screenings (%)**		**Retention (%)**	
N rate	**-PGR**	**+PGR**	**-PGR**	**+PGR**	**-PGR**	**+PGR**	**-PGR**	**+PGR**	**-PGR**	**+PGR**
0 kg N/ha	2.49	3.02	9.8	9.1	62.4	63.2	0.5	0.7	97.5	97.1
40 kg N/ha	3.10	3.83	9.6	9.2	63.1	63.0	0.4	0.6	98.3	97.6
80 kg N/ha	3.85	4.66	9.5	9.5	63.5	63.9	0.3	0.4	98.5	98.5
LSD(P≤0.05) PGR	ns		0.3		ns		0.15		ns	
N rate	0.55		ns		0.55		ns		0.5	
PGR x N rate	ns		ns		ns		ns		ns	

Summary / implications

With many reports of lodging/crop loss in the Mid-North area during the 2016 season, the application of a PGR could be beneficial in these situations. In all cases, the economic viability of applying a PGR should be considered. On average the application of Moddus Evo provided 0.69 t/ha increase in grain yield (irrespective of N rate). Based on a $140 t/ha Feed 1 delivery price and a $35/ha cost of the application of Moddus Evo, a $61/ha return on investment would be achieved. This falls short of a two for one return on investment, indicating that an application of PGR is not a viable economic management strategy for the Hart area. In higher yielding environments the return on investment may be greater and warrant a PGR application/s.

References

Porker, K, Fettell, N, Coventry, S, Chong, P, McDonald, G and Eglinton, J (2017). *Drivers of barley yield in Southern Australia*. GRDC Update papers 2017.

Wheat grain yield and protein in response to sowing date, nitrogen and variety

Marianne Hoogmoed, Victor Sadras, Rob Wheeler (retired), SARDI, Waite
Sarah Noack, Peter Hooper, Hart Field-Site Group
Barry Mudge, Barry Mudge Consulting

Key findings

- Grain yield responded to the interaction between season, variety, N rate and sowing date.
- The dry finish to the 2015 season meant sowing later reduced yield. Nitrogen application did not affect yield regardless of sowing time.
- The end of 2016 was characterised by a wet and cool finish and yield increased with N, but there was no sowing time effect.
- Nitrogen application generally increased protein. Only in 2015 did late sowing increase protein further.

Why do the trial?

Nitrogen management remains one of the most important and risky decisions for farmers. Breeding for yield over the past five to six decades (and continuing) has resulted in varieties that take up and use more nitrogen. This means that nitrogen management of new varieties needs to continuously be assessed and adjusted. In addition, there is increasing interest in adjusting sowing time to stretch the time window for completing all sowing operations on farm. Early sowing of some varieties (e.g. Trojan) was also shown to increase yield under low frost risk. To improve yield and maintain protein content under adjusted sowing times, it is important to consider which varieties are most suited, and if N management needs to be adjusted.

Here we present results of a 2-year scoping study aimed at unravelling the combined effects of variety, sowing time and N, on yield and its components.

How was it done?

Plot size	1.75 m x 10.0 m	
Seeding dates 2015	30th of April ("early") and 26th of May ("late")	
Seeding dates 2016	17th of May ("early") and 2nd of June ("late")	
Seeding rate	210 plants / m^2	
Fertiliser (urea N)	0 kg N/ha	
	60 kg N/ha split between seeding and beginning of tillering (GS20)	
Initial mineral soil N 2015	30th of April:	89 kg N/ha
(in 0-100 cm soil layer)	26th of May:	123 kg N/ha
Initial mineral soil N 2016	22nd of April:	84 kg N/ha
(in 0-100 cm soil layer)	31st of May:	89 kg N/ha
Wheat varieties	Axe, Cobra, Mace, Scout, Spitfire and Trojan	

Methods

The trial was repeated over the 2015 and 2016 seasons, and had a randomised block design with two sowing dates, six wheat varieties, two N rates and three replicates. Soil samples were taken the day before, or on the day of sowing for each sowing date. Soil cores were taken to a depth of one metre, separated into 20 cm layers and analysed for initial soil moisture and N content.

Biomass was sampled in two (inner) rows of 50 cm at anthesis and two (inner) rows of one metre at maturity. The biomass was oven dried at 60°C and weighed. The anthesis samples were separated into leaf, ear and stem, and weighed separately to assess biomass distribution in the plant. A whole shoot subsample was analysed for total shoot N. The maturity samples were separated into ears and remaining shoot. The remaining shoot was analysed for N content and the ears were used for determination of yield and yield components: 1000-grain weight, number of ears per m^2, harvest index (i.e. grain weight / total biomass), screenings and protein content.

Results and Discussion

Please note that in this section, we refer to "early" and "late" sowing as relative to each other. The "early" sowing treatments were actually conventional sowing dates, not 'early in the season'. See the actual sowing times in the "how was it done" section.

Seasons

The 2015 and 2016 growing seasons were markedly different in terms of rainfall and end of season temperature. In 2015 the overall growing season rainfall (April-October) was below the long-term average of 300 mm with 230 mm. At the end of the 2015, the crop experienced a warm and dry finish with consecutive days of temperatures great than 30°C-35°C in early October. In contrast, 2016 had consistent rainfall early in the season and well above average rainfall in September. Overall, growing season rainfall reached 356 mm and conditions in October and November were cooler for grain fill.

Biomass

In 2015, for Mace, Cobra, Spitfire and Trojan, there was no difference in biomass at anthesis with early or late sowing. In 2016 however, later sowing resulted in significantly higher total biomass at anthesis for all varieties. Interestingly, this did not result in higher yield. A possible explanation could be that for the late sown crops, rainfall, temperature, and related N mineralisation and N uptake, was better synchronised with critical growth stages, resulting in an increase in biomass compared with the early sown treatment. When comparing the total N uptake of the crops in the early and late sown treatment of 2016, the late sown treatment indeed has a higher total amount of N taken up. However, at maturity the early sown treatment appeared to have caught up and biomass and total N taken up did not differ among the sowing time treatments at harvest time. Only Mace had significantly higher yield in the late sowing treatment of 2016 (Table 1).

Grain yield

Grain yields were significantly higher in 2016 (3.5 t/ha) than 2015 (2.7 t/ha). Figure 1 shows the average yields and protein, averaged over all treatments, among the varieties for 2015 and 2016. Most varieties (except Axe and Mace) had higher yields when sown early compared with late in 2015. Furthermore, N application did not affect yield in 2015, except for Trojan. For Trojan, N application decreased yield in 2015, but only in the late sowing treatment. The lack of effect from time of sowing and N on grain yield for any varieties tested implies that water was the yield limiting factor this season.

The opposite was observed in 2016, where N application significantly increased yield for all varieties, but there was no sowing time effect (except for Mace). In the wet 2016, the lack of effect from sowing time implies that water was not limiting. Instead, N was the limiting factor for yield, resulting in the increase of yield with N application, regardless of sowing time. We found no differences in N requirements among the varieties tested here (measured by the correlation between total N taken up by the crop, and yield (data not shown)).

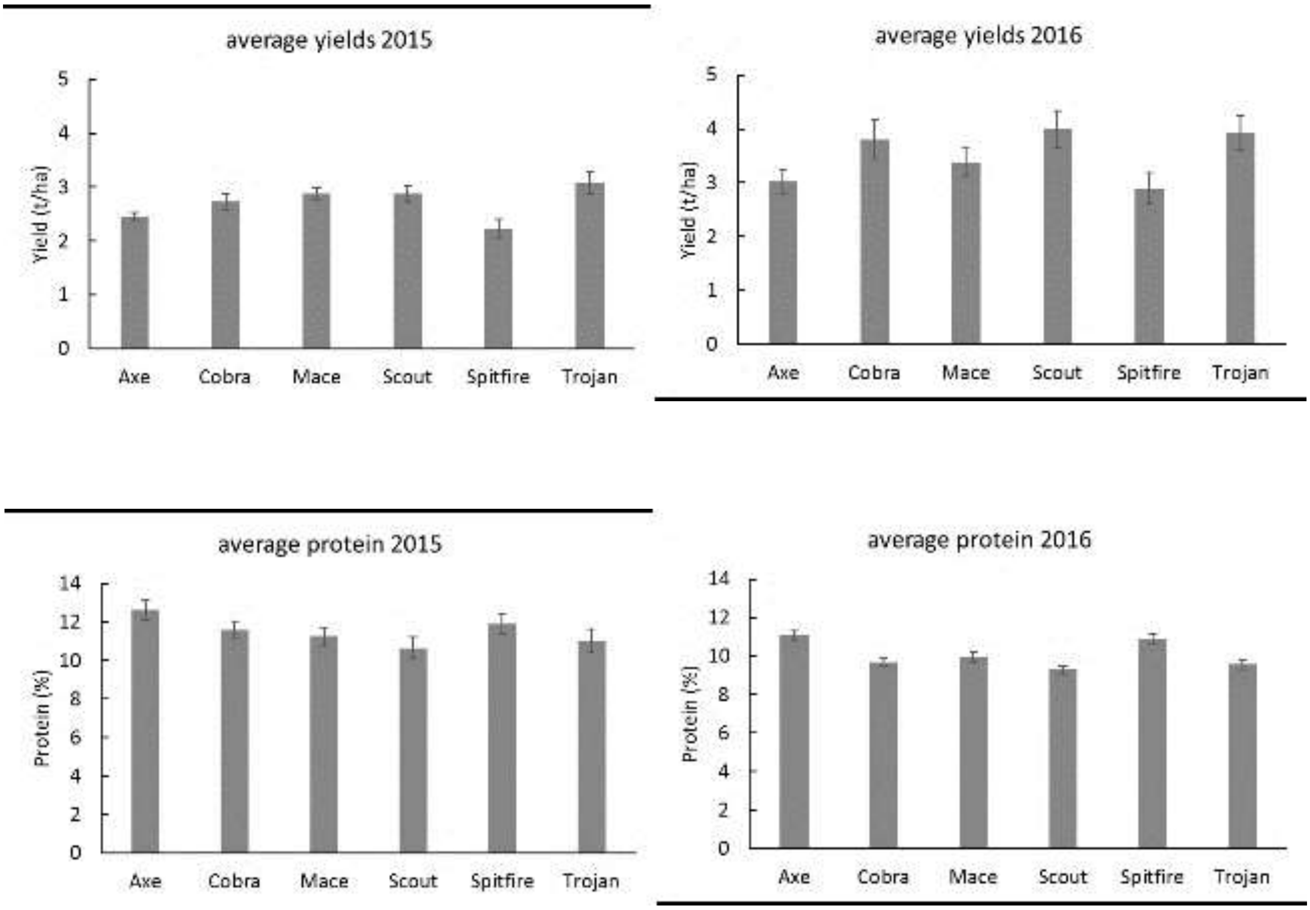

Figure 1. Yield (top graphs) and protein (bottom graphs) for each variety in 2015 and 2016. Bars indicate the average of the 2 N rate x 2 time of sowing treatments with 3 replicates (i.e. average of 12 samples). Error bars indicate two standard errors.

Protein

Among the varieties tested, in both years, protein generally increased with N application (though not always significantly, see Table 1). In 2015, late sowing increased protein further, though only significantly so for Axe and Scout. The increase in protein correlated with a decrease in 1000-grain weight (data not shown).

Table 1. Average yield and protein, affected by sowing time and N application in 2015 and 2016. Different letters indicate significant differences within a variety only.

2015		Yield (t/ha)		Protein (%)	
	sowing time	0 kg N/ha	60 kg N/ha	0 kg N/ha	60 kg N/ha
Axe	early	2.3	2.6	12.3 b	13.2 b
Axe	late	2.4	2.4	10.1 a	15.0 c
Cobra	early	2.8 a	3.2 a	10.3 a	11.8 ab
Cobra	late	2.3 b	2.6 b	10.4 a	13.8 b
Mace	early	2.7	3.2	11.0 ab	12.6 b
Mace	late	2.7	2.9	9.5 a	12.2 ab
Scout	early	3.0 ab	3.6 b	9.4 a	10.5 a
Scout	late	2.5 a	2.7 a	9.9 a	14.0 b
Spitfire	early	2.2 b	2.9 b	10.5 a	12.7 ab
Spitfire	late	1.7 a	1.9 a	10.2 a	14.2 b
Trojan	early	3.3 bc	4.0 c	9.9 a	11.3 ab
Trojan	late	2.6 ab	2.4 a	9.2 a	13.8 b
2016		**Yield (t/ha)**		**Protein (%)**	
	sowing time	**0 kg N/ha**	**60 kg N/ha**	**0 kg N/ha**	**60 kg N/ha**
Axe	early	2.2 a	3.3 b	11.1	11.5
Axe	late	2.9 a	3.6 b	11.0	10.7
Cobra	early	2.6 a	5.0 b	9.4	10.5
Cobra	late	2.8 a	4.8 b	9.2	9.6
Mace	early	2.4 a	3.9 b	9.5 a	11.4 b
Mace	late	2.9 a	4.4 b	9.5 a	9.4 a
Scout	early	2.8 a	5.2 b	8.9 a	10.2 b
Scout	late	3.1 a	4.8 b	8.8 a	9.4 ab
Spitfire	early	1.8 a	3.7 b	10.7	11.7
Spitfire	late	2.3 ab	3.7 b	10.5	10.5
Trojan	early	3.3 a	4.5 ab	8.8 a	10.3 b
Trojan	late	2.9 a	5.1 b	9.3 a	10.0 b

Conclusions

Sowing time and N rate affected yield and protein, but was dependent on variety and season.

The timing of rainfall and related N availability plays an important role. In the dry 2015 season, N application did not increase yield. There was a sowing time effect for most varieties, with early sowing increasing yield relative to late sowing. Nitrogen application did increase protein, and late sowing increased protein further due to lower yields. In contrast, in the wet 2016, yield increased with N, but there was no sowing time effect on yield or protein. The varieties tested did not differ in N requirements.

Acknowledgements

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A three year strategy to manage clethodim resistant ryegrass without oaten hay

Sam Kleemann[1], Sarah Noack[2], Gurjeet Gill[1] & Chris Preston[1]

School of Agriculture, Food & Wine, The University of Adelaide[1]
Hart Field-Site Group[2]

Key Findings

- Effective management of clethodim-resistant ryegrass can be achieved by using combinations of control tactics, effective herbicide strategies, and more competitive crops.
- Oaten hay remains one of the most effective phases for ryegrass management but effective control of ryegrass regrowth and seed set are of critical importance.

Why do the trial?

Clethodim (i.e. Select®) has been an important herbicide for controlling annual ryegrass in break crops in South Australia, allowing weed populations to be reduced prior to sowing wheat. However, clethodim resistance in annual ryegrass is increasing across the Mid-North of South Australia and this could threaten the value of break crops in cropping rotations.

Crop rotation is important to the overall success of long-term ryegrass management. Oaten hay is a popular and profitable option for growers to reduce ryegrass numbers. However, not all growers want to include oaten hay in their rotations. Therefore, other suitable strategies for managing clethodim resistant annual ryegrass need to be identified.

A three year rotation trial was established at the Hart Field-Site on a population with resistance to clethodim and butroxydim to examine the impact and profitability of different strategies for managing clethodim-resistant annual ryegrass.

How was it done?

In year 1 of the study (2013), ryegrass seed from Roseworthy with low-medium level resistance to clethodim and butroxydim was hand broadcast and lightly incorporated across the site to establish a seedbank.

The trial comprised two three year rotations of pea/wheat/barley and canola/wheat/barley. In 2014 field peas and canola were sown, followed by wheat in 2015, and barley last season (2016). A standard knife-point press wheel system was used to sow the trials on 22.5 cm (9") row spacings. Sowing and fertiliser rates were undertaken as per district practice.

Herbicide strategies reflected low (HS1), medium (HS2) and high (HS3) intensity of ryegrass management:

Herbicides for Kaspa field peas:

HS1. Trifluralin (1.6 L/ha) + clethodim (0.7 L/ha)
HS2. Triallate (2.0 L/ha) + propyzamide (1.0 L/ha) + trifluralin (1.6 L/ha) + clethodim (0.7 L/ha) + CT (paraquat)
HS3. Triallate + propyzamide + trifluralin + clethodim (2×) + Factor (180 g/ha) + CT (paraquat)

Herbicides for ATR-Stingray canola:

HS1. Trifluralin (1.6 L/ha) + clethodim (0.5 L/ha)
HS2. Triallate (2.0 L/ha) + propyzamide (1.0 L/ha)
HS3. Propyzamide + clethodim + CT (glyphosate)

Herbicides for Mace wheat:

HS1. Trifluralin (1.6 L/ha) + triallate (2.0 L/ha) IBS
HS2. Sakura (118 g/ha) + triallate (2.0 L/ha) IBS
HS3. Sakura (118 g/ha) + triallate (2.0 L/ha) IBS + Boxer Gold (2.5 L/ha) POST (crop 2-3 leaf)

Herbicides for Compass barley:

HS1. Trifluralin (1.4 L/ha) + triallate (2.0 L/ha) IBS
HS2. Triallate (2.0 L/ha) + Boxer Gold (2.0 L/ha) IBS
HS3. Triallate (2.0 L/ha) + Boxer Gold (2.0 L/ha) IBS + Boxer Gold (2.0 L/ha) POST (crop 2-3 leaf)

The trial was established in a split-plot design; with crop rotation assigned to main-plots and herbicide strategies to sub-plots with 3 replicates. Assessments included ryegrass control (reduction in plant and seed set), crop establishment, grain yield and quality.

Results and discussion

The ryegrass population established at the site was resistant to clethodim with more than ten-fold greater clethodim dose required to control the population than the standard susceptible population. The population was only weakly resistant to butroxydim.

In 2014, excellent ryegrass control was initially obtained in field peas and canola with pre-sowing herbicides under herbicide strategies two and three (Table 1). By contrast herbicide strategy one was the weakest treatment where control was poor with trifluralin exposing more annual ryegrass to clethodim, to which the population is moderately resistant.

Table 1. Changes in annual ryegrass weed and head density (no./m^2) in response to the herbicide strategy (1-3) employed in field peas and canola in 2014, in wheat in 2015, and in barley in 2016 at Hart.

Crop sequence	Herbicide strategy (HS)	2014		2015		2016	
		Plants	Heads	Plants	Heads (*no./m^2*)	Plants	Heads
Field peas/ wheat/barley	1	48a	17a	5	8	15a	18a
	2	3b	0b	5	3	9b	8b
	3	1b	0b	4	2	3b	8b
Canola/ wheat/barley	1	55a	34	30a	42	17	21a
	2	24b	23	4b	19	9	9b
	3	12b	23	10b	10	14	4b

Letters within columns for each crop sequence indicate significantly different data. Where no letters are present, the data are not significantly different.

In 2015, a significant amount of ryegrass was controlled by knockdown herbicides before the crop was sown, exposing less ryegrass to pre-emergent treatments in wheat. However, annual ryegrass numbers were generally higher following canola than following field peas. This is most likely due to greater efficacy of crop-topping peas with paraquat compared to crop-topping canola with glyphosate.

Despite the low weed infestation in 2016 (<20 plants/m2), ryegrass control in barley was more effective under herbicide strategy two and three compared to strategy one. These strategies (HS2 & HS3) combined with the competitive barley crop were able to suppress ryegrass seed set (<9 heads/m^2) even though conditions were favourable for seed production. Competition is often an underutilised tool, however when combined with effective pre-emergent herbicides it can greatly reduce the seed set of ryegrass.

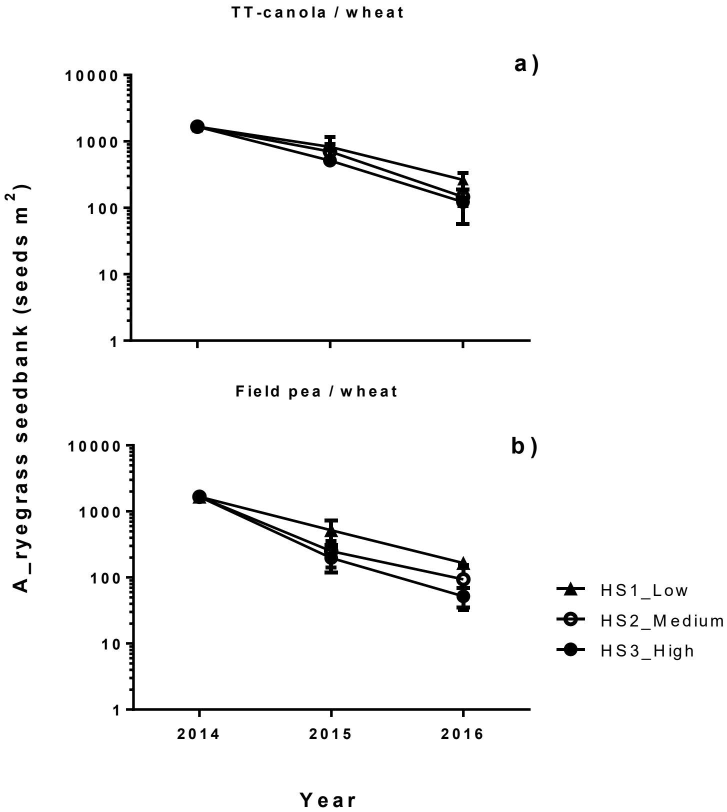

Figure 1. Change in ryegrass seedbank in response to herbicide strategy (HS1-3) in TT-canola/wheat (a), and field pea/wheat crop sequences at Hart. Vertical bars represent SE.

Although the ryegrass seedbank declined more rapidly following field peas than following canola in year one (Figure 1), by year three the Autumn seedbank had been significantly reduced (84-97%) under both crop sequences (Table 2). The seedbank declined further under wheat, due in part to the effectiveness of the pre-emergent herbicide treatments, but also because of the extremely dry Spring conditions which would have reduced the ability of ryegrass to set seed in 2015. Herbicide strategy three treatment under both field pea/wheat and canola/wheat crop sequences provided the greatest reduction in ryegrass seedbank (97 & 93%) from 2014 to 2016.

Combination of effective pre-emergent herbicides under HS2 and HS3 with a more competitive barley crop may have helped reduce the seedbank further. However, the benefits of the practice won't be known until seedbank sampling is again undertaken in April 2017.

Although there were significant differences in ryegrass control between HS treatments (Table 1), this had little effect on the grain yield of barley (P=0.88). This is not surprising given ryegrass on per plant basis is a relatively weak competitor, with much higher weed infestations (>100 plants/m^2) required to produce measurable yield losses. Given the effectiveness of the HS to maintain ryegrass density at low levels, the competitive influence of ryegrass would have been negligible.

When data were combined over HS and presented as the average of cropping sequence (Table 3), differences in barley yield between the two crop sequences were significant (P<0.01). Barley yield was higher in field pea/wheat/barley rotation (5.09 t/ha) than in canola/wheat/barley rotation (4.74 t/ha).

Table 2. Impact of crop sequence and herbicide strategy (HS1-3) on % reduction in ryegrass seedbank from 2014 to 2016 at Hart. Detailed description of herbicide strategies are provided in the materials & methods section. Canola and field peas were sown in 2014, and wheat in 2015.

Crop sequence	Herbicide strategy (HS)	% reduction in ryegrass seedbank from 2014 to 2016
Field peas/wheat/barley	1	90
	2	94
	3	97
Canola/wheat/barley	1	84
	2	91
	3	93

Table 3. Impact of crop sequence and herbicide strategy (HS1-3) on the grain yield of barley at Hart in 2016.

Herbicide strategy (HS)	HS1	HS2	HS3	Average
Crop sequence	Barley grain yield (t/ha)			
Field peas/wheat/barley	5.20	5.11	4.97	5.09
Canola/wheat/barley	4.57	4.76	4.88	4.74
Average	4.87	4.94	4.92	
Interaction	NS			
Crop sequence	P<0.01			
Herbicide strategy	NS			

Conclusion

The results of this study have shown that long-term management of clethodim resistant ryegrass is achievable without oaten hay when appropriate herbicide strategies and cropping sequences are deployed. Where clethodim is no longer effective, it is essential that seed control tactics are used to stop resistant ryegrass seed from returning to the seedbank. In field peas, crop-topping with paraquat can be effective, in canola crop-topping with Weedmaster DST or windrow burning can be used to reduce ryegrass seedbank. In wheat and barley robust pre-emergent herbicides should be used in order to maintain or decline the ryegrass seedbank further. Crop competition is also an easy and simple to use tool, and selection of more competitive crops (e.g. barley) and their cultivars can be an effective means of weed management.

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Further information:

Sam Kleemann
University of Adelaide
samuel.kleemann@adelaide.edu.au

Right: Kathy Fisher, SARDI, harvesting the trial at Hart, 2016.

Legume and oilseed herbicide tolerance

Key findings

- In the post emergent treatments a range of herbicides produced very good control of all oilseed and legume crops included.

Why do the trial?

To compare the tolerance of legume and canola varieties to a range of herbicides and timings.

How was it done?

Plot size	2.0 m x 3.0 m	**Fertiliser**	MAP (10:22) + 2% Zn @ 80-100 kg/ha
Seeding date	2nd June 2016		

Thirteen strips of canola, pasture, vetch, chickpea, faba bean, field pea and lentils were sown. Sixty herbicide treatments were applied across all 13 crops at different timings.

The timings were:

Post seeding pre-emergent (PSPE)	7th June
Early post emergent (3-4 node)	14th July
Post emergent (5-6 node)	4th August
Late post emergent (8 node)	25th August

Treatments were visually assessed and scored for herbicide effects approximately four weeks after application (Table 1).

Crop damage ratings were:

1 = no effect
2 = slight effect
3 = moderate effect
4 = increasing effect
5 = severe effect
6 = death

Results

Many of the herbicides are not registered for the crops that have been sprayed. It is important to check the herbicide label before following strategies used in this demonstration. Herbicide effects can vary between seasons and depend on soil and weather conditions at time of application.

In 2016, a number of the herbicide treatments produced different crop tolerance affects compared to other seasons and care should be taken when interpreting these results. *The trial was located over the previous year's commercial canola (44Y89) crop which received 455 mL/ha of intervix on 23/07/2015. In general it was hard to see any significant carry over herbicide effects in the nil strips for any of the crop types or varieties selected. Hurricane lentils and Angel medic were the only crop/varieties to show minor damage symptoms in the nil strips.*

Majority of the post sowing pre-emergent (PSPE) herbicide applications in 2016 had no effect on crop growth compared to the nil. This would not usually be expected and contrary to many experiences in the field this season.

In 2013 Broadstrike was one of the safest herbicides at the 3rd node stage, but in 2016, 2015 and 2014 produced severe effects to both vetch varieties (RM4 and Volga) and Frontier/Zulu II clover and Wilpena Sulla. Simazine caused similar damage on the chickpea and Jumbo 2 lentils compared to 2015. At this timing, metribuzin was also more damaging to both lentil varieties. Ecopar is only currently registered in pastures and its use in other crops is off label. However, at the 3rd node stage it appeared to give only slight damage to most of the legumes, but moderate damage to the lentils.

In the post emergent treatments a range of herbicides produced very good control of all the oilseed and legume crops. These included Ecopar, carfentrazone, Conclude, Paradigm, Precept, Velocity, Flight, Triathlon and Banvel M. Ecopar was safer on field peas in 2016, but this result would not normally be expected.

Pixxaro herbicide with Arylex active (16.25 g/L Arylex + 250 g/L fluroxypyr) is a post-emergent herbicide for use in all Winter cereals from 3 leaf to flag leaf for the control of a range of broadleaf weeds, including marshmallow. Use in Summer fallow will also be an option. Pending registration for use in 2017. It gave very good control of the legume crops in 2016.

Rexade is a new post emergent grass plus broadleaf herbicide for use in wheat. It contains the group B herbicide pyroxsulam plus the new Group I herbicide Arylex (halauxifen-methyl). It can be tank mixed with a range of broadleaf herbicides, typically MCPA LVE. Pending registration for use in 2017. It also gave very good control of the legume crops, with improved control of canola.

Talinor (37.5 g/L bicyclopyrone and 175 g/L bromoxynil) is a new fast acting cereal broadleaf herbicide that offers broad spectrum post-emergent weed control in wheat and barley (excluding durum). Talinor controls more than 38 weeds including tough to control weeds like bifora, wild radish, fumitory, wireweed and volunteer pulses. Pending registration for use in 2017. It also gave excellent control of all the legume and oilseed crop types in 2016.

In the 8 node treatments Gunyah peas were a standout by tolerating MCPA sodium and amine, and a low rate of 2,4-D ester. In the knockdown treatments both vetch lines were the most difficult to control, with the woolly pod vetch being the hardest. Gramoxone B-power or glyphosate mixed with 2,4-D amine or dicamba gave the best control in 2016.

Table 1. Crop damage ratings for legume and oilseed herbicide tolerance trial at Hart 2016.

				Pasture			Lentil		Vetch		C/pea	Pea	Bean	Canola		
				Wilpena Sulla	Zulu II	Sultan SU	Hurricane	Jumbo 2	Volga	RM 4	Genesis090	Gunyah	Nura	Pioneer 44Y90	Hyola®559TT	Nuseed diamond
Number	Timing	Herbicide (ai/ kg or L)	Rate (g or mL/ha)	10	8	10	55	45	45	45	80	100	140	5	5	5
1	PSPE 07/06/2016	NIL		1	1	1	1	1	1	1	1	1	1	1	1	1
2		Diuron (900g/kg)	550	6	6	1	1	1	1	1	1	1	1	3	3	3
3		Diuron (900g/kg)	825	6	6	1	1	1	1	1	1	1	1	5	5	5
4		Simazine (900g/kg)	550	4	5	2	1	1	1	1	1	1	1	3	1	2
5		Simazine (900g/kg)	825	5	6	2	1	1	1	1	1	1	1	3	1	4
6		Diuron (900g/kg) +Simazine (900g/kg)	410 + 410	5	6	2	1	1	1	1	1	1	1	3	3	4
7		Metribuzin (750g/kg)	280	4	5	2	1	1	2	2	1	1	1	6	4	6
8		Metribuzin (750g/kg)	420	5	6	2	2	2	2	3	1	1	1	6	4	6
9		Terbyne (750g/kg)	1000	6	6	5	1	1	1	1	1	1	1	6	1	5
10		Terbyne (750g/kg)	1500	6	6	6	1	2	1	1	1	1	1	6	3	6
11		Spinnaker (700g/kg)	100	3	1	1	1	5	1	1	1	1	1	1	6	6
12		Spinnaker (700g/kg) + Simazine (900g/kg)	40 + 550	3	4	2	1	2	1	1	1	1	1	2	6	6
13		Balance (750g/kg)	100	6	6	6	5	5	3	3	1	2	2	6	5	5
14		Balance (750g/kg) + Simazine (900g/kg)	100 + 550	6	6	6	5	5	3	3	1	2	2	5	5	5
15	3-4 Node 14/07/2016	NIL		1	1	1	1	1	1	1	1	1	1	1	1	1
16		Simazine (900g/kg)	850	3	5	3	2	2	2	2	1	1	1	4	1	3
17		Metribuzin (750g/kg)	280	1	6	5	4	4	5	5	2	2	3	6	3	6
18		Broadstrike (800g/kg) + wetter	25/ 0.2%	2	3	1	2	2	4	5	2	1	3	1	5	5
19		Brodal Options (500g/L)	150	6	4	4	2	2	3	3	4	2	3	5	5	4
20		Brodal Options (500g/L) + MCPA Amine (Dimethylamine Salt)(750g/L)	150 + 100	5	4	4	3	3	4	4	4	2	4	6	5	5
21		Spinnaker (700g/kg) + wetter	70/ 0.2%	2	3	1	1	5	2	1	3	2	1	3	6	6
22		Raptor (700g/kg) + wetter	45/ 0.2%	1	3	1	1	5	1	1	2	1	2	1	6	5
23		Ecopar (20g/L)	800	1	2	1	3	3	2	2	2	2	2	2	3	2
24	5-6 Node 04/08/2016	NIL		1	1	1	1	1	1	1	1	1	1	1	1	1
25		Ally + wetter	7/ 0.1%	6	6	5	5	6	4	6	6	6	6	4	6	6
26		Eclipse SC + wetter	50/ 0.1%	4	6	5	5	6	6	5	5	5	5	4	6	6
27		Ecopar + MCPA Amine (Dimethylamine Salt)(750g/L)	400 + 330	4	4	4	4	4	4	4	4	3	4	5	5	5
28		Carfentrazone + MCPA Amine (Dimethylamine Salt)(750g/L)	100 + 330	4	5	5	4	5	4	4	5	4	4	6	6	6
29		Vortex + Uptake	820/ 0.5%	6	6	5	6	6	6	6	6	6	6	6	6	6
30		Paradigm + Uptake	25/ 0.5%	6	6	6	6	6	6	6	6	6	6	4	6	6
31		Igran	650	1	1	1	2	2	3	2	3	1	2	4	1	3
32		Precept + Uptake	1000/ 0.5%	5	5	5	6	6	4	5	4	5	5	6	6	6
33		Velocity + Uptake	670/ 0.5%	5	6	5	5	5	5	5	4	6	5	6	6	6
34		Talinor + Hasten	750/ 0.5%	6	6	6	6	6	6	5	5	6	6	6	6	6
35		Flight	720	5	3	4	5	5	5	5	5	3	5	6	6	6
36		Triathlon	1000	5	3	4	5	5	5	4	5	3	5	6	6	6
37		Banvel M	1000	5	5	5	6	6	6	5	5	5	5	6	5	5
38		Intervix + Hasten	600/ 1.0%	4	5	1	1	5	3	3	5	4	3	1	6	6
39		Hussar OD + wetter	100/ 0.25%	5	6	5	5	6	6	6	5	6	6	2	6	6
40		Rexaid + wetter	100/ 0.25%	4	6	5	5	6	6	6	5	5	6	1	6	6
41		Atlantis OD + Hasten	330/ 0.5%	6	6	5	3	5	6	6	5	5	5	1	6	6
42		Atrazine (900gai) + Hasten	833/ 1.0%	3	6	4	4	4	3	3	5	3	3	5	1	5
43		Lontrel Advance	150	6	6	6	6	6	6	6	6	6	6	1	1	1
44		Starane Advance	330	1	3	4	6	6	6	5	6	6	4	4	4	4
45		Pixxaro	300	5	6	6	6	6	6	6	6	6	5	3	3	3
46	8-9 node 25/08/2016	MCPA Sodium (250 g/L)	700	1	4	1	2	2	2	1	2	1	2	2	2	1
47		MCPA Amine (750 g/L)	350	2	2	1	3	2	3	3	3	2	4	4	4	2
48		Amicide Advance 700	1200	5	4	4	5	4	5	6	6	4	6	6	6	4
49		2,4-D Ester (680 g/L)	70	2	1	1	1	2	2	2	3	2	3	2	1	1
50		NIL		1	1	1	1	1	1	1	1	1	1	1	1	1
51		Sprayseed	2000	3	5	4	6	6	5	3	6	6	5	6	6	6
52		Gramoxone	1000	2	4	2	4	5	4	2	3	6	4	4	5	5
53		Gramoxone B-power + wetter	2400	4	5	6	6	6	6	5	6	6	5	6	6	6
54		Glyphosate (540 g/L)	1000	2	5	4	5	5	3	1	4	5	3	5	6	5
55		Glyphosate (540 g/L) + Terrain	1000 + 30	3	4	5	5	5	3	2	6	6	4	5	5	5
56		Glphosate (540 g/L) + Ecopar	1000 + 150	3	4	6	5	5	4	1	5	6	3	5	5	5
57		Glyphosate (540 g/L) + Goal (or Cavalier)	1000 + 75	2	3	5	5	6	4	2	5	6	3	5	6	5
58		Glyphosate (540 g/L) + Hammer	1000 + 50	3	4	5	6	6	4	2	5	6	4	5	5	5
59		Glyphosate (540 g/L) + Amicide Advance 700	1000 + 650	5	5	6	5	6	5	6	6	6	5	6	6	6
60		Glypohsate (540 g/L) + Dicamba	1000 + 240	5	6	6	6	6	6	6	6	6	6	3	4	4

Early or delayed sowing for improved ryegrass control: summary of three seasons

Sarah Noack, Hart Field-Site Group
Peter Hooper, Hooper Consulting
Sam Kleemann, Chris Preston and Gurjeet Gill, University of Adelaide

Key findings

- Delayed sowing provided no advantage over early sowing in reducing ryegrass plant or head number.
- In two out of three seasons, later sown crops were lower yielding and did not provide as good crop competition allowing ryegrass head number to increase.
- Sowing time had no effect on the performance of pre-emergent herbicides for ryegrass control.

Why do the trial?

In 2008 a ryegrass control trial at Hart showed the best additional management strategy to herbicide application was delaying sowing by seven days (Hooper 2008). Delayed sowing reduced ryegrass numbers by 55% for all herbicide treatments. However, this strategy often results in lower grain yield and a less competitive crop against any surviving ryegrass.

Since this research was conducted, the introduction of new residual pre-emergent herbicides has reduced the reliance on post emergent selective grass sprays and provided an improved option for dry sowing. Pre-emergent herbicides however, have more variables that can affect efficacy than post-emergent herbicides. This is because pre-emergent herbicides are applied before the weeds germinate and a number of considerations (eg. soil moisture, rainfall, soil type) come into play. Anecdotal grower evidence suggests dry or early sown crops, using adequate rates of residual pre-emergent herbicide provides similar levels of ryegrass control to delayed sowing with an additional one or two knockdowns. The aim of this trial was to investigate the effect of early or delayed sowing on reduction of ryegrass numbers in combination with different pre-emergent herbicides.

Pre-emergent herbicides trialled

Across three seasons the efficacy of pre-emergent herbicides on ryegrass were trialled in combination with time of sowing. To ensure even annual ryegrass establishment across the trial site, seed was broadcast the year prior to trial establishment at a rate of 25 kg/ha. Prior to seeding an additional 5 kg/ha ryegrass seed was spread and lightly tickled in.

The trial was a split-plot design with one wheat variety (Scout 2014, Estoc 2015, Mace 2016), two times of sowing and six pre-emergent herbicides (Table 1).

Table 1. Pre-emergent herbicide treatments evaluated in time of sowing wheat trials at Hart in 2014 - 2016.

Treatment no.	Herbicide and rate applied
1	Nil
2	IBS Boxer Gold 2.5 L/ha
3	IBS Sakura 118 g/ha
4	IBS Boxer Gold 2.0 L/ha + IBS tri-allate 2.0 L/ha
5	IBS Sakura 118 g/ha + IBS tri-allate 2.0 L/ha *2015 & 2016 IBS trifluralin 1.5 L/ha + tri-allate 1.6 L/ha*
6	IBS Boxer Gold 2.0 L/ha + PS (crop 2-3 leaf) Boxer Gold 1.5 L/ha *2015 & 2016 IBS Prosulfocarb 3.0 L/ha*

Pre-sowing herbicides were incorporated by sowing (IBS) within a few hours of application. Post sowing Boxer Gold was applied at the 2-3 leaf crop growth stage. Annual ryegrass control (plant and head number), and wheat grain yield and quality were assessed each season.

Results and discussion

Grain yield and quality

Grain yield was higher for the early time of sowing in the two seasons (2014 and 2015) characterised by dry and warm finishes (Table 2). Protein was also higher in the later time of sowing which can be attributed to yield dilution effects (lower yield = higher protein). In 2016 however, the effect of time of sowing favoured the later sown crop given the cooler and wet conditions during grain fill. In addition to this, the first time of sowing was sown into marginal soil moisture, and germination across the plots was variable. Pre-emergent herbicide treatments did not affect final grain yield or quality.

Table 2. Summary of wheat grain yield, protein, test weight and screenings for time of sowing one and two at Hart, 2014 – 2016.

Year	Time of sowing	Grain yield t/ha	Protein %	Test weight kg/hL	Screenings %
2014	4th May	4.1	10.2	81.6	3.0
	2nd June	2.9	11.4	81.5	3.0
	LSD (P≤0.05)	0.4	0.9	ns	ns
2015	30th April	2.2	9.4	81.1	1.7
	27th May	1.5	12.3	78.5	12.1
	LSD (P≤0.05)	0.1	0.8	0.8	1.4
2016	20th April	3.6	8.7	79.2	0.8
	2nd June	4.9	7.1	81.5	0.8
	LSD (P≤0.05)	0.2	0.1	0.4	ns

Starting soil moisture

The behaviour of pre-emergent herbicides in the soil is driven by three key factors; herbicide solubility, binding characteristics and rate of breakdown (Preston 2014). This trial focused on the influence of soil moisture conditions and rainfall on pre-emergent herbicide performance.

In two out of three seasons (2014 and 2015), moist soil conditions in late April meant a good germination of ryegrass had occurred prior ToS 1 (Figure 1a and b). The knockdown herbicide controlled the initial germination and the plots were sown into good moisture in 2014 and 2015. Even though more ryegrass was effectively controlled prior to sowing because of the ideal starts in 2014 and 2015, ryegrass was still found at moderate infestation levels (18-77 plants/m^2) in the nil control (Table 3).

In 2016 however, plots were sown into marginal moisture (Figure 1c) and there was little ryegrass germination prior to ToS 1. Furthermore, the dry sowing conditions resulted in patchy crop establishment for ToS 1 (96 plants/m^2) compared to ToS 2 (158 plants/m^2; data not shown), and more ryegrass was consequently found in ToS 1 where the competitive ability of the crop had been compromised (Table 3).

In all three seasons soil moisture conditions were similar and favourable prior to sowing ToS 2, with good rainfall received the week leading up to sowing (Figure 1).

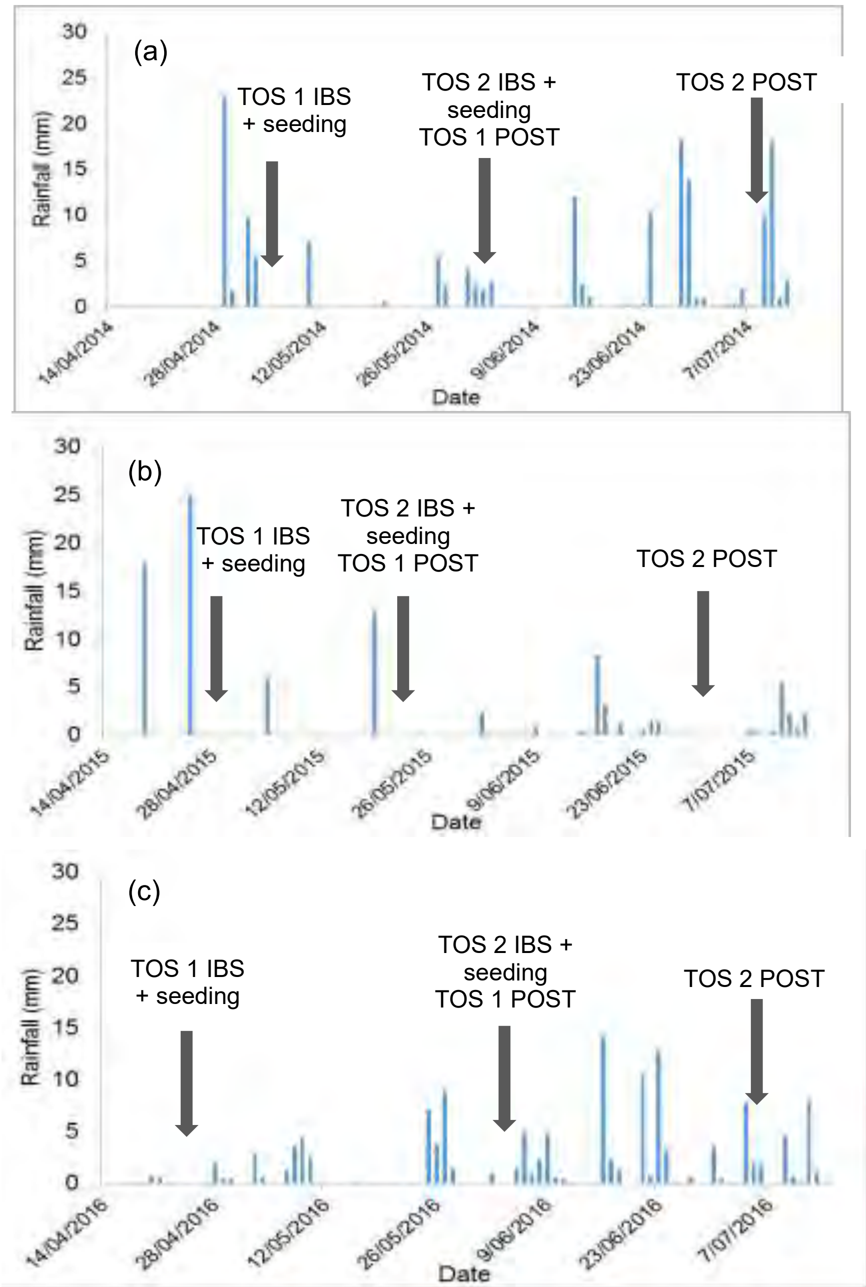

Figure 1. Starting season rainfall from 14th of April through 14th of July at Hart in (a) 2014, (b) 2015 and (c) 2016. Seeding and herbicide application dates indicated.

Pre-emergent herbicide activity and annual ryegrass control

Across the three seasons all pre-emergent herbicides provided similar control regardless of sowing date (Table 3). Early ryegrass counts showed all pre-emergent herbicides reduced ryegrass numbers compared to the control. Boxer Gold was particularly effective in the drier years, however it did appear to run out of steam when growing conditions were extended. Sakura appeared to provide better control in the wetter year, however spilt application of Boxer Gold (IBS plus POST) was just as effective. Sowing time had little or no effect on the performance of pre-emergent herbicides against ryegrass.

Despite the contrasting starts to each season, and better opportunities for knockdown weed control, delayed sowing provided little or no advantage over early sowing in reducing ryegrass numbers or seed set. The exception to this was last season, with fewer ryegrass in ToS 2, where there was plenty of opportunity for knockdown control as sowing was delayed by more than 6 weeks (20th April versus 2nd June). Similar research (Preston 2016) has shown that ryegrass appears to be synchronising its germination more with the sowing operation, meaning that irrespective of the time of sowing most ryegrass is emerging after the crop has been sown. Such changes in germination behaviour of ryegrass would therefore compromise the effectiveness of delayed sowing.

Table 3. Effect of different pre-emergent herbicides on annual ryegrass density (plants/m^2) at Hart, 2014 - 2016.

Herbicide treatment	2014		2015		2016	
	ToS 1	ToS 2	ToS 1	ToS 2	ToS 1	ToS 2
	Ryegrass density (plants/m^2)					
T1 (nil)	59	77	18	6	42	13
T2	21	12	3	1	17	33
T3	8	8	1	2	12	13
T4	6	12	2	2	25	15
T5	3	3	0	1	22	8
T6	8	6	1	2	17	14
Average	***17***	***20***	***4***	***2***	***23***	***16***
ToS x Herb (P≤0.05)	*ns*		*ns*		*19*	
Herb (P≤0.05)	*11*		*5*		-	

Not surprisingly similar responses to weed density were observed for ryegrass head numbers. Pre-emergent herbicides which provided greatest reduction in weed density were also the most effective at reducing ryegrass seed set (Table 3 and 4). There was however a significant effect (P≤0.05) of both herbicide, ToS, and their interaction on ryegrass head density in every year of the study. Even though ryegrass densities were similar between ToS treatments in 2015 and 2016, ryegrass seed set appeared higher for ToS 2 treatments. The early sown wheat appeared to be far more competitive than the later sown crop and as a consequence reduced ryegrass head production. Furthermore, in the absence of competition ryegrass heads in the delayed sown plots were visually more obvious and were situated higher in crop canopy (Figure 2).

Table 4. Effect of different pre-emergent herbicides on annual ryegrass head numbers (heads/m^2) at Hart, 2014 - 2016.

Herbicide treatment	2014		2015		2016	
	ToS 1	ToS 2	ToS 1	ToS 2	ToS 1	ToS 2
	Ryegrass heads (heads/m^2)					
T1 (nil)	350	164	45	44	116	99
T2	74	35	5	9	43	37
T3	39	41	3	13	12	15
T4	20	36	6	14	41	52
T5	32	9	0	15	37	35
T6	71	14	8	9	45	35
Average	***98***	***50***	***11***	***17***	***49***	***46***
ToS x Herb (P≤0.05)	*89*		*12*		*21*	

Figure 2. Nil treatment - first time of sowing (left) compared to second time of sowing (right), photo taken on 17 September, 2014. Note the healthier looking ryegrass in the less competitive later sown crop (right). Source: C. Preston.

Summary and implications

The results of this study suggest:

- Delayed sowing provided no advantage over early sowing in reducing ryegrass plant and head numbers.
- Wheat sown early is generally more vigorous and competitive against ryegrass.
- Time of sowing had no effect on the performance of the different pre-emergent herbicides.
- Wheat yields were higher with early sowing, the exception was last season where the delayed sown wheat was able to better capitalise on the extended growing season.

Some points worthy of consideration:

- Sowing under dry conditions may effect herbicide incorporation, particularly on heavier soils, were poor tilth can result in shallow sowing and/or cloddy conditions; this may effect herbicide performance but also jeopardise crop safety.
- Whilst most of the new pre-emergent herbicides are relatively stable, exposure to extended periods of dry have been shown to adversely affect performance; most pre-emergent herbicides work best under moist soil conditions.

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Hart Field Day 2016

International Year of Pulses at Hart in 2016

Brome grass management
Part I: selecting the right rotation and herbicide

Sam Kleemann, Chris Preston and Gurjeet Gill
School of Agriculture, Food & Wine, University of Adelaide

Key findings

- The ecology of brome grass has changed, making it more problematic to control in crops. Higher levels of seed dormancy are allowing brome to escape pre-sowing control tactics, resulting in greater in-crop emergence.
- Increased seed dormancy associated with a requirement for cold or chilling. Under field conditions this increased chilling requirement would not be met until late Autumn or early Winter.
- Knockdown herbicides are less effective in the management of highly dormant populations of brome. Therefore, brome grass management has become heavily reliant on Group A and B herbicides, especially the Clearfield™ technology, which is expected to increase the risk of herbicide resistance development.
- High levels of seedbank persistence from one year to the next (approximately 25%) means multiyear control of brome grass is required to exhaust seedbanks to manageable levels. **Plan a three-year rotation.**

Why do the trial?

The spread of brome grass in South Australia

Brome grass has been infesting crops in SA for many years; however its status as a troublesome weed in cereal crops has become more prevalent in recent years (Llewellyn *et al.* 2015). Increased occurrence of brome appears to be associated with the adoption of no-till farming and the intensification of cereal-based cropping systems (ie. wheat on wheat), where few effective herbicides are available for its control.

Some of the increase in abundance in SA could also be explained by the adoption of earlier sowing or dry sowing. In paddocks where brome has become established, it can reduce wheat yields by as much as 30-50%. In addition the seeds of brome are often found as contaminants in grain samples, resulting in down grading upon delivery to grain handling facilities.

The two main species of brome grass commonly found infesting crops are *Bromus diandrus* and *Bromus rigidus* with accepted common names of great and rigid brome. Both species have similar appearance in early vegetative stage of growth (i.e. hairy leaves and pronounced striping at the base of the stem), but they are clearly distinguished in the reproductive stage with *B. diandrus* possessing a looser or nodding panicle in contrast with the erect or rigid panicle of *B. rigidus*. *B. diandrus* is more prevalent in crops across the Mid-North where it can be found on acid or alkaline sandy or loamy sands, whereas *B. rigidus* is more common on calcareous sands in the coastal regions.

A change in brome grass behaviour

Selection for increased seed dormancy could be responsible for the increased dominance of this weed species over the last ten years. Research has clearly shown higher levels of seed dormancy in brome grass populations collected from cropping fields than those from non-crop situations such as fence-lines or roadsides (Figure 1).

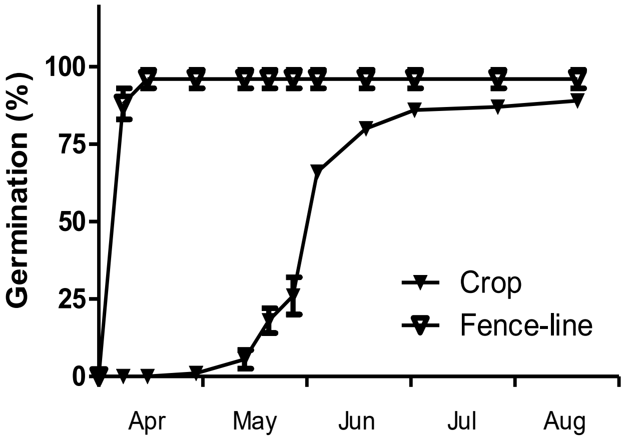

Figure 1. Differences in germination and seedling emergence between in-crop and fence-line populations of great brome collected from the same farm at Warnertown, SA. Bars show ± standard error.

These results clearly indicate that management practices used by farmers to control brome in cropping paddocks can cause a shift in weed population behaviour. This increase in seed dormancy appears to have been caused by the selection of individuals in these populations that possess greater seed dormancy to escape pre-sowing weed control tactics such as tillage or knockdown herbicides. The process of selection for increased seed dormancy would be similar but slower than selection for herbicide resistance. Over time weed management in cropping paddocks would select for biotypes that possess higher dormancy and select against or kill plants with low dormancy.

Germination of dormant seeds of brome grass was overcome by the addition of gibberellic acid (GA) rather than by seed coat removal indicating that dormancy is under hormonal control in the embryo. Seed of these dormant populations of brome grass were also responsive to chilling (i.e. exposure to 5°C), a process which has been shown to increase GA production within the seed. In the field this means that the dormant brome grass requires not only moisture, but also a period of cold temperatures to germinate. Therefore, significant germination of highly dormant brome populations would not be expected until cooler-moist conditions in late Autumn-early Winter, allowing it to evade early control tactics and emerge within crops. Another biological mechanism that appears to be contributing to delayed emergence is the strong inhibitory effect of light on seed germination. Strong photo-inhibition is likely to aid brome survival in the field by preventing germination in seeds present on the soil surface until after the sowing of the crop, thus preventing seedlings from being killed by seed-bed preparation. This feature of brome grass ecology would enable this species to proliferate under no-till, where seeds remain on the soil surface until burial by the sowing pass that would overcome the inhibitory effect of light.

Selection for greater seed dormancy in brome grass is likely to have contributed to the development of more persistent seedbank. A field study undertaken at Lock showed that seedbank carryover of brome from one season to the next was 20%, with seeds remaining viable on the soil surface for up to three years (Figure 2). Similar levels of persistence were also shown in the long-term study at Balaklava where more than 25% of seedbank persisted from one season to the next. Seedbank carryover of this magnitude could be an important factor in the proliferation of brome grass where crop rotations have provided only a single year's intervention (ie pasture-wheat rotation) or a single break crop in rotation with cereals or under cereal monoculture where few effective herbicide options have been available in the past.

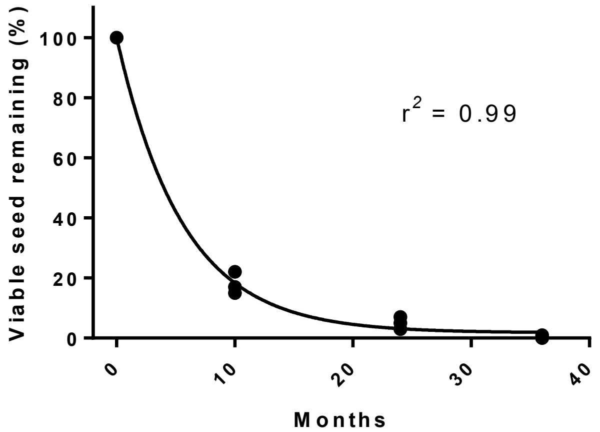

Figure 2. Longevity of brome grass seed in the field at Lock from 2003 to 2006.

How was the trial done?

Trial location:	Balaklava	**Plot size:**	5.8 m x 15 m
Rotation	**Cropping phase**	**Herbicide strategy (HS)**	
Lupin/TT canola/wheat/barley	Lupin	HS1: Simazine pre haloxyfop post HS2: Simazine pre haloxyfop post paraquat crop-top	
	TT canola	HS1: Atrazine pre atrazine plus haloxyfop post HS2: Propyzamide pre atrazine plus haloxyfop post glyphosate crop-top	
	Wheat (CLF)	HS1: Trifluralin pre Intervix post HS2: Sakura plus avadex pre Glyphosate crop-top	
	Barley (CLF)	HS1: Trifluralin plus metribuzin pre HS2: Trifluralin pre Intervix post	

The trial design is a split-plot; with four crop phases assigned to main-plots and two herbicide strategies to sub-plots with three replicates. Pre-sowing herbicides were incorporated by sowing within a few hours of application, while post-emergent herbicides were applied following label recommendations. Brome seedbank (seeds/m^2) was monitored in March and September of each year from 2014 to 2016 to determine combined effectiveness of cropping phase and herbicide strategy against brome (% of the initial population).

Results and discussion

Lupins followed by TT-canola provided two consecutive years of effective control and reduced brome seedbank by 93-96% (Figure 3a). Similar levels of seedbank depletion (93%) was achieved when CLF-wheat followed TT-canola. The effectiveness of combinations of pre- and post-sowing herbicides, plus seed-set control tactics, used in these rotations were able to deplete the seedbank to low levels within two years (from ~600 seeds to <30 seeds/m^2).

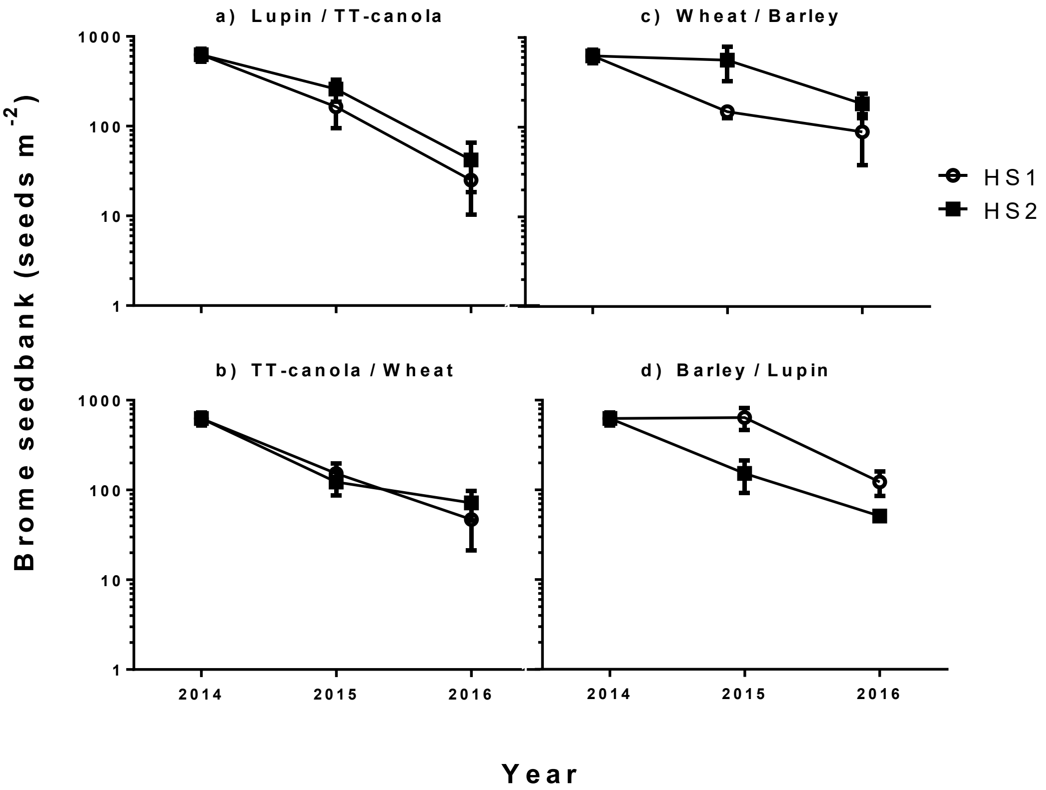

Figure 3. Change in brome seedbank in response to herbicide strategy (HS1-2) in (a) lupin/TT-canola, (b) TT-canola/wheat, (c) wheat/barley, and (d) barley/lupin rotational phases at Balaklava. Vertical bars represent standard error. The initial brome seedbank was 626 seeds/m^2.

Brome control in lupins was particularly effective because crop-topping with paraquat ensured late escapes were unable to set viable seed. Recent registration of Weedmaster® DST® (glyphosate) at windrowing or desiccation also provides an opportunity for seed-set control in canola. Even though brome seedbank declined under crop phases of wheat-barley and barley-lupin (Figure 3c & d), brome seedbank remained higher, which could be the legacy effect of less effective control by pre-sowing herbicides and absence of seed set control in cereals. Because brome is a prolific seed producer it would expected to rebound quickly under these phases of the rotation to cause high levels of crop yield loss and harvest contamination.

Herbicide efficacy

Recent introduction of several imidazolinone-tolerant crops as part of the Clearfield™ system provides excellent opportunity to control brome and avoid herbicide residue issues. However, overreliance on this herbicide group (ALS-inhibitor, Group B) has unfortunately led to resistance to these herbicides, with the first SA case recently reported (pers. comm. P Boutsalis). Many populations from the Victorian Mallee already show confirmed resistance to Group A herbicides Targa and Verdict. Alternate herbicide and cultural tactics for controlling brome should be implemented as part of an effective IWM plan to help delay herbicide resistance development.

Recognising the need to find more effective alternatives to the heavily used Group A and B herbicides, several herbicide efficacy trials funded by GRDC have been undertaken over the past four years in SA and Victoria. The trials have compared several new and experimental pre-emergent options against common farmer practice of IBS (incorporated by sowing) trifluralin plus logran in wheat (see Figure 4).

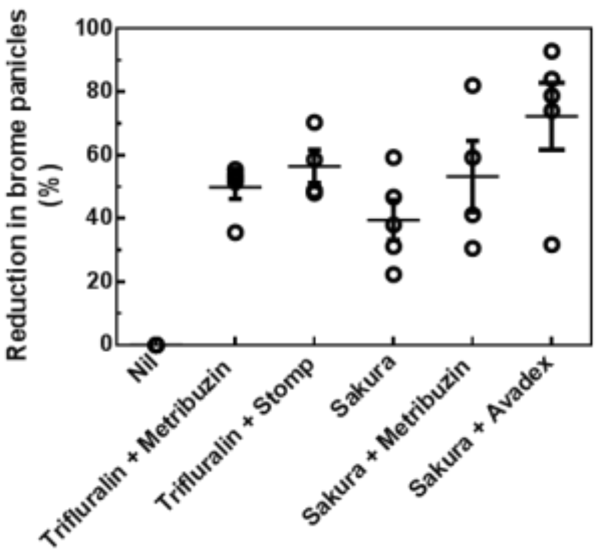

Figure 4. Performance of different pre-emergent herbicides on brome grass from several field trials undertaken across SA and Vic. Horizontal and vertical bars represent the average and standard error.

Of the herbicides examined, Sakura plus Avadex provided the best brome control (averaging >75%) at most of the field trials (Figure 4). However, in seasons with below-average rainfall, the mixture was less effective (<35% weed control). While Sakura plus Avadex has been the most consistent option, it is unfortunately cost prohibitive ($70/ha) for many growers in low rainfall environments where herbicide budgets are constrained by low crop yields. At low brome infestations, tank mixes of trifluralin with either Stomp or metribuzin, whilst providing lower control (50-60%) have been far more cost effective.

Participants of a brome grass workshop inspecting the herbicide efficacy trial which include current and new chemistry. Balaklava, September 2016.

Brome grass management
Part II: paddock monitoring across the Mid-North

Sarah Noack, Hart Field-Site Group
Peter Hooper, Hooper Consulting
Ben Fleet, Samuel Kleemann, Chris Preston and Gurjeet Gill, School of Agriculture, Food & Wine, University of Adelaide

Key findings

- Many techniques can be employed to deplete the brome seedbank but an integrated weed management (IWM) approach reduces reliance on herbicides (ie. imi's).
- In the best managed paddocks, two years of effective management reduce brome grass seedbank to <50 seeds/m^2 (8-32 seed/m^2).
- The most effective rotations for reducing brome populations incorporated oaten hay, break crops, legumes and CLF cereals.

Why do the trial?

Refer to Part I of this article.

How was it done?

Ten grower paddocks across the Mid-North were sampled pre-seeding for three consecutive years from 2013 to 2015 (Figure 5). Within each paddock a single fixed transect was established through a known brome infestation and sampled across each year. In some instances when brome plants had germinated prior to sampling, quadrat counts were also taken to account for the germinated plants.

Soil cores were taken every 20 paces, totalling 16 soil cores per site and bulked into two samples from each paddock. The soil samples were spread in trays and germinated brome seedling were counted and reported as brome seedbank/m^2.

Figure 5. The location of grower paddocks sampled for brome seedbank monitoring in the Mid-North.

Results and discussion

Effective brome control

One of the main messages from the paddock monitoring was that two years of effective management reduced brome numbers to low levels (8-32 seeds/m^2) but did not completely exhaust the seedbank. A brief summary of the effect of different management practices used in the paddocks sampled has been presented in Table 1. The results showed the three best crop rotation and herbicide strategies were:

1) Cereals cut for hay

Hay production can quickly reduce brome and other weeds, by reducing the quantity of viable seeds set or removing viable seeds to prevent seedbank replenishment. In our study, oaten hay reduced brome seedbank by 69 to 86% when used effectively. Paddock one achieved a 69% reduction in brome population after oaten hay and proved more successful than CLF wheat at this location (Figure 6). A slightly better result was achieved with oaten hay in Paddock six where 86% control was observed (Figure 7). Cutting time is important for the best weed control and particularly important for brome grass as it can develop quickly, set seed early and shed seed before the crop is ready to be cut. Regrowth also needs to be controlled with a non-selective herbicide to prevent further seed set, particularly in wet years. This point is demonstrated well in Paddock nine where brome seedbank increased by 207% (from 187 to 574 seeds/m^2) when hay cutting was too late. These results align with previous work (Bowcher *et al*. 2005) which reported silage and hay offer 40 – 80% brome control (average 60%).

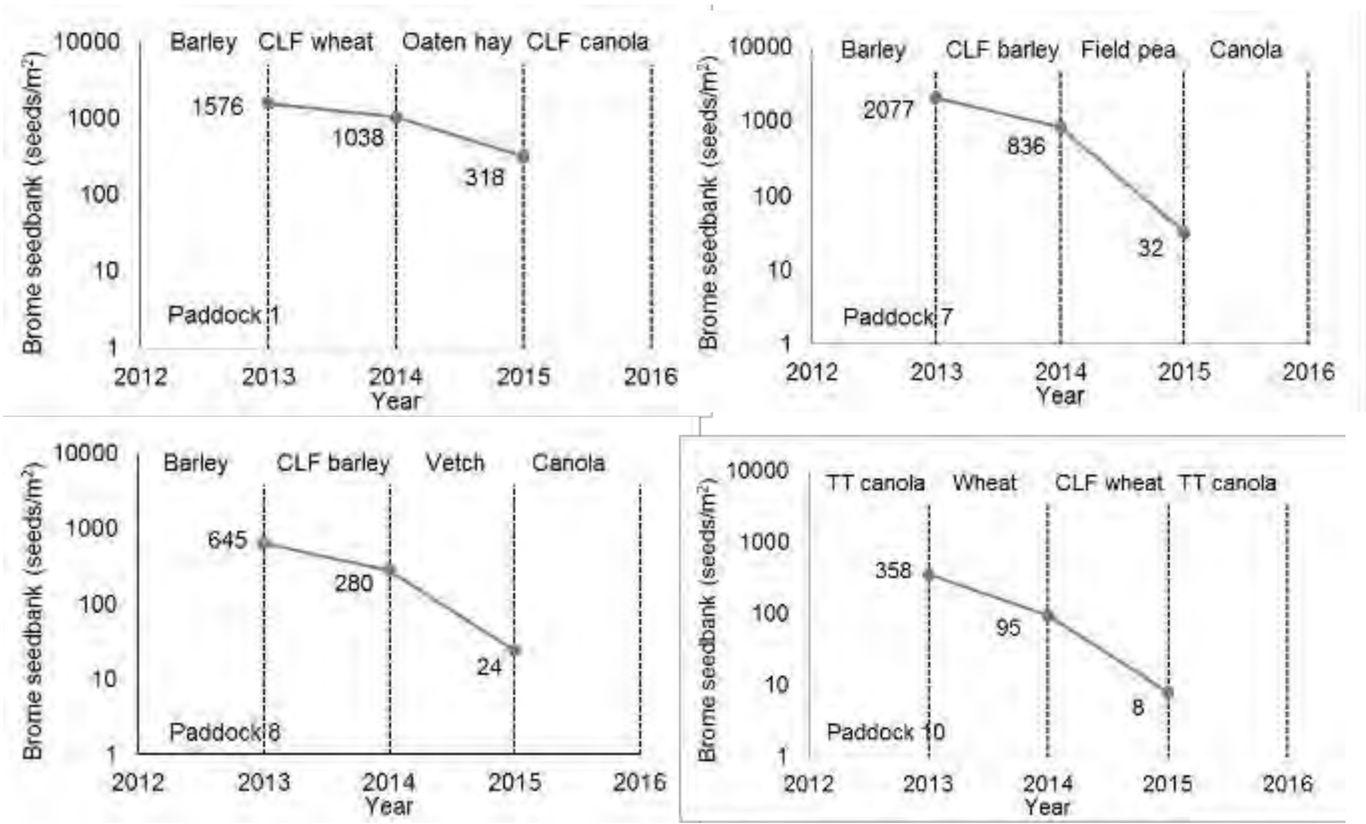

Figure 6. Paddocks monitored with effective rotations to reduce brome numbers over a three year period from 2013 – 2015.

2) Break crops

The benefit of break crops for brome control is their ability to increase the range of herbicide groups used in the rotation and at different crop growth stages which can aid control of later germinations of brome grass. Paddocks seven and eight were good examples of successful use of break crops (field pea and vetch), where brome seedbank declined by 91 to 96%.

Both paddocks were followed by canola, offering a second break crop in the management strategy. While the effects of this second break year were not assessed in this study, canola allows other herbicides and management techniques to be used. As discussed in Part I, Weedmaster® DST® is registered for use from 20% colour change in standing canola or under the cutter bar at windrowing. This earlier timing of glyphosate gives greater opportunity to control seed set in brome grass. Other weed seed capture techniques can be used such as narrow windrow burning and chaff carts, however they are dependent on the effective capture and burn of weed seeds.

3) Clearfield cereals

A common feature to all paddocks with a reduction in the brome seedbank was the use of CLF crops. In the paddocks presented here, the control ranged from 34 – 92% and on average CLF wheat or CLF barley provided 60% reduction in brome seedbank (Figures 6 and 7). It is one of the best tools for control, however Intervix® is at risk of developing herbicide resistance in brome and should not be used where other options are likely to work effectively. Growers in this study also followed the recommendation of not re-sowing a CLF variety in consecutive years. It is recommended that Intervix® not be used two years in a row, or at least without another weed control method.

Poor brome control

Cereals are not likely to be part of a strong three year rotation strategy to prevent brome seed set as they rely heavily on pre-emergent herbicides or selective Group B herbicides, and control levels can be low. The population in Paddock six was low early (2013), however a cereal phase in a paddock with a known brome issue increased the seedbank by ten-fold that season (Figure 7).

Many of the paddocks selected for this study were coming out of a cereal phase in 2012. Paddocks seven and eight were selected due to poor control during the barley phase in 2012 (Figure 6). The herbicide strategy for grass control in barley consisted of metribuzin and Boxer Gold. Metribuzin can give some control of brome in barley but its efficacy depends on soil type and seasonal conditions. It is most effective when applied in conditions with good soil moisture and with follow up rainfall within two weeks. Low metribuzin rates and insufficient rainfall in Paddocks seven and eight may have contributed to the poor control. Higher rates of metribuzin give better control but this needs to be balanced with the potential for crop damage. In light sandy soils that have a high pH, metribuzin is more available in the soil and can cause crop damage. Lower rates need to be used to prevent crop damage but often may not give adequate control.

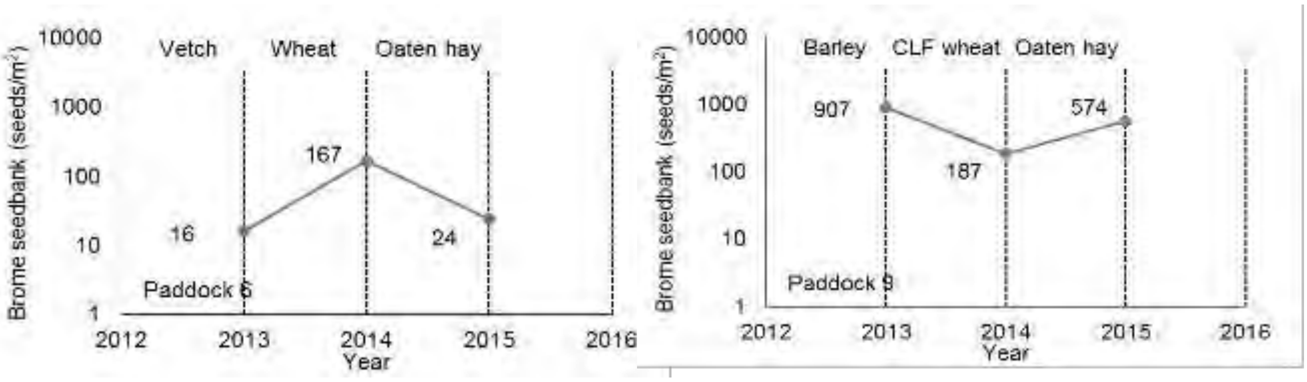

Figure 7. Grower paddocks where increases in brome seedbank were observed in the three year sampling period from 2013 – 2015.

The research conducted in part I and II of this study measured the effects of rotation and herbicide options on brome management. There are many other herbicide and cultural tactics listed in Table 2, which can be employed for controlling brome and may help in delaying herbicide resistance development.

Table 1. Summary of the change in brome grass seedbank in response to the management practices used by the growers in the Mid-North of SA.

Crop	Average seedbank reduction (%)	Range	Comments
CLF barley	58.2	57 to 60%	Consistent but moderate effect (2 paddocks)
CLF wheat	62.9	34 to 92%	Consistent performance in 2 paddocks but only 34% reduction in brome seedbank in Paddock 1 (3 paddocks)
Oaten hay	77.5	69 to 86%	207% increase in Paddock 9 which was excluded from the calculation; most likely related to late cutting and recovery (3 paddocks)
Legumes	93.8	91 to 96%	Consistent good performance (2 paddocks)
Wheat		73 to -944%	Inconsistent effect; 73% reduction to nearly ten-fold increase in brome seedbank

Table 2. Effectiveness of different management tactics and techniques for brome grass control (Source: Bowcher et al. 2005).

Tactic	Likely % control (range)	Comments on use
Burning residues	70 (60-80)	Sufficient crop residues are needed – not recommended on light soil types.
Autumn tickle	50 (20-60)	Depends on seasonal break. Seed burial through shallow cultivation enhances seed depletion through germination, especially in *B. diandrus* with its shorter dormancy and faster germination.
Delayed sowing	70 (30-90)	Depends on seasonal break and brome population - less effective for dormant brome.
Knockdown (non-selective herbicide)	80 (30-99)	If possible delay spraying until full emergence and youngest plants have two leaves.
Pre-emergent herbicide	80 (40-90)	Follow label recommendations, especially on incorporation requirements of some herbicides. Use triazines and trifluralin mainly in pulses.
Post-emergent (selective)	90 (75-99)	Apply when weeds have 2-6 leaves and are actively growing – consult label.
Pasture spray-topping	75 (50-90)	Timing is critical. Respray or graze survivors.
Silage & hay	60 (40-80)	Hay freezing works well. Silage is better than hay. Graze or spray regrowth.
Grazing	50 (20-80)	Graze infested areas heavily and continuously in Winter and Spring.
Residue collection at harvest	40 (10-75)	Works best on early harvested crops before weeds drop their seeds – less effective for *B. rigidus* because of its early maturity

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Contact details

Dr Sam Kleemann, Waite Campus, PMB1, Glen Osmond, SA 5064
samuel.kleemann@adelaide.edu.au
(08) 8313 7908

Above: germinated brome grass prior to sampling was assessed using a quadrat count.

Above: Ben and Ryan, University of Adelaide, soil sampling the brome monitoring paddocks in 2015.

Overdependence on agrichemicals – UNFS barley grass trial

Barry Mudge, Barry Mudge Consulting for Upper North Farming Systems (UNFS)

Key findings

- The 2016 trial results looking at cultural control techniques for barley grass largely confirmed the 2015 findings.
- Increasing barley seeding rate in the presence of barley grass can provide substantial benefits to both yield and reduced weed seed carry-over. This applies particularly to competitive varieties such as Fathom, but also to less competitive varieties such as Hindmarsh.
- In contrast, doubling the seeding rate of wheat had no beneficial effect on yield or weed carry-over.
- Doubling the district practice seeding rate in barley substantially reduced the competitive effect of barley grass to the stage where crop yields were similar to those plots where herbicide was applied.

Why do the trial?

Barley grass is becoming an increasingly problematic weed in lower rainfall farming systems across South Australia, particularly in the Upper North. It has a very short growing season which allows it to set seed even in the driest of seasons. Control in the past has been relatively simple in non-cereal years with cheap and effective selective herbicides. However, there is now widespread concern about the potential for herbicide resistance; Group A resistance is becoming increasingly common through the region.

There is the need to explore the effectiveness of cultural methods of grass suppression which do not involve the use of herbicides. An important requirement is to find practices which both maximise crop yield in the presence of background grass populations and also suppress weed seed carry-over.

This trial completed at Appila in the Upper North, 2016 represents a component of a coordinated approach across a number of low rainfall farming systems groups as part of a GRDC-funded 'Overdependence on Agrochemicals' project. The same trial was completed at Port Germein in 2015. This trial was reported in EPFS 2016, pp. 166-170.

How was it done?

Location Appila, Upper North Kevin and Ben Ritchie	**Rainfall** Av. Annual: 386mm Av. GSR: 232mm 2016 Total: 605mm 2016 GSR: 375mm
Paddock history 2015: Medic Pasture 2014: Barley 2013: Wheat	**Yield** Potential: 6.2 t/ha according to Yield Prophet Actual: Note frost affected. Highest barley yield was 3.64 t/ha
Soil type Grey soil with surface and sub-surface lime	**Plot size** 20 m x 1.8 m x 4 reps
Yield limiting factors Frost, weeds, possible root disease	

A replicated field trial was established near Appila to study the interaction of cereal type and variety and seeding rate on crop yield and grass suppression on a known weedy site. The trial was direct drilled using knife points and press wheels on 12 May 2016 after receiving 19 mm of rainfall from 8-10 May. The site had a modest level of broadleaf weeds (medic and thistles) from an earlier germination and these were targeted with Sprayseed prior to sowing. There was very little grass evident at sowing. Soil conditions at seeding were damp on the seedbed, but drier at depth. PAW estimates taken on 3 May 2016 showed 21 mm in the soil profile prior to seasonal opening rains.

One wheat variety (Scepter) and two barley varieties (Fathom, a vigorous, more competitive variety and Hindmarsh which is considered less competitive) were sown with three treatments for each variety. This involved two seeding rates (60 and 120 kg/ha) and a further treatment which aimed at best practice weed control (high seeding rate of 120 kg/ha plus appropriate chemical weed control of Sakura @ 118 g/ha on wheat and TriflurX @ 2.5 L/ha on barley). The crop was established using 72 kg/ha 18:20:0:0 fertiliser with 70 kg/ha urea banded below the seed. Yield Prophet was used to monitor the site throughout the year, and this showed no need for further nitrogen applications.

Initial plant establishment counts were taken on 15 June followed by crop and weed early biomass assessments at crop tillering stage on 8 August. Anthesis crop and weed biomass and weed panicle assessments were completed on 13 October. For the purpose of the trial, it was assumed that panicle counts would provide a good indication of weed seed carry-over. Plot grain harvest was completed on 12 December with grain samples retained for subsequent quality analysis (this analysis was still to be completed at the time of writing this report).

Data was analysed using Analysis of Variance in GENSTAT version 16.

The Predicta B root disease test results completed prior to seeding showed cereal cyst nematode was below detection levels, haydie/take-all and crown rot was at low risk level, and rhizoctonia at moderate risk level.

What happened?

Crop establishment from seedbed moisture was good but was further consolidated by rainfall occurring ten days after seeding. The remainder of the season saw above average rainfall culminating in a very wet September.

Table 1. Monthly and growing season rain at Appila in 2016 compared with historical average.

Month	April	May	June	July	August	Sept	October	April-Oct
2016 rainfall (mm)	9	40	69	34	59	136	28	375
Historical average	28	37	42	41	43	43	37	232

Good levels of barley grass recruitment were observed during the early crop establishment phase. The control treatments which involved herbicide applications on the wheat plots (Sakura @ 118 g/ha) achieved good grass control, but the trifluralin treated barley plots only saw minor levels of grass control. There was moderate late-season development of broadleaf weeds (mainly saffron thistle and volunteer vetch).

A late frost at early grain fill reduced the grain yields of wheat plots. Barley was relatively unaffected by the frost with satisfactory yields being recorded.

Seeding rate impact of Scepter wheat

Crop establishment of Scepter at the lower seeding rate of 60 kg/ha was in line with district practice and resulted in plant populations of 161 plants/m^2 (Table 2). The high sowing rate of 120 kg/ha resulted in plant populations of around 280 plants/m^2, which would be regarded as very high. Different seeding rates (with no herbicide treatments) had no influence on initial weed establishment levels. The herbicide treatment (Sakura @ 118 g/ha) resulted in a significant reduction in barley grass establishment.

Table 2. Impact of different seeding treatments of Scepter wheat on crop growth and weed infestation through the season.

	Treatment and sowing rate			
	60 kg/ha (no herbicide)	120 kg/ha (no herbicide)	120 kg/ha (plus herbicide)	LSD ($P \leq 0.05$)
Early Crop Establishment Crop (plants/m^2)	161	275	288	*41*
Barley grass (plants/m^2)	118	142	21	*45*
Broadleaf (plants/m^2)	14	10	10	*ns*
Tillering Crop biomass (g/m^2)	123	154	149	*ns*
Weed biomass (g/m^2)	32	26	1	*12*
Total weed tillers (no/m^2)	415	333	24	*130*
Anthesis Crop biomass (g/m^2)	695	701	919	*115*
Grass biomass (g/m^2)	264	274	6	*129*
Total grass panicles (no/m^2)	341	326	16	*124*
Harvest Crop yield (t/ha)	1.21	1.24	1.50	*0.26*

At tillering and at anthesis, there were no significant differences between high and low seeding rates on the density of barley grass and other weeds where herbicides were not applied. There was also no observed influence of seeding rate on total weed panicles measured at crop anthesis. High seeding rate in Scepter wheat did not result in increased competition and did not influence weed density. At anthesis, there was no observed difference between the crop biomass in the high and low seeding rate plots, indicating that the wheat sown at low seeding rates had effectively compensated.

Although frost-affected, there was no difference in the final yield of the Scepter wheat sown at the two different seeding rates with no herbicide treatments. This means there was no benefit to yield from any crop competition effects from higher seeding rates.

The herbicide treatment resulted in significant reductions in grass levels at all crop stages. Crop biomass was also significantly greater at anthesis than the non-herbicide treated plots. As would be expected, the final crop yield of the herbicide treated plots was significantly higher although still substantially affected by the frost.

Seeding rate impact of Fathom barley

As with Scepter wheat, crop establishment of Fathom barley was good. Barley plant numbers in the high seeding rate plots were double that of the lower seeding rate ones. There was no influence of seeding rate on early grass establishment. The pre-sowing herbicide treatment of 2.5 L/ha of TriflurX (incorporated by sowing) was moderately effective at controlling grass with grass establishment levels at about one quarter of levels in non-herbicide applied plots.

Table 3. Impact of different seeding treatments of Fathom barley on crop growth and weed infestation through the season.

	Treatment and sowing rate			
	60 kg/ha (no herbicide)	120 kg/ha (no herbicide)	120 kg/ha (plus herbicide)	LSD (P= 0.05)
Early Crop Establishment Crop (plants/m^2)	88	162	161	*17*
Barley grass (plants/m^2)	149	136	59	*37*
Broadleaf (plants/m^2)	14	15	11	*ns*
Tillering Crop biomass (g/m^2)	172	239	245	*ns*
Weed biomass (g/m^2)	32	13	13	*11*
Total weed tillers (no/m^2)	503	290	197	*132*
Anthesis Crop biomass (g/m^2)	920	1146	1029	*ns*
Grass biomass (g/m^2)	198	78	45	*87*
Total grass panicles (no/m^2)	246	115	68	*85*
Harvest Crop yield (t/ha)	2.70	3.53	3.64	*0.25*

By tillering, crop competition effects from the high seeding rate were evident. Both weed biomass and weed tillers under the high seeding rate (with no herbicide applied) were significantly lower than at the low rate. Statistically there was no significant difference in weed measurements between the herbicide applied and non-herbicide applied plots at the high seeding rate. However, there was a trend of lower numbers in the plus herbicide treatment and these observations continued to apply at anthesis.

The application of herbicide reduced weed recruitment, however a high seeding rate reduced the impact of weeds to a similar level. In terms of weed seed carry-over, the high seeding rate reduced total grass panicles by about half that of the low seeding rate.

The final Fathom barley yield from the high seeding rate was significantly higher (by 0.8 t/ha) than the low rate. There was no significant difference between the yield of the herbicide treated and non-herbicide treated plots at the high seeding rate. This indicates the effectiveness of crop competition in the absence of herbicide.

Seeding rate impact of Hindmarsh barley

Seeding rate (without herbicide) had no influence on the levels of early grass weed establishment. The herbicide application reduced grass weed levels on average by 60% (Table 4).

Table 4. Impact of different seeding treatments of Hindmarsh barley on crop growth and weed infestation through the season.

	Treatment and sowing rate			
	60 kg/ha (no herbicide)	120 kg/ha (no herbicide)	120 kg/ha (plus herbicide)	LSD (P= 0.05)
Early Crop Establishment Crop (plants/m^2)	106	204	199	*24.1*
Barley grass (plants/m^2)	150	140	53	*56*
Broadleaf (plants/m^2)	14	13	8	*ns*
Tillering Crop biomass (g/m^2)	146	226	222	*67*
Weed biomass (g/m^2)	33	24	9	*18*
Total weed tillers (no/m^2)	434	408	152	*169*
Anthesis Crop biomass (g/m^2)	780	1062	1079	*167*
Grass biomass (g/m^2)	187	105	65	*79*
Total grass panicles (no/m^2)	229	143	83	*58*
Harvest Crop yield (t/ha)	2.75	3.28	3.38	*0.41*

At crop tillering, there were no difference in barley grass numbers at the different seeding rates. However, by anthesis, weed biomass and total grass panicles were almost halved under the high seeding rates. Crop biomass at both tillering and anthesis was significantly higher under the high seeding rates. It is likely this extra competition affected weed growth later in the season. Hindmarsh crop biomass at the high seeding rate with no herbicide applied was not significantly different to the treatment with herbicide.

In contrast to the results seen in 2015, the final crop yield of Hindmarsh barley at the high seeding rate was about 0.5 t/ha higher than the low seeding rate treatment. Similar to the Fathom results, the application of herbicide at the high seeding rate did not achieve a further significant increase in yield.

Comparison of species and variety impact on weed infestation and seed set at different seeding rates

At the high seeding rate of 120 kg/ha (refer Table 6), weed measurements taken at anthesis showed that both barley varieties had reduced grass weed panicles to well under half that observed in the wheat plots. At the low seeding rate (Table 5), this reduction in grass seed carry-over was still evident, but not to the same extent. The analysis did not reveal any significant differences between the two barley varieties in terms of their impact on weed levels.

Table 5. Crop and variety impact on barley grass at 60 kg/ha seeding rate.

	60 kg/ha Seeding Rate			
	Scepter	Fathom	Hindmarsh	LSD ($P \leq 0.05$)
Tillering Weed biomass (g/m^2)	32	32	33	*ns*
Total grass weed tillers (no/m^2)	416	434	503	*ns*
Anthesis Weed biomass (g/m^2)	264	198	187	*ns*
Total grass weed panicles (no/m^2)	341	246	229	*69*

Table 6. Crop and variety impact on barley grass at 120 kg/ha seeding rate.

	120 kg/ha Seeding Rate			
	Scepter	Fathom	Hindmarsh	LSD ($P \leq 0.05$)
Tillering Weed biomass (g/m^2)	26	13	24	*12*
Total grass weed tillers (no/m^2)	333	290	408	*ns*
Anthesis Weed biomass (g/m^2)	274	78	105	*105*
Total grass weed panicles (no/m^2)	326	115	143	*76*

What does this mean?

The results obtained in 2016 strongly supported the findings from the previous year. Doubling the standard district seeding rate in both varieties of barley in the presence of barley grass had a significant benefit in terms of improved yield. In 2015, only the more competitive variety, Fathom, showed improved yield from higher seeding rates. The yield benefit (0.5 t/ha in Hindmarsh and 0.8 t/ha in Fathom) represented $75-$120/ha at a barley price of $150/tonne. This was a very good return on the extra seed cost (60kg/ha at a clean seed cost of $200/tonne) of $12/ha.

Similar to 2015, there was the additional benefit from high seeding rates in both varieties of reducing grass weed carry-over by about half as measured by panicles at anthesis.

In the presence of barley grass, wheat performed poorly against both of the barley varieties. Wheat showed barley grass carry-over of two to three times that of barley. As in 2015, doubling the wheat seeding rate provided no benefit. Yield data is confounded due to the level of frost impact.

Acknowledgements

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Evaluation of pre-emergent herbicides for brome grass in barley

Sam Kleemann, Gurjeet Gill & Chris Preston, School of Agriculture, Food & Wine, University of Adelaide

Key findings

- Brome grass is increasing in prevalence across southern Australia and control in cereals is heavily reliant on Group B herbicides (sulfonylurea and imidazolinones).
- Experimental herbicides evaluated in this study were effective on brome (>90% control), but were also unsuitable for barley causing severe crop damage; trials undertaken this season (2017) will focus on wheat.
- Identifying effective but safe herbicide options for brome in cereals remains a high priority.

Why do the trial?

Achieving effective control of brome with pre-emergent herbicides has become more difficult as cropping populations have been selected for greater dormancy and extended seedling emergence during the growing season. These high-dormancy populations can reduce early weed control by germinating after the activity of residual herbicides has diminished. Pre-emergent herbicides can enhance the performance of grass selective herbicides such as Crusader®, Atlantis® and Intervix® by reducing the amount of brome requiring in-crop control. Such combinations also help to delay onset of herbicide resistance as herbicides from several different MOA's can be used within a single cropping phase.

In cereals, only Group B herbicides can be used for post-emergent control of brome grass. The over-reliance on sulfonylurea herbicides has resulted in increasing resistance in this spp. in South Australia and Victoria (Peter Boutsalis, pers. comm.). Growers have responded by sowing Clearfield cereals and using imidazolinone herbicides for weed control. In recent years, resistance to the imidazolinone herbicides has been identified in some populations of brome from South Australia and Victoria. There is an urgent need to identify suitable alternatives to imidazolinone herbicides for brome grass control in cereals.

Here we report results from a field trial undertaken at Balaklava in 2016 to evaluate the performance of several different pre-emergent herbicides and their mixtures on brome infestation in barley. Previous pot studies had identified experimental herbicides Expt_A, Expt_B, and Expt_C as potential options for brome. Therefore, these herbicides were investigated in this field trial.

How was it done?

The trial was established in a RCBD (randomised complete block) design, with four replicates of each treatment. The trial site, which has been under no-till management for the past 10 years, had a modest to high background population of great brome (*Bromus diandrus*).

Table 1. Crop management and herbicide application details for pre-emergent herbicide trial at Balaklava.

Seeding date	Barley cultivar	Seeding rate (*kg/ha*)	IBS application date
1 June	Compass	70	29 May

The trial was sown into a wheat stubble using a standard knife-point press wheel system on 27 cm (11") row spacings. Sowing and fertiliser rates were undertaken as per district practice (Table 1). Herbicide treatments were developed for experimental purposes only and many are not currently registered (Table 2). Herbicide treatments were incorporated by sowing (IBS) within a few days of application. This minor delay in incorporation was not considered an issue as these herbicides are highly stable (non-volatile). Assessments included brome grass control (reduction in plant and panicle density), crop establishment and growth (vigour and height), grain yield and quality (seed size and contamination).

Table 2. Pre-emergent herbicide treatments evaluated at Balaklava in 2016.

Herbicide treatment	Herbicides applied
1	Nil
2	*Sakura (118 g/ha)
3	Avadex Xtra (3.2 L/ha)
4	Terbyne Xtreme (1.2 kg/ha)
5	*Sakura (118 g/ha) + Avadex Xtra (3.2 L/ha)
6	Expt_A (250 g/ha)
7	Expt_A (250 g/ha) + Avadex Xtra (3.2 L/ha)
8	Expt_A (250 g/ha) + Terbyne Xtreme (1.2 kg/ha)
9	Expt_B (1.56 kg/ha)
10	Expt_B (1.56 kg/ha) + Avadex Xtra (3.2 L/ha)
11	Expt_B (1.56 kg/ha) + Terbyne Xtreme (1.2 kg/ha)
12	Expt_C (4 kg/ha)
13	Expt_C (4 kg/ha) + Avadex Xtra (3.2 L/ha)
14	Expt_C (4 kg/ha) + Terbyne Xtreme (1.2 kg/ha)

*Sakura is not registered for use in barley, and was used for experimental purposes only.

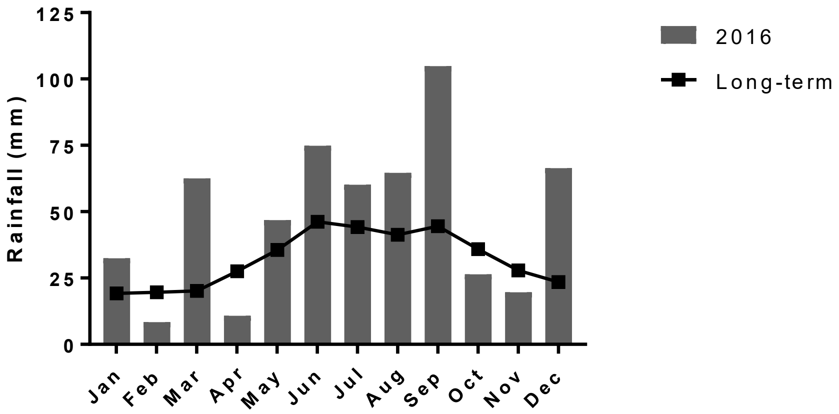

Figure 1. Long-term and monthly total rainfall at Balaklava in 2016.

Results and discussion

The site received above average rainfall from sowing through Winter to early Spring (Figure 1). The month of June alone received nearly double (75 mm) the long-term average rainfall (46 mm) resulting in favourable conditions for pre-emergent herbicide activity. Therefore good brome control (>70%) was found seven weeks after sowing (WAS) with 10 out of 13 of the herbicide treatments evaluated (Table 3). Even Terbyne, known for its inconsistency against brome, provided control as high as 86%. However, herbicides Expt_A and Avadex provided <58% control of brome relative to the untreated nil (495 plants/m^2). Similar to other triazine herbicides, Terbyne's (terbuthylazine) activity is known to be highly sensitive to soil moisture and poor grass control is usually associated with dry soil conditions.

In this season however, wet soil conditions throughout Winter would have maintained a high level of activation and herbicide absorption by weed seedlings with Terbyne control persisting beyond 12 WAS (93%). Not surprisingly, herbicide mixtures with Terbyne were also effective with Expt_A + Terbyne, Expt_B + Terbyne and Expt_C + Terbyne providing 90-96% control respectively.

Table 3. Effect of pre-emergent herbicide treatments on brome grass control at Balaklava in 2016.

Treatments	Brome grass (plants/m^2)		Brome grass (panicles/m^2)
	7 WAS	12 WAS	
Nil	495	429	244
*Sakura (118 g/ha)	146	125	143
Avadex Xtra (3.2 L/ha)	207	246	218
Terbyne Xtreme (1.2 kg/ha)	68	31	61
*Sakura (118 g/ha) + Avadex Xtra (3.2 L/ha)	160	169	146
Expt_A (250 g/ha)	259	297	269
Expt_A (250 g/ha) + Avadex Xtra (3.2 L/ha)	127	117	153
Expt_A (250 g/ha) + Terbyne Xtreme (1.2 kg/ha)	55	19	53
Expt_B (1.56 kg/ha)	91	62	85
Expt_B (1.56 kg/ha) + Avadex Xtra (3.2 L/ha)	63	30	90
Expt_B (1.56 kg/ha) + Terbyne Xtreme (1.2 kg/ha)	77	42	39
Expt_C (4 kg/ha)	81	52	116
Expt_C (4 kg/ha) + Avadex Xtra (3.2 L/ha)	124	67	116
Expt_C (4 kg/ha) + Terbyne Xtreme (1.2 kg/ha)	71	41	88
LSD ($P \leq 0.05$)	89.7	111.1	67.4

*Sakura is not registered for use in barley, and was used for experimental purposes only.

In contrast to Expt_A, both Expt_B and Expt_C were far more effective against brome (85-88% versus 31% control). Even though severe bleaching of brome was observed initially from Expt_A, this bleaching appeared transient in nature, and the plants appeared to recover quickly. Brome was also strongly bleached from Expt_B, but the symptoms appeared to persist; whereas Expt_C stunted plant growth.

Sakura plus Avadex, which has consistently performed well in wheat (>90% control), was less effective in this study (61%), which could be related to the high brome density (>400 plants m^2) at the site. Similarly Avadex at 3.2 L/ha proved ineffective (43% control) but was better when applied as a tank-mix with Expt_A (73%) and Expt_B (93%). Whilst the exact reason for improved control with mixtures of Avadex is unclear, it could simply be related to differences in primary uptake (i.e. more coleoptile rather than root uptake) and position of germinating brome in the soil (i.e. additional control of deeper germinating brome via coleoptile uptake).

Terbyne and its mixtures with Expt_A, Expt_B and Expt_C provided the greatest reduction in brome panicle density (<90 panicles/m^2); whereas other treatments resulted in unacceptable and similar seed production to the control (244 panicles/m^2; Table 3). The extended persistence of Terbyne was clearly evident even after 12 WAS with brome showing strong symptoms of PSII inhibitor (i.e. severe leaf chlorosis followed by necrosis). Even though Spring conditions were favourable these plants were unable to fully recover, and seed set was subsequently lower for these treatments.

Regardless of herbicide treatment there was a strong hyperbolic relationship (r^2=0.89) between brome plant and panicle density (Figure 2). The slope of the relationship showed that seed production per plant increased sharply at lower plant densities but began to plateau at densities above 300 plants/m^2, most likely because of greater intraspecific competition between brome plants.

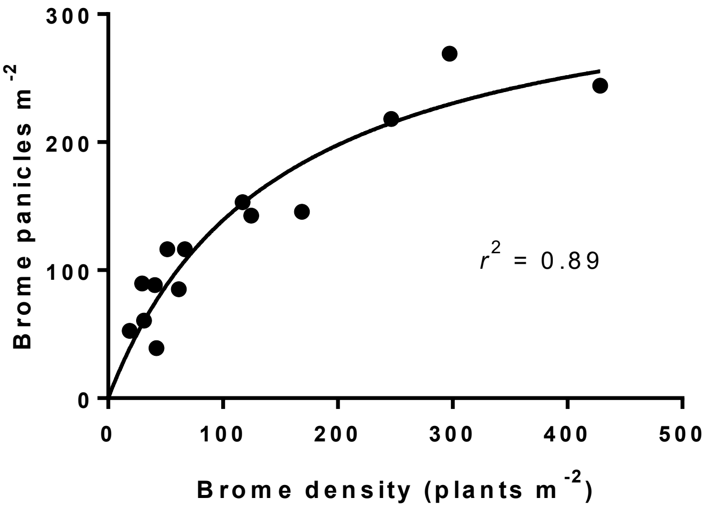

Figure 2. Relationship between average plant density and average panicle density of brome grass across all herbicide treatments at Balaklava. Each data point represents the average of four replicates.

In this study, herbicides which were most effective on brome were also the most damaging to the barley crop. Finding safe yet effective herbicides for brome in cereals has been elusive. In a preliminary pot study (Preston and Lenorage 2016) many of these herbicides at low rates appeared safer in wheat than barley, but damage to barley was generally <10%. Given the herbicide damage observed to barley in this field trial, evaluations planned for this season (2017) will focus on wheat.

Crop establishment was significantly (P<0.05) reduced relative to the control (100 plants/m^2) in seven of the 13 herbicide treatments (Table 4). Whilst the symptoms varied, Terbyne, Expt_B and Expt_C were all damaging to barley. Combination of Terbyne and Expt_B was the most damaging treatment, significantly (P<0.05) reducing barley emergence, growth (vigour and height), and ear density relative to the untreated nil. The combination of low clay and OM content of the soil with above average rainfall would have increased the mobility and uptake of these herbicides by the crop. Despite the initial setback in crop emergence by Expt_B and Expt_C, barley in these treatments appeared to compensate for lower density by increasing tiller production. As a consequence, ear numbers and subsequent grain yield for these treatments were similar to the nil (Table 4 and Figure 3).

Table 4. Effect of pre-emergent herbicide treatments on barley establishment, vigour, ear no. and anthesis height at Balaklava in 2016.

Treatments	Barley density (plants/m^2)	Barley vigour (1=poor; 10=good)	Ear no. (ears/m^2)	Anthesis height (cm)
Nil	96	10.0	254	77.6
*Sakura (118 g/ha)	98	5.5	222	69.9
Avadex Xtra (3.2 L/ha)	107	8.8	273	80.3
Terbyne Xtreme (1.2 kg/ha)	74	5.1	171	70.1
*Sakura (118 g/ha) + Avadex Xtra (3.2 L/ha)	100	6.6	275	70.5
Expt_A (250 g/ha)	102	9.3	273	77.3
Expt_A (250 g/ha) + Avadex Xtra (3.2 L/ha)	104	7.6	291	78.7
Expt_A (250 g/ha) + Terbyne Xtreme (1.2 kg/ha)	73	3.4	150	66.7
Expt_B (1.56 kg/ha)	73	3.8	272	70.1
Expt_B (1.56 kg/ha) + Avadex Xtra (3.2 L/ha)	68	3.5	278	69.2
Expt_B (1.56 kg/ha) + Terbyne Xtreme (1.2 kg/ha)	45	2.5	90	61.7
Expt_C (4 kg/ha)	83	3.6	241	70.8
Expt_C (4 kg/ha) + Avadex Xtra (3.2 L/ha)	76	3.8	229	65.9
Expt_C (4 kg/ha) + Terbyne Xtreme (1.2 kg/ha)	65	3.6	178	68.1
LSD (P≤0.05)	13.7	1.2	59.3	8.0

*Sakura is not registered for use in barley, and was used for experimental purposes only.

There was a significant (P≤0.05) effect of herbicide treatment on barley yield (Figure 3a). Although 2016 received well above average Winter and Spring rainfall (Figure 1), barley yields were highly variable (0.92 to 4.01 t/ha) in response to weed control but also herbicide damage. Furthermore, grain yield was strongly (P≤0.001) and positively (r^2≥0.9) correlated to crop growth and barley ear density. About ½ of the herbicide treatments resulted in a modest yield improvement relative to the nil (Figure 3.). Despite the improved weed control with Terbyne, and its tank-mix with either Expt_A, Expt_B or Expt_C, these treatments produced significantly less grain (0.92 to 2.05 t/ha) compared to the untreated nil (3.12 t/ha). Herbicide damage was so severe in these treatments that even though weed competition was reduced, barley could not benefit from reduced weed competition.

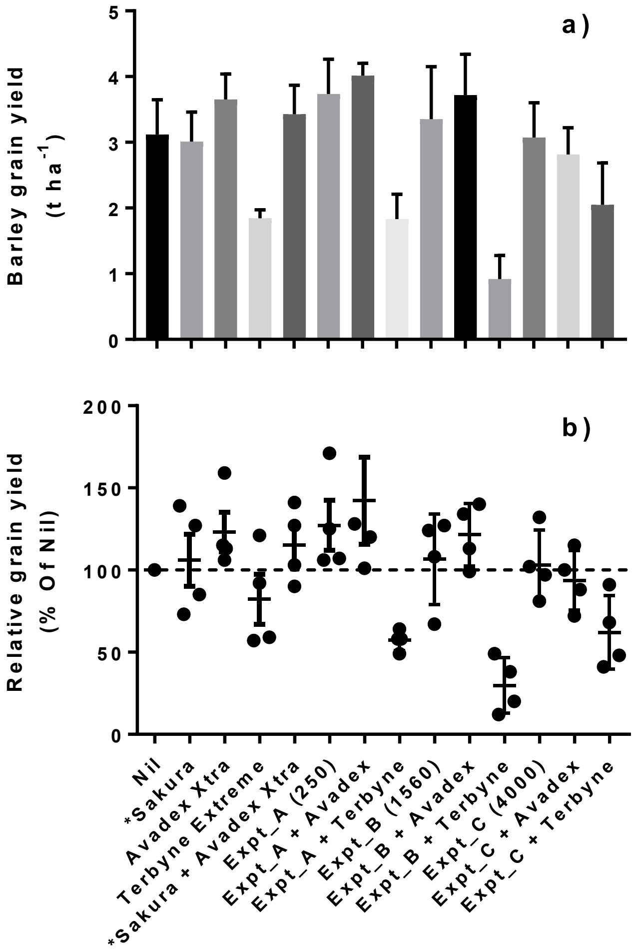

*Figure 3. Effect of pre-emergent herbicides on grain yield (a) and relative grain yield (% of nil) of barley (b) at Balaklava in 2016. *Sakura is not registered for use in barley, and was used for experimental purposes only.*

Conclusions

This field trial clearly demonstrated that experimental herbicides Expt_A, Expt_B and Expt_C applied as a tank-mix with Terbyne were capable of providing effective residual brome control (>90%). However, these treatments are unsuitable for use in barley because of severe crop damage. Consequently herbicide evaluations planned for this season (2017) will focus on wheat, which was shown to have superior tolerance to these herbicides.

As a consequence of the increasing prevalence of brome across southern Australia, the need to identify effective but safe herbicides for use in cereals remains a high priority.

Acknowledgements

We are grateful to GRDC (Grains Research and Development Corporation) for providing project funding (project UQ00080), Nufarm and AgNova Technologies for supplying herbicides, Phil Arbon for allowing us to undertake the trial on his property, and Jerome Martin and Alicia Merriam for providing technical support.

Further information:

Sam Kleemann, University of Adelaide, samuel.kleemann@adelaide.edu.au

Managing clethodim resistant ryegrass in canola with crop competition and pre-emergent herbicides

Sam Kleemann, Gurjeet Gill & Chris Preston
School of Agriculture, Food & Wine, University of Adelaide

Key findings

- Ryegrass seed production was reduced by more than 50% for the hybrid cultivar compared to open-pollinated.
- Pre-simazine or pre-propyzamide/simazine with post-atrazine, were more effective than herbicide strategies that relied just on pre-emergent herbicides.
- Combination of effective pre-emergent herbicides with competitive canola cultivars of canola can significantly reduce ryegrass seed set.

Background

Clethodim (i.e. Select®) has been a major herbicide used for the control of annual ryegrass in canola and pulse crops. However, resistance to clethodim in ryegrass has been increasing steadily in the southern region, which makes it more difficult for growers to control. Some growers have responded by using increased rates of the herbicide but weed control achieved can still be disappointing. As canola is more sensitive to clethodim than pulse crops, increasing clethodim dose can cause crop damage. Even though there are currently three different types of herbicide tolerant canola available (TT, triazine tolerance; CLF, imidazolinone tolerance; RR, glyphosate tolerance), each of these types has weaknesses for weed management and all have relied on clethodim to manage annual ryegrass.

Here we report results from a field trial undertaken to demonstrate that crop competition offered by a hybrid canola in combination with pre-emergent herbicides can greatly reduce ryegrass seed set. Competition, therefore, could provide an easy and simple to use tool for integrated management of grass weeds in canola.

What's been undertaken?

A field trial was established at Roseworthy in 2016 to investigate the effect of crop competition and different pre-emergent herbicides and their mixtures on annual ryegrass control in canola. The trial was established in a split-plot design to compare a triazine (TT) open-pollinated (OP) cultivar (ATR-Stingray) with a TT-Hybrid (Hyola559TT) under six pre-emergent herbicide strategies (Table 1).

Table 1. Pre-emergent herbicide strategies used in canola competition trial at Roseworthy in 2016.

Herbicide treatment	Herbicides applied
1	Nil
2	Propyzamide 500 g/L (1 L/ha) pre
3	Propyzamide 500 g/L (1 L/ha) + tri-allate 500 g/L (2 L/ha) pre
4	Simazine (1.1 kg/ha) pre + atrazine (1.1 kg/ha) post
5	Propyzamide 500 g/L (1 L/ha) + simazine (1.1 kg/ha) pre
6	Propyzamide 500 g/L (1 L/ha) + simazine (1.1 kg/ha) pre + atrazine (1.1 kg/ha) post

Seeding rate was adjusted according to germination and size to obtain a target density of 35 plants/m^2. This resulted in ATR-Stingray sown at 1.6 kg ha^{-1} and Hyola559TT at 2.4 kg/ha^{-1} on May 14th. The replicated trial was sown into a faba bean stubble using a standard knife-point press wheel system on 22.5 cm (9") row spacing. Fertiliser rates were applied as per district practice with 100 kg ha^{-1} DAP banded below the seed at sowing, and 50 kg/ha urea top dressed when the crop was at the six true-leaf growth stage. Pre-sowing weed control was glyphosate (2.5 L/ha) + oxyfluorfen (90 mL/ha). Lontrel Advance® (150 mL/ha clopyralid) was applied early post-sowing on June 14th to provide broad-leaf weed control. Insecticide chlorpyrifos (Lorsban) was applied on May 24th at 900 mL/ha. Pre-emergent herbicides were applied with a 2 m pressurised handboom on May 12th. Atrazine was applied post-emergent (treatments 4 & 6) on June 25th to ryegrass at the 1-3 leaf growth stage. Assessments included ryegrass control (reduction in plant and seed set), crop establishment and grain yield.

Results and discussion

There was no significant effect of herbicide treatment on canola establishment, averaging 37 and 41 plants for ATR-Stingray and Hyola559TT, respectively (data not presented).

There was a significant effect of herbicide treatment on ryegrass present in the crop at six and 12 weeks after sowing (WAS), but no effect of cultivar (Table 2 & 3). Despite the high ryegrass pressure, all herbicide treatments significantly reduced the size of the ryegrass population (~60-80%). Herbicide treatments four and six, which combined either pre-simazine or pre-propyzamide/simazine with post-atrazine were the most effective and provided 78% control relative to the nil at 12 WAS (722 plants/m^2; Table 3). Relative to just pre-propyzamide/simazine (treatment five), addition of post-atrazine to treatment six provided a 27% improvement in control. This result highlights the importance of extended residual control that post-applied residual herbicides can provide, particularly in the absence of effective grass selective herbicides (i.e. loss of clethodim to resistance).

In this study, application timing for post-atrazine was ideal, with much of the treated ryegrass no more advanced than 3-leaf growth stage. Furthermore, rainfall during early Winter was well above average and would have provided ideal soil moisture conditions for incorporation and uptake of this moderately soluble herbicide.

Table 2. Influence of canola cultivar and herbicide strategy on ryegrass density six weeks after sowing at Roseworthy in 2016.

Herbicide treatment	**T1**	**T2**	**T3**	***T4**	**T5**	***T6**	**Average**
	Ryegrass density (plants m^{-2})						
Cultivar							
ATR-Stingray	559	210	176	214	235	167	260
Hyola559TT	568	253	185	194	240	227	278
Average	564	231	181	204	237	197	
Herbicide × cultivar	ns						
Herbicide	<0.001						
Cultivar	ns						

*Post atrazine not yet applied.

Table 3. Influence of canola cultivar and herbicide strategy on ryegrass density 12 weeks after sowing at Roseworthy in 2016.

Herbicide treatment	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**Average**
	Ryegrass density (plants m^{-2})						
Cultivar							
ATR-Stingray	773	437	325	179	386	127	371
Hyola559TT	671	417	299	140	321	182	338
Average	722	427	312	160	353	155	
Herbicide × cultivar	ns						
Herbicide	<0.001						
Cultivar	ns						

There were significant effects of both herbicide treatment and cultivar on the number of ryegrass heads produced (Table 4). For herbicide treatments four and six, which provided greatest reduction in ryegrass plants, there were ~50% fewer heads found compared to the nil treatment (967 heads/m^2). These treatments of either pre-simazine or pre-propyzamide/simazine with post-atrazine, were far more effective than herbicide strategies that relied just on pre-emergent herbicides. In fact ryegrass seed set was similar to the untreated nil (967 heads/m^2) for pre-propyzamide (897 heads/m^2), and pre-propyzamide + tri-allate (915 heads/m^2). High seed set under these treatments would have resulted in a considerable blow-out in the seedbank, making management of this population difficult for years to come.

Table 4. Influence of canola cultivar and herbicide strategy on ryegrass head density at Roseworthy in 2016.

Herbicide treatment	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**Average**
	Ryegrass heads (heads m^{-2})						
Cultivar							
ATR-Stingray	1186	1062	1135	498	753	610	874
Hyola559TT	748	733	694	212	510	367	544
Average	967	897	915	355	631	489	
Herbicide × cultivar	ns						
Herbicide	<0.001						
Cultivar	<0.001						

Between the two cultivars, there were significantly more heads in ATR-Stingray (874 heads/m^2) compared to the hybrid Hyola559TT (544 heads/m^2). This is despite there being no difference in the number of ryegrass plants present between the two cultivars. The relationship between average plant and average head density of ryegrass for the two canola cultivars (Figure 1) clearly shows that seed set per plant was approx. 2-fold higher for ATR-Stingray compared to Hyola559TT. This result supports previous research that showed hybrids are more competitive against ryegrass than standard OP cultivars (Lemerle et al. 2014).

The increased competitiveness of the hybrid over the OP most likely relates to the superior vigour and early growth of the hybrid compared to the OP. NDVI, a measure of green vegetative growth showed higher NDVI values (approx. 2-fold) recorded from crop emergence through to flowering for Hyola559TT relative to ATR-Stingray (Figure 2).

Previous research (Lemerle *et al*. 2014) has also shown that hybrids were generally more competitive than OP cultivars, and concluded that suppression of weed growth was negatively correlated with crop biomass. The authors also speculated that traits such as: rapid early growth, height, early flowering; sufficient large, thin leaves to effectively shade weeds, combined with a vast root system to compete for nutrients and water, would be of importance to the competitiveness of canola. Traits which appear more strongly aligned to the growth displayed by hybrids.

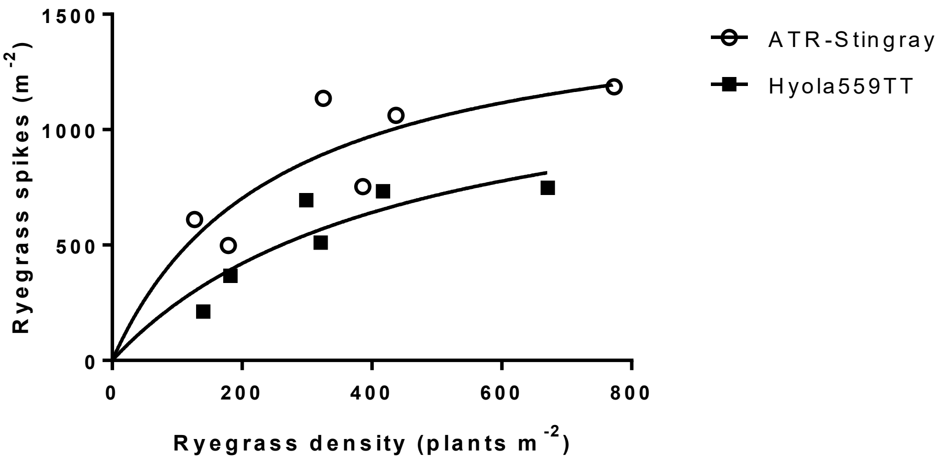

Figure 1. Relationship between average plant density and average head density of ryegrass across all herbicide strategies for canola cultivars ATR-Stingray and Hyola559TT. Each data point represents the average of four replicates.

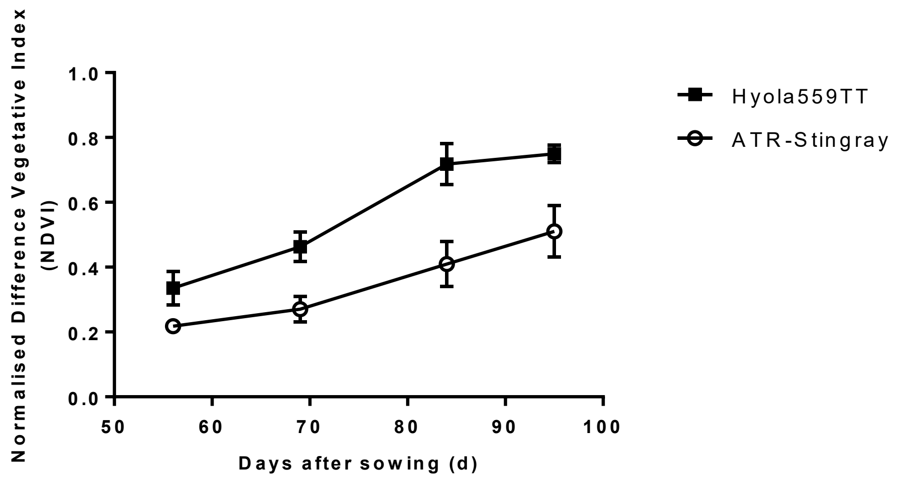

Figure 2. NDVI (Normalised difference vegetative index) of canola cultivars, ATR-Stingray (O) and Hyola559TT (■) measured during pre-flowering crop development. To avoid confounding effect of ryegrass on NDVI values only data from herbicide treatment four where ryegrass control was greatest, are presented.

There were significant effects of both herbicide treatment and cultivar on canola yield (Table 5). Although 2016 received well above average Winter and Spring rainfall, canola yields were generally low and ranged from 0.17 to 1.7 t/ha in response to the high weed pressure. Most herbicide treatments resulted in higher yield outcomes relative the nil, however herbicide treatment four and six, where ryegrass control was greatest produced the highest yields for both ATR-Stingray (0.97 & 0.99 t/ha) and Hyola559TT (1.70 & 1.41 t/ha).

Table 5. Influence of canola cultivar and herbicide strategy on grain yield at Roseworthy in 2016.

Herbicide treatment	T1	T2	T3	T4	T5	T6	Average
	Grain yield (t ha^{-1})						
Cultivar							
ATR-Stingray	0.17	0.24	0.45	0.97	0.54	0.99	0.56
Hyola559TT	0.96	1.07	0.94	1.70	1.12	1.41	1.20
Average	0.56	0.66	0.70	1.33	0.83	1.20	
Herbicide × cultivar	ns						
Herbicide	<0.001						
Cultivar	<0.001						

Despite there being no difference in ryegrass density between the two cultivars, the grain yield of Hyola559TT averaged across all herbicide treatments was over double that of ATR-Stingray (1.2 t/ha *vs* 0.56 t/ha). Furthermore when the data was shown as a percentage (relative yield) of the nil a negative relationship between ryegrass density and grain yield was revealed (Figure 3). The yield of ATR-Stingray declined more sharply at low to moderate densities of ryegrass compared to Hyola559TT, and appeared to reach maximum yield loss at densities above 500 plants/m, where competition of ryegrass would have been severe. These results appear consistent with the earlier findings of Lemerle et al. (2014) who reported that hybrid cultivars could better maintain grain yield in the presence of weeds, and were therefore more tolerant of weed competition than the less competitive OP conventional varieties. The extended growing season would have also favoured Hyola559TT which is a later flowering type than ATR-Stingray.

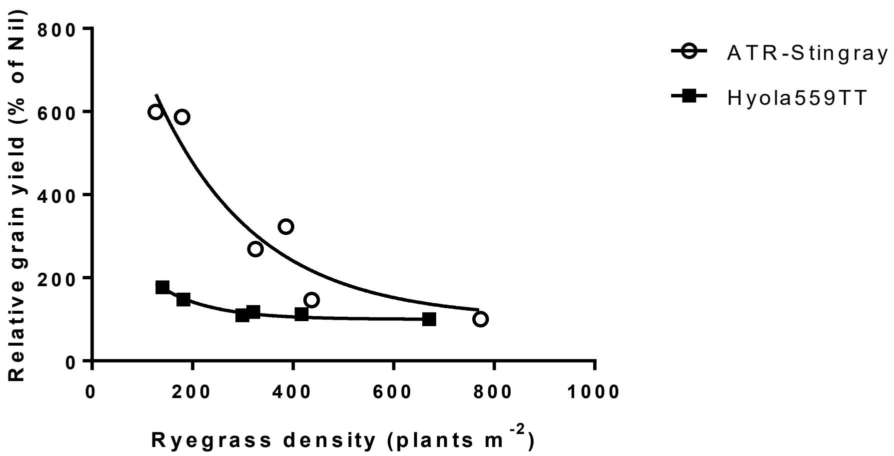

Figure 3. Relationship between average ryegrass density after application of herbicide treatments and relative grain yield for canola cultivars ATR-Stingray and Hyola559TT. Each data point represents the average of four replicates.

Conclusions

The results from this study have clearly demonstrated that where effective herbicides were integrated with more competitive cultivars of canola, ryegrass seed production was reduced by more than 50% for the hybrid cultivar Hyola559TT compared to open-pollinated ATR-Stingray. Furthermore, the hybrid appeared to better maintain grain yield in the presence of weeds, and was therefore more tolerant of weed competition than canola cultivar ATR-Stingray. Combination of effective pre-emergent herbicides with more competitive cultivars of canola can significantly reduce ryegrass seed set, and may play a critical role in the longer-term management of this troublesome weed.

Acknowledgements

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Further information:

Sam Kleemann, University of Adelaide, samuel.kleemann@adelaide.edu.au

Re-thinking the current ascochyta blight control strategy in field peas

Christine Walela[1], Larn McMurray[1], Jenny Davidson[2], Leigh Davis[3*]

[1]SARDI Clare, [2]SARDI Waite, [3]SARDI Minnipa Agricultural Centre,*(Formerly SARDI)
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Key findings

- The recommended industry practice of P-Pickel T® (PPT) seed treatment and two foliar fungicides of mancozeb failed to significantly reduce disease infection levels or increase grain yield over untreated control treatments under high blackspot disease pressure in 2016.
- Early disease control applications (four weeks after sowing) were important for reducing initial blackspot infection levels at Minnipa, conversely later Spring applications were important at the higher rainfall site of Hart.
- Over two consecutive years, a yield benefit of at least 15% has been obtained from application of new experimental fungicide actives over the current industry practice treatment.
- Further research is required to understand the interaction in efficacy between fungicides and timing of disease infection, together with the drivers of ascochyta blight onset and progression in different field pea growing environments.

Why do the trial?

Ascochyta blight (AB) commonly known as blackspot is an important disease in field peas, and a concern in low rainfall zones where, in high disease forecast situations, the risk is managed by delaying sowing which in turn often leads to yield loss. To enable earlier sowings, foliar fungicides for the control of AB are an important component of disease management which assists in maintaining yield potential.

The current trials are in the second year, as part of ongoing research aimed at developing improved AB disease control management strategies through the use of fungicides. The existing industry practice for AB control in field peas was developed by SARDI (McMurray *et al.*) and includes the use of a fungicide application strategy of P-Pickel T® seed dressing followed by two foliar applications of mancozeb (2 kg/ha at 9 node and early flowering). This strategy developed in 2011 has been shown to suppress AB and is generally a viable economical option for crops yielding 1.5 t/ha or greater. Research conducted in 2015 to test the efficacy of alternative fungicides alongside the current industry practice has indicated improved AB disease control together with a yield benefit of up to 15% over the current industry practice. This research also identified that the severity of disease onset was higher at an earlier growth stage in low rainfall environments such as Minnipa, SA. As such, the timing of the first foliar fungicide, at eight weeks after sowing (WAS) was thought to be too late for effective control of AB in these environments. Further, in medium rainfall environments, more favourable Spring conditions often extend late season disease progression and therefore sprays towards the back-end of the growing season may be required. The aim of the 2016 trials was to further assess these new experimental fungicides alongside the current strategy and also include variations in fungicide application timings to improve disease control efficacy.

How was it done?

Field trials were conducted in two major field pea production areas in South Australia; Hart (medium rainfall zone, Mid-North) and Minnipa (lower rainfall zone, Upper Eyre Peninsula). Trials were designed as randomised complete block design (RCBD), replicated three times with twelve fungicide treatments including an untreated control (nil). Fungicides were applied either as a seed dressing, as fluid injection, or as combinations of seed dressing/fluid injection and foliar fungicide(s) at strategic growth stages as shown in Table 1. Fortnightly applications of chlorothalonil were included as a second control treatment which was aimed at maximum control of AB disease. The dual purpose (grain/forage) field pea type PBA Coogee was sown at 55 plants/m^2 at all sites, selected for its increased biomass production, lodging and AB susceptibility over Kaspa. The plot sizes were 10 m by 2 m with six rows sown on 9 inch (22.5 cm) and 10 inch (26 cm) spacings at Hart and Minnipa respectively. Trial sowing dates were 10 May at Hart and 6 May at Minnipa. The sowing dates at the two sites corresponded to a medium blackspot risk sowing window as forecasted by the Blackspot Manager, DAFWA Crop Disease Forecasts, May 2016.

In order to accelerate AB infection in both trials field pea stubble infested with AB from the previous season was uniformly spread adjacent to seedlings at 1 to 2 nodes growth stage. The disease severity of AB within a plot was assessed as the percentage of plants covered by AB symptoms (purplish-black necrotic lesions on leaves) x frequency of infected plants per plot at vegetative (7 node) and early bud development (13 node) growth stages. Further, a quantitative assessment on the vertical progression of AB on individual plants was conducted at mid to late flowering stage by randomly selecting five plants per plot and assessing the number of girdled nodes as a proportion of total nodes per plant per plot and thereafter using the scores to develop a disease index (DI).

***** Some of the fungicide treatments in this research contain unregistered fungicides, application rates and timings and were undertaken for experimental purposes only. The results within this document do not constitute a recommendation for that particular use by the author or author's organisation.***

Dr Jenny Davidson, SARDI talking to farmers on fungicide management in pulses at the Hart Winter Walk, 2016.

Table 1. Summary of fungicide treatments and application timings as applied to field pea AB management trials at Hart (Mid-North) and Minnipa (Upper Eyre Peninsula), SA 2016.

Treatment*	Seed tmt	Seeding	4 WAS^	6 WAS^	9 WAS^	Early flower	Mid Flower	Late Flower
Nil								
PPT	PPT							
Chloro	PPT		Chloro	10 sprays (applied fortnightly) →				
Sys	PPT							
Flu		Flu						
Av.Xpro	PPT			Av.Xpro		Av.Xpro		
Ami.Xtra	PPT			Ami.Xtra		Ami.Xtra		
Uni+Ami.Xtra		Uni		Ami.Xtra		Ami.Xtra		
Flu+Avi.Xpro		Flu		Av.Xpro		Av.Xpro		
Ami.Xtra	PPT			Ami.Xtra		Ami.Xtra		
Av.Xpro early + Manc	PPT		Av.Xpro		Av.Xpro	Manc.		
Manc. Low	PPT		Manc.		Manc.	Manc.	Manc.	Manc.
Manc Std.	PPT			Manc.		Manc.		

***Fungicide treatment legend and application rates**

1. Nil = no treatment applied
2. PPT = P Pickle T® (PPT) - 200 ml/100 kg seed
3. Chloro = chlorothalonil - 2 L/ha
4. Sys = Systiva – 150 ml/100 kg seed
5. Flu = fluid injection: Flutriafol – 400 ml/ha
6. Uni = fluid injection: Uniform – 400 ml/ha
7. Avi.Xpro = Aviator Xpro® - 600 ml/ha
8. Ami.Xtra = Amistar Xtra® - 600 ml/ha
9. Manc low = mancozeb – 0.5 kg/ha
10. Manc Std. = mancozeb – 2 kg/ha

All treatments were treated with Apron® (350 g/L Matalaxyl-M) seed dressing to control downy mildew.

^WAS = weeks after sowing

Results and discussion

In 2016, the growing season rainfall (GSR) was above long term averages at both sites. A total of 356 and 268 mm was recorded for the months of April to October, at Hart and Minnipa respectively. The two trials were sown in late Autumn in relatively dry seed bed conditions, however, this was followed by wet conditions in Winter and a relatively cool Spring which resulted in prolonged maturation of the crop especially at Hart.

Effect of fungicide treatments on disease severity

The results obtained from the assessment of disease severity at the late vegetative (7 node) and early bud development (13 node) growth stage indicated a site x fungicide treatment interaction. This suggests that fungicide treatment response in controlling AB disease changed significantly with environmental (site) conditions. Assessment of AB disease responses at 7 node only evaluated the effect of fungicides that had been applied at seeding, four and six WAS (weeks after sowing) while that conducted at 13 node evaluated the effect of fungicides that had been applied at seeding, four, six, and nine WAS.

Disease severity at the 7 node assessment period was higher in the nil treatment at Minnipa (42%) than at Hart (13%) (Table 2). This was a similar finding to that found in 2015 highlighting the importance of early season disease control at Minnipa. Aviator Xpro® applied at four WAS and fortnightly chlorothalonil treatments (first treatment commenced at 4 WAS) showed varying but improved disease control over all other treatments at both sites. This indicated that early application timings at between 2 and 4 node improved early season disease control over later application at six WAS (5-6 node). The current industry practice, mancozeb (2 kg/ha) applied at six WAS reduced infection levels compared to nil at Hart but not at Minnipa where disease severity was higher. This finding suggests that there may be differences in efficacy between fungicides depending upon the level of disease pressure.

At the 13 node assessment period, the current industry practice, mancozeb (2 kg/ha) treatment, reduced infection levels similar to the fortnightly chlorothalonil and all the Aviator Xpro® treatments at Hart only (Table 2). This suggested that in some instances where AB infection is relatively low, these three fungicides may offer similar levels of disease control. At Minnipa, however, the fortnightly chlorothalonil had the highest level of disease control over all other treatments. Differences between other foliar fungicides were less obvious and only the Flutriafol + Aviator Xpro® treatment applied at six WAS showed improved disease control over the nil treatment. In most instances, Amistar Xtra® treatments and the lower rate of mancozeb (500 g/ha) treatment did not reduce infection levels over the nil or the current industry standard of mancozeb (2 kg/ha) treatments.

The disease index scores at the mid flowering stage showed that the effect of fungicide treatments in controlling disease was similar across both sites. Notably, disease infection was high among all treatments including the fortnightly chlorothalonil treatment which was shown to have up to 60% infection level across both sites (Figure 1). However this treatment, as expected, still had an improved level of disease control over all other treatments at both sites. This was followed by the flutriafol + Aviator Xpro® treatment which also had lower AB infection levels than the current industry practice of mancozeb (2 kg/ha). Again this observation suggested that Aviator Xpro® as a product had better efficacy in improving disease control (20%) over the industry practice mancozeb (2 kg/ha) treatment especially at this critical period of mid-late flowering and pod-filling.

Table 2. Ascochyta blight disease severity assessed at 7 and 13 node (percentage plot severity) in field pea (PBA Coogee) under different fungicide treatments at Hart (Mid-North) and Minnipa (Upper Eyre Peninsula), SA, 2016.

	Disease severity at 7 node (% plant disease)				Disease severity at 13 node (% plant disease)	
Fungicide Treatment*	**Hart Log (base 10)**	**Hart Raw data**	**Minnipa Log (base 10)**	**Minnipa Raw data**	**Hart**	**Minnipa**
Nil	1.12	13.1	1.62	41.6	32	51
Sys	1.03	10.6	1.58	38.3	35	45
PPT	0.84	6.8	1.62	41.6	36	46
Flu	0.77	5.8	1.6	40	24	51
Manc.Std	0.77	5.8	1.6	40	24	47
Manc. Low	0.82	6.5	1.6	40	32	47
Ami.Xtra	0.84	6.8	1.62	41.6	33	49
Avi.Xpro	0.77	5.8	1.6	40	24	46
Uni+Ami.Xtra	1.05	11.3	1.58	38.3	32	47
Flu + Avi.Xpro	0.5	3.2	1.54	35	19	41
Avi.Xpro early + Manc	0	1	0.9	7.9	17	42
Chloro	0.1	1.3	0.5	3.1	14	25
LSD (P<0.05)	**0.19**		**0.19**		**7.8**	

*Refer to treatment legend in Table 1 for treatment identification

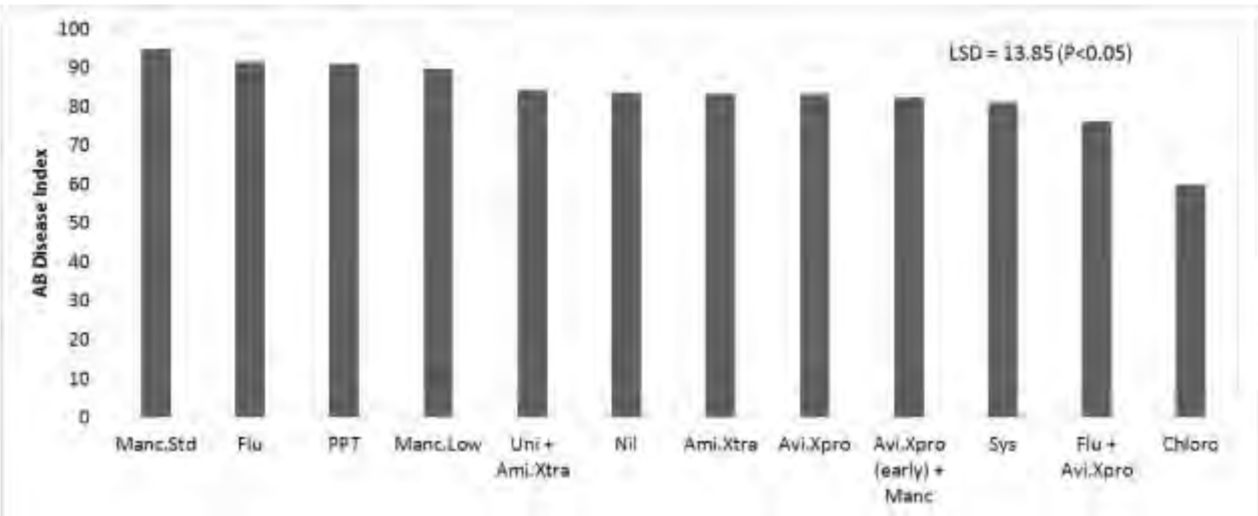

*Figure 1. Ascochyta blight disease index developed from a quantitative assessment of the number of girdled nodes on individual field pea plants at mid-late flowering under different fungicide treatments at Hart (Mid-North) and Minnipa (Upper Eyre Peninsula), SA, 2016. (*Refer to treatment legend in Table 1 for treatment identification.)*

Effect of fungicide treatments on grain yield

There was a site by fungicide interaction for grain yield. Higher yields were recorded at Hart (1.74 t/ha) than at Minnipa (1.30 t/ha) which is likely to be due to higher rainfall and a longer and more favourable season finish (Table 3). The disease index scores showed that disease was strongly correlated (R^2=0.72, P≤ 0.05, data not presented) with grain yields across the two sites hence disease was a major driver in yield loss in 2016. At Hart, the highest grain yields were recorded from the fortnightly chlorothalonil (2.67 t/ha) treatment over all other treatments. This treatment received its last fungicide spray in early Spring, 8 November, which was almost three and half months after the early flowering stage compared when most other treatments had ceased having foliar sprays (15 August). Comparatively at Minnipa the last chlorothalonil spray was applied on the 19 October, two months after the early flowering stage sprays (17 August) highlighting the longer and more favourable finishing conditions experienced at Hart. Yields at Hart were improved by 20% from the use of Aviator Xpro® and Amistar Xtra® treatment over the current industry practice, mancozeb (2 kg/ha) and the nil treatment which both yielded similarly.

At Minnipa, the fortnightly chlorothalonil treatment yielded similar to a number of treatments including all Aviator Xpro® treatments, one of the Amistar Xtra® and the lower rate of mancozeb (500 g/ha) which was applied at five separate occasions. The performance of these fungicides in grain yield response was quite remarkable given that the fortnightly chlorothalonil treatment had received up to 10 sprays whereas the other treatments had only received sprays ranging from two to five in number. Notably, there was no yield improvement from the application of the current industry practice, mancozeb (2 kg/ha) over the nil treatment. These results suggested that both application timing and type of product were important for disease control under high disease pressure conditions at both sites in 2016.

Table 3. Average yield (t/ha) of field pea (PBA Coogee) under different fungicide treatments at Hart (Mid-North) and Minnipa (Upper Eyre Peninsula) SA, 2016.

	Grain yield (t/ha)	
Fungicide treatment*	**Hart**	**Minnipa**
Nil	1.49	0.95
Sys	1.55	1.19
PPT	1.33	1.05
Flu	1.49	1.1
Manc. Std	1.54	1.19
Manc. Low	1.6	1.37
Ami.Xtra	1.84	1.32
Avi.Xpro	1.93	1.4
Uni. + Ami.Xtra	1.91	1.21
Flu. + Avi.Xpro	1.89	1.57
Avi.Xpro (early) + Manc.	1.65	1.58
Chloro	2.67	1.67
LSD (P<0.05)	**0.336**	

*Refer to treatment legend in Table 1 for treatment identification.

Summary / implications

Above average rainfall together with effective inoculation of AB favoured early and high disease development and progression at Minnipa. In contrast cooler Spring conditions and higher rainfall amounts led to a longer maturation period and prolonged exposure of unprotected new plant growth to late AB disease infection at Hart. These differences in environmental conditions are likely to have accounted for site by fungicide treatment interaction for disease severity and grain yield response between the two sites.

The current industry practice of two strategic foliar sprays of mancozeb (2 kg/ha) at vegetative and early flowering growth stages did not effectively control disease or result in a yield improvement over the unsprayed nil treatment in a susceptible field pea variety under high disease pressure in 2016. In comparison, Aviator Xpro® and Amistar Xtra® in various combinations, showed improved levels of disease control over the current industry practice of mancozeb (2 kg/ha) and the nil treatment. At Minnipa the early application of Aviator Xpro® showed improved control and reduced early infection levels over later application timings of similar treatments. Reducing the rate of application of mancozeb from 2 kg/ha to 500 g/ha and splitting applications over five timings, showed improved disease control at Hart but not at Minnipa. While the fortnightly chlorothalonil treatment reduced disease pressure considerably over other treatments it only achieved a disease index rating of 60% across both sites at the early flowering stage indicating a large amount of disease infection still occurred. Higher relative yields at Hart from the prolonged application of the fortnightly chlorothalonil treatment demonstrate the importance of late disease control especially in longer more favourable seasons and environments.

In comparison to the current industry practice, of mancozeb (2 kg/ha), the two experimental fungicide products, Aviator Xpro® and Amistar Xtra® showed yield benefits of at least 19% across the two sites under high disease severity. A similar trial conducted in 2015 also showed a yield benefit of approximately 15% from the application of these new fungicide products. Further testing will be carried out in the 2017 season to confirm these findings across seasons and environments. It is also worth noting that the levels of AB inoculation from infested pea stubble may be higher than those commonly encountered in the paddocks, therefore our results should be interpreted with caution.

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Subsoil amelioration – results from year two

Stuart Sherriff and Sam Trengove, Trengove Consulting

Key findings

- Grain yield at Hill River was increased on two soil types by 12% and 33% through the addition of soil amendments to the surface or subsoil.
- There was no yield difference between applying amendment to the surface or subsoil in 2016, except at one of the seven sites sown to lentils.
- There was little difference between applying large rates of synthetic fertiliser or applying 20 t/ha chicken litter.

Why do the trial?

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

How was it done?

Plot size	2.5 m x 12.0 m
Seeding date	Hill River: 18th May Hart: 17th May Bute: 12th May
Base treatments applied in 2015	Hill River: Trojan wheat, 120 kg/ha 32:10 kg/ha IBS, 160 kg/ha post emergent urea
	Hart: PBA Hurricane XT Lentil 60 kg/ha MAP IBS
	Bute: Compass barley 60 kg/ha DAP IBS, 50 kg/ha post emergent urea

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

Soil types

Hart east	Calcareous gradational clay loam High pH and moderate to high ESP below 30cm
Hart west	Calcareous loam High pH, Boron and ESP below 30cm
Bute northwest	Calcareous transitional cracking clay High pH, Boron and ESP below 30cm
Bute mid	Calcareous loam High pH, Boron and ESP below 60cm
Bute southwest	Grey cracking clay with high exchangeable sodium at depth High pH, Boron and ESP below 30cm
Hill River east	Black cracking clay
Hill River west	Loam over red clay Moderate ESP below 60cm and moderate Boron below 90cm

The initial treatments (Table 1) were established prior to sowing in 2015. Ripping and subsoil treatments were applied with a purpose built trial machine loaned from Victoria DPI. The machine is capable of ripping to a depth of 600 mm and applying large volumes of product to a depth of 400 mm. Chicken litter was sourced from three separate chicken sheds for ease of freight, the average nutrient content is shown in Table 2. After the treatments were implemented the plots at all sites were levelled using an offset disc. No further treatments have been made to the plots since 2015.

The trials at Hill River were sown in both 2015 and 2016 using a commercial parallelogram knifepoint and press wheel seeder on 250mm spacing. In 2015 the Hart west trial was sown using a John Deere 1980 single discs on 152 mm (6") row spacing, closer wheels and press wheels and the Hart east trial was sown using narrow points on 225 mm (9") row spacing. Both sites at Hart were sown with narrow points and presswheels in 2016. In 2015 the Bute trials were re sown due to poor establishment using a 6 row plot seeder with narrow points and press wheels on 225 mm spacing. In 2016 the Bute sites were sown with a Concord seeder on 300 mm spacing with 150 mm sweep points and press wheels.

Commercial rates of seeding fertiliser, post emergent urea and pesticides were applied by the growers in their standard paddock operations over the top of all trial treatments to provide adequate nutrition and crop protection for the control treatments.

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

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

Treatment	Nutrition	Ripping	Placement
1	Nil	No	Nil
2	Nil	Yes	Nil
3	20 t/ha chicken litter	No	Surface
4	20 t/ha chicken litter	Yes	Surface
5	20 t/ha chicken litter	Yes	Subsoil
6	MAP, MoP, SoA, Urea	No	Surface
7	MAP, MoP, SoA, Urea	Yes	Surface
8	MAP, MoP, SoA, Urea	Yes	Subsoil

Table 2. Average nutrient concentration from the three sources used in Hart subsoil manuring trials 2015.

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

Assessments including segmented soil tests to 120 cm, plant establishment, Greenseeker NDVI, grain yield and grain quality were conducted in 2015 and 2016 and results analysed using Genstat ANOVA.

In 2016, the Bute Mid and SE sites were affected by hail prior to harvest which may have affected results.

Results and discussion

Hill River sites

Grain yield at the Hill River sites averaged 7.85 t/ha and 8.00 t/ha for the east and west sites, respectively (Table 3). The main treatment effect was from the addition of either the 20 t/ha of chicken litter or the '3 t/ha combo' of MAP, MoP, SoA and urea in 2016. There was no significant difference between these two amendments and the response was irrespective of the position they were placed (surface or in the subsoil). The amendments increased grain yield by 0.85 t/ha at the east site with the red loamy clay soil and 2.1 t/ha for the higher yielding west site on black cracking clay soil.

Grain protein was also significantly affected by the application of either of the amendments increasing protein from 9% to 10.2% at the east site and 8.8% to 10.7% at the west site. Test weight appears to have been reduced with the application of the 3 t/ha combo to the subsoil. However, it was also lower in ripping alone at the west site.

Table 3. NDVI captured 19th July, grain yield and grain quality for the Hill River subsoil manuring trials in 2016.

Treat.	Nutrition	Ripping	Placement	Hill River East NDVI 19th Jul	Hill River East Grain yield (t/ha)	Hill River East Protein (%)	Hill River East Test weight (kg/hL)	Hill River East Screenings (%)	Hill River West NDVI 19th Jul	Hill River West Grain yield (t/ha)	Hill River West Protein (%)	Hill River West Test weight (kg/hL)	Hill River West Screenings (%)
1	Nil	No	Nil	0.39	7.27	9.0	72.2	2.0	0.66	6.16	8.9	70.8	1.6
2	Nil	Yes	Nil	0.45	7.14	9.1	72.1	2.0	0.61	6.68	8.8	69.0	2.0
3	20 t/ha chicken litter	No	Surface	0.52	8.37	10.8	72.0	2.0	0.62	8.41	10.0	71.4	1.6
4	20 t/ha chicken litter	Yes	Surface	0.54	8.25	11.2	71.7	2.0	0.68	8.61	10.4	71.1	1.8
5	20 t/ha chicken litter	Yes	Subsoil	0.54	7.99	11.4	72.2	2.1	0.67	8.66	11.6	71.5	1.5
6	MAP, MoP, SoA, Urea	No	Surface	0.60	7.91	11.0	72.3	2.1	0.62	8.68	10.3	70.6	1.7
7	MAP, MoP, SoA, Urea	Yes	Surface	0.56	7.69	11.7	72.4	1.9	0.60	8.56	10.3	70.2	1.8
8	MAP, MoP, SoA, Urea	Yes	Subsoil	0.52	8.17	11.3	70.7	2.3	0.63	8.22	11.8	69.3	1.9
			LSD (P≤0.05)	0.05	0.72	0.7	ns	ns	0.04	0.68	0.7	ns	ns

Hart sites

Lentil Greenseeker NDVI was reduced at the east site in the surface applied 3 t/ha combo treatment indicating reduced biomass (Table 4). At the west site the treatment NDVI was increased with the addition of 20 t/ha chicken litter to the surface. Lentil NDVI results were not reflected by grain yield at the east site where grain yield was maximised in the nil nutrition treatments and the 20 t/ha chicken litter applied to the subsoil. At this site the 3 t/ha combo treatment applied to the surface with ripping and applied to the subsoil also produced equal highest yields.

At the west site NDVI captured on the 12th August has an inverse relationship with grain yield. Where the lowest biomass treatments produced the greatest grain yield. These included the nil nutrition treatments, the 20 t/ha chicken litter applied to the subsoil and all of the 3 t/ha combo treatments. Of the two Hart sites the west site has the higher levels of subsoil constraints with high levels of boron below 30 cm.

Table 4. NDVI captured on 12th August, grain yield and grain quality for the Hart subsoil manuring trials in 2016.

Treat.	Nutrition	Ripping	Placement	Hart East NDVI 12th Aug	Hart East Grain yield (t/ha)	Hart West NDVI 12th Aug	Hart West Grain yield (t/ha)
1	Nil	No	Nil	0.55	2.64	0.41	3.43
2	Nil	Yes	Nil	0.53	2.71	0.48	3.35
3	20 t/ha chicken litter	No	Surface	0.53	1.82	0.63	2.53
4	20 t/ha chicken litter	Yes	Surface	0.62	1.83	0.62	2.39
5	20 t/ha chicken litter	Yes	Subsoil	0.53	2.76	0.47	3.36
6	MAP, MoP, SoA, Urea	No	Surface	0.45	1.88	0.44	3.55
7	MAP, MoP, SoA, Urea	Yes	Surface	0.46	2.38	0.42	3.16
8	MAP, MoP, SoA, Urea	Yes	Subsoil	0.56	2.49	0.48	3.30
		LSD (P≤0.05)	*Fpr = 0.053	0.10*	0.53	0.06	0.44

Bute sites

The middle (M) and south east (SE) sites were affected by hail prior to harvest in 2016. There was also minor hail damage observed in the north west (NW) site.

NDVI values at all Bute sites were measured on 20th July and by this time all treatments produced values greater than 0.71 and results were not significantly different. However, the results for the mid site indicate that biomass was slightly lower in the nil nutrition treatments (Tables 5 a, b and c).

At the NW site grain yield was maximised in the two nil nutrition treatments averaging 6.65 t/ha indicating that the farmer practice of 60 kg/ha of DAP at sowing and 50 kg/ha post emergent urea was enough to produce maximum yield at this site (in March 2015 153 kg of available soil N was measured to a depth of 120 cm). Chicken litter and the 3 t/ha combo treatments applied to either the surface or subsoil with ripping produced the lowest grain yields averaging 6.22 t/ha. Grain yield was lower at the SE site and there was a significant positive response to addition of either amendment when applied to the surface without ripping. Chicken litter applied to the surface with ripping also performed well at the SE site. Grain yield at the Mid site averaged 5.54 t/ha and was not significantly affected by treatment.

Grain protein was lowest in the nil nutrition treatments at all sites. Ripping in these nil treatments increased protein by 1% at all three Bute sites. This may be attributed to the soil disturbance during ripping and therefore increased N mineralisation. Poor establishment and low grain yields in 2015 in these treatments could also explain the difference at the NW and SE sites as grain N removal was lower in these treatments (Table 6). When comparing among the other treatments 3 – 8, deep ripping produced higher protein (approximately 1%) compared to the same nutrition treatments applied to the surface. This response occurred for all sites and amendments accept for the mid site with chicken litter.

Other grain quality parameters performed as expected with higher nutrition treatments producing generally lower test weight, lower retention and higher screenings. The inclusion of ripping in the nil nutrition treatment in 2015 had a slight negative impact on these attributes at all three sites.

Table 5. NDVI captured on 20th July, grain yield and grain quality for the Bute subsoil manuring trials a) north west, b) south east and c) middle in 2016.

a)

Treat.	Nutrition	Ripping	Placement	Bute NW NDVI 20th Jul	Grain yield (t/ha)	Protein (%)	Test Weight (kg/hL)	Retention (%)	Screenings (%)
1	Nil	No	Nil	0.86	6.65	13.4	63.9	85.8	4.4
2	Nil	Yes	Nil	0.86	6.64	14.6	64.6	82.2	6.2
3	20 t/ha chicken litter	No	Surface	0.86	6.44	16.5	60.0	72.2	11.4
4	20 t/ha chicken litter	Yes	Surface	0.87	6.22	17.2	61.3	72.7	11.3
5	20 t/ha chicken litter	Yes	Subsoil	0.86	6.22	17.0	61.7	74.0	10.8
6	MAP, MoP, SoA, Urea	No	Surface	0.85	6.46	16.2	62.2	76.5	8.9
7	MAP, MoP, SoA, Urea	Yes	Surface	0.87	6.17	17.2	62.1	74.7	9.9
8	MAP, MoP, SoA, Urea	Yes	Subsoil	0.87	6.19	17.0	61.9	73.2	10.9
			LSD (P≤0.05)	ns	0.32	1.0	2.4	3.5	2.0

b)

Treat.	Nutrition	Ripping	Placement	Bute SE NDVI 20th Jul	Grain yield (t/ha)	Protein (%)	Test weight (kg/hL)	Retention (%)	Screenings (%)
1	Nil	No	Nil	0.86	4.85	12.1	65.6	88.6	3.2
2	Nil	Yes	Nil	0.86	4.99	13.4	63.9	86.8	4.0
3	20 t/ha chicken litter	No	Surface	0.86	5.38	16.2	61.5	71.9	10.5
4	20 t/ha chicken litter	Yes	Surface	0.87	5.37	17.1	60.9	71.0	11.4
5	20 t/ha chicken litter	Yes	Subsoil	0.86	4.92	17.4	61.6	75.1	9.1
6	MAP, MoP, SoA, Urea	No	Surface	0.86	5.55	16.5	62.7	76.2	8.3
7	MAP, MoP, SoA, Urea	Yes	Surface	0.86	5.02	17.0	61.7	72.5	10.1
8	MAP, MoP, SoA, Urea	Yes	Subsoil	0.86	5.14	17.1	61.6	75.4	8.9
			LSD (P≤0.05)	ns	0.33	1.2	1.6	3.2	1.5

c)

Treat.	Nutrition	Ripping	Placement	Bute Mid NDVI 20th Jul	Grain yield (t/ha)	Protein (%)	Test weight (kg/hL)	Retention (%)	Screenings (%)
1	Nil	No	Nil	0.71	5.45	10.3	68.2	95.1	1.4
2	Nil	Yes	Nil	0.77	5.42	11.1	68.0	91.4	2.4
3	20 t/ha chicken litter	No	Surface	0.87	5.35	16.4	62.4	79.4	7.5
4	20 t/ha chicken litter	Yes	Surface	0.87	5.59	16.1	61.3	76.4	9.0
5	20 t/ha chicken litter	Yes	Subsoil	0.86	5.56	15.6	62.8	77.2	8.3
6	MAP, MoP, SoA, Urea	No	Surface	0.86	5.48	15.3	61.8	78.5	7.2
7	MAP, MoP, SoA, Urea	Yes	Surface	0.86	6.07	16.0	62.0	77.3	7.8
8	MAP, MoP, SoA, Urea	Yes	Subsoil	0.85	5.38	16.9	61.8	77.7	7.7
			LSD (P≤0.05)	ns	ns	1.2	1.6	4.7	2.1

Table 6. Wheat grain N removal for the NW, SE and Mid site at Bute, 2015.

Treat.	Nutrition	Ripping	Placement	2015 grain N removal Bute NW	Bute SE	Bute Mid
1	Nil	No	Nil	55	51	63
2	Nil	Yes	Nil	21	18	62
3	20 t/ha chicken litter	No	Surface	43	37	83
4	20 t/ha chicken litter	Yes	Surface	19	25	76
5	20 t/ha chicken litter	Yes	Subsoil	19	*	72
6	MAP, MoP, SoA, Urea	No	Surface	46	44	84
7	MAP, MoP, SoA, Urea	Yes	Surface	23	24	74
8	MAP, MoP, SoA, Urea	Yes	Subsoil	24	27	75

Summary / implications

There have been large yield responses reported from subsoil manuring in high rainfall environments, particularly south western Victoria. However in recent seasons with lower rainfall these yield responses have declined. The results from the first season of the Hart and Bute trials (2015) were negative with the high nutrition treatments and deep ripping producing lower grain yields than the nil. Responses at all seven sites in 2016 were better than the first year due to better crop establishment and the wetter and cooler Spring.

Deep ripping alone did not have any significant impact on grain yield at any of the seven sites. However, at Bute there was a significant protein response indicating more access to nutrients. The response to either amendment at any given site was similar, with a few exceptions, indicating that after two seasons there is little difference between the two products. This suggests that the main response to the application of chicken litter is nutritional as the levels of nitrogen, phosphorus, potassium and sulphur are matched in each treatment.

The placement of the product, either chicken litter or the matched synthetic fertiliser (3 t/ha combo) did not have any impact at five of the seven sites. At the Hart west site placing chicken litter in the subsoil compared to the surface reduced Greenseeker NDVI (19th July) which in turn prevented a yield reduction from the application of the chicken litter. At the Bute SE site screenings were reduced by placing either amendment in the subsoil compared with the surface. It is likely that both of these responses are a result of delayed access to the nutrition in the amendment.

Impacts of crop management strategies on nutrient stratification and soil test interpretation

Rochelle Wheaton, Hart Field-Site Group
Sean Mason, University of Adelaide and Agronomy Solutions

Key Findings

- Concentrated chaff distribution had no significant impacts on nutrient stratification either horizontally or vertically across the landscape at three sites.
- Chicken litter applications appear to compliment traditional chemical fertiliser applications by increasing P availability.
- All nutrients assessed were well above established critical levels and there was a tendency for all nutrients to be concentrated at the surface (0-5 cm) regardless of the known differences in mobility between N, P, K and S.

Why do the trial?

Nutrient stratification is where nutrients such as nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) occur naturally as layers or bands through the soil profile as a resulted of pedological processes or may occur through anthropogenic (man-made) processes. Nutrient stratification can significantly reduce grain production through limiting effective spatial and temporal synchronisation between soil nutrient supply and crop demand. Nutrient mobility in the soil can further magnify stratification. Mobile nutrients like N and S can move deeper into the profile leading to potential crop nutrient deficiencies in the topsoil where most plant roots are located, while immobile fertiliser nutrients like P and K tend to be concentrated in the top 10 to 15 cm.

In no-tillage systems, the lack of mixing means banded immobile nutrients become more stratified. This can be either in drill rows (horizontal) or by vertical concentration in surface or subsurface layers. The principal management issue from stratification is that current soil tests (0-10 cm) may not accurately reflect the potential response of the crop to applied fertiliser and so this becomes a significant issue to be accounted for when making agronomic decisions. Furthermore, mismatches between the location of roots and nutrients (and water) can significantly limit crop growth.

The aim of this study was to investigate two management strategies applicable to the Mid-North region that could influence nutrient stratification. These strategies include the concentration of harvest residues areas of the paddock and the application of chicken litter as an alternative or supplement to fertiliser programs.

How was it done?

The study involved sampling several field sites investigating nutrient distribution around concentrated chaff lines at sowing (n=3) and where growers have routinely applied chicken litter (n=3). Soil samples were taken prior to sowing and analysed for concentrations of N, P, K, S and carbon (C).

Chaff residue distribution with controlled traffic

Over the past decade, we have seen a shift in width of headers fronts, on average from 8-9 m to now 12 m. This means the chaff spread out the back of the header also needs to travel a greater distance to be spread evenly. In scenarios where the chaff is not spread evenly over consecutive years there is the potential for nutrients (particularly N, P, K & S) to become horizontally stratified across the soil surface as chaff residues can contain significant amounts of these nutrients. A common example is K deficiency identified through increased dry matter growth of crops sown over concentrated windrows.

Sites were located at Spalding, Hacklins Corner and Redhill in paddocks with long term controlled traffic. Site information collected included previous crop type and yield, fertiliser applications, harvester comb width, harvest date and number of years using guidance systems. Four cores were taken at each sampling point (Figure 1) with soil taken from each core separated into three depths (0-5 cm, 5-10 cm and 10-20 cm) and combined into one bulk sample for each sampling point and depth. Four replicates were taken at each site at 10 m intervals along the chaff line/harvester tracks. An example of chaff distribution at two sampling points is shown within Figure 2.

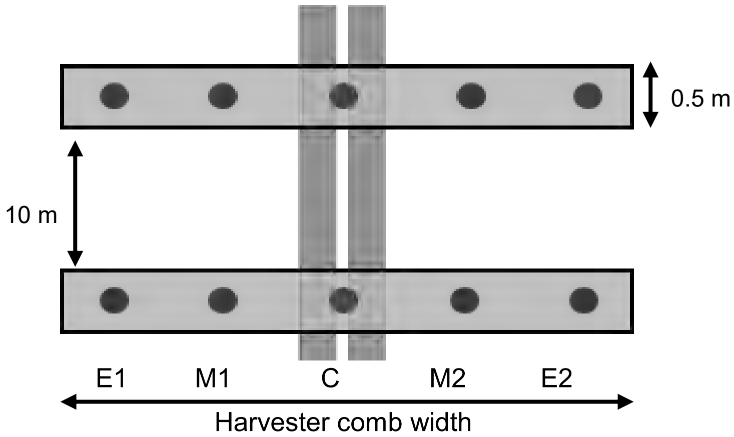

Figure 1. Sampling points along the width of a harvester comb. Four cores were taken per sampling point (E= end, M = middle and C = centre) with each sampling point a certain distance away from the chaff line.

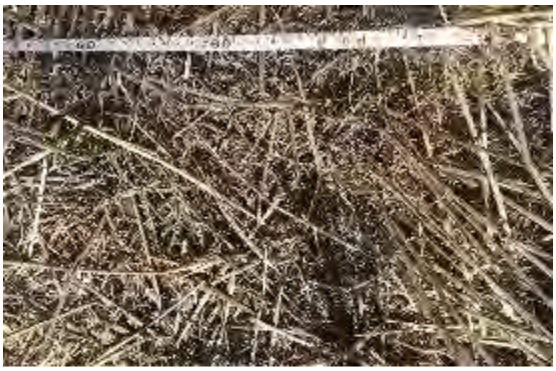

Figure 2. Chaff residue distribution at sampling point 'C' (left) and 'E1' (right) at the Redhill site.

Broadcast application of chicken litter

The use of chicken litter (CL) is a common nutrient source in the Mid-North to compliment traditional fertiliser programs. Chicken litter contains both macro and micro nutrients that can be beneficial to crop growth. Concentrations of these nutrients can vary between types and batches of CL. Most growers will usually spread CL on their whole farm using a three to four year rotation system and select a portion of their paddocks to be spread every year. Chicken litter is mostly commonly spread on the soil surface several weeks prior to seeding at a rate of 2.5 to 3 t/ha. The effect of nutrient accumulation at the soil surface may be amplified in systems that combine CL application with no-till seeding operations. This is due to the topsoil (~5 cm) being prone to drying which can reduce the availability of nutrients to the crop and therefore decrease plant uptake.

Three sites were chosen where a simple comparison of CL application vs normal fertiliser inputs could be achieved. One site (Marrabel) had an area within the paddock of no applied CL while the rest of the paddock had CL applications on top of a regular fertiliser program. The second site (Hill River) was simply a paired paddock comparison of no CL + fertiliser vs CL + fertiliser and the third (Hart) was a comparison of an area with applied CL vs a fence line sample. The authors note that it was not possible to account for differences between paddocks through different crop rotations and potentially different inputs at site two. Site information collected included number of CL applications, rate of CL application (Table 1), spreader type and width, type of CL and additional fertiliser. Eight different sampling points were taken within the paddock which had CL applied at depths of 0-5 cm, 5-10 cm and 10-20 cm.

Table 1. Chicken litter application details (t/ha) for all three sites.

Site location	Chicken litter application details
Marrabel	3 applications - 2009 2.0 t/ha, 2012 2.4 t/ha and 2014 3.0 t/ha
Hill River	5 applications of 2.0 to 2.5 t/ha over 10 years
Hart	3 applications - 2008 4.0 t/ha, 2009 3.4 t/ha and 2012 2.1 t/ha

Results and discussion

It should be noted that due to different sizes in increments the 0-5 cm and 5-10 cm layers cannot be directly compared with the 10-20 cm layer. In order to compare results with the 10-20 cm layer an average of the 0-5 cm and 5-10 cm layer must be determined.

Chaff residues

Across all three sites there was no significant effect ($P \leq 0.05$) of chaff lines on the distribution of nitrate (mg/kg) horizontally. The distribution of nitrate horizontally at the Spalding site is shown within figure 3. The concentration of nitrate in the 0-5 cm layer was significantly higher than the 5-10 cm layer at both the Spalding and Redhill sites indicating vertical stratification (Table 2). At the Hacklins Corner site vertical stratification of nitrate was not present between soil layers.

Table 2. Average nitrate concentration for all three sites. Where present, different letters denote significant differences (P≤0.05) between depths at the same site only.

Site	Depth	Nitrate NO_3 (mg/kg)
Spalding	0-5	60.0 [a]
	5-10	33.8 [b]
	10-20	20.3
	LSD (P≤0.05)	6.6
Redhill	0-5	58.1 [a]
	5-10	24.2 [b]
	10-20	20.1
	LSD (P≤0.05)	8.4
Hacklins Corner	0-5	45.7 [a]
	5-10	32.3 [a]
	10-20	26.3
	LSD (P≤0.05)	15.2

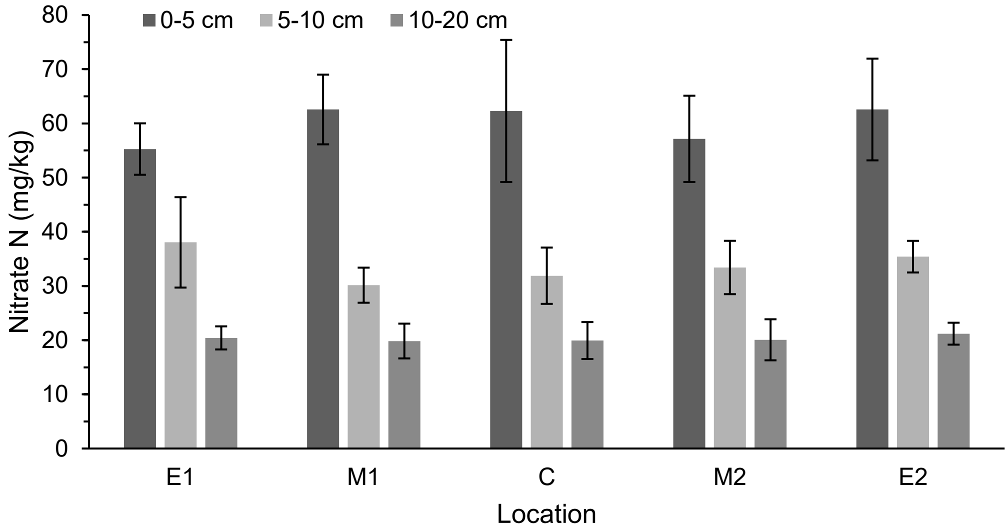

Figure 3. Nitrate distribution across a concentrated line of chaff residue and with depth at the Spalding site. Refer to Figure 1 for location of the sampling points (E1, M1, C, M2, E2).

The Hacklins Corner site was the only site analysed for exchangeable K concentration (mg/kg). Similarly, there was no significant effect of chaff lines on the distribution of exch-K horizontally (Figure 4). Irrespective of location across harvester width, vertical stratification occurred between all three soil layers. The 0-5 cm layer consisted of the highest average concentration of exch-K across all sampling points with 445 mg/kg. The 10-20 cm layer also consisted of a lower exch-K amount when compared to the average of the 0-5 cm and 5-10 cm layers with values of 205 and 357 mg/kg.

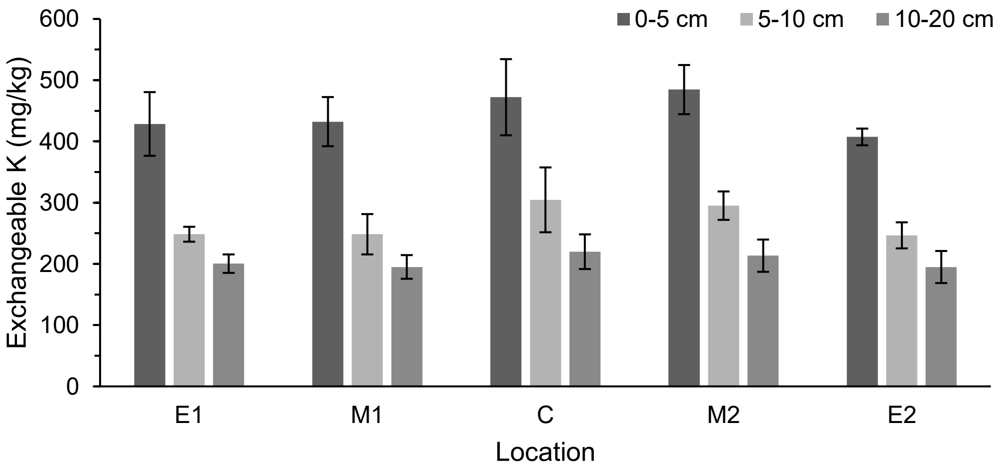

Figure 4. Exchangeable K distribution across a concentrated line of chaff residues and also with depth at the Hacklins Corner Site. E = end, M = middle and C = centre of harvester chaff spread.

Chicken Litter

Significant P stratification ($P \leq 0.05$) occurred in two out of three sites, with available P measures (DGT and Colwell P) both concentrated in the 0-5 cm region (Table 3). The availability of P in the 0-5 cm profile was between 50 to 100% higher than the 5-10 cm interval. Very low P availability was measured in the 10-20 cm region indicating severe stratification of P in these management systems. Phosphorus is an immobile nutrient and doesn't move far away from point source and residue P from fertiliser applications will be restricted to the area of application. Comparison of P distribution with CL application and conventional P application methods indicate that stratification was less severe when CL is applied (Figure 5). This observation needs verification as there was only one control sample taken at each site.

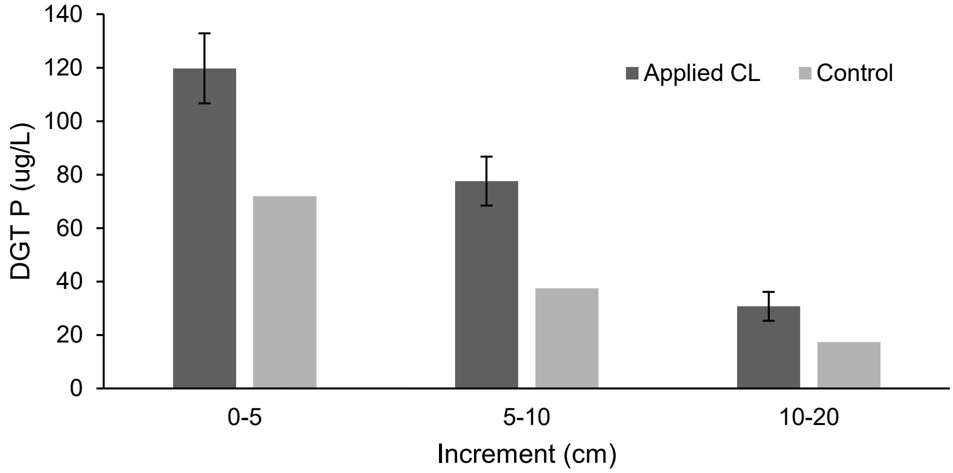

Figure 5. Phosphorus availability (DGT) with depth at the Marrabel site.

Stratification of nitrate occurred at all three sites with the 0-5 cm layer consisting of significantly higher concentrations than the 5-10 cm layer (Table 3). This effect was also evident with total nitrogen (%) where there was a significant stepwise decrease between layers. Comparison of total nitrogen distribution with conventional fertiliser methods indicated that total N concentration was significantly higher with conventional methods at the Marrabel site (Figure 6).

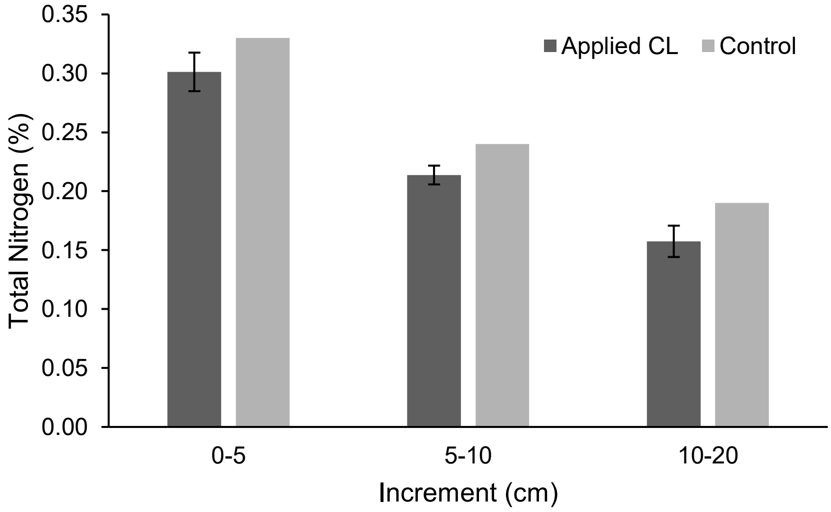

Figure 6. Total nitrogen (%) with depth at the Marrabel site.

Table 3. Average concentrations of nitrate (NO_3 mg/kg), total nitrogen (%), Colwell P (mg/kg), DGT (ug/L), MCP sulphur (mg/kg) and total carbon (%) for all three sites where chicken litter has been applied. Where present, different letters denote significant differences (P≤0.05) between depths at the same site only.

Site	Increment (cm)	NO_3 (mg/kg)	Total N (%)	Colwell P (mg/kg)	DGT P (ug/L)	MCP S (mg/kg)	Total C (%)
Marrabel	**0-5**	79.2 [a]	0.30 [a]	53.6 [a]	119.7 [a]	19.5 [a]	2.93 [a]
	5-10	23.7 [b]	0.21 [b]	39.6 [b]	77.6 [b]	10.6 [a]	1.36 [b]
	10-20	22.4	0.16	23.6	30.7	13.3	1.99
	LSD(P≤0.05)	8.5	0.02	3.5	17.7	2.0	0.23
Hill River	**0-5**	51.7 [a]	0.28 [a]	63.6 [a]	101.9 [a]	19.4	3.18 [a]
	5-10	32.2 [b]	0.23 [b]	45.1 [b]	49.1 [b]	20.0	2.56 [b]
	10-20	24.9	0.12	19.0	9.5	21.6	1.45
	LSD(P≤0.05)	7.7	0.04	6.4	24.6	ns	0.31
Hart	**0-5**	44.7 [a]	0.23 [a]	32.4 [a]	77.8 [a]	10.7 [a]	2.46 [a]
	5-10	38.3 [b]	0.18 [b]	33.2 [a]	66.4 [a]	11.4 [a]	2.01 [c]
	10-20	25.9	0.14	15.1	11.9	6.2	2.11
	LSD(P≤0.05)	4.6	0.01	10.4	51.2	2.9	0.10

Sulphur levels (mg/kg) were significantly higher in the top 10 cm at the Hart site only. At all three sites there was no difference in concentration between the 0-5 cm layer and the 5-10 cm layer (Table 3). Vertical S stratification did not occur at Hill River, indicating that S may not be a nutrient prone to stratification in this soil type/environment.

Carbon (total C%) concentration varied significantly between soil layers at all three sites. A stepwise decrease occurred at both the Marrabel and Hill River site (Table 3). At the Hart site the 0-5 cm layer consisted of the highest concentration of C. Comparison of C distribution with conventional methods at the Hill River site indicated that C concentration was higher with conventional fertiliser applications (Figure 7). This will need further verification to account for other differences between samples (location, soil type, previous crop type etc.).

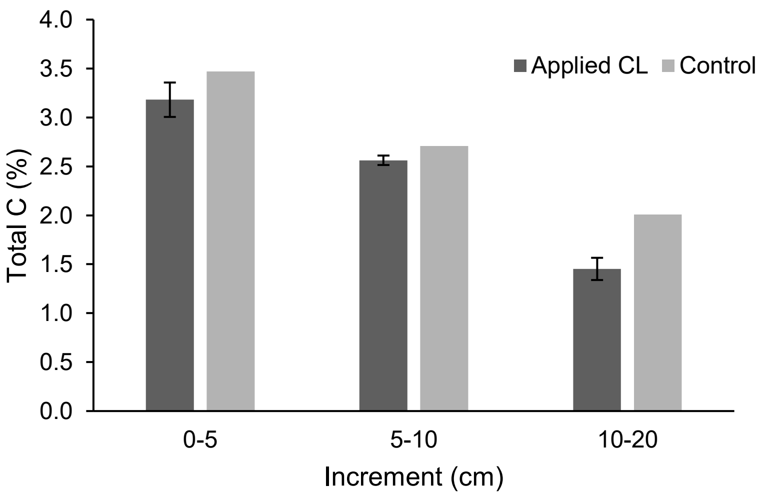

Figure 7. Total carbon (%) with depth at the Hill River site.

Summary / implications

This survey highlights that chaff distribution had no significant impacts on nutrient stratification either horizontally or vertically across the landscape at these three sites. Chicken litter applications appear to compliment traditional chemical fertiliser applications by increasing P availability which supports recent glasshouse and field trial results. Of note is that all nutrients assessed were well above established critical levels. There was a tendency for all nutrients to be concentrated at the surface (0-5 cm) regardless of the known differences in mobility between N, P, K and S.

Grain crops can utilise significant amounts of nutrients located below the surface layer which need to be accounted for in soil sampling protocols if an accurate prediction of nutrient availability is to be achieved. For some nutrients, root uptake efficiency is maximised when the entire root surface has access to nutrients (in an appropriate chemical form) rather than supply only a small proportion of the root system with nutrients.

Deep soil sampling to depth (0 – 60 cm or deeper) prior to sowing by growers/advisers has been a recommendation for N only (and very recently for K and S) for some time, although the actual adoption of this practice varies greatly but is generally thought to be low. Soil testing to depths >10 cm for plant available P is a relatively new concept and has not typically been employed to predict fertiliser responses under commercial conditions. Assessing the accuracy of soil testing for sub-surface nutrients has been dominated by data from WA (K and S) and QLD (K and P).

Hart's regional intern Rochelle Wheaton soil sampling paddocks for the nutrient stratification field survey, 2016.

Selecting a wheat and barley variety for phosphorus efficiency or yield potential – which one is the winner?

Sean Mason, University of Adelaide
Glenn McDonald, University of Adelaide

Key Findings

- Higher P rates (more than typical replacement P rates) were required on sites with moderate to high PBI values.
- There were no significant trends in P use efficiency between wheat and barley varieties selected.
- Variety choice should be made on yield potential and not any potential savings from growing a P efficient variety.

Why do the trial?

Phosphorus (P) deficiency still occurs in many regions across SA with major yield limitations occurring due to inadequate applications of P. Low soil P test values are commonly associated with soils that have moderate to high P buffering indices (> PBI 100). In these soil types replacement P programs may not be sufficiently accounting for the low fertiliser recoveries, generating inadequate P replacement rates. In some cases application rates > 40 kg P/ha might be required to maximise yields, a fertiliser rate that under some circumstances might not be the most economic if yields are low. Identifying these sites and assessing under which circumstances (yield potential, fertiliser prices) high rates of P are economical will be valuable to the grains industry.

Wheat and barley varieties may vary in their responsiveness to P either by having root traits that increase access to soil P or by more efficient use of the P that is taken up. In combination with different yield potentials external P requirements and phosphorus use efficiency (PUE) could vary. Identifying varieties that have greater PUE in deficient soil may benefit SA growers, due to the relatively low P levels driven by moderate to high P fixing soils in many regions.

This article summarises two years of P response trials located in three different locations each year.

How was it done?

Replicated (four) P response trials were performed at three different locations in both 2015 (Cummins, Pinery and Sherwood) and 2016 (Condowie, Cummins and Urania). Six different rates of P as MAP (0, 5, 10, 20, 30, 50 kg P/ha) were sown with the seed. Extra nitrogen (N) applied with greater MAP rates was balanced with urea so all treatments had the equal amount of N at sowing. The P response of four different wheat (Cobra, Corack, Mace and Trojan) and barley (Commander, Compass, Fathom, LaTrobe) varieties were tested. Trials were maintained (weeds, top up N) in order to try and match maximum yield potentials. Trials in both years were sown between 21st May and 2nd of June.

Results and discussion

Soil test results for each site are presented in Table 1. Most sites were expected to be responsive to applications of P with the higher PBI sites generally having lower available P levels as measured by DGT. The Sherwood site was the exception, this site did not have a history of cropping and therefore previous P inputs had been low. Unfortunately, the 2016 Cummins site had levels above critical values and therefore not expected to be responsive. However, the 2015 Cummins site also had levels that suggested P was adequate, but the site varied considerably with available P values and was highly responsive in parts.

Table 1. Summary of soil P characteristics at each of the six sites. Critical values for DGT is 56 (marginal = 48-67) for wheat and 68 (marginal = 50-94) for barley.

Site	Year	Crop	PBI	Critical Colwell P (mg/kg)	Colwell P (mg/kg)	DGT P (µg/L)
Cummins	2015	Barley	59	22	25	71
		Wheat	43	22	26	81
Pinery	2015	Barley	135	29	28	17
		Wheat	135	29	31	14
Sherwood	2015	Barley	41	22	17	25
		Wheat	39	22	11	16
Condowie	2016	Wheat	146	29	29	26
		Barley	147	29	22	15
Urania	2016	Wheat	142	29	37	40
		Barley	118	22	36	59
Cummins	2016	Site	54	22	37	77

2015

Yields varied between the three locations with favourable growing conditions at Cummins resulting in yields reaching 7 t/ha. Tough finishes from a warm and dry September/October at Pinery and Sherwood resulted in lower yields, but still relatively high amounts of P were required to produce optimal yields. The economical rates matched the optimal P rates at Cummins and Sherwood but a flat response curves at Pinery saw economical rates drop back to around 30 kg P/ha compared to rates > 50 kg P/ha required to maximise yield. There was no standout in terms of wheat or barley variety across the three sites as the highest yielding varieties changed depending on location. There was no P x variety interaction which means the variety most suited to that particular region will produce the highest yields and should be the variety of choice.

Table 2. Summary of the 2015 grain yield results at each site for the four wheat and barley varieties sown. Shaded varieties returned the highest economical net return ($/ha) when P deficiency was alleviated.

Location	Variety	Yield (0P) t/ha	Yield (Max.) t/ha	Yield increase with P t/ha	Optimal P rate (kg/ha) yield	Optimal P rate (kg/ha) economic
Cummins	Cobra	5.07	6.15	1.08	6	10
	Corack	5.38	6.35	0.97	12	15
	Mace	4.99	6.18	1.19	26	26
	Trojan	5.42	6.43	1.01	50*	40
	Commander	4.30	6.16	1.86	19	21
	Compass	5.50	7.09	1.59	34	34
	Fathom	5.05	6.38	1.33	22	24
	LaTrobe	5.39	6.71	1.32	18	22
Pinery	Cobra	2.19	2.99	0.80	55*	28
	Corack	2.66	3.58	0.92	55*	30
	Mace	2.45	3.35	0.90	55*	30
	Trojan	2.5	2.81	0.31	55*	0
	Commander	2.40	3.20	0.80	22	20
	Compass	2.82	3.88	1.06	55*	34
	Fathom	2.78	3.68	0.90	46	28
	LaTrobe	2.94	3.95	1.01	46	50
Sherwood	Cobra	0.23	0.74	0.51	14	12
	Corack	0.16	0.87	0.71	14	16
	Mace	0.35	1.19	0.84	37	26
	Trojan	0.03	0.59	0.56	21	16
	Commander	0.32	1.05	0.73	21	18
	Compass	0.59	1.66	1.07	55*	34
	Fathom	0.76	1.41	0.65	10	12
	LaTrobe	0.64	1.23	0.59	19	16

2016

The recent growing season produced excellent yields across all three sites with maximum yields reaching nearly 7 t/ha at Condowie, 8 t/ha at Cummins and 9.5 t/ha at Urania. There were some contrasting variety performances compared to the 2015 season. In particular the cool/wet finish to the season was favourable for Trojan yields at both Condowie and Urania.

LaTrobe barley performed well at all three sites. Unfortunately, the Cummins site was not responsive to applications of P. At Condowie higher than normal replacement rates were required to maximise yields and these rates were economical. Lower P rates were required at Urania due to the higher P status of this site. As with 2015 there was no interaction between P rates and varieties and therefore the variety that returned the highest yield was the most profitable.

Table 3. Summary of the 2016 grain yield results at each site for the four wheat and barley varieties sown. Shaded varieties returned the highest economical net return ($/ha) when P deficiency was alleviated.

Location	Variety	Yield (0P) t/ha	Yield (Max.) t/ha	Yield increase with P t/ha	Optimal P rate (kg/ha) yield	Optimal P rate (kg/ha) economic
Condowie	Cobra	5.21	6.64	1.43	55	42
	Corack	4.14	4.96	0.82	33	21
	Mace	4.58	5.64	1.06	46	28
	Trojan	5.64	6.88	1.25	55	34
	Commander	4.21	5.13	0.92	13	15
	Compass	4.38	5.42	1.04	55	50
	Fathom	4.26	5.50	1.24	14	17
	LaTrobe	4.57	5.85	1.28	37	30
Cummins	Cobra	5.24	6.11	0.87	Site was not responsive to applications of P	
	Corack	5.59	5.50	0		
	Mace	5.92	6.39	0.47		
	Trojan	5.93	5.65	0		
	Commander	6.38	6.55	0.17		
	Compass	7.53	7.54	0.01		
	Fathom	7.89	7.85	0		
	LaTrobe	7.21	7.94	0.73		
Urania	Cobra	8.55	9.58	1.03	55*	30
	Corack	7.01	7.86	0.85	37	23
	Mace	7.55	8.13	0.58	5	6
	Trojan	8.87	9.34	0.47	20	12
	Commander	6.71	7.31	0.60	41	18
	Compass	6.34	6.98	0.64	16	13
	Fathom	7.46	7.66	0.20	NR	2
	LaTrobe	6.68	7.12	0.44	19	12

For more information:
Dr Sean Mason, Agronomy Solutions, 0422 066 635, sean@agronomysolutions.com.au

Sulphur management in a three year rotation

Leet Wilksch, AgByte

Key Findings

- The addition of sulphur increased wheat grain yield at both trial sites.
- Grain yield at the clay loam site was consistent for all of the sulphur rates, sources (gypsum and SoA) and application times tested.
- In contrast, there was variation in grain yield for the sulphur treatments tested at the sandy dune location due to the poor nutrient holding capacity of this soil type.

Why do the trial?

Over the past decade in the upper Northern Yorke Peninsula region, various crops have suffered from sulphur deficiency. This has been caused by the off take of sulphur greater than input. Both Sulphate of Ammonia (SoA) and gypsum are readily available sources of sulphur which can be applied to soil.

This research aims to establish product, rates and timings suitable to achieving the most economic return for managing sulphur deficiency. The trial will establish methods for managing sulphur over a medium term time frame (three years) in both sand dune and clay loam swale soil types.

How was it done?

Location	Bute, SA	**Fertiliser**	MAP (10:22) @ 90kg/ha on 11th May. Urea (46:0) applied to balance nitrogen rates across site. Sulphur applied as per rates listed in Table 1 and 2.
Plot size	1.5 m x 11.0 m		
Seeding date	11th May 2016		
Variety	Mace @ 60 kg/ha		

The trials were located across two sites in the paddock (1) red brown sandy clay loam in swale and (2) red sand on dune with moderate soil moisture at planting. Starting soil sulphur levels (KCl-40) were measured in 2015 and ranged from 1.8 – 2.6 mg S/kg for the sandy dune site and 2.2 – 4.7 mg S/ kg for the clay loam site (Table 1). All except one sample were below the current critical limit of 4.5 mg S/kg. The trial was established in 2015 to lentils and sulphur treatments are outlined in Tables 2 and 3. Total growing season rainfall in 2016 was 420 mm. All sulphur products were applied pre-planting on 11th of May. Clay loam treatments were replicated four times, sand dune replicated three times.

Crop assessments include early vigour, NDVI and grain yield.

Table 1. Soil properties (pH and EC) and available sulphur, (KCl-40), nitrogen (nitrate and ammonium) and phosphorus (DGT-P) for sand dune and clay loam trial sites on Yorke Peninsula, SA. Soil cores were taken in Autumn 2015.

Measurement		**Sand dune**			**Clay loam**		
		0 – 10 cm	10 – 30 cm	30 – 60 cm	0 – 10 cm	10 – 30 cm	30 – 60 cm
pH CaCl		7.16	7.38	7.7	7.69	7.83	8.27
EC 1:5	dS/m	0.1	0.09	0.07	0.1	0.12	0.18
Sulphur	mg/kg	1.9	1.8	2.6	2.2	4.7	3.7
Nitrate	mg/kg	3	1	1.4	1.9	5.8	2.9
Ammonium	mg/kg	3.1	2.8	1.6	2.1	2.1	1.6
DGT-P	ug/L	36			10		

Results and discussion

Wheat crop establishment and growth was excellent, due to good seasonal conditions. Ample nitrogen was applied to maximise yield potential with yields averaging 5.4 t/ha on the clay loam and 3.15 t/ha on the sand dune site. The potential for nitrogen to leach out of the system was high with heavy rainfall in Winter and late September. However, NDVI assessments taken during the growing season indicated no significant differences between the treatments.

A subset of plots were tissue sampled at GS32 (2nd node 2 cm above 1st node) in the nil, gypsum at 1 t/ha and SoA at 150 kg/ha. The results did not indicate any differences in sulphur content (data not shown) with the average leaf content of 0.4% sulphur.

All sulphur treatments significantly yielded above the nil untreated on the clay loam soil type (Table 2). At this site there was no differences between any of the gypsum or SoA sulphur treatments, with yield ranging from 5.28 to 5.63 t/ha. Interestingly, treatments where sulphur was applied in year one were able to yield as well as those which received a second application. This indicates the long-lasting benefits of both gypsum and SoA as a source of sulphur at this site.

Table 2. Summary of NDVI and wheat grain yield for sulphur treatments at the clay loam site, 2016. A tick in the year column indicates the corresponding sulphur treatment was applied in that year. Averages followed by the same letter do not significantly differ.

Site: Clay loam					**NDVI**	**Yield**	**Yield**
Trt No	**Product**	**Rate kg/ha**	**2015**	**2016**	**08-Aug**	**t/ha**	**% of nil**
3	Gypsum	3000	√		0.758	5.63ᵃ	119
6	SoA	150	√	√	0.771	5.60ᵃ	118
7	SoA	150	√		0.745	5.51ᵃ	116
8	SoA	100	√	√	0.742	5.51ᵃ	116
4	Gypsum	1000	√	√	0.726	5.49ᵃ	116
10	SoA	75	√	√	0.770	5.48ᵃ	116
5	SoA	300	√		0.748	5.45ᵃ	115
12	SoA	50	√	√	0.757	5.42ᵃ	114
2	Gypsum	1000	√		0.745	5.40ᵃ	114
9	SoA	150	√		0.752	5.28ᵃ	111
11	SoA	75	√		0.758	5.28ᵃ	111
1	Nil				0.741	4.74ᵇ	100
				CV	3.8%	6.8%	
				LSD (P≤0.05)	0.03	0.39	

On the sand dune site there was greater variation among the sulphur treatments tested with yields ranging from 2.93 t/ha – 3.60 t/ha. In 2016 all of the SoA treatments yielded above the nil however, the gypsum treatments did not (Table 3). Four out of the five highest yielding treatments on the sand dune had SoA applied in 2016. This indicates residual sulphur from the 2015 SoA treatments was minimal & likely leached out of the root zone in this sandier soil type (keep in mind that the 2015 lentils yielded very poorly).

Table 3. Summary of NDVI & wheat grain yield for sulphur treatments at the sand dune site, 2016. A tick in the year column indicates the corresponding sulphur treatment was applied in that year. Averages followed by the same letter do not significantly differ.

Site: Sand dune					**NDVI**	**Yield**	**Yield**
Trt No	**Product**	**Rate kg/ha**	**2015**	**2016**	**08-Aug**	**t/ha**	**% of nil**
6	SoA	150	√	√	0.743	3.60[a]	131
10	SoA	75	√	√	0.762	3.41[ab]	124
12	SoA	50	√	√	0.777	3.34[abc]	122
5	SoA	300	√		0.758	3.14[bcd]	114
7	SoA	150	√		0.732	3.18[bcd]	116
8	SoA	100	√	√	0.747	3.17[bcd]	116
9	SoA	150	√		0.755	3.10[bcd]	113
2	gypsum	1000	√		0.748	3.06[cde]	111
3	gypsum	3000	√		0.767	3.07[cde]	112
4	gypsum	1000	√	√	0.767	3.00[de]	109
11	SoA	75	√		0.766	2.93[de]	107
1	Nil				0.738	2.75[e]	100
				CV		6.5%	6%
				LSD (P≤0.05)		0.083	0.32

Acknowledgements

Thanks to SAGIT for project funding to complete this research. Also thanks to NSS and Garrett Bettess.

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Long term comparison of seeding systems

Sarah Noack, Hart Field-Site Group

Key findings

- Seeding systems did not affect wheat grain yield, averaging 5.3 t/ha.
- Good rainfall and cool temperatures during grain fill increased yield potential and the higher N rate resulted in a 1.2 t/ha yield advantage.
- Available soil N pre-seeding ranged from 80 – 190 kg N/ha with 75 kg N/ha more accumulated under the high N rate.

Why do the trial?

To compare the performance of three seeding systems and two nitrogen (N) strategies. This is a rotation trial (Figure 1) to assess the longer term effects of seeding systems and higher fertiliser input systems on soil fertility, crop growth and grain yield and quality.

How was it done?

Plot size	35 m x 13 m	**Fertiliser**	MAP (10:22) at seeding @ 70 kg/ha
Seeding date	24th May 2016 (disc and no-till) 25th May (strategic)	**Medium nutrition** **High nutrition**	UAN (42:0) @ 75 L/ha on 9th Aug UAN (42:0) @ 75 L/ha on 9th Aug and 75 L/ha on 29th Aug Twin Zn (700 g/L Zn) @ 0.5 L/ha on 12th Sept
Variety	Scepter wheat @ 107 kg/ha (Figure 1)		

The trial was a randomised complete block design with three replicates, containing three tillage/seeding treatments and two N treatments. In addition to this in 2015 all disc treatments were harvested using a stripper front. Both the no-till and strategic stubble height were harvested at 15 cm. Snails were a significant issue in the 2015 canola phase and the trial was cabled and baited over Summer to provide control (Figure 2). Prior to this standing stubble load in the disc treatments was 1.2 t/ha and 0.6 t/ha for the no-till and strategic treatments.

The disc, strategic and no-till treatments were sown using local growers Tom Robinson, Michael Jaeschke and Matt Dare's seeding equipment, respectively.

2000	2001	2002	2003	2004	2005	2006	2007
Sloop barley	ATR-Hyden canola TT	Janz wheat	Yitpi wheat	Sloop barley	Kaspa peas	Kalka durum	Janz wheat

2008	2009	2010	2011	2012	2013	2014	2015	2016
Janz wheat	Flagship barley	Clearfield canola	Correll wheat	Gunyah peas	Cobra wheat	Commander barley	44Y89 (CL) canola	Scepter wheat

Figure 1. Crop history of the long-term cropping systems trial at Hart.

Seeding treatments:

- Disc – sown into standing stripper front stubble with John Deere 1980 single disc at 152 mm (6”) row spacing, closer wheels and press wheels.
- Strategic – worked up pre-seeding, sown with 100 mm (4”) wide points at 200 mm (8”) row spacing with finger harrows.
- No-till – sown into standing stubble in one pass with a Flexicoil 5000 drill, 16 mm knife points with 254 mm (9”) row spacing and press wheels.

Nutrition treatments:

- Medium – starter fertiliser plus one in-season N application (district practice).
- High – starter fertiliser plus two in-season N applications and Zn.

All plots were assessed for soil available N (0-20, 20-40, 40-60 and 60-80 cm) on the 15th of April. Nitrogen mineralisation potential was estimated using a 21-day laboratory incubation method (Gupta et al. 1994) where 75 g soil was wet up to 18% moisture and incubated at 25°C.

Plant establishment and tiller number was assessed by counting 4 x 1 m sections of row across each plot on 20th of June at GS13 (three leaf) and 29th July at GS30 (start stem elongation), respectively. Plots were scanned using a Greenseeker® to measure crop canopy greenness at GS31 (first node) on 12 of August. All plots were assessed for grain yield, protein, test weight and screenings at harvest (6th December).

Figure 2. (Left to right) Scepter wheat sown in the strategic, no-till and disc treatment on 20th June, 2016. Canola stubble was cabled for snail control during Summer.

Results and discussion

Soil available N was measured in Autumn and ranged between 80 kg N/ha (disc, medium) and 190 kg N/ha (strategic, high). The high nutrition treatment had accumulated 75 kg N/ha more compared to the medium treatment averaging 88 kg N/ha and 163 kg N/ha, respectively (Figure 3). This difference is a result of the additional N applied and the low yielding canola crop in 2015 which left residual fertiliser N in the system. Seeding system however, did not affect the amount of available soil N pre-seeding.

The potentially mineralisable N in-season followed a similar pattern with 10 kg N/ha more available in the high nutrition treatment. The trial average N mineralisation potential was 27 kg N/ha which may have been taken up by the crop or incorporated back into the soil microbial pool.

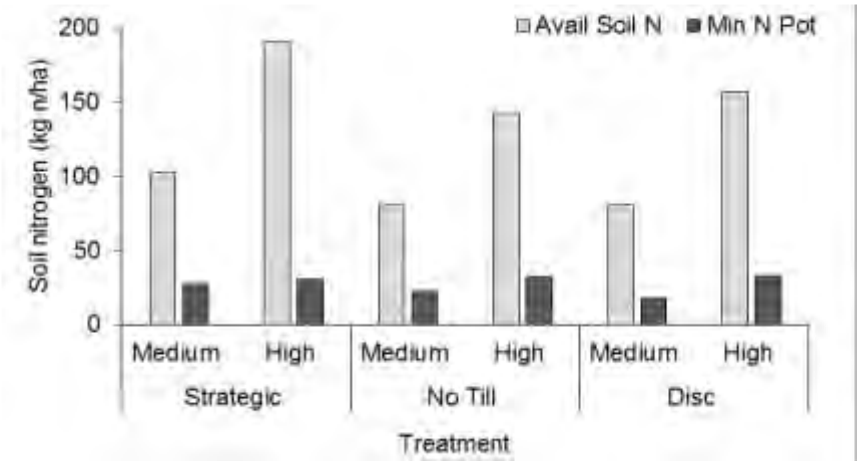

Figure 3. Soil available nitrogen pre-seeding (nutrition LSD = 27 at P≤0.05) and mineralisation N potential (nutrition LSD = 3.7 at P≤0.05).

Plant establishment and tiller number was highest for disc seeding systems 206 and 450 counts per square metre, respectively (Table 1). This high plant and tiller number also corresponded to a high NDVI value for 0.70. The remaining seeding systems did not differ in crop growth measures. This result is not consistent with previous years where more uniform establishment and tiller number has been observed across all three seeding systems.

Table 1. Plant establishment and tiller count (number/m^2) and NDVI for seeding treatments in 2016.

Seeder	**Plant count**	**Tiller count**	**NDVI**
	number/m^2		
Strategic	134^b	263^b	0.58^b
No Till	141^b	301^b	0.60^b
Disc	206^a	450^a	0.70^a
LSD seeder (P≤0.05)	22	49	0.07

Seeding system had little effect on wheat grain yield, averaging 5.3 t/ha (Table 2). The cooler and wet finish to 2016 allowed good grain fill and as a result the high nutrition out yielded the medium across all seeding systems on average by 1.2 t/ha. Similarly the higher nutrition treatment had a higher protein content but, overall N was limiting and protein levels were low (Table 2). No differences were observed in test weight with all treatments higher than the required 76 kg/hL (minimum required for maximum grade). Screening level across the trial were low averaging, 1.2%.

Table 2. Grain yield (t/ha), protein (%), test weight (kg/hL) and screenings (%) for nutrition and seeding treatments in 2016.

		Grain yield	Protein	Test weight	Screenings
		t/ha	**%**	**kg/hL**	**%**
Strategic	Medium	4.8^{b}	8.3	81.4	1.1
	High	5.9^{a}	10.3	80.8	1.3
No Till	Medium	4.2^{c}	6.7	81.4	1.2
	High	5.8^{a}	9.8	79.6	1.6
Disc	Medium	5.0^{b}	7.4	81.4	1.2
	High	5.9^{a}	9.3	81.3	1.0
LSD nutrition ($P \leq 0.05$)			0.5	ns	
LSD seeder x nutrition ($P \leq 0.05$)		0.3	ns	ns	0.2

Read the full summary of 16 years of results at http://www.hartfieldsite.org.au/pages/trials-results/hart-long-term-seeding-systems-trial.php.

Acknowledgements

The HFSG thank the South Australians Grains Industry Trust (SAGIT) for providing funding to support this research (H116). They also thank all the growers and SARDI Clare who assisted with trial seeding, spraying and harvesting. Thanks to Australian Grain Technologies for donating the Scepter wheat for the trial.


Tom Robinson seeding the disc plots in the trial (above left), Matt Dare seeding the no-till treatments (above right), Hart 2016.


Third year UofA ag students taking plant sampling in the trial (above left), Greg Butler and James Barr talking to farmers about innovative seeding technology at the Hart Field Day 2016 (above right).

Yield Prophet® performance in 2016

Sarah Noack, Hart Field-Site Group

Key findings

- Yield prophet closely predicted wheat grain yields in the Hart district.
- Heavy rainfall in September meant the difference between 20% and 80% of years was only 0.2 t/ha towards the end of the season.

Why do the trial?

Wheat growth models such as APSIM are highly valuable in their ability to predict wheat yield.

Yield Prophet® is an internet based service using the APSIM wheat prediction model. The model relies on accurate soil character information such as plant available water and soil nitrogen levels, as well as historical climate data and up to date local weather information to predict plant growth rates and final hay or grain yields.

This early prediction of grain yield potential means it can be used to directly influence crop input decisions. No other tool is currently available to growers, which can provide information of this accuracy at such a useful time of the season.

How was it done?

Seeding date	1st May 2016	**Fertiliser**	40 kg N/ha 1st May 30 kg N/ha 4th July
Variety	Mace wheat @ 180 plants per square metre		

Yield Prophet® simulations were run throughout the season to track the progress of wheat growth stages and changes in grain yield predictions.

20%, 50% and 80% levels of probability refer to the percentage of years where the corresponding yield estimate would have been met, according to the previous 100 years of rainfall data.

Results

At the first simulation, 6th June 2016 Yield Prophet® predicted that Mace wheat sown on the 1st May would yield 4.5 t/ha in 50% of years (Figure 1). After average rainfall in June and July it is not surprising that this yield prediction remained almost unchanged at 4.7 t/ha in late July. This yield prediction was closely maintained up until the end of August.

The Yield Prophet® simulation on the 5th of October for grain yield, increased by a further 0.4 t/ha. This was driven by the receival of 119 mm for September, 75 mm than the long-term average. The 80% of years prediction was also 5.1 t/ha and a further 0.2 t/ha in the top 20% of years. The actual grain yield for Mace wheat sown in early May was variable at Hart in 2016, ranging from 3.7 t/ha to 5.4 t/ha in the wheat variety and time of sowing trials. In cases where the yield prediction was poorer, can be attributed to both weather damaged (grain loss observed later in the season from wind/hail) and where crops were nitrogen limited. In general however, Yield Prophet® closely predicted wheat grain yields in the Hart district as it has in previous seasons.

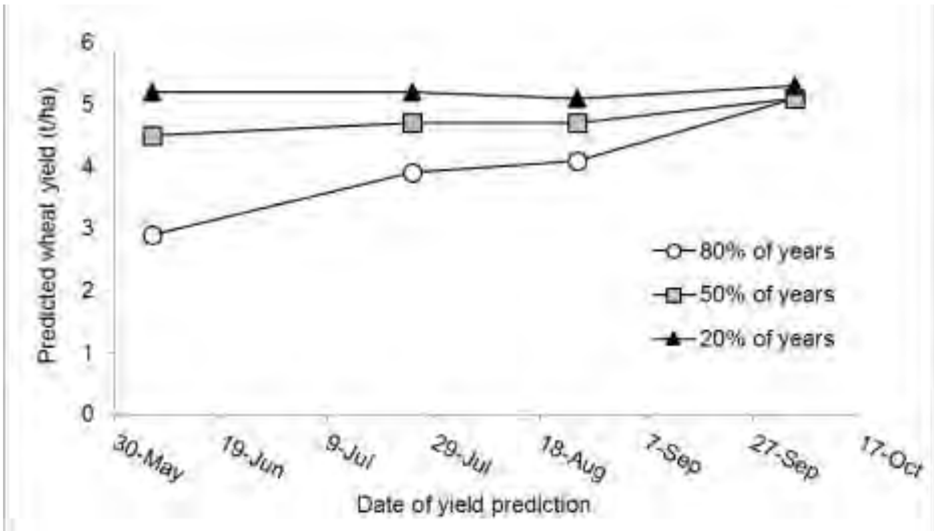

Figure 1. Yield Prophet® predictions from 6th June to the 5th October for Mace wheat sown on the 1st May, 2016. 80%, 50% and 20% represent the chance of reaching the corresponding yield at the date of the simulation.

Plant available water (PAW) (0-90 cm) when the first simulation was run at the beginning of June was 33 mm (Figure 2). This was 19 mm less stored moisture compared to the same time in 2015. Plant available water increased during July and remained steady across August. From early September the soil moisture level increased to 112 mm. At the end of October PAW started to decline however, even in early November there was still 75 mm PAW remaining (data point not shown). This soil moisture combined with 14 mm and 53 mm in November and December respectively meant there was soil moisture left in the profile after harvest.

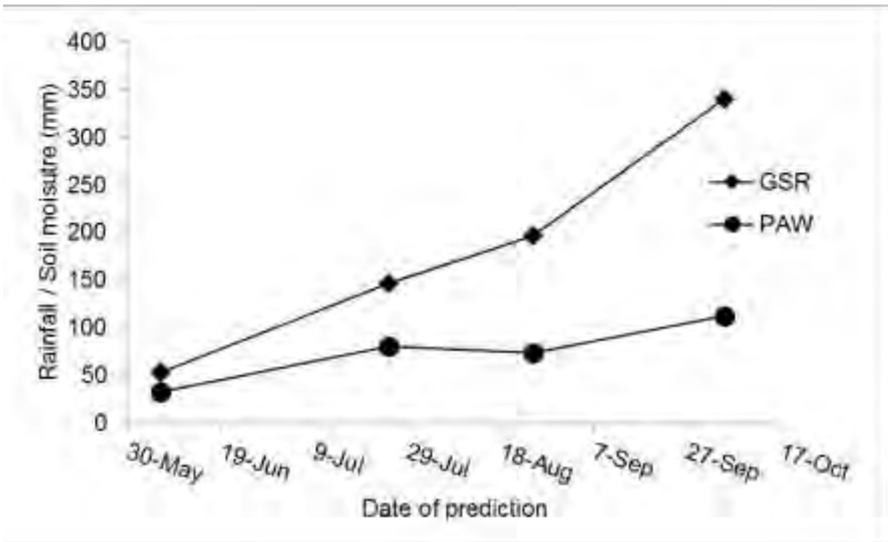

Figure 2. Predicted plant available water (PAW) and recorded cumulative growing season rainfall from 6th of June to 5th of October at Hart in 2016.

Around the site 2016


SAGIT visit, Sep 16


Getting The Crop In seminar, Mar 16


Hart chairman Damien Sommerville & regional intern Rochelle Wheaton


Hart Eve Dinner 2016; Kathy Fisher & Sarah Day, SARDI
Rochelle Wheaton, Sandy Kimber & Sarah Noack, Hart


Hart weather station

Spring Twilight Walk 2016

Notes

Notes

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