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Front cover photo taken at the 2014 Hart Field Day: our sincere thanks to Joe Koch, Booleroo.

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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 2 treatments are different, and so in some cases a non-significant result may still be useful.

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Diary dates

Hart Calendar 2015

Getting The Crop In
Wednesday 11th March 2015

Hart Field Day
Tuesday 15th September 2015

Winter Walk
Tuesday 21st July 2015

Spring Twilight Walk
Tuesday 20th October 2015

Photo: Getting The Crop In seminar 2014

Comparison of wheat varieties

Sarah Noack, Hart Field-Site Group

Key Findings

- Cobra and Cosmick were the highest yielding AH varieties at Hart in 2014 yielding 5.17 and 5.03 t/ha, respectively.
- Corack and Trojan were the highest yielding APW varieties at 5.48 and 5.17 t/ha, respectively.
- Test weight and screening levels across the trial averaged 83.0 kg/hL and 2.7%.
- Axe produced the highest wheat grain protein at 10.6%.

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% @ 70 kg/ha
Seeding date	8th May 2014		UAN (42:0) @ 85 L/ha, 8th July
			UAN (42:0) @ 45 L/ha, 15th Aug

The trial was a randomised complete block design with 3 replicates and 21 varieties. Fungicides were applied as necessary to keep the crop canopy free of disease ie. stripe rust.

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

Results and discussion

Wheat grain yields at Hart in 2014 ranged from 3.94 t/ha for RAC1843 up to 5.48 t/ha for Corack (Table 1), with an average site yield of 4.80 t/ha. Varieties which yielded above 5.0 t/ha were Corack, Cobra, Trojan (LPB08-1799), Cosmick (IGW3423) and Mace.

Wheat grain protein levels ranged from 9.13% (Corack) to 13.73% (RAC1843). The lower yield and high protein content for RAC1843 can be attributed to frost damage which occurred in August 2014. RAC1843 is an early maturing variety (slightly earlier flowering than Axe) and usually better suited to later sowing dates.

All varieties except RAC1843 fell below the protein level of 11.5% required for Hard 2. However, a number of varieties were above 10.5% (Axe, Espada, Estoc and Gladius) for APW classification.

Screening levels at the site averaged 2.7% and all varieties fell below the maximum level of 5% for APW and Hard classification.

Grain test weights across the trial averaged 83.0 kg/hL and all varieties exceeded 76 kg/hL, the minimum required for maximum grade.

Table 1. Grain yield (t/ha), protein (%), test weight (kg/hL) and screenings (%) of wheat varieties at Hart in 2014.

Quality	Variety	Grain yield t/ha	% of site average	Protein %	% of site average	Test Weight kg/hL	% of site average	Screenings %	% of site average
AH	Axe	4.53	94	10.6	105	83.6	101	2.0	75
	Catalina	4.52	94	9.8	96	84.9	102	2.0	75
	Cobra	5.17	108	9.6	95	82.0	99	2.7	98
	Correll	4.79	100	10.3	102	81.4	98	3.7	135
	Cosmick (IGW3423)	5.03	105	9.5	94	83.4	101	3.9	143
	Dart	4.41	92	10.1	100	82.9	100	3.5	130
	Emu Rock	4.93	103	9.9	98	83.7	101	4.2	155
	Gladius	4.77	99	10.6	104	82.7	100	2.3	85
	Grenade CL Plus	4.46	93	9.6	94	82.2	99	1.9	71
	AGT Katana	4.99	104	10.1	99	85.2	103	2.1	79
	Kord CL Plus	4.91	102	10.4	103	83.2	100	3.9	145
	Mace	5.01	104	9.6	94	82.2	99	2.3	86
	Phantom	4.68	97	9.8	96	82.1	99	3.2	119
	Scout	4.89	102	9.7	95	83.7	101	2.9	106
	Shield	4.86	101	10.1	100	81.1	98	3.6	134
	Wallup	4.61	96	9.8	96	83.5	101	1.4	53
APW	Espada	4.89	102	10.6	104	80.8	97	2.9	106
	Estoc	4.80	100	10.6	104	83.3	100	2.3	86
	Corack	5.48	114	9.1	90	83.6	101	1.9	71
	Trojan (LPB08-1799)	5.17	108	9.9	97	84.3	102	1.9	70
Unclassified	RAC1843	3.94	82	13.7	135	82.3	99	2.0	75
	Site Average	4.80	100	10.2	100	83.0	100	2.7	100
	LSD (P≤0.05)	0.46		0.6		1.0		0.7	

Comparison of barley varieties

Sarah Noack, Hart Field-Site Group

Key Findings

- Fathom and Keel were the highest yielding feed barley varieties at Hart averaging 5.3 t/ha.
- GrangeR was the highest yielding malt variety at 5.13 t/ha.
- Unclassified line Compass (undergoing malt accreditation) yielded similarly at 5.27 t/ha.

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 m	**Fertiliser**	DAP (18:20) + Zn 2% @ 70 kg/ha
Seeding date	15th May 2014		UAN (42:0) @ 85 L/ha, 8th July

The trial was a randomised complete block design with 3 replicates and 21 varieties. Fungicides were applied as necessary to keep the crop canopy free of disease ie. net blotch.

All plots 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

Fathom and Keel were the highest yielding feed barley varieties at Hart in 2014, averaging 5.3 t/ha (Table 1). The site average yield across all feed varieties was 4.88 t/ha. The lowest yielding feed variety was Maritime at 3.97 t/ha.

The highest yielding malt variety was GrangeR at 5.13 t/ha. Compass, currently undergoing malt accreditation was not significantly different to GrangerR yielding 5.27 t/ha. These varieties were closely followed by Charger, Commander, and unclassified lines Skipper and La Trobe. The average yield across all malt varieties at Hart was 4.63 t/ha.

Grain protein for all barley varieties ranged between 12.7% for Scope and 15.3% for Flinders. There was no significant difference in protein content for any varieties. All varieties were above the allowable protein range of 9-12% for malt classification.

All malt varieties except Navigator (also seen at Hart in 2013) exceeded the minimum test weight specification of 65 kg/hL. Wimmera (undergoing malt accreditation) was also below the minimum test weight at 64.6 kg/hL. All feed barley varieties exceeded the minimum test weight specification for F1 feed barley of 62.5 kg/hL (Table 1).

Screening levels across the trial averaged 12.2%. Varieties Wimmera, Flagship and Oxford produced the highest screenings at 25.0, 22.4 and 20.3%, respectively.

GrangeR was the only malt variety to produce a retention (76.7%) greater than the required 70% for malt 1 barley (Table 1). Compass (undergoing malt accreditation) also had a high retention percentage at 81.6%.

Table 1. Grain yield (t/ha), protein (%), test weight (kg/hL), screenings and retention (%) of barley varieties at Hart 2014.

Quality	Variety	**Yield** t/ha	% of site average	**Protein** %	% of site average	**Test wt** kg/hL	% of site average	**Screenings** %	% of site average	**Retention** %	% of site average
Feed	Fathom	5.35	113	14.1	102	69.0	102	4.8	39	76.0	146
	Fleet	5.04	106	13.5	98	66.4	98	5.2	43	70.3	135
	Hindmarsh	4.89	103	14.0	101	68.6	101	14.7	121	38.9	75
	Keel	5.30	112	13.8	100	69.5	103	8.3	68	69.6	133
	Maritime	3.97	84	14.1	102	67.4	100	6.0	49	65.7	126
	Oxford	4.74	100	13.5	98	65.8	97	20.3	167	28.9	55
Malting	Bass	4.71	99	14.1	102	68.4	101	11.9	98	50.7	97
	Buloke	4.74	100	13.3	96	68.1	101	14.9	122	35.9	69
	Charger	5.04	106	14.1	102	66.0	98	16.0	132	52.9	101
	Commander	4.99	105	13.2	95	68.8	102	8.8	72	68.1	131
	Flagship	4.08	86	15.0	108	67.5	100	22.4	184	30.8	59
	Flinders	4.18	88	15.3	111	66.2	98	18.3	150	33.5	64
	GrangeR	5.13	108	13.4	97	68.9	102	5.4	44	76.7	147
	Navigator	4.80	101	13.6	99	64.4	95	9.9	81	56.5	108
	Schooner	4.11	87	14.7	107	68.8	102	14.7	121	41.0	79
	Scope	4.58	97	12.7	92	67.4	100	13.9	114	34.9	67
	Westminster	4.61	97	13.6	99	68.7	102	4.6	38	68.5	131
Pending malt accreditation	Compass	5.27	111	12.9	94	68.1	101	3.9	32	81.6	157
	La Trobe	4.99	105	13.1	95	68.9	102	16.7	137	28.6	55
	Skipper	5.01	106	13.9	101	69.7	103	9.8	81	63.1	121
	Wimmera	4.01	85	14.0	101	64.6	95	25.0	205	22.7	44
	Site Average	**4.74**	100	**13.8**	100	**67.7**	100	**12.2**	100	**52.1**	100
	LSD (P≤0.05)	0.24		1.76		1.36		6.46		10.65	

Comparison of durum varieties

Sarah Noack, Hart Field-Site Group

Key findings

- Grain yields for all durum varieties were good, averaging 4.23 t/ha compared to average wheat and barley trial grain yield of 4.80 t/ha and 4.74 t/ha, respectively.
- Test weight values were higher than previous years and screening levels low.

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% @ 70 kg/ha
Seeding date	8th May 2014		UAN (42:0) @ 85 L/ha, 8th July
			UAN (42:0) @ 45 L/ha, 15th August

The trial was a randomised complete block design with 3 replicates and 7 varieties.

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 4.09 t/ha (Hyperno) to 4.53 t/ha (Yawa), with a site average yield of 4.23 t/ha (Table 1). Grain protein levels ranged from 9.4% to 10.6%, with a site average of 9.9%. There was no difference in grain yield or protein level for any varieties trialled in 2014.

All varieties were above the minimum test weight value of 76 kg/hL. Caparoi had the highest test weight followed by Saintly, Tamaroi, Hyperno and DBA-Aurora. Screening levels across all varieties were low ranging from 1.6% (Caparoi) to 5.6% (Yawa). All varieties except Yawa were below 5% screenings.

Table 1. Grain yield (t/ha), protein (%), test weight (kg/hL) and screenings (%) for durum varieties at Hart, 2014.

Variety	Grain yield t/ha	% of site average	Protein %	% of site average	Test Weight kg/hL	% of site average	Screenings %	% of site average
Caparoi	4.22	100	10.6	107	83.8	102	1.6	51
DBA-Aurora (UAD0951096)	4.21	100	9.4	95	81.9	99	3.0	93
Hyperno	4.09	97	9.8	99	82.0	100	3.6	111
Saintly	4.11	97	9.4	95	83.1	101	2.6	81
Tamaroi	4.14	98	10.3	104	82.3	100	3.2	100
Tjilkuri	4.31	102	10.3	104	81.6	99	2.8	88
Yawa	4.53	107	9.5	95	81.7	99	5.6	175
Site Average	**4.23**	100	**9.9**	100	**82.3**	100	**3.2**	100
LSD (P≤0.05)	ns		ns		0.5		0.8	

Canola growth and development – impact of ToS and seasonal conditions

Andrew Ware, SARDI, Pt Lincoln
Sarah Noack, Hart Field-Site Group
Stuart Sherriff, formerly of SARDI, Clare

Key findings

- Early sowing opportunities may provide a great opportunity to maximise canola yield, but selection of the correct variety is important.
- Understanding the drivers behind canola development will help to improve canola management and variety selection.
- Varietal maturity ratings don't always correlate with varietal phenology.

Why do the trial?

Despite the success of canola in Australian cropping systems, significant gaps remain in the underlying knowledge of canola physiology and agronomy. This situation was exacerbated by the release of new technologies including vigorous hybrid varieties with herbicide tolerance. Although growers recognise the high profit potential and the farming system benefits of canola, there remains a perceived risk of growing canola largely due to the high level of input required (eg. seed, nitrogen fertiliser, sulphur fertiliser, windrowing). There is a need to determine the level of investment appropriate for these inputs on a regional scale and the agronomic management practices (for example sowing date decisions) that reduce the overall risk and increase the profitability of canola.

This trial is part of a new five year GRDC project "Optimised canola profitability – understanding the relationship between physiology and tactical agronomy management". In year one the trial aimed to identify variety x sowing date combinations to achieve optimum flowering window.

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 – 14th April ToS 2 – 1st May ToS 3 – 16th May ToS 4 – 2nd June		UAN (42:0) @ 100 L/ha, 13th Jun UAN (42:0) @ 95 L/ha, 7th July ToS 1 and 2 only UAN (42:0) @ 70 L/ha, 15th August

The trial was randomised complete block design consisting of four replicates, six varieties and (44Y88(CL), 45Y88(CL), Hyola575CL, Hyola559TT, ATR Gem and Hyola971CL) and two seeding rates (15 or 45 plants/m^2).

Canola establishment was assessed on all plots at the 2-4 leaf stage, by counting the number of plants along 3 X 1 m lengths of row sampled randomly from the central plot rows. Bud visible and flowering were assess 2-3 times weekly by identifying one random point in the center of each plot. From this point 10 plants were examined and the number of plants at bud visible or flowering were recorded until 50% of all 10 plants had reached the required growth stage. All plots were assessed for grain yield and oil content.

Results and discussion

Results of 50% flowering dates are presented in Table 1. They show that when planted early, Hyola 575CL reaches flowering up to two weeks before the other varieties trialled in 2014. Hyola 971CL, when planted in mid-April, failed to reach flowering at all sites prior to 1 October. The other varieties trialled generally flowered within a few days of each other, with any differences becoming smaller by the last time of sowing.

Table 1. 50% flowering dates recorded for each variety and each time of sowing at the Hart, 2014.

Variety	Time of sowing			
	14-Apr	1-May	16-May	2-Jun
Pioneer 44Y87CL	15-Jul	20-Aug	2-Sep	8-Sep
Pioneer 45Y88CL	16-Jul	17-Aug	4-Sep	9-Sep
ATR Gem	6-Jul	10-Aug	3-Sep	10-Sep
Hyola 559TT	6-Jul	8-Aug	1-Sep	8-Sep
Hyola 575CL	29-Jun	2-Aug	31-Aug	6-Sep
Hyola 971CL	2-Oct	1-Oct	4-Oct	7-Oct

Table 2 shows the different responses in grain yield to two different establishment rates (15 and 45 plants/m^2) recorded at Hart. Establishment rate only became significant at the third and fourth times of sowing (16th May and 2nd June), where having the higher seeding rate improved yields. This shows that while canola has the ability to compensate for poor establishment, in some situations having a poorly established crop will cost yield and needs to be factored into management.

Table 2. Grain yield of canola comparing two different establishment rates (15 and 45 plants/m^2) at Hart over four sowing dates in 2014.

Plants/m^2	Time of sowing			
	14-Apr	1-May	16-May	2-Jun
15	1.70	1.89	1.69	1.28
45	1.70	1.94	1.94	1.62
LSD(P=0.05)	0.17			

Pioneer 45Y88CL yielded the highest at Hart when planted in mid-April (Table 3). The early May time of sowing, showed yield of all varieties, with the exception of ATR Gem and Hyola 971CL, as being very similar. Results from the Hart trial didn't show any yield reduction when seeding was delayed to mid-May (third time of sowing) compared to early-May. The relative poor yield of Hyola 575CL in the mid-April sowing time is interesting. The early flowering of this variety was not advantageous in 2014, and may have led to increased damage from frost.

Table 3. Grain yield from canola sown at four sowing times at Hart site in 2014.

Variety	Time of sowing			
	14-Apr	1-May	16-May	2-Jun
Pioneer 44Y87CL	1.62	1.80	1.89	1.82
Pioneer 45Y88CL	1.98	1.96	1.89	1.42
ATR Gem	1.29	1.52	1.56	1.15
Hyola 559TT	1.76	1.84	1.74	1.32
Hyola 575CL	1.49	2.06	2.05	1.61
Hyola 971CL	0.37	0.40	0.49	0.25
LSD(P=0.05)	0.24			

Some of the differences in yields and plant development observed in the time of sowing trial can, in part, be explained by the drivers behind the development of each canola cultivar. There are three main controls of the development of canola; vernalisation response, photoperiod response and basic temperature response. Each of these will play a differing role in every variety.

Vernalisation affects canola from sowing to flowering. Varietal response to vernalisation will manifest as reduced time taken from sowing to flowering as well as a reduced number of leaves at flowering. It is expected that early sowing of canola into a relatively warm period (sowing in early April v mid May) will lead to a delay in the accumulation of vernalisation, which will exacerbate the differences in flowering dates of varieties with different vernalisation requirements.

Varietal response to photoperiod occurs between emergence and flowering. Canola is a long day plant, meaning that the duration from sowing to flowering is reduced in long day situations. In recent studies, varieties commonly responded to day length in the range of 11 to 16 hours. For canola plants emerging in mid-April after an early April sowing, there is potential that some of the photoperiod requirement could be met in autumn where day length is longer than mid-winter.

The basic temperature response is essentially the response of a variety to thermal time (degree-days) when both photoperiod and vernalisation requirements are met. Although there are differences in the basic temperature response amongst commercial varieties in terms of time taken to flowering, it is generally less important than the differences as a result of vernalisation or photoperiod response. The basic temperature response is however the main driver of development after flowering.

Using the data collected from South Australia and New South Wales in 2014 we can start to draw some conclusions about how some of the varieties trialled develop.

Hyola 971CL has a strong vernalisation requirement. When this variety was sown in mid-April in the low to medium rainfall area of South Australia flowering didn’t commence until the first week in October. Dry conditions through spring at all locations led to this variety being the lowest yielding in all trials.

Hyola 575CL appears to have a relatively flat thermal time requirement, regardless of when it is sown. This resulted in Hyola 575CL being the first variety to commence flowering when sown early. Results from the first time of sowing in all trials show that the yield of Hyola 575CL was lower compared to Pioneer 45Y88CL, meaning that it was a disadvantage to plant this variety early in 2014. The variety description of Hyola 575CL indicated it should have a mid-season maturity, similar to 45Y88CL.

Pioneer 44Y87CL showed a reduction in thermal time requirement as sowing was delayed. Further research is needed to understand why this occurred but may have been due to a greater vernalisation requirement of 44Y87CL compared to Hyola 575CL, with early sowing taking longer to accumulate vernalisation than the later sowing dates. This may have helped 44Y87CL avoid some damage from early frost events.

Information generated by trials such as this into the future will add value to other trial results such as NVT and help explain difference in varietal adaptation, and performance as a starting point to growing more profitable canola.

Summary / implications

The way each canola variety develops can have a large influence the resulting yield, when planted at different times, and in different environments. The challenge for this project, going forward, is to be able to develop and deliver information on new varieties in a way that is timely and relevant to growers and advisors. Growers and advisors will be able to use this information to help select a suite of varieties that are suited to sowing opportunities that occur in their district and also to capitalise on early or delayed sowing opportunities as the seasons dictate.

Optimising cultivar x time of sowing in wheat and barley

James Hunt, CSIRO Agriculture
Sarah Noack and Peter Hooper, Hart Field-Site Group

Key Findings

- Despite damage from August frosts, the highest wheat yield in this trial came from Trojan sown mid-April.
- Trojan (mid-maturing) complements Mace (fast-maturing) in a cropping program and allows growers to sow earlier and achieve higher yields (16%) than they could with Mace alone sown in its optimal window.
- Barley yield is less sensitive to time of sowing and in this trial highest yields came from faster maturing cultivars sown in early-mid May.

Why do the trial?

The majority of our current wheat varieties need to be sown in the first half of May to flower during the optimal period for grain yield. Recent research in southern NSW has shown they have well adapted winter and slow maturing spring cultivars that when sown in mid-late April will out-yield fast maturing cultivars sown in May. However, the same cannot be said for SA where no cultivar x ToS options have been shown to out-yield Mace sown in its optimal window.

Currently options for growers in SA who wish to sow early are not well known. The aim of this trial was to investigate time of sowing for individual wheat cultivars with different maturities. The majority of research to-date has focused on wheat varieties so in addition to wheat, four barley varieties with varying maturities were included.

How was it done?

Plot size	1.75 m x 10.0 m	**Fertiliser**	DAP (18:20) + 2% Zn @ 80 kg/ha @ seeding
Seeding date	ToS 1 – 14th April ToS 2 – 8th May ToS 3 – 2nd June		Urea @ 120 kg/ha split application across @ GS30 and GS32 for each ToS

The trial was a split block design with three replicates, five wheat and four barley cultivars (Tables 1 and 2). Fungicides were applied as necessary to keep the crop canopy free of disease (ie. stripe rust, net blotch). All plots were assessed for grain yield, protein, test weight and screenings with a 2.0 mm screen for wheat and a 2.2 mm screen and retention with a 2.5 mm screen for barley.

Table 1. Wheat cultivars and their maturity used in this trial.

Variety	Maturity	Comments
EGA_Wedgetail	Mid-maturing winter (strong vernalisation moderate photoperiod)	The early sowing and dual purpose standard in SNSW and an excellent grain-only option. May be too slow in most of SA, only has APW quality and can be quite intolerant of problems associated with alkaline soils (CCN, boron, aluminium)
Rosella	Fast-maturing winter (strong vernalisation weak photoperiod)	Slightly faster than Wedgetail and seems to have better adaption to alkaline soils. However, it now only has GP quality.
Trojan	Mid-fast maturing spring (moderate vernalisation, moderate photoperiod)	Has demonstrated good adaption to SA and has an unusual photoperiod gene which may allow it to be sown in late April and flower at the optimal period
Mace	Fast-maturing spring (weak vernalisation, weak photoperiod)	No introduction necessary! SA main-season benchmark and in the trial as a control from a mid-late May sowing.
RAC1843	Very fast maturing spring (no vernalisation, no photoperiod)	A pre-release line that has imidazolinone tolerance (Clearfield®) bred into an Axe background.

Table 2. Barley cultivars and their maturity used in this trial.

Variety	Maturity	Comments
Oxford	Late maturing (no vernalisation, strong photoperiod)	Feed variety, suited to earlier sowing in medium to high rainfall areas where leaf rust is prevalent.
Navigator	Late maturing (no vernalisation, strong photoperiod)	Malt variety similar maturity to Gairdner, suited to early sowing in higher rainfall zones. Best sown before the middle of May in SA to flower in optimal period.
Compass	Early to mid-season maturing (no vernalisation, weak photoperiod)	Newly developed line from University of Adelaide currently undergoing malt accreditation, Superior adaptation and new yield benchmark for SA main season barley. Slightly earlier and less sensitive to photoperiod than Commander but similar flowering times with later sowing such as mid-June.
Fathom	Early to mid season maturing (no vernalisation, moderate photoperiod)	Well adapted dedicated feed variety that performs well in unfavourable conditions. It will mature slighter later than Compass from early sowing but similar to Hindmarsh with delayed sowing.

Results and discussion

Wheat

Trojan sown on 14th April and 8th May were the highest and second highest yielding wheat treatments (Table 3), out-yielding Mace sown on 8th May by 1.0 and 0.6 t/ha, respectively. A similar result was achieved in experiments at Minnipa, Cummins, Pt Germein and Tarlee (Figure 1). Slow maturing cultivars bred in other states (e.g. EGA Wedgetail and Rosella) showed poor adaptation to SA and this was also reflected at other sites. Protein (Table 4) tended to relate to yield dilution effects (higher yield=lower protein), the only point of interest being that Trojan had the same protein content as Mace at the last two times of sowing despite yielding significantly more. Screenings (Table 5) were generally stable or increased slightly with delayed sowing, with the exception of RAC1843 where the first time of sowing was severely frosted and most yield came from secondary tillers which grew after the frost. Test weight (Table 6) declined with time of sowing in Wedgetail and Rosella, was stable in Mace and Trojan and was very high at the first time of sowing in RAC1843 again due to frost damage.

Table 3. *Mean yield for wheat cultivars at different times of sowing at Hart in 2014.*

Yield (t/ha)	Time of sowing		
Cultivar	**14-Apr**	**8-May**	**2-Jun**
Wedgetail	4.5	4.0	3.0
Rosella	4.3	3.7	2.8
Trojan	5.7	5.3	3.7
Mace	3.9	4.7	3.3
RAC1843	0.8	3.6	3.5
P-value	<0.001		
LSD (P=0.005)	0.3		

Table 4. *Mean protein for wheat cultivars at different times of sowing at Hart in 2014.*

Protein (%)	Time of sowing		
Cultivar	**14-Apr**	**8-May**	**2-Jun**
Wedgetail	11.0	12.0	12.6
Rosella	10.7	12.1	12.4
Trojan	9.9	10.1	10.5
Mace	12.8	9.8	9.8
RAC1843	17.4	13.4	10.5
P-value	<0.001		
LSD (P=0.005)	1.0		

Table 5. *Mean screenings for wheat cultivars at different times of sowing at Hart in 2014.*

Screenings (%)	Time of sowing		
Cultivar	**14-Apr**	**8-May**	**2-Jun**
Wedgetail	1.4	2.0	1.6
Rosella	2.2	3.7	4.1
Trojan	1.2	2.1	1.9
Mace	1.1	1.9	2.1
RAC1843	7.2	1.4	1.9
P-value	<0.001		
LSD (P=0.005)	1.1		

Table 6. *Mean test weight for wheat cultivars at different times of sowing at Hart in 2014.*

Test Weight (kg/hL)	Time of sowing		
Cultivar	**14-Apr**	**8-May**	**2-Jun**
Wedgetail	79.0	78.7	74.5
Rosella	80.7	79.4	76.6
Trojan	84.9	84.2	84.0
Mace	78.9	80.1	79.8
RAC1843	47.9	82.9	82.7
P-value	<0.001		
LSD (P=0.005)	2.5		

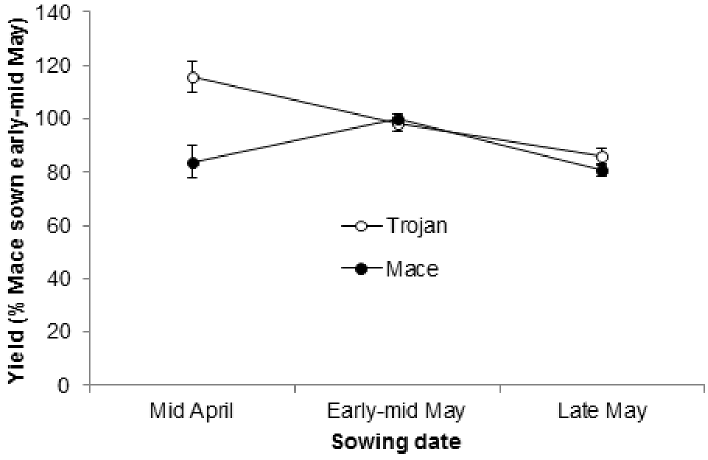

Figure 1. Mean yield performance (Minnipa, Cummins, Port Germein, Hart, Tarlee) of Trojan and Mace at different times of sowing relative to Mace sown in its optimal window of early-mid May. Error bars are standard error of means.

Photo: RAC1843 (left) and Mace (right). Photo taken 14th July 2014 at Hart.

Barley

Highest yields for all cultivars other than Oxford came from the 8 May sowing date (Table 7). Yield of Oxford decline with sowing date, but at the first time of sowing equalled the yields of faster cultivars sown 8 May. Protein related to yield dilution effects (Table 8), retention (Table 9) decreased and screenings (Table 10) increased with later sowing (disastrously so in the case of Oxford), and test weight (Table 11) decreased with later sowing.

Table 7. *Mean yield for barley cultivars at different times of sowing at Hart in 2014.*

Yield (t/ha)	Time of sowing		
Cultivar	**14-Apr**	**8-May**	**2-Jun**
Oxford	5.4	5.2	3.6
Navigator	5.0	5.4	4.3
Compass	4.8	5.5	4.6
Fathom	4.8	5.6	4.8
P-value		<0.001	
LSD (P=0.005)		0.5	

Table 8. *Mean protein for barley cultivars at different times of sowing at Hart in 2014.*

Protein (%)	Time of sowing		
Cultivar	**14-Apr**	**8-May**	**2-Jun**
Oxford	11.3	12.0	13.0
Navigator	11.6	11.4	12.5
Compass	11.4	11.4	11.2
Fathom	13.3	12.4	12.3
P-value		0.006	
LSD (P=0.005)		0.9	

Table 9. *Mean retention for barley cultivars at different times of sowing at Hart in 2014.*

Retention (%)	Time of sowing		
Cultivar	**14-Apr**	**8-May**	**2-Jun**
Oxford	84.8	59.2	34.1
Navigator	89.6	81.1	76.6
Compass	93.5	91.8	91.2
Fathom	94.9	89.7	92.4
P-value		<0.001	
LSD (P=0.005)		7.1	

Table 10. *Mean screenings for barley cultivars at different times of sowing at Hart in 2014.*

Screenings (%)	Time of sowing		
Cultivar	**14-Apr**	**8-May**	**2-Jun**
Oxford	2.4	7.5	18.7
Navigator	1.7	3.9	3.6
Compass	1.6	2.2	2.1
Fathom	1.7	2.5	2
P-value		<0.001	
LSD (P=0.005)		1.8	

Table 11. *Mean test weight for barley cultivars at different times of sowing at Hart in 2014.*

Test Weight (kg/hL)	Time of sowing		
Cultivar	**14-Apr**	**8-May**	**2-Jun**
Oxford	73.3	69.6	66.7
Navigator	69.8	67.2	66.1
Compass	71.3	69.9	67.3
Fathom	69.1	69.1	69.2
P-value		<0.001	
LSD (P=0.005)		1.4	

Implications

Based on the 2014 trial data, growers in SA could improve whole-farm yields by including Trojan in their cropping program to complement Mace (Figure 1). Trojan has an unusual photoperiod sensitivity allele inherited from a European parent which is rare in Australian cultivars. This allele seems to delay flowering from an April sowing relative to Mace quite successfully (Table 12).

Despite performing strongly from a mid-April sowing in these trials, it is not recommended that Trojan be planted this early in the majority of SA locations as it incurs excessive frost risk. As a rough rule of thumb, it is best suited to being planted 7-10 days earlier than Mace. As an example of how it may fit in a program, if 10 May is the optimal sowing time for Mace in a given environment, then the optimal sowing time for Trojan is 1 May. If a grower has a 20 day wheat sowing program and wants to grow half Trojan and half Mace, to maximise whole farm yield they should start with Trojan on 25 April, switch to Mace on 5 May and aim to finish on 15 May.

Barley is less sensitive to sowing time that wheat, and other trials have shown that highest yields tend to come from faster maturing cultivars such as Compass, Fathom, Latrobe and Hindmarsh when sown in mid May. This trial has demonstrated that if growers wish to sow very early (i.e. mid-April) that there are cultivars available (e.g. Oxford) that will be more successful when sown at this time.

Table 12. *Flowering dates for Trojan and Mace from different times of sowing at Minnipa in 2014.*

Flowering date - Minnipa	**Time of sowing**		
Cultivar	**11-Apr**	**13-May**	**28-May**
Trojan	6-Aug	10-Sep	17-Sep
Mace	8-Jul	6-Sep	13-Sep

Acknowledgements

The Hart Field-Site Group acknowledges the CSIRO contribution to this experiment funded by GRDC project CSP00178.

Photo: Compass (left) and RAC1843 (right). Photo taken 14th July 2014 at Hart.

Effect of rhizobia and other microbial inoculation treatments on field pea

Ross Ballard, Elizabeth Drew, Steve Barnett and Nigel Charman, SARDI
Xuyen Le, Flinders University

Key findings

- The Hart field site has a background of pea rhizobia that are numerous, but only moderately effective.
- Inoculation treatment did not affect measured root parameters.
- Some inoculation treatments increased shoot biomass and pod number, but not grain yield or grain N content.
- The N benefit from the extra biomass residues is estimated to be 51 kg N/ha.

Why do the trials?

This trial is part of a broader network of 15 trials sown across South Australia and Victoria, to investigate the potential of inoculation technologies to improve the nitrogen fixation and/or production of field pea. A treatment common to all trials has been a high rate of seed inoculation with rhizobia, to try and overcome any symbiotic constraints at the sites.

How was it done?

Plot size	1.75 m x 10 m	**Fertiliser**	80 kg/ha MAP (10:22) + 2% Zinc
Seeding date	28th May, 2014		Nil post sowing

The trial was arranged in a randomised complete block design with 3 replicates, each comprising an uninoculated control and 6 inoculation treatments. There were four rhizobia treatments (3 strains applied to seed and one applied as a slurry in furrow) and two other microbes suggested to promote plant growth. Rhizobia treatments were applied at approximately 100 fold the rate recommended commercially. Treatments were applied to Kaspa field pea which were sown to achieve a seedling density of 50 plants/m^2. The site was sampled at sowing to determine soil chemistry (analysed by CSBP) and the number and N_2-fixation capacity of the rhizobia present in the soil, using a greenhouse bio-assay.

Six plants were sampled from each plot on 14th August (7 weeks after sowing) and nodule number and nodule dry weight per plant determined. Root health (0 = no damage, 15 = severe damage) of each plant was assessed for symptoms caused by soil borne pathogens and a mean root damage score calculated. An additional ten plant shoots were sampled from each plot on 14th October (late pod fill) and used to estimate shoot biomass, pod number per plant and to estimate the % N derived from fixation (analysis pending). Plots were machine harvested to estimate grain yield and subsamples used for the determination of grain protein (Total N Leco, CSBP).

Results and discussion

Number of rhizobia in the soil, before the trial was sown, exceeded the threshold considered adequate (300 rhizobia/g soil) for prompt legume nodulation. This is often the case for soils with a history of pea cropping (last grown 2012) and neutral to alkaline pH (this site 7.6). The N_2-fixation capacity of the soil rhizobia was moderate (68%) when compared to the commercial inoculant strain SU303 (Table 1).

Table 1. Soil chemistry (0-10 cm), number and N_2-fixation capacity of pea rhizobia at sowing.

Soil pH (0.01M $CaCl_2$)	Soil N Nitrate (mg/kg soil)	Soil N Ammonium (mg/kg soil)	Number of pea rhizobia (per g soil)	Effectiveness of soil rhizobia (% SU303)
7.6	24	2	420	68

In the field trial, un-inoculated plants formed 45 nodules per plant (Table 2), which is about half the median number measured in similar trials across SA and Victoria, and well below the maximum of 151 per plant. Even so, inoculation treatment had no effect on number or mass of nodules (Table 2), or their distribution between the tap and lateral roots (data not shown). Root weight was not affected.

Root damage symptoms attributable to soil-borne disease were very low (root disease score<1.5) at the site and accordingly there was no effect of inoculation treatment on the level of root damage.

Table 2. Nodulation of Kaspa field pea plants at seven weeks after sowing.

Treatment	Nodule Number (number/plant)	Nodule Mass (mg DM/plant)
-Not inoculated	45	7.1
+Rhizobia (Group F WSM1455 on seed)	56	8.2
+Rhizobia (Group F WSM1455 in furrow)	62	8.6
+Rhizobia (Group E SU303 on seed)	54	8.6
+Rhizobia (SARDI strain on seed)	57	8.1
+Microbe B to control soil borne disease	51	7.6
+Microbe X to improve N_2-fixation	47	7.2
	NS	NS

Although there was no obvious effect of inoculation treatment on the roots, maximum shoot (& pod) biomass was significantly increased by two of the rhizobia treatments and microbes B and X (Table 3). Bio-control Microbe B resulted in the greatest increase (+54%) even though there was no indication that soil borne disease was an issue at the site. Rhizobia strain WSM1455 applied in furrow was the most effective of the rhizobia treatments, increasing shoot biomass by 42%.

Pod number per plant was increased by inoculation treatments, except rhizobia strain SU303. Microbe B was most effective, increasing pod number by 51%, compared to the un-inoculated treatment (Table 3).

Improvements in shoot biomass and pod number did not translate to increased grain yield or grain N content (Table 3). Accordingly, harvest index (HI) was lower in the inoculated treatments, except for treatment SU303.

Overall, responses to inoculation at this site were inconsistent; there were no measured effects on the roots, significant effects on biomass, pod number and harvest index, but no effect on grain yield or quality.

The lack of effect of rhizobial inoculation on nodule number and mass is consistent with the results at 13 other sites, where responses have usually been small or absent when rhizobia were already present at reasonable number in the soil. However, these measures do not indicate which strains of rhizobia occupy the nodules and in particular if displacement of the less effective naturalised soil rhizobia has occurred. It is plausible that shoot biomass and pod number responses were due to a shift in nodule occupancy, but this remains to be confirmed using nodules collected from the trial.

Table 3. Shoot & pod biomass, pod number, grain yield, harvest index and grain protein.

Treatment	Shoot & pod biomass (g/plant)	Pod number (#/plant)	Grain yield (kg/ha)	Harvest index (%)	Grain N (%)
-Not inoculated	15	8.0	1897	34	3.67
+Rhizobia (Group F WSM1455 on seed)	18	10.6*	1837	26*	3.63
+Rhizobia (Group F WSM1455 in furrow)	21*	10.3*	2017	26*	3.64
+Rhizobia (Group E SU303 on seed)	15	8.5	1883	33	3.61
+Rhizobia (SARDI strain on seed)	21*	10.9*	1777	23*	3.76
+Microbe B to control soil borne disease	23*	12.0*	1973	23*	3.73
+Microbe X to improve N_2-fixation	19*	10.4*	1953	27*	3.67
LSD	4	1.9	NS	6	NS

**Significantly different from un-inoculated control*

The poor correlation (P = 0.49, R^2 = 0.09) between biomass and grain yield may indicate water or some other limitation to grain production. Biomass estimates were high and HI lower than expected, indicating the main effect of inoculation was on plant growth rather than yield.

Nitrogen supply, from fixation by the naturalised soil rhizobia and soil N reserves, was adequate to meet grain yield requirements at Hart. Grain yields have similarly been unresponsive to inoculation with rhizobia (Group F WSM1455 applied to seed at 100 times recommended rate) across the broader data set (14 sites). However, across these sites highly significant (P<0.01) increases in grain N concentration and amount provide evidence of inoculation benefits, other than to grain yield.

At this site, we estimate (assuming 2.3% N in residual herbage) the N benefit from the extra biomass residues to be 51 kg/ha for the best rhizobia treatment, noting that very high rates of inoculation were used. The proportion of this N derived from fixation is still to be determined.

So far, microbes B and X have been tested at two other sites, also in 2014. They increased shoot biomass and pod number by approximately 30% overall (multi-site analysis) however, as was the case at Hart, had no effect on grain yield. Whilst the biomass responses are encouraging, further work is needed to validate and understand the basis of the responses.

Summary & implications

At sites where substantial populations of pea rhizobia reside in the soil, even very high rates of inoculation with rhizobia have failed to improve grain yield. However, other benefits to grain N content have been measured and show that potential for symbiotic improvement exists. Capturing this potential will probably be contingent on the provision of better inoculants that increase the number of rhizobia delivered.

Inoculation of field pea with rhizobia is still strongly recommended if there has been no previous history of a rhizobia host crop (pea, bean, lentil, vetch) or if soil pH is less than 6.0. In these situations, there is a strong likelihood of response to inoculation for nodulation, biomass production, N_2-fixation and grain yield.

Acknowledgements

The trials was sown and managed by the New Variety Agronomy Group (SARDI, Clare). Funding was provided through GRDC project Optimising Nitrogen Fixation – southern region (DAS 00128).

Photo: Field pea trial at Hart in 2014

Forage peas – a potential new break crop option

Larn McMurray and Michael Lines, SARDI

Key findings

- Forage pea varieties produced similar levels of biomass to other peas and less than vetch at Hart in 2014. They were also more susceptible to blackspot than other pea varieties.
- The value of PBA Hayman as an alternative to vetch will depend largely on being able to sow it early and control blackspot disease infection. This will often be difficult to achieve and sowing dates will need to be as early as possible around safe "black spot manager" predictions.
- Where sowing of field peas was delayed, biomass was maximised by increasing sowing densities above 50 plants/m^2 with little negative effect on grain yield.

Why do the trial?

These trials form part of a SAGIT funded project which aims to assess the potential of the newly released forage (PBA Hayman) and dual purpose (PBA Coogee) field pea varieties as alternatives to vetch and grain field peas. Outcomes from these trials and similar trials at Lameroo, Minnipa and Tarlee will be used to develop agronomic management guidelines to allow the successful production of these varieties in SA.

How was it done?

Plot size	1.75 m x 10 m	**Fertiliser**	MAP (10:22) + 2% Zn @ 90 kg/ha
Seeding dates	7th May and 28th June		

Two forage experiments were undertaken at Hart in 2014 following on from similar trials held in 2013. The first experiment aimed to compare field pea and vetch varieties for biomass and grain yield potential, and the second to determine optimum sowing dates and sowing densities for maximising biomass production of field pea varieties. In the first trial, four field pea varieties (Kaspa, Morgan, PBA Coogee and PBA Hayman) and four vetch varieties (Morava, Rasina, Capello and RM4) were sown at two sowing dates. The second trial included four field pea varieties sown at four plant densities (25, 50, 75 and 100 plants/m2) sown on the same dates. Trials were set up as split plot design with three replicates. In both trials biomass measurements were taken during flowering and at maturity. Cuts during flowering were timed to correlate with early pod development (1-2 flat pods per plant, approximately 10-14 days after commencement of flowering). Final grain yield, nitrogen fixation and hay quality assessments were all measured.

Results and discussion

Above average rainfall and warm temperatures favoured rapid early plant growth but also high levels of blackspot disease pressure. The blackspot manager disease prediction for Blyth up until the 18th of May was for a medium risk level indicating that a yield loss in field peas of 20-35% could occur. Late autumn and early winter rainfall was well above average and frequent rainfall events occurred favouring disease spread. Moderate to high levels of black spot disease infection did occur and restricted early vegetative growth particularly in the early time of sowing. Higher levels of disease infection were observed in PBA Hayman compared with all other varieties at both sowing dates (Table 1). Disease infection was particularly severe in PBA Hayman at the early sowing date indicating this variety is more susceptible to this disease than other varieties. Rainfall ceased in spring and the finish to the season was characterised by a dry but relatively cool finish to the season. Grain yields of Kaspa field peas were 1.6 t/ha across both sowing dates with no effect of sowing timing due to the higher blackspot disease intensity at the May 7th sowing date cancelling out any benefit from earlier sowing last year.

Table 1. Blackspot disease severity (% plant infection) of field pea varieties, Hart 2014

Sow Date	Variety			
	Coogee	Hayman	Kaspa	Morgan
7-May	40	60	20	26.7
28-May	13.3	30	13.3	13.3
LSD (0.05)		11.25		

Trial 1: Comparison of field pea and vetch cultivar performance

An interaction between sowing date and variety for Early Pod Development Stage (EPDS) biomass production occurred in 2014. Delaying sowing by 3 weeks from early May to late May resulted in an increase in biomass production in Kaspa and PBA Coogee field peas but no response in Morgan and PBA Hayman (Figure 1). This result was in contrast to the 2013 result where a similar delay in sowing resulted in a reduction in biomass production in PBA Hayman and Kaspa. The 2014 response was most likely due to the impact of the high black spot disease infection at the first time of sowing. Apart from the early maturing variety Rasina all vetch varieties were reduced in biomass as sowing was delayed (Figure 1).

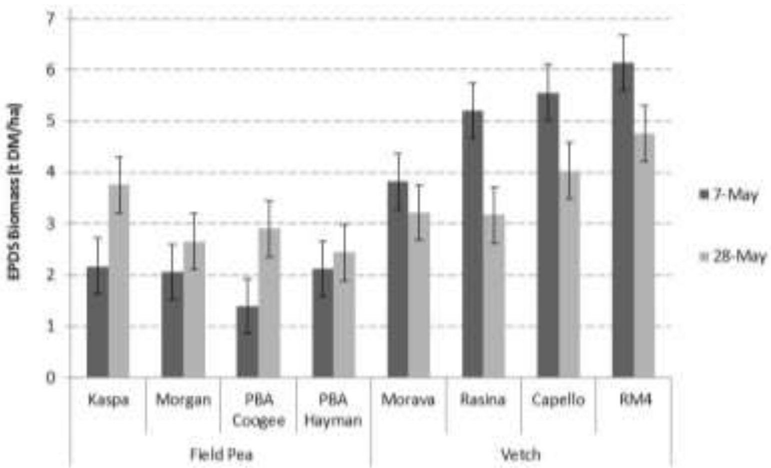

Figure 1 Effect of sowing date on early pod development stage (EPDS) biomass yield (t/ha) of field pea and vetch varieties, Hart 2014.

All vetch varieties also had higher biomass production than the field pea lines when sown early, a result again reflecting the impact of black spot on field peas. At the later sowing date biomass production was generally similar in all varieties except for the woolly pod variety RM4. This variety had higher biomass levels compared to all lines except for Kaspa and its fellow woolly pod type Capello. Biomass levels at maturity (data not presented) were similar to the EPDS levels with all field pea lines having similar levels regardless of sowing date. At the early sowing time all vetch varieties yielded similar and around double that of the peas however at the late sowing date they were similar to all pea lines.

Grain yields (Figure 2) were not affected by sowing date in 2014. A similar result occurred in 2013 with only Kaspa and Morgan showing grain yield reductions with a delay in sowing. Last year Kaspa and Morgan had higher grain yields than the dual purpose PBA Coogee, the forage type PBA Hayman and Morava vetch but similar yields to the other vetch lines including, somewhat surprisingly, the woolly pod types.

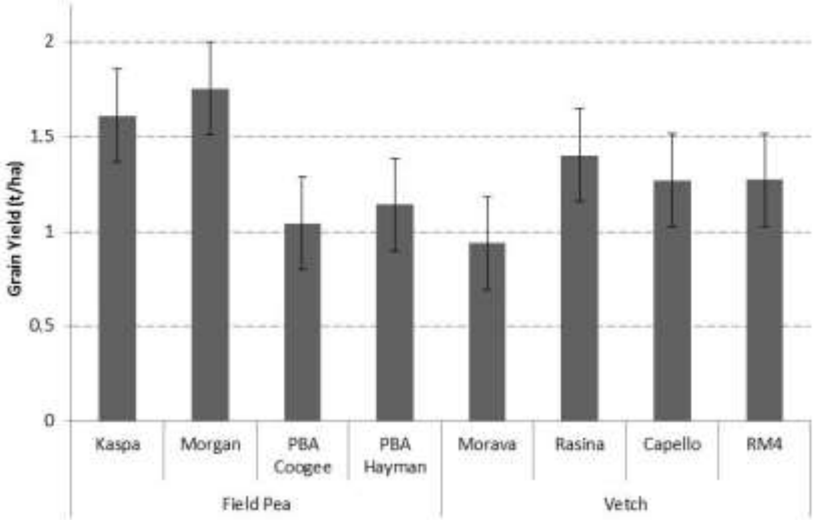

Figure 2. Grain yield (t/ha) of field pea and vetch varieties across two sowing dates, Hart 2014

Trial 2: Maximising biomass potential of forage and dual purpose field pea varieties through sowing date and plant density

As found in 2013, all field pea varieties responded the same to changes in seeding density. Maximum biomass production occurred at 75 plants/m^2 (Figure 3) and grain yield was maximised at 50 plants/m^2 (Figure 4). However, there was no yield penalty associated with increasing rates to 75 plants/m^2. In 2013 EPDS biomass was maximised at 50 plants/m^2 but no production penalty occurred when increasing to 75 plants/m^2. Again this difference found in 2014 compared with 2013 is likely to be a reflection of the increased disease levels last year.

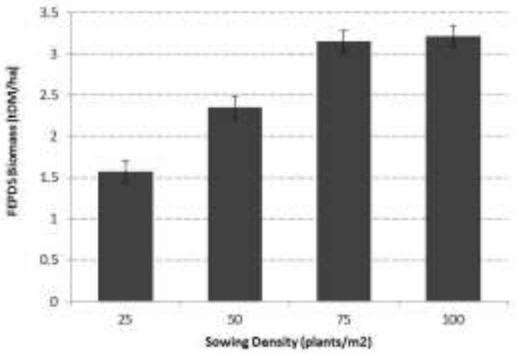

Figure 3. Effect of sowing density on early pod development stage (EPDS) biomass yield (t/ha) of field pea varieties, Minnipa 2014

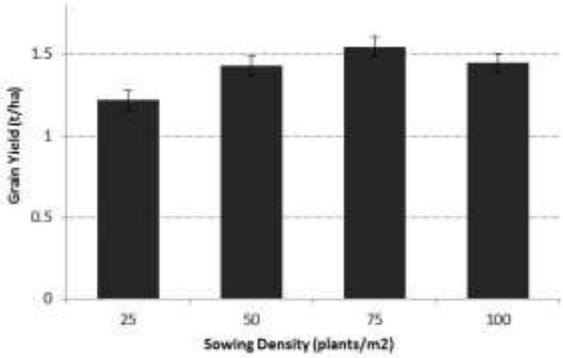

Figure 4. Effect of sowing density on grain yield (t/ha) of field pea varieties, Minnipa 2014

Summary / implications

Dual purpose and/or forage field pea varieties were developed with the aim of providing growers with a competitive alternative to vetch and other current break crop options. Dual purpose field pea varieties may also provide growers with the flexibility to react to seasonal conditions eg. frost, drought, or high grain/hay prices.

These pea types were compared with grain field peas and vetch at Hart and three other sites in 2013 and 2014 providing an understanding of their performance and potential as a break crop option in SA farming systems. The forage field pea variety PBA Hayman agronomically performed very differently to the grain variety Kaspa and dual purpose varieties Morgan and PBA Coogee. PBA Hayman was found to have a higher biomass production potential than all other field pea varieties evaluated producing grain yields 50-70% greater than Kaspa and Morgan at Hart and Tarlee in 2013. In some situations it produced greater biomass levels than both the common and woolly pod vetch varieties evaluated. However, it performed poorly at Minnipa in 2014 and only similar to Kaspa at Hart in 2014 due to increased susceptibility to blackspot and poor adaptation to shorter and drier seasons.

The increased susceptibility of PBA Hayman to blackspot is of significant concern as delayed sowing (the management strategy for reducing blackspot infections) also reduced its biomass production advantage over other field peas in some situations. This was most likely due to its later maturity and relatively slower early growth rate. While these plant characteristics are likely to reduce the potential biomass yield of PBA Hayman in low rainfall environments, they tend to suit varieties sown for hay. PBA Hayman has significantly lower grain yield potential than other field pea varieties (20-80% lower) however due to its small seed size (14g/100 seeds) a lower seeding rate can be used. The value of PBA Hayman as an alternative to vetch in SA will depend largely on being able to sow it early and control blackspot disease infection.

Across all forage experiments in SA, biomass production of the dual forage/grain field pea variety PBA Coogee was generally only similar to Kaspa and Morgan. Its grain yield was always lower than Kaspa (14-54%) and equal or lower than Morgan. This suggests Kaspa or Morgan remain the variety of choice for grain yield or “dual purpose” situations apart from in disease prone areas as PBA Coogee has improved resistance to bacterial blight over Kaspa and is the only option with resistance to powdery mildew.

Biomass comparisons between field peas (Kaspa, Morgan and PBA Coogee) and vetch were complex, varying with site, year, variety and sowing date. Generally vetch varieties produced equal or greater biomass levels when blackspot was present or in favourable growing environments.

Current recommendations for maximising grain yield in field pea will also maximise biomass production, ie earliest sowing around 'Blackspot Manager' recommendations and sowing densities of 50 plants/m^2. Where the sowing date is delayed past optimum to manage blackspot or due to late season breaks, biomass yield can be maximised by increasing sowing density of all varieties to 75 plants/m^2, with little negative effect on grain yield.

These trials contained 46 rows or 138 plots and almost 400 biomass cuts were completed by the Clare SARDI team.
Photo courtesy of Trevor & Kathy Fischer, Hilltown.

Effects of N fertiliser rates and variety on crop growth and grain yield

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Sarah Noack, Peter Hooper, Hart Field-Site Group
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Key findings

- At Hart, higher N-fertiliser rate (180 and 240 kg N/ha) produced lower grain yields compared to lower N rates (0, 60 and 120 kg N/ha).
- Nitrogen fertiliser rate did not affect yield at the Yield Prophet® site at Wandearah.
- Across all N rate treatments, RAC1843 delivered the highest yield of 5.4 t/ha.

Why do the trial?

Nitrogen (N) is an important nutrient for crop growth. Due to inherently low levels of N in many Australian soils and the financial risk associated with fertiliser applications, this nutrient is often limiting for agricultural production.

Despite the importance of N for crop yields, there is no appropriate benchmark to assess the maximum yield attainable in relation to N use. Therefore, we do not know if cropping systems are getting the maximum benefit for their investment in N fertiliser.

A difficulty in comparing wheat yields among N fertiliser treatments, across different sites and seasons, is that N concentration in wheat is strongly related to the actual biomass of the crop. However, crop biomass in turn is also highly variable and influenced by factors such as soil, variety, sowing date and season. Therefore we cannot compare the N status of crops, without taking the crop biomass into account.

In this project, we are developing a N dilution curve, specifically for the current wheat varieties and the dry climate of South Australia. This curve relates crop biomass to crop N concentration and can then be used to benchmark the N status of grower's crops and determine if fertiliser is applied at a rate that is too low, too high or just right.

At the time the Hart trial results book went to press, we did not have the N concentration data available to produce the Nitrogen Dilution Curve. In this publication we present data on biomass and yield components in an experiment at Hart. At a site at Wandearah, Yield Prophet® was run and N fertiliser rates were compared.

How was it done?

Hart trial

Plot size	1.75 m x 10 m	**Fertiliser - urea (46:0) at:**	1) 0 kg N/ha 2) 60 kg N/ha applied at seeding 3) 120 kg N/ha split between seeding and beginning of tillering (GS20) 4) 180 kg N/ha split between seeding and beginning of tillering (GS20) 5) 180 kg N/ha split between seeding, beginning of tillering (GS20) and mid stem elongation (GS31). 6) 240 kg N/ha split between seeding and beginning of tillering (GS20)
Seeding date	16th May, 2014		
Seeding rate	180 plants / m^2		
Initial mineral soil N in the 0 - 60 cm soil layer	47.5 kg N/ha		
Wheat varieties	Mace, RAC1843, Scout, Trojan		

Yield prophet® site (at Wandearah)

Plot size	1.75 m x 10 m	**Fertiliser – all plots received urea at 12 kg/ha at seeding. Top dressing urea at:**	1) 0 kg/ha 2) 50 kg/ha 3) 100 kg/ha 4) 150 kg/ha 5) 200 kg/ha
Seeding date	8th May, 2014		
Seeding rate	150 plants / m^2		
Initial mineral soil N in the 0 - 70 cm soil layer	48.2 kg N/ha		
Wheat variety	Kord CL Plus		

Methods

The trial at Hart was a randomised block design with 3 replicates, 4 wheat varieties and 6 N fertiliser rates. Three replicate soil samples were taken in the 0 – 30 and 30 - 60 cm soil layer prior to seeding, and analysed for soil moisture and N content. Biomass cuts were taken approximately every 2 weeks from tillering until maturity. At each sampling time, phenology was recorded and canopy traits were measured: chlorophyll content in the leaves was measured using a SPAD meter and the canopy size was measured with a Greenseeker. Both traits will be investigated as proxies for crop N status.

Biomass was oven dried at 60°C, weighed and then separated into leaves, stems and ears. The relative weights of the plant components were recorded and biomass was then analysed for N content. Yield components were determined at maturity: yield, 1000-grain weight, number of ears per m^2, number of grains per ear, number of grains per m^2, grain efficiency (i.e. number of grains per ear / mass of non-grain ear), harvest index (i.e. grain weight / total biomass weight), screenings (data not available yet) and protein content (data not available yet).

At the Yield Prophet® site, soil samples were also taken just before seeding. Biomass samples were taken twice, at flowering and maturity. Biomass at the Yield Prophet® site was separated into leaves stems and ears and then analysed for N content. For the trial at Hart, treatment and variety effects were statistically tested using two-way ANOVA with a 5% significance level.

Results and Discussion

Hart; N rate x variety trial

Both wheat variety and N fertiliser treatment had significant effects on biomass and grain yield and quality. An interaction was only found for leaf:stem ratio. Therefore, data for the N rate are presented with all varieties pooled together, and data for the variety effect are presented with all N rates pooled together.

Nitrogen effect

The higher N-fertiliser treatments (180 and 240 kg N/ha) produced lower yields compared to the lower N-fertiliser treatments (0, 60 and 120 kg N/ha, see Table 1). The nil-fertiliser treatment had a significantly lower grain efficiency and lower number of grains per square metre compared with the fertilised plots. However, the nil treatment had a significantly higher 1000-grain weight compared to the fertilised plots, which resulted in a yield similar to the 60 and 120 kg N/ha rates.

Overall, an increase in N application decreased 1000-grain weight. This has been found by others (e.g. Hocking *et al*., 2001) and is associated with one or more of the following (i) higher vegetative growth resulting in early depletion of soil water and thus increased water stress during grain filling, (ii) reduced storage of water soluble carbohydrates, which are the largest sources of assimilates for translocation during grain fill, and (iii) increased proportion of intrinsically smaller grains from lower hierarchy in the spike. The results showed that while the number of grains per ear increased with increased N application, the weight of those grains decreased. In addition, while total biomass did not differ among the treatments, the leaf:stem ratio at flowering did increase with increased N application (Table 1) as well as chlorophyll content (data not shown).

Variety effect

Across all N-rates, RAC1843 delivered the highest yield (5.4 t/ha), though not statistically different from Mace or Trojan (both yielded 5.0 t/ha, Table 1). Scout had the lowest grain yield of 4.7 t/ha. RAC1843 had the lowest number of grains per square metre, but this was compensated for by a high 1000-grain weight. Total biomass did not differ at maturity or flowering. However the leaf:stem ratio at flowering was higher for Scout and Trojan compared with Mace and RAC1843 (Table 1).

Table 1. Nitrogen and variety effects on yield components and total biomass at maturity at Hart. Averages ± standard error. Different superscript letters indicate a statistical difference ($P < 0.05$) between the treatments.

	Yield (t/ha)	Biomass (t/ha)	1000-grain weight (g)	Fruiting efficiency	Harvest Index	Ears / m^2	Grains /ear	Grains / m^2 (x 1000)	Leaf:stem ratio at flowering
N application rate (kg N/ha)	**Nitrogen effects at Hart:**								
0	5.4 ± 0.2 ^{ab}	12.0 ± 0.3 ^{a}	44.5 ± 0.9 ^{a}	71.4 ± 2.4 ^{a}	0.45 ± 0.01 ^{a}	400 ± 14 ^{a}	34 ± 1 ^{a}	13.6 ± 0.6 ^{a}	0.21 ± 0.01 ^{a}
60	5.7 ± 0.2 ^{a}	12.9 ± 0.3 ^{ab}	38.9 ± 1.7 ^{ab}	83.9 ± 5.1 ^{ab}	0.45 ± 0.01 a	497 ± 27 ^{b}	34 ± 1 ^{a}	16.8 ± 1.2 ^{ab}	0.27 ± 0.01 ^{a}
120 (2 x 60)*	5.4 ± 0.2 ^{ab}	13.4 ± 0.2 ^{b}	33.0 ± 1.5 ^{bc}	87.2 ± 1.9 ^{b}	0.40 ± 0.01 ^{ab}	499 ± 8 ^{b}	37 ± 1 ^{a}	18.5 ± 0.5 ^{b}	0.32 ± 0.01 ^{b}
180 (2 x 90)*	4.8 ± 0.2 ^{bc}	12.7 ± 0.4 ^{ab}	29.5 ± 1.4 ^{c}	88.3 ± 2.6 ^{b}	0.37 ± 0.01 ^{bc}	503 ± 24 ^{b}	38 ± 2 ^{a}	18.9 ± 0.9 ^{b}	0.34 ± 0.02 ^{b}
180 (3 x 60)*	4.7 ± 0.1 ^{bc}	12.4 ± 0.2 ^{ab}	29.1 ± 1.1 ^{c}	87.3 ± 2.4 ^{b}	0.38 ± 0.01 ^{bc}	486 ± 22 ^{b}	38 ± 3 ^{a}	17.9 ± 0.9 ^{b}	0.36 ± 0.02 ^{b}
240 (2 x 120)*	4.2 ± 0.3 ^{c}	12.7 ± 0.4 ^{ab}	27.3 ± 1.7 ^{c}	89.1 ± 2.6 ^{b}	0.33 ± 0.02 ^{c}	493 ± 15 ^{b}	41 ± 2 ^{a}	19.9 ± 0.8 ^{b}	0.36 ± 0.02 ^{b}
Variety	**Variety effects at Hart:**								
Mace	5.0 ± 0.3 ^{ab}	13.2 ± 0.3 ^{a}	32.8 ± 1.9 ^{a}	88.9 ± 3.3 ^{ab}	0.38 ± 0.02 ^{a}	475 ± 16 ^{ab}	38 ± 1 ^{a}	18.1 ± 0.8 ^{ab}	0.28 ± 0.01 ^{a}
RAC1843	5.4 ± 0.2 ^{a}	12.6 ± 0.2 ^{a}	39.9 ± 1.7 ^{b}	75.8 ± 1.8 ^{c}	0.43 ± 0.01 ^{b}	520 ± 16 ^{a}	30 ± 1 ^{b}	15.9 ± 0.7 ^{a}	0.28 ± 0.01 ^{a}
Scout	4.7 ± 0.2 ^{b}	12.3 ± 0.3 ^{a}	29.3 ± 2.1 ^{a}	92.5 ± 2.1 ^{a}	0.38 ± 0.01 ^{ab}	480 ± 21 ^{ab}	39 ± 1 ^{a}	18.9 ± 1.0 ^{b}	0.34 ± 0.02 ^{b}
Trojan	5.0 ± 0.2 ^{ab}	12.6 ± 0.2 ^{a}	33.1 ± 2.2 ^{a}	80.6 ± 1.8 ^{bc}	0.39 ± 0.01 ^{ab}	442 ± 12 ^{b}	40 ± 2 ^{a}	17.5 ± 0.8 ^{ab}	0.35 ± 0.02 ^{b}

**Split applications i.e. 2 times 60 kg N/ha.*

Yield Prophet® site

Yield and grain traits at the Yield Prophet® site responded slightly different to the range of N application rates, compared with the trial at Hart. Yield did not differ among the N rates. While the biomass, grain efficiency and number of ears per m^2 were similarly lowest in the nil-N treatment, the differences with the other N rates were not significant. There was also no trend of a decrease in 1000-grain weight with an increase in N rate (Table 2), as was observed at Hart.

At Hart we suggested that the increase in leaf:stem ratio in response to higher N rates could point to higher water use throughout the growing season. Consequently increased water stress during grain fill, which might explain the decrease in 1000-grain weight with higher N rates. At the Yield Prophet® site, we did not find such an increase in leaf:stem ratio (Table 2) or total biomass at flowering (data not shown). The lack of a difference in yield may be due to a similar degree of water stress during grain filling among all the N rates.

Table 2. Treatment effects on yield components and total biomass at maturity at the Yield Prophet® site and the farmers' fields. Averages ± standard error. Different superscript letters indicate a statistical difference between the treatments.

	Yield (t/ha)	Biomass (t/ha)	1000-grain weight (g)	Fruiting efficiency	Harvest Index	Ears / m^2	Grains / ear	Grains / m^2 (x 1000)	Leaf:stem ratio at flowering
N application rate (kg N/ha)	**Nitrogen effects at the Yield Prophet site**								
0	4.4 ± 0.2 ^{a}	9.2 ± 0.5 ^{a}	41.6 ± 0.9 ^{ab}	70.6 ± 1.6 ^{a}	0.48 ± 0.01 ^{a}	298 ± 17 ^{a}	35 ± 4 ^{a}	10.6 ± 1.6 ^{a}	0.40 ± 0.03 ^{a}
50	5.3 ± 0.3 ^{a}	11.8 ± 0.5 ^{a}	43.7 ± 0.9 ^{a}	75.5 ± 1.2 ^{a}	0.45 ± <0.01 ^{a}	413 ± 18 ^{b}	34 ± 1 ^{a}	14.1 ± 0.7 ^{a}	0.39 ± 0.01 ^{a}
100	4.6 ± 0.3 ^{a}	10.7 ± 0.5 ^{a}	39.8 ± 1.2 ^{ab}	74.4 ± 2.8 ^{a}	0.43 ± 0.01 ^{a}	368 ± 11 ^{ab}	34 ± 2 ^{a}	12.7 ± 0.8 ^{a}	0.40 ± 0.01 ^{a}
150	4.9 ± 0.2 ^{a}	11.0 ± 0.4 ^{a}	43.3 ± 1.4 ^{a}	72.3 ± 3.6 ^{a}	0.45 ± < 0.01 ^{a}	379 ± 14 ^{ab}	34 ± 1 ^{a}	12.7 ± 0.1 ^{a}	0.40 ± 0.01 ^{a}
200	5.1 ± 0.3 ^{a}	11.5 ± 1.3 ^{a}	37.9 ± 1.0 ^{b}	72.8 ± 2.0 ^{a}	0.45 ± 0.04 ^{a}	407 ± 34 ^{b}	35 ± 2 ^{a}	14.2 ± 1.1 ^{a}	0.42 ± 0.02 ^{a}

Conclusions

At Hart, the high N-fertiliser treatments (180 and 240 kg N/ha) produced lower yields than the lower N-fertiliser treatments (0, 60 and 120 kg N/ha). This was apparently driven by a reduction in 1000-grain weight. At the Yield Prophet® site, there was no difference in yield or 1000-grain weight among the N rates. Further analyses will be performed which may help explain this difference: i.e. the N nutrition index to assess the N status of the crops, ^{13}C analysis to assess the degree of drought stress that the crop has experienced, and water soluble carbohydrates, to assess the ability of the crop to continue grain fill after photosynthesis declines.

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Management strategies for improved productivity and reduced nitrous oxide emissions

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Key findings

- The amount of nitrogen lost as nitrous oxide was small, 0.4 kg N/ha after 204 days (seeding-harvest).
- Highest emissions came from applications of 80 kg N/ha applied IBS compared to the same rate applied at GS31 and the nil N applied.
- In adjacent blocks Mace wheat sown on canola produced higher emissions and lower grain yields than wheat sown on lentils.

Why do the trial?

Nitrous oxide (N_2O) is a greenhouse gas, primarily produced from agricultural activities such as fertilisation and breakdown of livestock waste. Recent research has shown there are a range of reduction strategies that may benefit growers both environmentally and economically. The objectives of this trial was to measure and demonstrate on-farm strategies that can reduce nitrous oxide by trialling four key practices:

- Use of legumes in the cropping rotation.
- Application of nitrogen fertiliser at key stem elongation growth stages.
- The use of precision farming tools to be better measure N mineralisation.
- Use of nitrification inhibitors.

Soils also release dinitrogen (N_2) gas through denitrification however, we cannot measure this as dinitrogen naturally occurs in the Earth's atmosphere. There is a strong relationship between nitrous oxide emissions and denitrification. In general dinitrogen releases can be 20-30 times greater than N lost from nitrous oxide, though the exact relationship between the two gases depends on the water content of the soil.

How was it done?

Plot size	12.5 m x 22.5 m	**Fertiliser**	Urea/DAP (22:10) @ 10 kg N/ha at seeding
Seeding date	13th May 2014		
Crop	Mace wheat		All in-season N applications as specified by treatments below.

The trial was a factorial design with four replicates, two previous crop histories (2013 - 44C79 canola or Blitz lentils) and six N treatments. In 2013 the canola and lentil blocks were sown adjacent to each other on the same soil type and using identical management (with the exception of N).

In 2014 the trial was sown with Mace wheat. The six nitrogen treatments were applied as incorporated by sowing (IBS) on 13th May or at first node (GS31) on 21st July as follows;

1) Nil nitrogen applied (zero nitrogen control)
2) 40 kg N/ha applied as urea at first node (GS31) of the wheat crop
3) 80 kg N/ha applied as urea at first node (GS31) of the wheat crop
4) 80 kg N/ha as urea IBS
5) 80 kg N/ha applied as Entec urea (nitrification inhibitor) at first node (GS31) of the wheat crop
6) Real Time Tactical Treatment - determined using a Greenseeker® to measure crop canopy greenness. At GS31 25 kg N/ha (as urea) was applied to the ex-lentil plots and 51 kg N/ha (as urea) to ex-canola plots.

Soil assessments

A number of measurements were taken throughout the season including nitrous oxide monitoring in treatments 1 (nil), 3 (80 kg N/ha at GS31) and 4 (80 kg N/ha IBS). Sampling occurred once per week during the growing season and twice per week after the GS31 nitrogen applications for three weeks. Soil moisture content and temperature was also measured in the top 12 cm of the soil using a hand held time domain reflectometer (TDR) soil moisture metre and HOBO® temperature logger. Soil nitrogen was assessed in the canola and lentil blocks prior to seeding (8th May) at depths 0-30 cm and 30-60 cm.

Crop structure assessments

Fixed marker points were used for crop structure assessments, 2 markers x 1 m each side per plot. Plant establishment, tiller and head number were all assessed at these fixed marker points.

Dry matter and nitrogen content were sampled at GS30 and GS31 (1st node) for treatments 1 and 4 only and GS32, GS39 (flag leaf), GS65 (flowering) and GS99 for all treatments. Two metres of row were collected at two points in each plot, weighed, subsampled, oven dried at 60°C and final dry matter calculated.

Grain yield and quality

The trial was harvested on the 5th December 2014. All plots were assessed for grain yield, protein, test weight, screenings (<2.0 mm screen) and 1000 grain weight.

Results and discussion

The use of legume crops such as lentils generally leave higher residual levels of soil nitrogen. Prior to seeding the previous lentil and canola trials were assessed for soil nitrogen and the ex-lentil ground had 10 kg N/ha greater residual nitrogen compared to the canola (Table 1). The hypothesis was the lentil ground (with higher nitrogen reserves) will require less nitrogen fertiliser compared to the canola treatments, leading to better nitrogen use efficiency (NUE) and reduced nitrous oxide emissions.

Table 1. Soil nitrogen (kg N/ha) for ex-lentil and ex-canola ground sampled 8th May 2014.

Treatment	Soil nitrogen (kg N/ha)
Ex Lentils: Nil N 0-30cm	20.7
Ex Lentils: Nil N 30-60cm	18.9
Ex Lentils: Nil N Total	**39.6**
Ex Canola: Nil N 0-30cm	16.8
Ex Canola: Nil N 30-60cm	13.0
Ex Canola: Nil N Total	**29.9**

Previous crop history affected all crop structure assessments. On average between the two crop histories lentils always had greater establishment (17 plants/m^2), tiller number (175 tillers/m^2) and final head number (86 heads/m^2) compared to the canola (Figure 1a and b). Early in the season the 80 kg N/ha IBS did not affect crop establishment for wheat following lentils or canola. At GS31 the tiller number for nitrogen treatments following lentils were different. At this growth stage the IBS 80 kg N/ha had a higher tiller number compared to the control. The percentage of tillers which produced heads was higher for wheat sown after canola (76%) compared to wheat following lentils (68%).

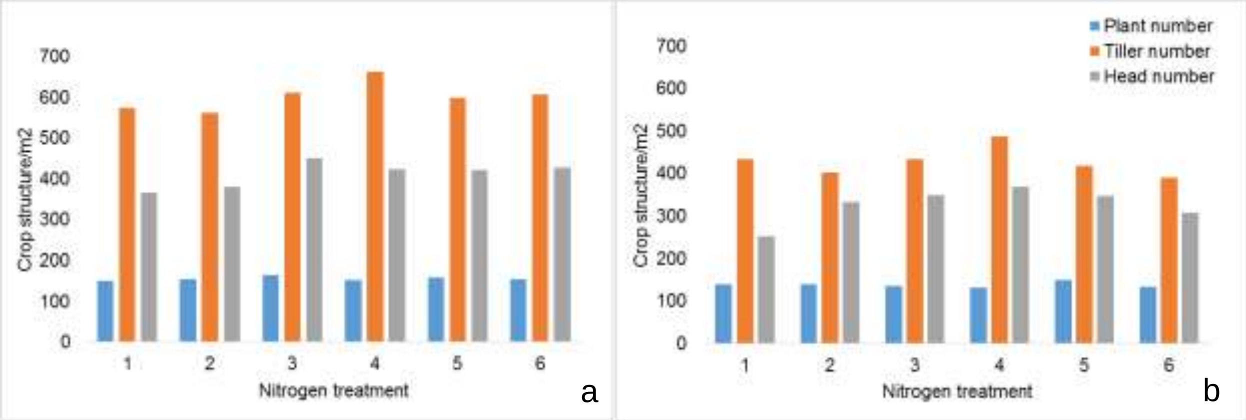

Figure 1. Plant, tiller and final head number/m^2 for Mace wheat following (a) lentils and (b) canola for all nitrogen treatments.

Dry matter production varied more for wheat after canola compared to lentils. This could be seen visually throughout the season and become more prominent as the season progressed. The early nitrogen up front (80 kg N/ha IBS) consistently had higher dry matter production compared to all other treatments (Figure 2b). While this did not affect grain yield, grain protein content was lower for this treatment (Table 2).

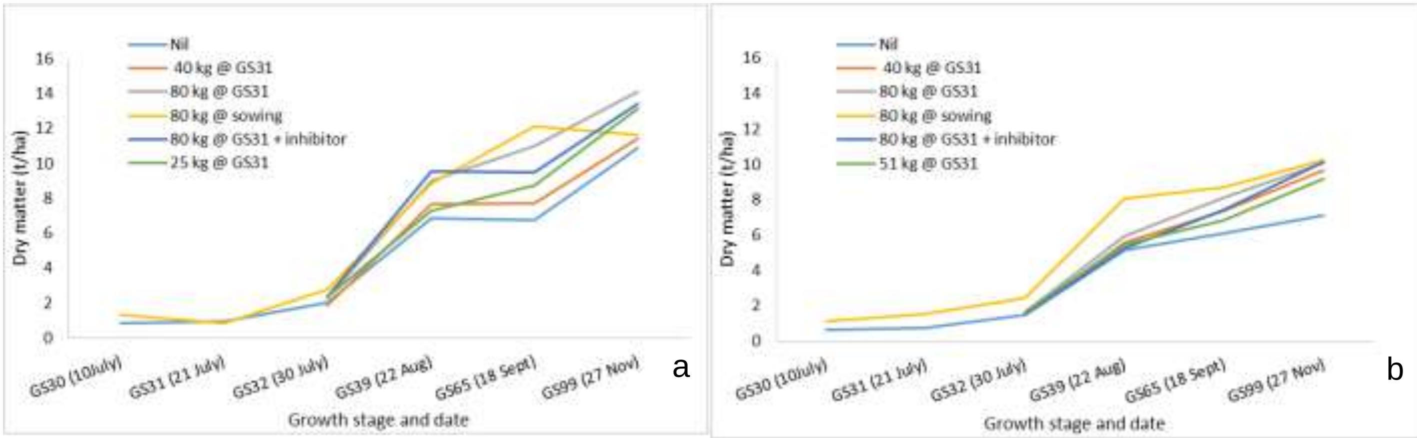

Figure 2. Dry matter production of Mace wheat following (a) lentils or (b) canola for all nitrogen treatments.

The effect of nitrogen application on grain yield and grain protein varied according to the time of application. Generally applications of N up to mid-stem elongation can be seen as building the foundation of yield and have relatively little effect on protein while later applications of N can be used to maintain or increase protein, but have little or no effect on yield. The highest yielding nitrogen treatments were 80 kg N/ha applied IBS, GS31, GS31 with nitrification inhibitor and tactical treatment (Table 2). Application of only 40 kg N/ha yielded less than these treatments however, was significantly higher (0.96 t/ha) compared to the control. Similar trends were seen for grain protein however, for both crop histories the GS31 application of N as urea or Entec urea had higher protein (Table 2). Test weight and 1000 grain weight were not affected by nitrogen treatment and all screening levels were below 5% (maximum level for AH and APW).

Table 2. Summary of grain yield (t/ha), protein (%), test weight (kg/hl), screenings (%) and 1000 grain weight (g) for Mace wheat sown following lentils and canola for all nitrogen rates.

Previous crop	Nitrogen rate	Grain yield t/ha	Protein %	Test weight kg/hL	Screenings %	1000 grain wt g
Lentils	Nil	3.77c	7.3c	80.3	0.6d	45.6
	40 kg @ GS31	4.73b	8.8b	80.5	1.0cd	44.5
	80 kg @ GS31	6.07a	10.6a	79.8	1.5a	44.2
	80 kg @ sowing	5.49a	9.6ab	81.4	0.8cd	43.5
	80 kg @ GS31 + inhibitor	6.04a	10.8a	80.0	1.4ab	43.0
	25 kg @ GS31	5.54a	9.0b	80.5	1.0bc	44.2
	LSD (P≤0.05)	0.74	1.3	ns	0.4	ns
Canola	Nil	2.77d	6.5c	79.6	0.6	46.8
	40 kg @ GS31	4.12c	7.7b	81.0	1.0	46.2
	80 kg @ GS31	5.14a	10.2a	81.3	1.2	45.9
	80 kg @ sowing	4.39abc	8.4b	81.0	1.2	46.2
	80 kg @ GS31 + inhibitor	5.01ab	9.6a	80.9	1.4	45.2
	51 kg @ GS31	4.33bc	8.3b	80.8	1.2	46.2
	LSD (P≤0.05)	0.81	1.0	ns	ns	ns

Nitrous oxide emissions

Initial nitrous oxide losses from the first 17 days shows the impact of nitrogen application (80 kg N/ha) at seeding after 25 mm of rainfall was received by the end of May (Table 3). Emissions were higher following canola compared to the lentils. From June through to July the trial received 120 mm of rainfall, increasing soil moisture in the surface soil (Figure 3). Soil moisture is an important driver of nitrous oxide emissions through both the nitrification and denitrification process. Nitrification mostly occurs when soils are at field capacity. Denitrification occurs when soils are above field capacity and starting to become waterlogged.

Table 3. Nitrous oxide emissions (g N_2O/ha) for the period of 15th May – 4th December for nitrogen fertiliser × crop history treatments at Hart, 2014.

		May 15-31 (17 days)	June 1-30 (3 days)	July 1-23 (23 days)	July 24-31 (7 days)	August 1-31 (31 days)	Sept 1-30 (30 days)	Oct 1-31 (31 days)	Nov 1 - Dec 4 (34 days)	**Total (204 days)**
Ex-Crop	Trt					g N_2O/ha				
Canola	1	15.2	7.2	13.5	7.5	22.1	7.8	1.4	19.5	**94.4**
Canola	4	34.9	162.2	149.8	8.0	5.5	0.0	0.0	0.0	**360.4**
Canola	3				6.2	50.3	23.4	0.0	9.6	**89.6**
Lentils	1	0.0	28.7	16.6	17.3	53.0	5.6	0.4	13.1	**134.7**
Lentils	4	33.1	50.3	26.0	28.1	94.6	1.7	0.0	37.5	**271.3**
Lentils	3				23.1	44.8	4.9	5.3	28.0	**106.1**

**total N_2O emissions for treatment 3 assume emissions were same as nil prior to 24th of July.*

The GS31 application of nitrogen 21st July resulted in increased nitrous oxide emissions for 80 kg at GS31 (Figure 4). However, the emissions were not as high compared to 80 kg N/ha IBS which can be attributed to the drier soil conditions after the GS31 application (Figure 4). From early August the season conditions changed and for the majority of August, September and October the trial received only 11 mm, 11 mm and 2 mm, respectively.

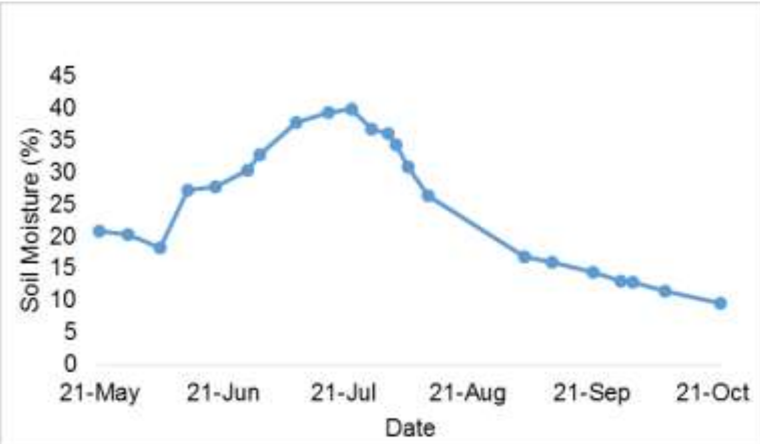

Figure 3. Average soil moisture (%) as recorded by a portable time domain reflectance (TDR) metre in the top 12 cm of the soil.

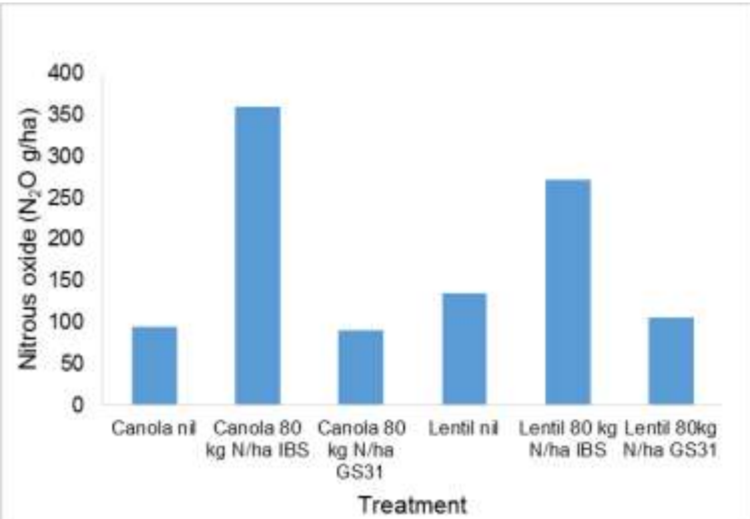

Figure 4. Total nitrous oxide emissions for nil, 80 kg N/ha IBS or applied at GS31 for lentil and canola treatments.

Actual nitrogen losses from the Hart nitrous oxide trial were small, maximum of 0.4 kg of nitrous oxide per hectare after 204 days (seeding – harvest). However, as mentioned previously nitrous oxide losses are strongly correlated to dinitrogen gas loss which is the main form of soil nitrogen gas lost. If dinitrogen emissions were calculated to be 20-30 times high than nitrous oxide, a loss of 0.4 kg nitrous oxide/ha might equate to 8-12 kg N/ha.

An identical trail was also established in Yarrawonga, Victoria (Riverine Plains) with the exception of a different legume sown in 2013 (field peas instead of lentils). Similar to Hart, nitrous oxide emissions were greatest after fertiliser application (Table 4). The IBS 80 kg N/ha also produced higher emissions compared to the 80 kg N/ha at GS31 in the first 115 days of this trial (Table 4). Interestingly, the Yarrawonga site had 4.5 times higher nitrous oxide emissions compared to Hart in just over half the trial time (205 day Hart compared to 115 days Yarrawonga). We suspect the differences between the sites are attributed to rainfall and differences in soil type (eg. drainage and soil structure).

Table 4. Nitrous oxide emissions (g N_20/ha) for the period of 9th May – 31st August for nitrogen fertiliser × crop history treatments at Yarrawonga, 2014

		May (23 Days)	**June (30 days)**	**July (23 Days)**	**July Post App (8 Days)**	**August (31 Days)**	**Total for 115 days**
Ex-Crop	Trt	g N20/ha					
Canola	1	61.3	106.2	8.0	-1.6	18.5	**192.4**
Canola	4	812.4	897.9	48.4	20.1	66.1	**1844.8**
Canola	3				8.1	77.2	**260.8**
Peas	1	41.5	179.2	12.4	6.8	12.2	**252.1**
Peas	4	472.1	1108.4	27.8	10.3	26.6	**1645.2**
Peas	3				47.6	57.4	**338.0**

**total N_2O emissions for treatment 3 assume emissions were same as nil prior to 24th of July.*

Acknowledgements
The authors acknowledge the department of Agriculture for funding this research project as part of Action on The Ground (AOTGR2-0015).

Australian Government

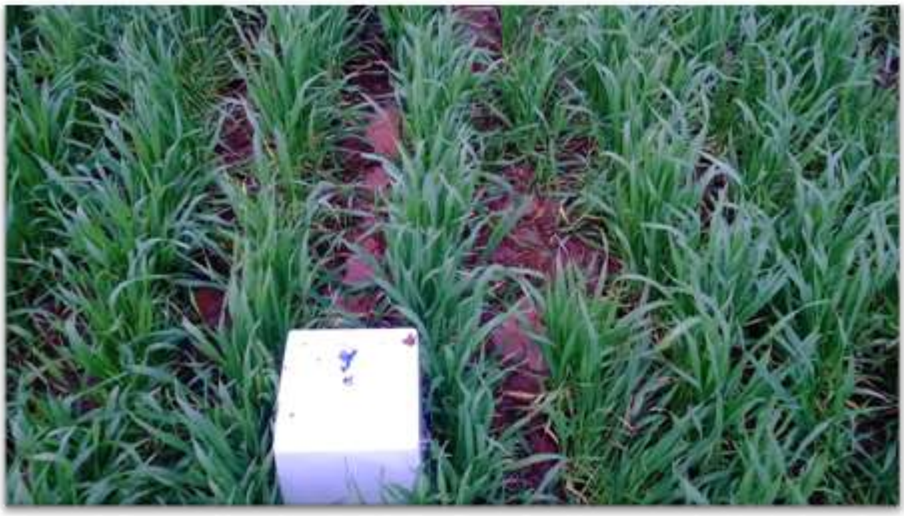

Photo: Nitrous oxide chamber in 2014 wheat crop at Hart.

Legume effects on soil N and wheat grain yield

Sarah Noack and Peter Hooper, Hart Field-Site Group

Key Findings

- Available soil N at the start of 2014 was 20-50 kg N/ha higher for legume treatments compared to wheat.
- Starting soil N did not affect grain yield for nil or additional N applied treatments.
- Differences in grain protein were correlated to starting soil N levels.

Why do the trial?

Currently, growers not utilising a legume within their rotation rely on synthetic nitrogen (N) forms i.e. urea or UAN to supply crop N. This requires a greater workload during the growing season and there is a risk of the N being lost (leaching and volatilisation) or not being taken up by the crop. Compared to legume soil N, which is mineralised for a number of years, synthetic N is a relatively short term supply. The aim of this trial was to grow a legume (field peas) and impose a range of treatments (hay, green manure etc) to create different starting soil N levels prior to sowing with wheat. Thus, keeping disease and moisture levels similar between the treatments. The wheat phase was used to measure the effect of different soil N levels on grain yield and quality, with and without additional fertiliser.

How was it done?

Plot size	5.0 m x 10.0 m	**Fertiliser**	DAP (18:20) + 2% Zn @ 60 kg/ha
Seeding date	15th May 2014		In-season N as specified in Table 1.
Crop variety	Mace wheat @ 180 plants/m^2		

Treatments in 2013

The trial was a randomised complete block design and all plots were sown with Kaspa peas (except one chickpea treatment) and a range of treatments were imposed to create differences in starting soil N in 2014.

1) Pea brown manure – Kaspa (120 kg/ha) sprayed out
2) Pea hay – Kaspa (120 kg/ha) cut and removed from plots
3) High seeding rate – Kaspa (120 kg/ha) plus Hayman (40 kg/ha)
4) Low seeding rate – Kaspa (65 kg/ha)
5) Peas inoculated – Kaspa (120 kg/ha) with 1 handful of peat inocculum down tube
6) Chickpeas – Striker @ 100 kg/ha

On 26th March 2014 all plots were soil cored to 80 cm. Soils were oven dried at 60°C and analysed by CSBP for soil available N (Table 1). Since a number of the legume treatments resulted in similar starting soil N, treatments were split so they received a nil or N application targeting 4.9 t/ha or 6.1 t/ha for 50% and 100% yield probability as determined by Yield Prophet® in early July.

Table 1. Summary of treatment sown in 2013, starting soil N measured in March 2014 and the N fertiliser applied to each treatment.

Crop grown in 2013	**Starting soil N 2014**	**N fertiliser applied in 2014**		
		nil	**rate 1**	**rate 2**
	kg N/ha	kg N/ha	kg N/ha	kg N/ha
Pea inoculated	92	0	60	
Low seeding rate	92	0		80
High seeding rate	96	0	55	
Pea hay	97	0		80
Pea brown manure	124	0	25	
Chickpea	124	0		50
Wheat	74		50	80

Fertiliser N rate 1 based on a yield target of 4.9 t/ha (or 140 kg N/ha) and N rate 2 was based on a yield target of 6.1 t/ha (or 175 kg N/ha).

Results and discussion

Starting soil N across all legume treatments varied by 30 kg N/ha. All treatments were 20-50 kg N/ha greater compared to the wheat treatment (Table 1). This is consistent with a large number of farmer paddocks sampled in SA from 2002-2014 (Peoples et al. 2014). Their data showed soil N following legumes can be expected to be 25-35 kg N/ha higher than following cereals.

In the current trial, wheat grain yield was not affected by the different starting soil N values (Table 2). This can be attributed to the fact that not all legume N will be immediately available to the subsequent wheat crop. Legume N requires soil microbial processes to breakdown and release N, which takes longer, compared to synthetic N fertiliser sources (eg. urea).

However, application of N to these starting soil N treatments resulted in grain yield differences. Across all N rates the nil N yielded 0.29 t/ha more compared to the plus N treatments. Interestingly, wheat on wheat with 50 kg N/ha applied in season (74 starting N/ha + 50 kg N/ha in season = 124 kg N/ha) yielded the same as 124 kg N/ha soil N, with no N in season.

Table 2. Summary of 2013 crop treatment on 2014 wheat grain yield (t/ha) for nil N and plus N treatments.

Starting soil N kg N/ha	N rate kg N/ha	Grain yield t/ha	N rate kg N/ha	Grain yield t/ha
(pea inoc.) 92	0	4.96	60	4.69
(low seed) 92	0	4.84	80	4.57
(high seed) 96	0	4.80	55	4.68
(pea hay) 97	0	4.93	80	4.48
(pea BM) 124	0	4.90	25	4.39
(chickpea) 124	0	4.83	50	4.70
(wheat) 74			50	4.97
LSD (P≤0.05) Starting soil N		ns		

Treatments with lower starting soil N produced grain with lower protein and vice versa (Figure 1). Between the two N treatments there were also significant differences in protein. All treatments with additional N applied in season averaged 1.3% higher protein compared to the nil (Table 3). This can be attributed to the above average rainfall early in the season setting yield potentials high followed by below average rainfall from August onwards. This lead to a situation of too much N in the plus N treatments for the yield potential, increasing grain protein.

These results are in agreement with Peoples et al. (2014) who did not observe grain yield differences following different starting soil N level (from lupins, wheat and canola). Similarly, wheat protein levels were much higher for treatments with higher starting soil N.

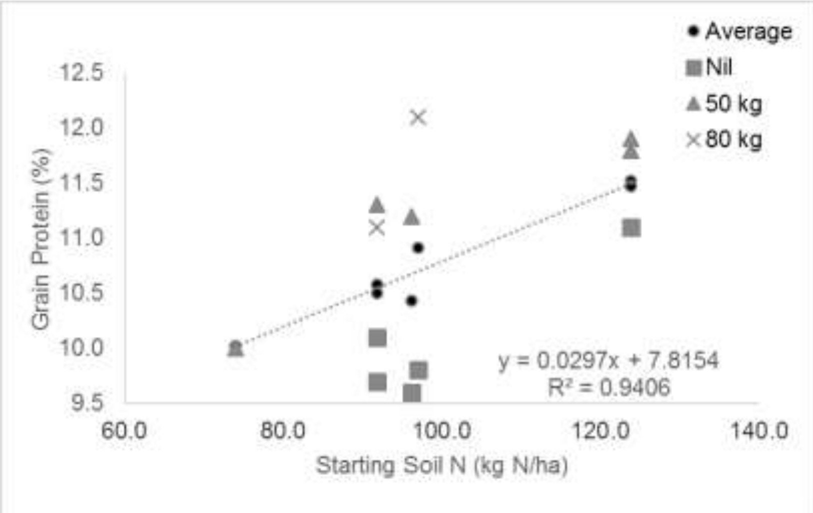

Figure 1. Relationship between starting soil N level (kg N/ha) and final wheat grain protein for the 2013 crop treatments and N rates (nil applied, 50 kg N/ha (45, 55 and 60 kg N/ha grouped), 80 kg N/ha and average N applied).

Table 3. Summary of 2013 crop treatment on 2014 wheat grain protein (%) for nil N and plus N treatments.

Starting soil N kg N/ha	N rate kg N/ha	Protein %	N rate kg N/ha	Protein %
(pea inoc) 92	0	9.7	60	11.3
(low seed) 92	0	10.1	80	11.1
(high seed) 96	0	9.6	55	11.2
(pea hay) 97	0	9.8	80	12.1
(pea BM) 124	0	11.1	25	11.9
(chickpea) 124	0	11.1	50	11.8
(wheat) 74			50	10.0
LSD (P≤0.05)				
Starting soil N		0.7		
N rate applied		0.3		
Starting soil N x N rate		ns		

Comparing legume and synthetic nitrogen sources

Nitrogen removed in wheat grain ranged from 81 – 97 kg N/ha across all treatments (Table 4). The results show 50-60 kg N/ha supplied as urea was required to match an additional 30 kg/ha legume N at the start of the season (Table 4). Therefore at least an extra 30 kg/ha of synthetic N or $30/ha was required in systems with lower starting soil N.

Table 4. Nitrogen removed (kg N/ha) in harvested wheat grain 2014 for all starting soil N treatments.

Starting soil N	N rate	N removal*	N rate	N removal
kg N/ha	kg N/ha			
(pea inoc) 92	0	84	60	93
(low seed) 92	0	86	80	89
(high seed) 96	0	81	55	92
(pea hay) 97	0	84	80	95
(pea BM) 124	0	95	25	91
(chickpea) 124	0	94	50	97
(wheat) 74			50	87

**N removal = grain yield × protein × 1.75*

References

Peoples et al. (2014) Inputs of fixed N by legumes and contributions of legume N to wheat. Hart Field Day Guide, pg 88-92.

Photo: Hart lentil trials at Pinery in 2014.

Is there a preferred wheat or barley variety to grow in a P deficient soil?

Sean Mason[1], Glenn McDonald[1], Bill Bovill[2], Willie Shoobridge[3], Rob Wheeler[3]

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Key findings

- At low available soil P and moderate PBI levels relatively high P inputs are required to maximise yields.
- Replacement P programs should incorporate a measure of PBI in order to effectively balance available P across different soil types.
- Significant yield differences between varieties of wheat and barley could not be attributed to varying P uptake efficiencies.

Why do the trial?

Aim: To investigate responses to phosphorus (P) fertiliser of common wheat and barley varieties on a P deficient soil.

The imperative for efficient use of P in broad acre agriculture is an increasing issue due to the likelihood of increased fertiliser prices contributing to greater production costs in the future. Maximising yields on the basis of providing adequate P nutrition can be achieved by applying sufficient amounts of P fertiliser to soils where P is limited. Fertiliser applied to the crop contributes only 5-30% to the crops total P uptake and therefore the rest of the crop's P requirements needs to be supplied from existing soil P reserves. 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 is of great interest to farmers due to the relatively low P levels driven by highly P fixing soils in the region. Previous experiments conducted at Minnipa and Mallala in 2012 and 2013 revealed small significant responses to P applications among various wheat and barley varieties, however no significant differences could be obtained for PUE potentially due to the relatively small yield response obtained (EPFS 2013 pg 129-131). Trials were repeated in 2014 at Condowie where very low P levels were measured in an attempt to generate greater yield responses to P and identify if there are any significant differences in PUE between varieties.

How was it done?

On 3rd June 2014, six varieties each of wheat and barley were sown at five rates of P: 0, 5, 10, 25 and 40 kg P/ha replicated three times. The varieties sown were selected from a range of current commercial varieties and some old varieties that have been reported to show differences in P responses (see table 2 for list of varieties used). The P was applied as triple superphosphate, drilled with the seed at sowing.

Soil samples were taken across the field site and analysed for available P (DGT and Colwell P) along with a buffering measure (PBI). Early crop growth was assessed by taking biomass samples at three times – 30th July, 14th August and 25th August. The biomass was estimated by measuring NDVI with a Greenseeker ™ and calibrating the readings with biomass cuts at each site. At the same time and at harvest, a soil sample was taken in-row from a selection of the 0 kg P/ha plots to measure available P with time.

The PUE is defined as the grain yield at 0 P relative to the maximum grain yield obtained which is calculated at the plateau of the response curve which is fitted through the yield response data. Phosphorus requirement was estimated as the rate that gave 90% of the overall yield response to P application. The economics of returns from obtained yield vs cost of applied P was calculated based on prices of $280/t for APW wheat and $270/t for Malt barley, and a fertiliser price of $750 (DAP) (PIRSA Gross margin guide 2015).

Results and discussion

Low levels of available P were present at the Condowie site as measured by either DGT P or Colwell P compared to their respective critical values (Table 1). The site had moderate phosphorus buffering index (PBI) value.

Table 1. Mean and spatial variation in available P values at Condowie. Ten cores were taken in 10 plots of each trial (wheat/barley) and measured separately. DGT P presented as μg P/L, critical value = 52 (47-56, 95% CI), Colwell P and critical Colwell P in mg P/kg. Data are shown as mean ± standard error of the mean.

	DGT P	Colwell P	PBI	Critical Colwell P
Wheat	17± 2.0	22± 2.0	97± 3.0	28
CV(%)	37	24	8	
Barley	17± 1.0	17± 1.0	85± 1.0	26
CV(%)	39	22	10	

Early biomass production of wheat and barley responded significantly to P fertiliser rate (Figure 1). There was a linear response to P with no evidence of a plateau in the response outlining a relative inefficiency of the P application potentially due to the late sowing date and cold temperatures experience soon after sowing. These factors would cause slow early growth rates and reduced diffusion of P from fertiliser granules.

Significant responses to P applications and among varieties were obtained for grain yield in both wheat and barley (Figure 2, Table 2). Despite overall larger responses to P compared to the 2012 and 2013 seasons there was no significant Variety x P interaction in either wheat or barley. In other words, for both wheat and barley the yield differences among the 6 varieties were too small to pick up significant differences in their responsiveness to P. Barley varieties tended to yield higher than wheat which in part can be attributed to the occurrence of yellow leaf spot at early development for susceptible wheat varieties (Scout, Correll) as the trial was sown into wheat stubble.

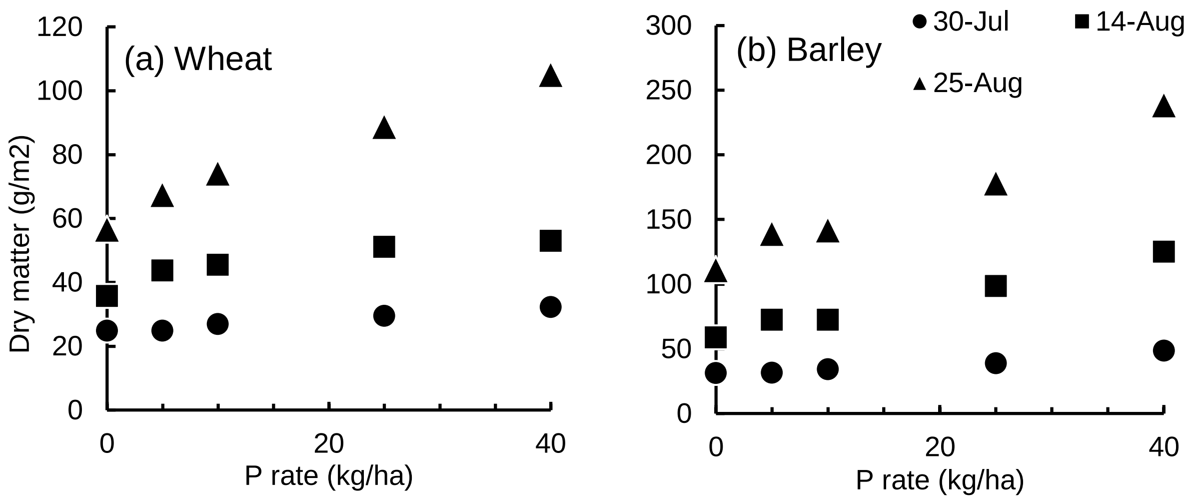

Figure 1. The responses in crop biomass to P of wheat and barley measured at three times during July and August.

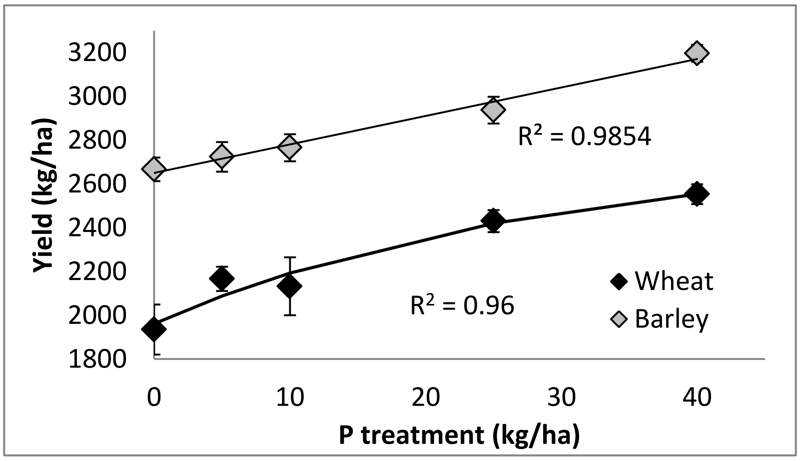

Figure 2. Mean wheat and barley grain yields across all varieties at each rate of P application. P < 0.001 (both wheat and barley), LSD = 202 and 115 kg/ha for wheat and barley respectively. Error bars represent standard error of replicates (18).

Table 2. Mean yields across all P rates for each variety at each field site.

Barley	Grain yield (kg/ha)	Wheat	Grain yield (kg/ha)
Variety		*Variety*	
Barque73	2962	Correll	2386
Commander	2962	Gladius	2294
Fleet	2939	Mace	2341
Galleon	2816	RAC875	2344
Hindmarsh	2853	Scout	1802
Yarra	2617	Wyalkatchem	2296
LSD (P=0.05)	254	LSD (P=0.05)	359
CV%	5	CV%	9

While highly significant grain yield responses to P were obtained the small response to P meant that yields at the low P rates were not significantly greater than the control for a number of the varieties. Significantly, greater yields were only achieved at 25 or 40 kg P/ha. Phosphorus deficiency could therefore be masked if trials on this soil type used rates below 25 kg P/ha and thereby give a false impression that P was not limiting.

There is a danger that current replacement P programs that attempt to match P removed off paddock in grain products are not flexible to varying fixation abilities of different soil types. Phosphorus rates required at Condowie were considerably higher than the replacement P rates required in 2014 based on average grain yields. Using the standard replacement rate of 3 kg P/tonne wheat grain, inputs for 2015 would be approximately 7-9 kg P/ha compared to predicted higher required rates based on outputs from 2014.

Despite required P rates at Condowie being calculated at the highest rate of P used (40 kg P/ha) or greater, the relatively flat linear response meant that the yields obtained in 2014 at these higher P rates (> 25 kg P/ha) were not necessarily the most economical with current grain and fertiliser prices (Table 3).

Table 3. Economic analysis based purely on fertiliser cost and yields obtained. Prices used can be found in the text. Economic optimal P rates for each category are highlighted in bold.

	Fertiliser cost	Returns from yield ($/ha)		Net return ($/ha)	
P treatment (kg/ha)	$/ha	wheat	barley	wheat	barley
0	0	542	720	542	**720**
5	19	607	735	**588**	717
10	38	597	747	560	709
25	94	681	793	**587**	699
40	150	715	863	565	713

The responses in yield to P were directly proportional to the responses in early biomass in both crops (Figure 3). This response appears to be different to N where high rates of N can promote vegetative growth without necessarily increasing yield.

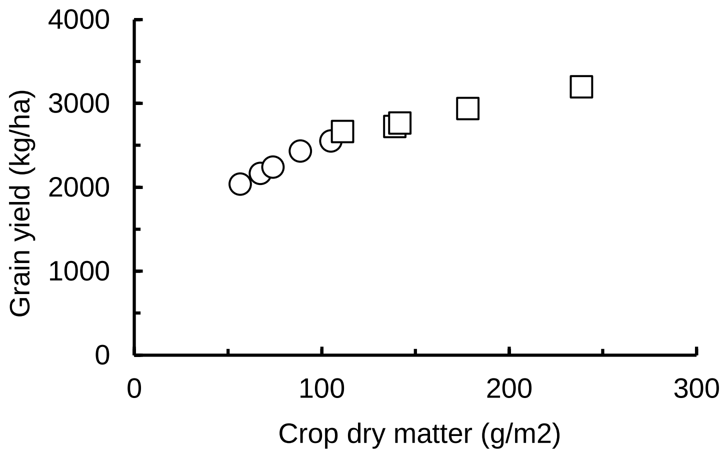

Figure 3. The relationship between crop biomass measured on 25th August and the grain yield of wheat (○) and barley (□).

Any difference in PUE between varieties has been difficult to observe due to natural field trial variability even though greater yield responses were obtained in 2014. Gains in yields through breeding new and improved varieties appear to outweigh any advantage of potentially growing P efficient varieties on P deficient soils. At current prices for fertiliser and grain it would be recommended to achieve maximum yields through sufficient P applications and growing appropriate varieties for the region as opposed to selecting potential high PUE varieties.

Summary / implications

Yield responses to P were associated with promotion of early crop biomass in both wheat and barley. Compared to N, there appears to be less risk of high P rates adversely affecting yields.

Despite large differences in yield among varieties, differences in responses to P have been small. At this stage variety selection should be based on yield rather than any differences in PUE to achieve the greatest return in investment from P.

Phosphorus nutrition levels should be continually monitored especially those on replacement P programs and soil types with moderate to high PBI levels. Unless the relative inefficiency of P applications and the capacity of some soils to fix P have been considered, replacement P inputs on these soil types could be driving down P levels. More efficient replacement P rates could be obtained if they are adjusted in accordance with PBI levels if they vary significantly within a paddock. We encourage the continued use of farmer strip trials (leave a strip of nil P fertiliser) in combination of with Colwell P and DGT results for on farm validation of the soil tests.

For paddocks with moderate to high PBI levels significant information could be obtained by incorporation of a P rich strip (e.g. 40 kg P/ha) next to the standard rate (10 kg p/ha) to ensure P deficiency is not masked by relative low fertiliser efficiency.

Acknowledgements

The experiments were run with the financial support of SAGIT (project code – UA1201). The trial was managed by Rob Wheeler and the expertise of his team is acknowledged.



Seeding at Hart 2014
(above)

Hart Winter Walk 2014
(above, below and left)



2014

Hart Field Day

Early or delayed sowing for improved ryegrass control?

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

Key findings

- The early break to the 2014 season meant soil moisture and rainfall conditions were similar between ToS 1 and 2 and there was little variation in annual ryegrass control among pre-emergent herbicides tested.
- Grain yield and quality were not affected by pre-emergent herbicide however, there was a 1.22 t/ha yield penalty for the later ToS.

Why do the trial?

A ryegrass control trial at Hart in 2008 showed that the best additional management strategy to herbicide application was delaying sowing by 7 days. Delayed sowing reduced ryegrass numbers by 55% for all herbicide treatments. However, this often results in lower crop yield and reduced subsequent crop weed competition.

Since then, the introduction of new residual herbicides has reduced the reliance on post emergent selective grass sprays and provided an improved option for dry sowing. Anecdotal grower evidence would suggest that dry or early sown crops, using adequate rates of residual pre-emergent herbicide provide similar levels of ryegrass control. 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.

How was it done?

Plot size	1.75 m x 10.0 m	**Fertiliser**	DAP (18:20) + 2% Zn @ 80 kg/ha
Seeding date	TOS 1: 4th May 2014		UAN (42:0) @ 95 L/ha on 8th July
	TOS 2: 2nd June		UAN (42:0) @ 100 L/ha on 15th Aug
Crop	Scout wheat @ 80 kg/ha		

To ensure even annual ryegrass establishment across the trial site annual ryegrass seed was broadcast at 25 kg/ha in 2013, prior to seeding. Again prior to seeding in 2014 an additional 5 kg/ha annual ryegrass seed was spread ahead of seeding & tickled in with a shallow pass with the seeder prior to herbicide application. The ryegrass used was previously harvested from commercial paddocks and has medium resistance to trifluralin. A standard knife-point press wheel system was used to sow the trial on 22.5cm (9") row spacings.

The trial was a split block design with one wheat variety, two times of sowing and six pre-emergent herbicides:

1. Nil
2. IBS Boxer Gold 2.5L/ha
3. IBS Sakura 118g/ha
4. IBS Boxer Gold 2.0L/ha + IBS triallate 2.0 L/ha
5. IBS Sakura 118 g + IBS triallate 2.0 L/ha
6. IBS Boxer Gold 2.0 L/ha + PS (crop 2-3 leaf) Boxer Gold 1.5 L/ha

Pre-sowing herbicides were applied within an hour of sowing & incorporated by sowing (IBS). The post-sowing herbicides were applied on the 2nd June (ToS 1) and 7th July (ToS 2) at the 2-3 crop leaf growth stage. Assessment of annual ryegrass plant number per square metre was made for 8th August and head number per square metre on 10th October for both ToS.

Five days prior to seeding ToS 1 the site received 40 mm of rainfall followed by 7.2 mm in the week after sowing (Figure 1). Conditions prior to the second ToS were 16 mm seven days prior and 4.6 mm in the week after sowing. The ToS 2 post herbicide treatment received 20 mm after the application.

Results and discussion

Grain yield was higher for the early ToS by 1.22 t/ha. Protein was 1.2% higher in the later time of sowing which can be attributed to yield dilution effects (lower yield=higher protein). Pre-emergent herbicide treatments did not affect final grain yield or any grain quality parameters.

Table 1. Summary of wheat grain yield, protein, test weight and screening for 4th May and 2nd June time of sowing.

Time of sowing	Grain yield t/ha	Protein %	Test weight kg/hL	Screenings %
4th May	4.15	10.2	81.6	3.0
2nd June	2.93	11.4	81.5	3.0
LSD (P≤0.05)	0.35	0.9	ns	ns

The moist conditions in late April meant a good germination of ryegrass had occurred prior to ToS 1, the knockdown herbicide controlled the initial germination and the plots were sown into good moisture (Figure 1). The early ryegrass control and optimum sowing conditions were not those initially anticipated (ie. dry sowing), however by early August there were still more than 59 ryegrass plants per square metre (Table 2).

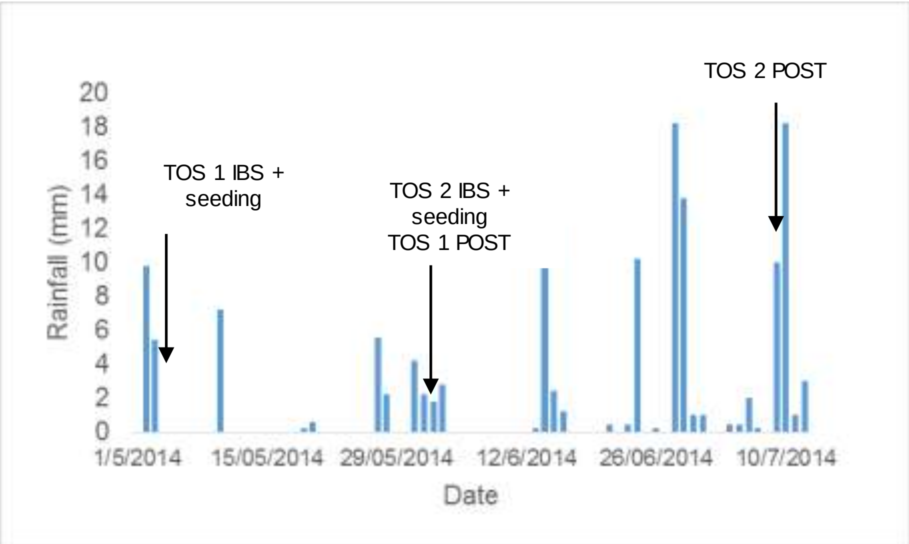

Figure 1. Rainfall from 1st May through 10th July at Hart with seeding and herbicide applications indicated.

The lack of difference in starting soil moisture and rainfall following the herbicide applications meant the pre-emergent herbicides behaved similarly across both ToS (Table 2). Early plant counts showed all pre-emergent herbicides reduced the annual ryegrass number compared to nil for both times of sowing (Table 2). The 2.5 L/ha Boxer Gold was the only treatment to have lower control compared to the other herbicides in ToS 1.

The final head count followed a similar trend to the early plant count. All treatments had reduced the number of heads to less than 25% compared to the nil. Overall, the head numbers were lower for the second ToS, highlighted by the lower head number in the nil.

Table 2. Effect of different pre-emergent herbicides on annual ryegrass plant (plants per square metre) and head density (heads per square metre) at Hart, 2014. Where a mean ryegrass count is appended by a different letter the pre-emergent herbicide had a significant effect (P≤0.05).

	Plant count (Aug 8) plant/m^2		**Head count (Oct 10) heads/m^2**	
Pre-emergent herbicide	*ToS 1*	*ToS 2*	*ToS 1*	*ToS 2*
Nil	59[a]	77[a]	350[a]	164[b]
IBS Boxer Gold	21 (36)[b]	12 (16)[b]	74 (21)[c]	35 (21)[c]
IBS Sakura	8 (13)[c]	8 (10)[b]	39 (11)[c]	41 (25)[c]
IBS Boxer Gold + triallate	6 (10)[c]	12 (16)[b]	20 (6)[c]	36 (22)[c]
IBS Sakura + triallate	3 (5)[c]	3 (4)[b]	32 (9)[c]	9 (6)[c]
IBS Boxer Gold + POST Boxer Gold	8 (13)[c]	6 (8)[b]	71 (20)[c]	14 (8)[c]
LSD Pre-emergent herbicide	10.5	11.7		
LSD Pre-emergent herbicide x ToS	ns		89	

As reflected by the grain yield, the second time of sowing produced a smaller and less competitive wheat crop. In the photos below we can see in the early ToS the ryegrass height is lower and not sitting in the crop canopy. In comparison the second ToS the ryegrass is much taller and sitting higher in the crop canopy as the wheat crop was less competitive.

Photos: Nil herbicide applied to (left) first time of sowing (right) second time of sowing, taken on 17th September. Source: C. Preston.

Summary/Implications

In year one of this research the strategy of early sowing in combination with residual pre-emergent herbicides has shown to have potential. Some caution needs to be used when interpreting the results as the conditions at both ToS were very good and so the situation of early 'dry' sowing was not simulated in 2014.

The results in 2014 suggest a strategy of delayed seeding into paddocks with higher weed numbers may not be the complete answer. Sowing early has a number of advantages:

- Early and vigorous crop growth in warm soil.
- Pre-emergent herbicides washed around the ryegrass seeds at germination, providing the best situation for control.
- Growing a high biomass and competitive crop to shade and out compete any weeds.
- Producing higher grain yields in paddocks normally limited by weed numbers or later ToS.
- An earlier maturing crop may be more suitable for crop topping.

There are certainly some possible disadvantages of sowing early (or dry) that also need to be taken into consideration:

- An early break and germination to the season, reducing the efficacy of pre-emergent herbicides.
- Increased herbicide damage from lack of tilth, shallow seeding or a cloddy paddock.
- A dry period following crop emergence could reduce the efficacy of some pre-emergent herbicides which rely on moisture to work well (i.e Boxer Gold and Sakura).

Future results will depend on a number of scenarios:

- Dry sowing, followed by wet conditions – is likely to provide the best results.
- Early season break and germination followed by dry conditions – may provide good results if the crop can emerge, but not the ryegrass. However, these conditions are less suited to herbicides like Sakura.
- Early season break and germination followed by moist conditions – the least likely to provide good results.

Acknowledgements

The financial assistance of GRDC to undertake this research is gratefully acknowledged.

Weed competition – determining best management practices in durum wheat

Simon Goss and Rob Wheeler, New Variety Agronomy, SARDI, Waite Campus

Key findings

- DBA Aurora and Mace showed similar ability to compete with weeds in 2014.
- Using higher seeding rates improved weed control.
- Increased crop seeding rate resulted in reduced crop screenings in 2014.

Why do the trial?

With limited safe and effective pre-emergent herbicides currently available for use in durum wheat, other techniques of improving weed control is becoming increasingly important. Durum wheat is typically less competitive with weeds than other crops such as wheat and barley. There are several agronomic techniques which can be used to increase durum's competitiveness and some of the techniques which are in the trial include seeding rate, seed bed utilisation, variety selection and row spacing.

The aim of this trial is to identify the most effective alternate techniques and discover the impacts they have on weed control, yield and grain quality.

How was it done?

Plot size	5.0 m x 1.75 m	**Fertiliser**	DAP (18:20) + 2% Zn @ 70 kg/ha
Seeding date	28th May 2014		UAN (42:0) @ 95 L/ha on 15th August

Annual rye grass was spread of the trail area at a rate of 10 kg/ha and gently tickled in prior to seeding. Selected plots were also treated with a pre-emergent herbicide, to create plots which were under varying weed pressure. The pre-emergent herbicide used was IBS trifluralin (1.2 L/ha) + triallate (1.2 L/ha) applied 28th May 2014.

Several different treatments (Table 1) were applied to test the effects on weed populations, grain yield and quality.

Table 1. Management treatment combinations of seeding rate, sowing boot and additional management used to compete with ryegrass at Hart 2014.

Variety	Seed rate (seeds/m^2)	Sowing Boot	Management change (relative to standard practice)
Mace wheat and DBA-Aurora	200	Standard	Standard (traditional practice)
	100	Standard	Lower seed rates
	300	Standard	Higher seed rates
	100	Spreader boot	Lower seed rates + increased seed bed utilisation
	200	Spreader boot	Increased seed bed utilisation
	300	Spreader boot	Higher seed rates + increased seed bed utilisation
	200	Standard	Narrow row spacing (11.5 cm)

Results and Discussion

For both DBA-Aurora and Mace the use of higher seeding rate gave the best annual ryegrass control in 2014 (Table 2). There was no benefit of using a spreader boot over a normal boot, in contrast to 2013 when the use of a spreader boot decreased annual ryegrass numbers. The medium and low seeding rates progressively increased annual ryegrass head number.

Both DBA-Aurora and Mace were similar in their ability to compete with annual ryegrass. This highlights the improved ability of DBA-Aurora compared to Tjilkuri which was less competitive compared to Mace in 2013.

The addition of pre-emergent herbicide gave very good ryegrass control (data not shown), as also seen in 2013 and the addition of other management strategies was unable to improve the control further.

Mace wheat resulted in lower yield losses (on average 8.2%) compared to DBA-Aurora (11.3%) when under high weed pressure (Table 2). The lowest yielding treatments were those sown with 100 seeds/m^2.

Table 2. The effect of seed rate and normal or spreader seeding boots on grain yield (t/ha) and grass seed set (heads/m2) for DBA-Aurora durum wheat and Mace wheat at Hart, 2014. (Yield loss percentage is the difference between plots with high weed pressure compared to no weed pressure).

Variety	Seeding boot	Seeding Rate	Ryegrass heads/m²	Yield t/ha	Yield loss %
DBA Aurora	Normal Boot	100	138	2.29	9.2
DBA Aurora		200	90	2.44	12.2
DBA Aurora		300	29	2.95	8.2
Mace		100	100	3.02	9.6
Mace		200	79	3.52	11.5
Mace		300	52	3.75	3.9
DBA Aurora	Spreader Boot	100	104	2.41	18.3
DBA Aurora		200	67	2.75	10.8
DBA Aurora		300	54	3.02	9.2
Mace		100	138	3.19	8.3
Mace		200	90	3.75	8.7
Mace		300	29	3.83	7.4
	LSD (P≤0.05)		*ns*	*0.27*	*2.6*

In Mace wheat and DBA-Aurora durum, increasing the seeding rate reduced rye grass head set and decreases screening percentage (Figure 1).

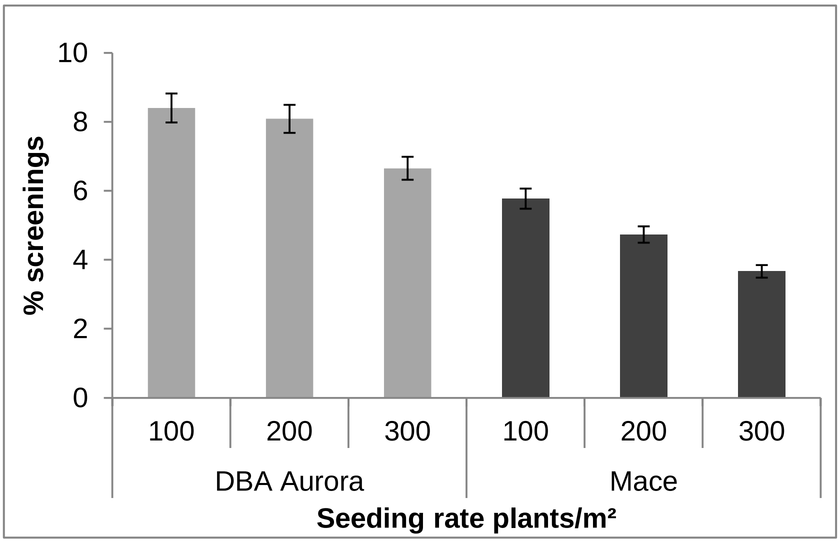

Figure 1. Effect of seeding rate and crop variety on screenings percentage (%<2.0 mm) when grown in the presence of annual rye grass.

Implications

The results show that increasing wheat seeding rates can reduce the suppression of grain yield resulting from high weed pressure. The trial also found that having a high seeding rate not only restricts annual ryegrass growth, but can also decrease the amount of screenings.

As many growers may have been turned away from durum due to its poor competitiveness, results show very similar levels of competition between Mace and DBA-Aurora in 2014. This should give confidence to growers re-entering the market in 2015, knowing there is a durum wheat variety that has improved competitive ability.

Canola tolerance to clethodim

Michael Zerner, The University of Adelaide

Key findings

- Grain yield losses of up to 40% can be caused by clethodim at particular rates and timings.
- Early application timings were the best to avoid crop damage.
- Variation does exist between herbicide tolerant crop types (Conventional, Clearfield and TT) and their level of sensitivity to clethodim.

Why do the trial?

Given the widespread importance of clethodim use in crop rotations and increased application rates to combat herbicide resistant annual ryegrass, a field trial at Hart was established to identify the level of crop tolerance to clethodim rates in canola. The level of yield losses that may occur from the use of high clethodim rates is relatively unknown. Observed crop damage symptoms include, delayed flowering, distorted flower buds and possible grain yield suppression. Symptoms appear to be more severe from later application timings. Other factors that may influence crop effects include herbicide rate, crop stress at herbicide application and possible varietal differences in tolerance. The purpose of this trial was to investigate the level of damage that may occur from clethodim applications and what factors might influence the degree of damage, over two seasons.

How was it done?

Plot size	1.75 m x 10 m	**Fertiliser**	DAP (18:20) 2% Zn @ 100 kg/ha
Seeding date	4th May 2014		UAN (42:0) @ 110 L/ha on 13th June
			UAN (42:0) @ 95 L/ha on 7th July

Table 1. Clethodim treatments applied at Hart during 2014.

CLETHODIM TREATMENTS
1. Untreated control
2. 0.5 L/ha applied at 4-leaf growth stage
3. 1 L/ha applied at 4-leaf growth stage
4. 0.5 L/ha applied at 8-leaf growth stage
5. 1 L/ha applied at 8-leaf growth stage
6. 0.25 L/ha applied at 4-leaf and 8-leaf growth stages (0.5 L/ha in total)
7. 0.5 L/ha applied at 4-leaf and 8-leaf growth stages (1 L/ha in total)
8. 0.5 L/ha applied at bud initiation (ie. first visible green buds)
9. 1 L/ha applied at bud initiation

Application of clethodim at 1 L/ha is not a registered rate and was undertaken for experimental purposes.

The trial was established as a split-plot design with three replicates. Three canola varieties were used; AV Garnet (conventional), ATR Gem (triazine tolerant) and Hyola 474 CL (Clearfield) to investigate the influence of clethodim rate and timing. Nine clethodim treatments were applied to each variety (Table 1). This trial was aimed at investigating the impact of clethodim on crop safety rather than weed control.

Spray treatments for each growth stage were applied on the same day for each variety. As a result the exact growth stage at the time of application for each variety may have differed slightly, despite all varieties used in this trial being of very similar maturity. Following each spray application NDVI readings using a Greenseeker and visual damage scores were recorded.

Results and discussion

This was the second year this trial has been run at Hart. The 2014 trial showed similar results across clethodim treatments that were observed in 2013 however, crop damage was less severe during 2014.

A range of damage symptoms were observed and consistent across both seasons. The first of which was a slight change in the colour of the crop canopy. The more damaged or sensitive plots become paler green in colour as compared to the untreated control plots. There were no visual changes in overall crop biomass or any significant change in NDVI between treatments in this particular trial. As the crop further developed to reach flowering the damage symptoms become more pronounced. The flower buds become distorted and failed to open up fully leading to poor pod development (Figure 1), which resulted in reduced grain yields. The grain yield losses were strongly correlated to the severity of the observed visual symptoms.

Figure 1. Canola displaying damage symptoms caused by clethodim (left) compared to healthy unaffected canola (right).

Of the varieties tested the conventional type variety AV Garnet appeared to show a greater level of tolerance to clethodim compared to the other varieties across both seasons. Both ATR Gem (TT) and Hyola 474CL were very similar in their response to clethodim, both incurring almost 40% yield losses in the most damaging clethodim treatment in both years (Table 2). In the same treatment AV Garnet only suffered an 8-10% yield reduction.

The latest application time caused the most visual crop damage resulting in the largest grain yield losses (Table 2). Applications of 0.5 L/ha within current label recommendations of up until flower buds become visible appear relatively safe in this trial across both seasons. All treatments sprayed with a single label rate application of 0.5 L/ha up to the 8-leaf growth stage were not significantly different from the unsprayed control for any variety. Early sprays (4-leaf growth stage) at 1.0 L/ha had no significant implications on grain yield for any variety over the two years of this trial (Table 2). Yield reductions were also not observed at the 1 L/ha rate when applied at 8-leaf growth stage during 2014. However, past results would suggest the risk of yield reductions is high with significant yield losses of up to 13% in ATR Gem and Hyola 474CL during 2013. The split application appeared to improve the safety of the 1.0 L/ha treatment when it was applied over two applications rather than in one application at the later 8-leaf timing during 2013. This wasn't observed in the 2014 trial as the single 8-leaf application did not cause any significant yield reduction.

Table 2. Effect of clethodim applied at different timings and rates on the grain yield of canola at Hart during 2013 and 2014. Highlighted values indicate significantly less than untreated ($p \leq 0.05$).

Application timing	**Clethodim rate**	**ATR Gem**		**AV Garnet**		**Hyola 474CL**	
		2013	*2014*	*2013*	*2014*	*2013*	*2014*
Untreated		1.11 t/ha	1.65 t/ha	1.37 t/ha	2.11 t/ha	1.69 t/ha	2.06 t/ha
		-------------------------grain yield % of control-----------------------					
4 leaf	0.5L/ha	98	95	99	101	100	101
	1L/ha	94	99	106	100	96	98
8 leaf	0.5L/ha	99	102	104	95	96	97
	1L/ha	87	101	106	97	87	99
4 leaf and	0.25L/ha + 0.25L/ha	91	103	102	98	92	104
8 leaf split	0.5L/ha + 0.5L/ha	95	103	103	98	91	102
Bud initiation	0.5L/ha	80	95	97	96	87	93
	1L/ha	61	66	90	92	61	60

The latest timing treatment used in this study at bud initiation which is outside current label recommendations was found to be highly damaging causing significant yield reductions in all varieties across both seasons (Table 2). Depending on the variety, grain yields could be reduced by as much as 20% at 0.5 L/ha and up to 40% at 1 L/ha.

Implications

Increased application rates of clethodim have created concern due to crop damage in canola, which is the most sensitive crop of those registered for clethodim use. Two seasons of trials at Hart has shown late timings (bud initiation) of clethodim can result in severe yield losses. Care should be taken to apply clethodim at correct growth stages and application rates. Applications exceeding 0.5 L/ha are at high risk of causing yield reductions in most canola varieties. From the trial results it is evident that the early application at 4-leaf growth stage of canola was the safest on the crop but this may not be always the best time of application for targeting weed control. For example, a large proportion of the weed population may germinate later, requiring additional follow up sprays or delaying initial spray applications. Or higher rates might be required to achieve acceptable control of weed populations developing resistance. This may require a compromise in rates and timings for best control weeds while minimising the risk of crop damage.

Acknowledgements

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Legume and oilseed herbicide tolerance

Sarah Noack and Peter Hooper, Hart Field-Site Group

Key findings

- In the post emergent treatments a range of herbicides produced very good control of all oilseed and legume crops included.
- Lucerne was significantly damaged by almost all herbicides applied.

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 @ 75 kg/ha
Seeding date	15th May 2014		

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

The timings were:

Incorporated by sowing (IBS)	15th May
Post seeding pre-emergent (PSPE)	20th May
Early post emergent (3-4 node)	16th June
Post emergent (5-6 node)	2nd July
Late post emergent (8 node)	22nd July

Treatments were visually assessed and scored for herbicide effects 4 and 6 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.

Majority of the incorporated by sowing (IBS) or IBS + post sowing pre-emergent (PSPE) herbicide applications in 2014 had no effect on crop growth compared to the nil. Sakura produced a slight effect to TT canola, chickpeas, balansa clover and Angel medic. The addition of simazine did not increase crop damage in these species, but did produce slight effects in both lentil varieties and the lucerne.

Applications of propyzamide (0.75 L/ha – 1.5 L/ha) as IBS or IBS + PSPE was recorded to give no damage symptoms for all crop varieties except, Frontier clover and Gem canola (Table 1). These results are similar to 2013 and 2012 for propyzamide applied IBS and 2011 applied as PSPE. The incidence of crop damage from propyzamide however, was increased when applied all PSPE particularly at the 1.5 L/ha rate.

In 2013 Broadstrike was one of the safest herbicides at the 3rd node stage, but in 2014 produced severe effects to both vetch varieties and all of the pasture varieties. Metribuzin was again very damaging at this stage, with Gunyah peas being the only exception.

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 2014, but this result would not normally be expected. Adding Metribuzin to carfentrazone did not generally improve the control of volunteer legumes, apart from Hurricane lentils and Frontier balansa clover.

Lucerne was a new crop addition in the 2014 trial and showed good crop safety to propyzamide. However, all other herbicides produced significant effects. This was unexpected, especially for Broadstrike, Spinnaker and Raptor, and so will be repeated in 2015.

Table 1. Crop damage ratings for legume and oilseed herbicide tolerance trial at Hart 2014.

Crop damage ratings:
1= no effect, 2 = slight effect, 3 = moderate effect,
4 = increasing effect, 5 = severe effect and 6 = death

				Canola			Bean	Pea	C/pea	Vetch		Lentil		Pasture		
				44Y84	Gem	Garnet	Farah	Gunya	Genesis 090	Capello	Rasina	Hurricane	Flash	Lucerne	Frontier	Angel
Number	Timing	Treatment	**Rate kg/ha**	5	5	5	140	100	80	45	45	45	55	15	15	10
1	**IBS 15/05/2014**	NIL		1	1	1	1	1	1	1	1	1	1	1	1	1
2		Propyzamide (500 g/kg)	0.75 L	1	1	1	1	1	1	1	1	1	1	1	1	1
3		Propyzamide (500 g/kg)	1.0 L	1	2	1	1	1	1	1	1	1	1	1	2	1
4		Propyzamide (500 g/kg)	1.5 L	1	2	1	1	1	2	1	1	1	1	1	3	1
5		Sakura	118g	1	2	1	1	1	2	1	1	1	1	1	4	2
6		Sakura + Simazine	118g/550g	1	1	1	1	1	2	1	1	2	2	2	4	3
7		Terrain	120 g/ha	1	2	2	1	1	2	1	1	1	1	2	2	2
8	**IBS + PSPE**	Propyzamide (500 g/kg)	0.5 L/0.5 L	1	1	1	1	1	1	1	1	1	1	1	1	1
9		Propyzamide (500 g/kg)	0.75 L/0.75 L	1	2	2	1	1	1	1	1	1	1	1	1	1
10	**PSPE 20/05/2014**	Propyzamide (500 g/kg)	0.75 L	1	1	1	1	1	1	1	1	1	1	1	1	1
11		Propyzamide (500 g/kg)	1.0 L	2	2	1	1	1	1	1	1	1	1	1	1	1
12		Propyzamide (500 g/kg)	1.5 L	1	3	2	1	1	2	1	1	2	2	1	2	2
13		Diuron	1275 g	6	6	5	2	2	2	1	2	1	2	6	6	4
14		Simazine	850 g	2	1	3	1	2	1	1	1	1	1	3	6	3
15		Simazine	1275 g	5	2	5	1	2	2	1	1	2	2	5	6	4
16		Diuron + Simazine	410 g /410 g	4	4	4	1	2	2	1	1	2	1	4	5	3
17		Metribuzin	280 g	4	3	5	1	2	1	1	1	1	1	1	6	1
18		Metribuzin	420 g	6	3	6	2	3	2	3	1	2	1	5	6	5
19		Terbyne (750 g/kg)	1000 g	4	2	6	2	2	1	1	1	3	2	6	6	5
20		Terbyne (750 g/kg)	1500 g	5	2	6	2	3	3	1	3	3	2	6	6	5
21		Spinnaker	100g	1	6	6	2	2	4	4	4	1	5	4	4	1
22		Spinnaker + Simazine	40 g/850 g	3	6	6	2	1	2	1	1	1	3	5	5	3
23		Balance	100 g	5	6	6	5	5	1	5	5	5	5	6	6	6
24		Balance + Simazine	100 g /830 g	6	6	6	5	5	2	5	5	5	5	6	6	6
25	**3-4 Node 16/06/2014**	NIL		1	1	1	1	1	1	1	1	1	1	1	1	1
26		Simazine	850 g	1	2	1	1	1	1	1	1	1	1	4	5	4
27		Metribuzin	280 g	6	2	6	5	2	5	5	4	3	3	5	6	6
28		Broadstrike	25 g	1	5	5	4	1	1	5	5	1	1	3	3	2
29		Brodal Options	150 mL	3	4	3	3	3	4	4	4	2	2	4	5	4
30		Brodal Options + MCPA Amine	150 mL/150 mL	5	5	4	5	4	5	5	5	4	4	4	4	4
31		Spinnaker + wetter	70 g/0.2%	1	6	6	2	2	4	3	3	1	5	4	4	1
32		Raptor + wetter	45 g/0.2%	1	6	6	2	1	4	3	4	1	5	4	3	1
33	**5-6 Node 02/07/2014**	NIL		1	1	1	1	1	1	1	1	1	1	1	1	1
34		Logran + wetter	10 g/0.1%	2	5	5	5	5	5	5	5	3	5	4	3	5
35		Ally + wetter	7 g/0.1%	2	5	5	5	5	5	6	5	3	5	5	5	5
36		Eclipse SC + wetter	50 mL/0.5%	2	5	5	5	5	5	5	5	3	5	5	5	5
37		Ecopar + MCPA Amine	400 mL/500 mL	5	5	5	5	3	4	4	5	4	4	4	6	5
38		Carfentrazone + MCPA Amine	100 mL/500 mL	6	6	6	5	5	6	5	5	4	5	5	5	5
39		Carfentrazone + Metribuzin + MCPA Amine	100 mL/150 g/500 mL	6	6	6	5	5	6	5	5	5	5	5	6	5
40		Conclude + Uptake	700 mL/0.5%	5	6	6	5	5	5	5	5	5	5	5	6	5
41		Paradigm + MCPA LV600 + Uptake	25 g/420 mL	5	6	5	5	5	6	6	6	5	5	6	6	6
42		Precept + Hasten	750 mL/1%	5	6	5	4	5	5	4	5	5	5	5	4	5
43		Velocity + Hasten	670 mL/1%	6	6	6	5	6	4	5	5	5	5	5	4	6
44		Flight EC	720 mL	5	5	5	4	4	5	5	5	4	4	5	4	5
45		Triathlon	1000 mL	5	5	5	5	5	6	5	5	5	5	5	3	4
46		Banvel M	1000 mL	5	5	5	5	5	5	5	5	4	4	5	4	5
47		Intervix + Hasten	600 mL/1%	1	6	6	4	4	4	5	5	1	4	5	5	2
48		Hussar OD + wetter	100 mL/0.25%	1	6	6	5	5	5	6	5	4	5	5	5	5
49		Crusader + wetter	500 mL/0.25%	1	6	5	5	5	5	5	5	3	4	5	5	3
50		Atlantis OD + Hasten	330 mL/0.5%	1	6	5	4	5	4	5	5	2	4	5	5	5
51		Atrazine + Hasten	833 g/1%	5	1	5	4	5	5	4	4	5	5	5	6	6
52		Lontrel 600	150 mL	1	1	1	5	5	5	5	5	5	5	4	5	3
53		Starane	300 mL	1	1	1	4	4	4	5	5	4	4	2	5	2
54	**8 Node 22/7/2014**	MCPA Sodium (250 g/L)	700 mL	3	3	3	4	3	3	4	4	3	3	3	3	1
55		MCPA Amine (750 g/L)	350 mL	4	4	4	4	2	3	4	3	3	3	3	2	2
56		Amicide Advance 700	1200 mL	4	4	4	4	4	4	4	4	3	3	3	3	2
57		2,4-D Ester (680 g/L)	70 mL	2	2	2	3	3	3	3	3	3	3	3	3	2

Managing clethodim-resistant ryegrass without oaten hay

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Background

An increasing number of paddocks in the Mid-North of South Australia contain clethodim (i.e Select) resistant annual ryegrass. Managing herbicide resistant ryegrass can come at a great expense.

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, there are a number of crop rotation options available to best suit individual growers in terms of success and profitability. In addition to crop selection, different herbicide strategies can be used to provide successful ryegrass control.

Aim: To conduct a multi-year trial to determine the effects of crop rotation and low, medium and high level herbicide management options to reduce clethodim resistant ryegrass without using hay.

Materials & methods

In year 1 of the study (2013) ryegrass seed with low-medium level resistance to clethodim and Factor® (ai butroxydim) was hand broadcast and lightly incorporated across the site for the purpose of establishing a seedbank. Resistance screening of the Hart population against a known susceptible population (SLR4) confirmed resistance to both clethodim and Factor (Table 2 and Figure 1).

Soil core samples (10 cm diam.) were taken across the trial site in April of last year (2014) to determine the size of ryegrass seedbank established. Soil samples were transferred to shallow trays and germinating ryegrass assessed at regular intervals. Seedbank was determined based on the total number of ryegrass seedlings to germinate, and the total area sampled (i.e. core area (πr^2) x number of cores sampled (n=120)) and converted to a unit area (i.e. seeds/m^2). The starting seedbank was determined to be ~1650 ryegrass seeds/m^2 (±153).

The first cropping phase of two 3-yr rotations (pea/wheat/barley and canola/wheat/barley) of field peas and canola was established in 2014. These breakcrop phases will subsequently be followed by wheat and barley in 2015 and 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 (Table 1). Herbicide strategies of low (HS1), medium (HS2) and high (HS3) input included:

Herbicides for Kaspa field peas:

1. Trifluralin (1.6 L/ha) + clethodim (700 mL/ha)
2. Triallate (2.0 L/ha) + propyzamide (1.0 L/ha) + trifluralin (1.6 L/ha) + clethodim (0.7 L/ha) + CT (paraquat)
3. Triallate + propyzamide + trifluralin + clethodim(2×) + Factor (180 g/ha) + CT

Herbicides for ATR-Stingray canola:

1. Trifluralin (1.6 L/ha) + clethodim (500 mL/ha)
2. Triallate (2.0 L/ha) + propyzamide (1.0 L/ha)
3. Propyzamide + clethodim + CT (glyphosate)

The trial design is a split-plot; with crop rotation assigned to main-plots and herbicide strategies to sub-plots with 3 replicates. Pre-emergent herbicides were applied within a few hours of being incorporated by sowing (IBS), while post-emergent (POST) clethodim and Factor were applied when most ryegrass had reached 3-4 leaf growth stage (Table 1). Crop-topping (CT) with paraquat and glyphosate were undertaken as per herbicide label directions. Assessments included ryegrass control (reduction in plant density, seed set and seedbank), crop yield and grain quality.

Table 1. Crop management and herbicide application details for the study site.

Seeding date	Crop/Cultivar	Seeding rate (*kg/ha*)	IBS and POST application date and weed/crop growth stage
15th May	Field pea/ Kaspa	100	15th May (IBS)
	Canola/ ATR-Stingray	5	21st July (POST1) Tillering/12 node & 7-leaf 23rd October (POST2) Milky to hard-dough/30 & 20% seed colour change

Results and discussion – year 1

The rate of clethodim to cause 50% reduction in survival (LD_{50}) and biomass (GR_{50}) was more than 10 and 6-fold higher for resistant Hart population when compared to the susceptible control (SLR4; Table 2). However, the same population showed much weaker resistance to Factor and was only 1.7 to 1.6-fold more resistant compared to susceptible SLR4 population. The genetic basis for resistance in this population is unknown; however resistance is likely due to one or more target site mutations in the ACCase domain, also see Figure 1.

Table 2. The rate of clethodim and butroxydim required for 50% mortality (LD_{50}) and for 50% biomass reduction (GR_{50}) of resistant (Hart) and susceptible (SLR4) ryegrass. Confidence intervals (95%) are shown in parenthesis. R/S is the ratio of LD_{50} and GR_{50} of resistant and susceptible biotypes.

Herbicide	Biotype	LD_{50} (*g ai/ha*)		R/S	GR_{50} (*g ai/ha*)		R/S
Clethodim	Hart	40.3	(23.9,68.1)	10.1	22.9	(11.7, 44.8)	6.0
	SLR4	4.0	(2.6, 6.4)	-	3.8	(2.9, 5.1)	-
Butroxydim	Hart	7.6	(4.8, 12.1)	1.7	5.9	(3.9, 9.1)	1.6
	SLR4	4.4	(3.4, 5.7)	-	3.6	(2.6, 4.9)	-

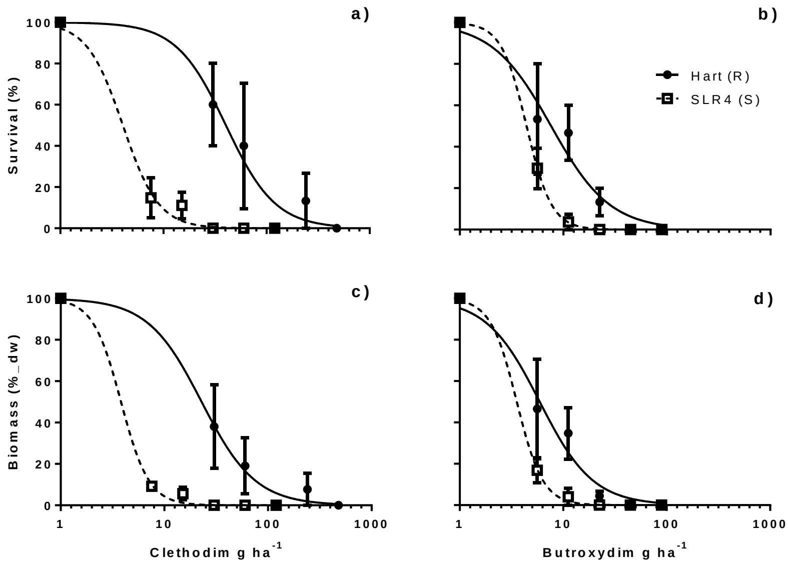

Figure 1. (a, b) Survival and (c, d) biomass (% of nontreated control) of resistant (●, Hart) and susceptible (□, SLR4) ryegrass biotypes to clethodim and butroxydim. Herbicide rates were 0, ½, 1, 2, 4 & 8× field rate of clethodim (250 mL/ha of Select) and 0, ¼, ½, 1, 2 and 4× field rate of butroxydim (180 g/ha of Factor). LD_{50} and GR_{50} values are presented in Table 2.

In both field peas and canola pre-emergent triallate and propyzamide (HS2 & 3) were very effective on ryegrass (Table 3). Excellent post-sowing rainfall appeared to assist the activity of propyzamide extending its residual activity beyond 6 weeks after sowing (WAS). Propyzamide has proven to be a reliable option for ryegrass provided the seedbed is moist and sufficient rain is received after sowing.

Table 3. Impact of cropping phase and herbicide strategy (1, 2 & 3) on grain yield of field peas and canola and reduction in Group A resistant ryegrass at Hart in 2014. The initial ryegrass seedbank was ~1650 ryegrass seeds/m^2.

Crop phase (rotation)	Herbicide strategy	Ryegrass density (plants/m^2)			Ryegrass (heads/m^2)	Grain yield
	(HS)	6 WAS	12 WAS	17 WAS		(t/ha)
Field peas (P/W/B)	1	48	24	5	17	2.18
	2	3	3	0	0	2.24
	3	1	2	0	0	2.11
LSD (P=0.05)		15.5	7.2	2.7	13.2	ns
Canola (C/W/B)	1	55	58	13	34	1.37
	2	24	23	6	23	1.41
	3	12	19	6	23	1.47
LSD (P=0.05)		19.9	20.5	5.1	ns	ns

ns, not significant.

In contrast, ryegrass control in both crops with trifluralin was relatively poor in HS1 with more ryegrass (~50 plants/m^2) requiring follow up control with clethodim. Although the population was not tested, resistance to trifluralin cannot be ruled out as the cause of lower control.

In field peas, above full label rate of clethodim (i.e. 700 mL/ha) in HS1 provided some initial control of ryegrass (50% control at 12 WAS), whereas the lower 500 mL/ha rate used in canola (HS1) provided no control.

Often agronomists and growers comment on improved control of otherwise ACCase-resistant (fop & dim herbicides) ryegrass with high rates of clethodim (>500 mL/ha) in pulses. Previous research from WA (Yu et al. 2007) showed that some clethodim-resistant populations were rate responsive, where increasing the herbicide rate could improve control. However, the research also showed that the response was not always the same between different populations resistant to clethodim and was dependent on several other factors including the mutation(s) endowing resistance and how they were being expressed by the plant. Whilst the exact mechanism (most likely one or more target site mutations) conferring resistance in this population is yet to be determined, it appears to endow low-level resistance at least to the current label rate of clethodim (500 mL/ha).

In the context of cropping phase resistant ryegrass was more prevalent in canola than field peas because of lower initial control from pre-emergent herbicides (Table 3). Of more concern was that under both cropping phases these resistant survivors were able to set viable seed in HS1, where no effective follow up seed set control was undertaken. Whilst some ryegrass was present late in the growing season in HS2 and 3, this ryegrass was either treated with crop-top of paraquat in field peas or over-the-top glyphosate in canola (HS3). Late seed set control tactics (i.e. crop-topping, chaff catching) can play an essential role in preventing resistance multiplication in the field and should be applied at all costs if resistance is suspected.

Although there were clear differences in ryegrass control between herbicide strategies, this had little effect on the grain yield of either canola or field peas (not significant; Table 3). This is not entirely surprising given ryegrass in its own right is a relatively weak competitor, with significant yield loss normally only seen when the weed is present at high infestations (>100 plants/m^2). Given the overall effectiveness of the pre-emergent herbicides to limit the size of the population initially (<50 plants/m^2), the competitive influence of ryegrass would have been negligible.

Conclusion

The 1st year of 3 year field study has been initiated at Hart with the aim of implementing alternate crop and herbicide strategies, other than hay, for effective long-term management of clethodim-resistant ryegrass. Whilst most of the herbicide strategies in field peas and canola were effective against ryegrass, resistant-survivors still were present late in the season. The seed set contribution of these individuals to the seedbank will not be fully realised until seedbank sampling is again undertaken in April of this year. However, it is hoped that were late seed set control tactics were used (HS2 and 3), fewer seeds and greater seedbank depletion has been achieved.

Acknowledgements

The financial assistance of GRDC and the collaboration of Hart Field-Site Group staff are gratefully acknowledged. We also wish to thank Stuart Sherriff (SARDI) and Malinee Thongmee (University of Adelaide) for providing technical assistance.

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Harvest weed seed control - narrow windrow burning

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

Key findings

- Narrow windrow burning canola can be an effective tactic against ryegrass provided weed seeds can be captured and concentrated at swathing & harvest.
- Of the ryegrass seed captured between 93-99% was controlled by burning narrow windrow canola.

Why do the trial?

The widespread evolution of multiple herbicide resistance in Australian cropping has forced the development of alternative, non-chemical weed control strategies, especially new techniques at grain harvest. Harvest weed seed control systems target weed seed during commercial grain harvest operations and act to minimise fresh seed inputs to the seed-bank. Harvest weed seed systems, include chaff carts, baling, Harrington seed destructor and narrow windrow burning.

Weed seed kill levels of 99% for both annual ryegrass and wild radish have been recorded from the narrow windrow burning of wheat, canola, and lupin chaff and straw residues (Walsh and Newman 2007). The simplicity and low cost of this narrow-windrow system has resulted in its adoption by an estimated 70% of crop producers in the major grain production state of Western Australia. In South Australia the adoption of this practice is not as high as there have been a limited number of trials able to show the reduction in weed seed number.

The aim of this study was to understand how effective narrow windrow burning is capturing annual ryegrass seeds (comparison of between row and inter-row measurements). Also to determine the reduction in ryegrass as a result of burning (comparison of burnt and unburnt sections of the row).

How was it done?

Three growers in the Mid-North who were planning to narrow windrow burn canola provided field sites for this study. Prior to narrow windrows being burnt in early 2014, an assessment of canola stubble/cutting height (cm) and biomass (t/ha) in the narrow windrow were assessed (Table 1). A 5 m section of chaff was removed in five rows to represent a non-burnt area.

After the narrow windrows were burnt, 10 soil samples (7 cm diameter core x depth 10 cm) were taken from five replicates per paddock in the following three locations:

1) Burnt section of windrow
2) Sample within 3 m on the non-burnt section
3) Inter-row

These 10 soil samples were combined to make one bulk sample per treatment. The soil samples were then transferred to shallow trays and germinating ryegrass assessed at regular intervals. Census of ryegrass was ceased when no new seedlings emerged over a 3-week period. Ryegrass seed number was determined from the total number of ryegrass seedlings to germinate, and the total area sampled (i.e. core area (πr^2) × number of cores sampled (n=10)) and converted to a unit area (i.e. seeds/m^2).

Table 1. Cutting height and stubble biomass of canola from 3 field sites across Mid-North of SA.

Field site	Stubble/cutting height (cm)	Stubble biomass (t/ha)
1	42.8	2.8
2	31.6	2.4
3	34.0	2.6

Photos: Field site one (left) measuring 5 m of canola narrow windrow to be removed prior to burning (right) inter-row area with canola and annual ryegrass stems remaining.

Photo: Burning narrow windrows 2014.

Results and discussion

The effectiveness of narrow windrow burning of canola is governed by the amount of weed seed captured and accumulated in the windrow by the swathing and harvest operation. Whilst ryegrass shows less of a tendency to shed seed relative to other grasses (i.e. wild oats, brome grass), it can be prone to lodging reducing the amount of seed collected. Furthermore, there has been some suggestion that ryegrass is more prone to lodging in canola than other crops because of a reduction in stem strength resulting from increased crop shading.

The effectiveness of seed capture and accumulation under narrow windrows was apparent at 2 of the 3 study sites, where up to 13-fold more ryegrass seed was found in the narrow windrow in comparison to the adjacent swath area (Table 2). The exception was site 1, where seed accumulation was only 2-fold higher in the narrow windrow. At this site the cutting height of canola was 10 cm higher (42.8 cm) than at sites 2 (31.6 cm) and 3 (34 cm), and much of the ryegrass had lodged according to the grower. This would have reduced the effectiveness of both the swathing and harvest operations to capture and concentrate seeds in the windrow. To improve seed capture some consideration must therefore be given to both the growth habit of ryegrass and subsequent swathing height.

Often cutting height of canola varies with the height and biomass of the crop at maturity and subsequently the cultivar grown. Not surprisingly hybrid-cultivars, which have tendency to grow taller, are usually swathed higher than their shorter TT-relatives. Consequently ryegrass is less likely to be captured under taller hybrids than TT-cultivars unless swathing height is adjusted accordingly.

Table 2. Effect of swathing and harvest on ryegrass (seeds m^{-2}) accumulation in narrow windrows at 3 field sites across the Mid-North of SA. Values in parenthesis represent SE (±) around the mean of five replicates.

Site	Narrow windrow	*Between windrow	Increase in ryegrass seed accumulation in narrow windrows
	ryegrass seed (no./m^2)		
1	8210 (1357)	3829 (820)	2.14-fold
2	8563 (789)	644 (231)	13.3-fold
3	10600 (979)	805 (271)	13.2-fold

**Expected accumulation based on 10 m swath into 0.75 m narrow windrow = 13.3.*

When canola and ryegrass were concentrated in narrow windrows, soil surface temperatures during burning were hot enough and their duration sufficient to kill >93% of ryegrass seed (Table 3). At site 3, the control was as high as 99%, with less than 52 viable seeds remaining in the burnt versus a possible 10600 seeds/m^2 in the unburnt windrow, respectively.

Pervious research from WA (Walsh & Newman 2007) showed that given sufficient canola residue had been concentrated burn temperatures exceeding 600°C were possible and well in excess of the 400°C required for at least 10 seconds to guarantee the death of ryegrass seeds. Their research concluded that higher biomass levels in narrow windrows increased mortality of ryegrass by increasing both burning temperatures and duration of these higher temperatures. They also found that wind speeds (higher better than low) were important by maintaining more consistent burning temperatures, improving the ability of the windrow to burn to the soil surface.

There are, however, some noteworthy disadvantages to burning narrow windrows which include summer rain reducing burning temperatures, associated unburnt residue heaps and trash flow issues at sowing, risk of burning entire field leading to increased erosion (less of problem with narrow than conventional windrows), redistribution of nutrients such as potassium in windrow area, and loss of important nutrients such as nitrogen and sulphur lost in smoke.

Table 3. Ryegrass (seeds m^{-2}) following burning of canola stubble concentrated into narrow windrows at 3 field sites across the Mid-North of SA. Values in parenthesis represent SE (±) around the mean of five replicates.

Site	Windrow treatment: Burnt	Windrow treatment: Unburnt	Ryegrass control	*P-value* Burnt Vs. unburnt
	ryegrass seed (no./m^2)		(%)	
1	540 (236)	8210 (1357)	93	***
2	88 (18)	8563 (789)	99	***
3	52 (15)	10600 (979)	99	***

*** *P < 0.001.*

Summary / implications

Narrow windrow burning canola appears to be an effective tactic for late seed set control of ryegrass provided weed seeds can be captured and concentrated into narrow windrow at swathing and harvest. To improve seed capture some consideration must be given to both the growth habit of ryegrass (lodged vs. erect) and subsequent swathing height (i.e. lodged ryegrass will require lower swathing height). Although not covered in this study, timing of swathing will also influence seed capture with earlier timing improving likelihood of capture as less ryegrass will have shed seed.

In canola, concentration of stubble residues into a narrow windrow using a simple chute mounted to the rear of the harvester is critical to obtain the fuel loads to achieve a longer, more reliable burn to the soil surface. A minimum of 400°C is required for at least 10 seconds to kill ryegrass seed (Walsh & Newman 2007); canola in narrow windrows can produce temperatures in excess of 600°C.

Our study showed that of the ryegrass seed captured, between 93 and 99% was controlled following burning of canola stubble concentrated into narrow windrows. This provides growers an excellent opportunity for late seed set control, particularly in situations where grass selective herbicides (i.e. Select®) have failed due to resistance and sizeable seedbank replenishment would undoubtedly cause production problems in the next crops of the rotation.

Acknowledgements

The financial assistance of GRDC is gratefully acknowledged. We also wish to thank Malinee Thongmee (University of Adaldie) for providing technical assistance and the three growers who provided field sites for this study.

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Fungicides for crown rot management

Margaret Evans (SARDI), Alan McKay (SARDI) and Jack Desbiolles (UniSA).

Key Findings:

- To date field trials funded by GRDC project DAS00136 have not been able to show that application of fungicides to seed provide significant reductions in yield loss caused by crown rot.
- Fungicides applied to seed or in-furrow at seeding can provide some suppression of pathogen growth through the plant early in the season (as measured using DNA techniques) but this effect is gone by early grain fill.
- In crop spray applications targeted at the base of plants have shown small yield benefits, but these benefits are not consistent between sites and across seasons.

Why do the trial?

As part of a series of South Australian trials to determine whether new or commercially available fungicides, combined with novel or standard application methods, can provide significant control of crown rot caused by the fungal pathogens *Fusarium pseudograminearum* and *F. culmorum*.

How was it done?

This trial is one of five undertaken to compare chemistries and application methods at Hart, Roseworthy, Pinery and Hamley Bridge over the period 2012-2014. This trial also builds on findings from four trials (2008-2011) assessing seed treatment efficacy for crown rot control at Cambrai, Roseworthy and Hart.

The 2014 Hart Field Site trial was direct drilled in plots of 6 rows x 14 m. Plots were split, with 3 rows of each plot treated and 3 rows untreated. Four seed treatments (including Rancona® Dimension @ 320 mL/100 kg seed), three in furrow at seeding treatments (including combinations with in crop sprays) and one in crop spray treatment were compared.

The incidence of plants with crown rot was determined at early tillering and early grain-fill and crown rot severity was assessed at early grain-fill all based on visual assessment of browning at the base of tillers which is characteristic of crown rot infection. Expression of white heads during grain filling and final grain yield were also recorded. Plant samples (yet to be assessed) were collected at early tillering and early grain-fill to determine concentrations of *Fusarium pseudograminearum* and *F. culmorum* DNA in plant tissues.

Results

Plant establishment was good in all plots and weeds and other diseases were not an issue.

Rainfall early in the season was well above average and despite low rainfall during grain-fill, yields from the trial averaged 4.7 t/ha).

The incidence of crown rot infection was reasonable with 30%-50% of plants showing visual symptoms of basal browning. However, disease severity was low, with basal stem browning scores ranging from 0.36-1.28, as was white head incidence (average 9%, range 0% to 24%). There were no significant differences between fungicide treatments and the untreated control in their effects on disease incidence, severity, white head expression or yield.

Discussion

The expression of crown rot symptoms (severity of basal browning and whiteheads) were limited at Hart in 2014. However, when considered in combination with results from other trials within the series, it is possible to make a number of statements about fungicide efficacy for crown rot control as outlined in the Key Findings section above.

Acknowledgements

Project funding from GRDC (DAS00136 - New fungicide technologies for crown rot management) is acknowledged for this research.

Photos from around Hart

Wheat in the crop rotation

Sarah Noack and Peter Hooper, Hart Field-Site Group

Key findings

- Previous crop (legume, oaten hay, cereal or fallow) had no affect on wheat grain yield in 2014.
- Grain protein values were lower following a cereal where there was less available soil N at the start of the season.

Why do the trial?

Wheat is commonly grown at the beginning of a cropping rotation, to take advantage of high soil nitrogen reserves, residual stored soil moisture and low levels of disease and weeds. This is to ensure reliable wheat grain yield and protein.

New technologies such as the Harrington Seed Destructor, chaff carts and Clearfield wheat lines now mean that wheat could be grown at different positions in a crop rotation. Wheat normally follows a legume crop. Legumes provide known benefits such as weed control, disease control, nitrogen and stored moisture however, economically they are often less profitable than other break crops such as canola or oaten hay, and less reliable.

How was it done?

Plot size 5.0 m x 10.0 m

Seeding date 15th May 2014

Crop variety Mace wheat @ 180 plants/m^2

Fertiliser DAP (18:20) + 2% Zn @ 60 kg/ha

The trial was a randomised complete block design with three replicates. In 2013 seven crop types were sown (Table 1) and in 2014 all plots were sown with Mace wheat which had two nitrogen application rates applied to all plots. Soil available nitrogen was sampled for wheat and pea plots which had 74 kg N/ha and 94 kg N/ha, respectively.

Table 1. Summary of previous crop sown in 2013 and nitrogen rates (kg N/ha) applied in 2014.

2013 crop	2014 Nitrogen rate 1 (kg N/ha)	2014 Nitrogen rate 2 (kg N/ha)
Oaten hay	50	80
Vetch brown manure (BM)	0	80
Wheat	50	80
Fallow	25	80
Canola	50	80
Barley	50	80
Field peas	25	80

Results and discussion

Wheat grain yield in 2014 was unaffected by previous crop or nitrogen rate (Table 1), ranging from 4.53 – 4.86 t/ha (Table 2). This contradicts previous research that has shown benefits of sowing wheat after legumes. This could be attributed to above average rainfall in 2014, limiting the effect of stored moisture from 2013. Also only a small portion of legume N is available in the subsequent year and will continue to breakdown over a number of seasons.

Table 2. Summary of Mace wheat grain yield (t/ha) and protein (%) following different positions in the crop rotation averaged across both N rates at Hart, 2014.

	Grain yield t/ha	Protein %
Oaten Hay	4.53	9.2[c]
Vetch BM	4.86	12.3[a]
Wheat	4.71	10.0[bc]
Fallow	4.67	13.2[a]
Canola	4.59	11.0[b]
Barley	4.77	10.7[b]
Peas	4.77	10.3[bc]
LSD (P≤0.05)	ns	1.3

This work does however, support previous research in the Mid-North under the GRDC water use efficiency project. Over a number of years the results showed wheat sown after a range of crop types yield equally as well. Wheat on cereal was able to yield as well as wheat following a legume, provided good management i.e weed control, time of sowing and nutrition were employed.

The protein values show wheat sown after a cereal generally has lower protein due to less soil available nitrogen and therefore more fertiliser N is required to contribute to grain protein. The N rates applied (Table 1) did effect grain protein with the average protein level for the 80 kg N/ha 1% higher compared to the 0, 25 and 50 kg/ha applied (data not shown).

Photo: Wheat at Hart.

Stubble direction – does it matter?

Sarah Noack, Hart Field-Site Group

Key findings

- Stubble direction and height (plus or minus stubble) had no effect on crop establishment or grain yield for Blitz and Ace lentils.
- Similarly stubble direction had no effect on grain yield or quality for Mace wheat or Commander barley.
- Annual ryegrass counts were the same in rows sown North-South and East-West.

Why do the trial?

There is evidence to suggest that the direction in which crops are sown and harvested can affect the shading of crops and weeds and potentially grain yield. In theory, stubble orientated east-west will encounter a higher number of hours in the day when the inter-row portion of soil is shaded. This may impact crop growth compared to stubble orientated North-South. This aim of the trials below was to:

1. Investigate if stubble/seeding direction and management (plus or minus stubble) effects lentil growth and yield **(lentil trial).**
2. Investigate if stubble/seeding direction effects crop competition and cereal grain yield **(cereal trial).**

How was it done?

Plot size	1.75 m x 10.0 m	**Fertiliser**	DAP (18:20) + 2% Zn @ 80 kg/ha
Seeding date	15th May (lentil trial) 28th May (cereal trial)		

Lentil stubble direction trial

In 2013 Wallup wheat (100 kg/ha) was sown in two directions, north-south and east-west. These plots were harvested and become the stubble/seeding direction treatments. In 2014 the trial consisted of two sowing directions (north-south, east-west), two lentil varieties (Ace and Blitz) and two stubble treatments (plus or minus stubble). Prior to seeding half the stubble plots were cut and straw removed (minus stubble, 15-20 cm) while the remaining plots were left standing (plus stubble, 40 cm).

All plots were assessed for plant establishment and grain yield.

Cereal stubble direction trial

In 2013 Wallup wheat (100 kg/ha) was sown in two directions, north-south and east-west. The trial area has an inherently high annual ryegrass seed bank. However, in 2014 an additional 5 kg/ha annual ryegrass seed was spread ahead of seeding & tickled in with a shallow pass with the seeder. The trial consisted of two sowing directions (north-south, east-west) and two cereal varieties (Mace wheat and Commander barley).

All plots were assessed for annual ryegrass plant establishment (8th August) and head number (10th October), grain yield, protein, test weight, screenings with a 2.2 mm screen and retention with a 2.5 mm screen (barley only).

Results and discussion

Plant establishment for both lentil varieties ranged from 117-136 plants per square metre with no effect from stubble direction or height (Table 1). Similarly lentil grain yield was not affected by stubble direction or height at Hart in 2014.

Table 1. The mean plant establishment and grain yield for Blitz and Ace lentils sown at Hart in 2014.

		Plant establishment (plants/m^2)		Grain yield (t/ha)	
Direction	**Stubble**	*Ace*	*Blitz*	*Ace*	*Blitz*
East-West	Removed	128	122	2.30	2.35
East-West	Standing	117	118	2.22	2.24
North-South	Removed	137	144	2.42	2.25
North-South	Standing	136	129	2.47	2.43

As observed in the above trial, stubble/sowing direction had no effect on grain yield or quality parameters for Commander barley and Mace wheat. While there was variation in the annual ryegrass plant number and final head count, there was no consistent effect or trend for either of the sowing directions.

Table 2. Summary of grain yield and quality for Mace wheat and Commander barley sown at Hart in 2014 and annual ryegrass plant establishment (8th August) and head number (10th October).

Direction	**Variety**	**Grain yield t/ha**	**Protein %**	**Test weight kg/hL**	**Screenings %**	**ARG plants/m^2**	**ARG heads/m^2**
East-West	Commander	3.31	11.8	68.9	3.5	86	180
East-West	Mace	2.44	9.6	78.6	3.3	58	158
North-South	Commander	3.51	11.7	69.1	3.3	66	124
North-South	Mace	2.39	9.6	79.6	3.2	86	153
	LSD ($P \leq 0.05$)						
	Variety	0.56	0.4	2	ns	ns	ns
	Direction	ns	ns	ns	ns	ns	ns

Long-term cropping systems trial

Sarah Noack, Hart Field-Site Group

Key findings

- Barley grain yield was not affected by tillage treatment averaging 4.25 t/ha.
- The medium nitrogen level increased grain yield by 0.61 t/ha compared to the high nitrogen level.

Why do the trial

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

How was it done?

Plot size	35 m x 13 m	**Fertiliser**	DAP/Urea (22:14:00:05) + 0.8% Zn
Seeding date	29th May 2014	**Medium nutrition**	No extra fertiliser applied
		High nutrition	UAN (42:0) @ 40 L/ha on 8th August
		Variety	Commander barley @ 70 kg/ha

The trial was a randomised complete block design with three replicates, containing three tillage/seeding treatments and two nitrogen treatments. In addition to this, in 2013 all disc treatments were harvested using a stripper front. Both the no-till and strategic stubble height were harvested at 15 cm. The disc, strategic and no-till treatments were sown using local growers Tom Robinson, Michael Jaeschke and Justin Wundke's seeding equipment, respectively.

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

2000	2001	2002	2003	2004	2005	2006	2007
Sloop barley	Canola	Janz wheat	Yitpi wheat	Sloop barley	Kaspa peas	Kalka durum	JNZ wheat

2008	2009	2010	2011	2012	2013	2014
JNZ wheat	Flagship barley	Clearfield canola	Correll wheat	Gunyah peas	Cobra wheat	Commander barley

Tillage treatments:

Disc – sown into standing stripper front stubble with John Deere 1980 single discs 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 narrow points at 225 mm (9") row spacing and press wheels.

Nutrition treatments:

Medium – No extra fertiliser applied post seeding.
High – Extra nitrogen was applied as UAN (42:0) at 40 L/ha on the 8th of August

All plots were assessed for soil available nitrogen (0-30, 30-60 cm) on the 12th of April and soil carbon (loss on ignition method) on the 22nd of May. Plant establishment was assessed by counting 4 x 1 m sections of row across each plot. All plots 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

Soil available nitrogen (N) to a depth of 60 cm was measured in autumn and ranged between 134 kg N/ha (disc, medium) to 160 kg N/ha (no-till, high). The high nutrition treatment had not accumulated more N compared to the medium treatment with an average difference of 8 kg N/ha.

Soil organic carbon levels ranged from 1.57% to 2.18% across all treatments in 2014. In comparison, the native vegetation area at the site contained 5.20% (data not shown) soil organic carbon.

Crop emergence was highest for the disc and no-till treatments with 149 and 144 plants per square metre, respectively. The strategic treatment had the lowest crop establishment with 118 plants per square metre.

Table 1. Available soil nitrogen (kg/ha) and plant emergence (plants/m^2) and soil organic carbon (%) for nutrition and tillage treatments in 2014.

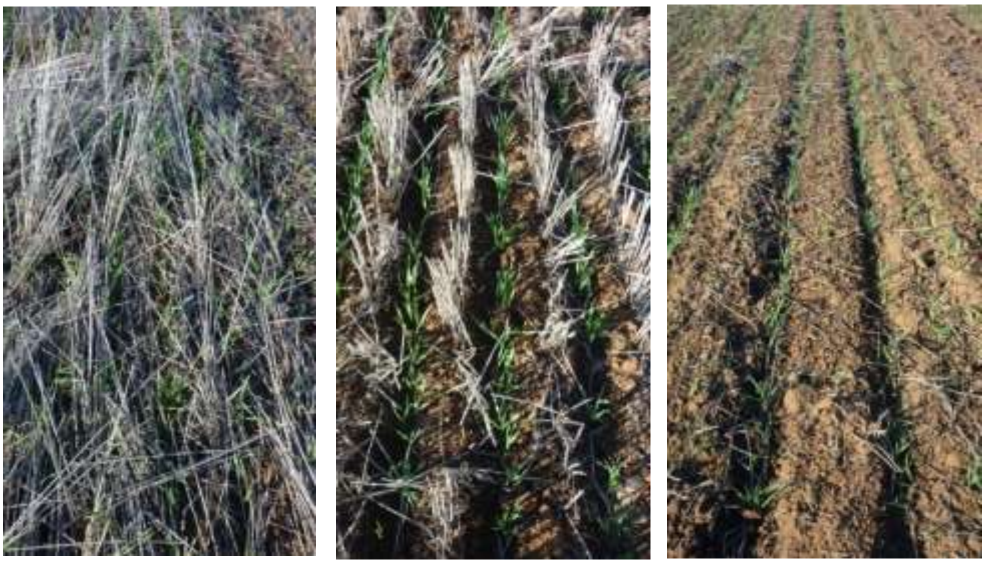
Tillage	Nutiriton	Available soil N kg N/ha	Emergence plants/m2	Soil organic carbon %
Strategic	Medium	140	122	1.98
	High	154	114	1.99
Disc	Medium	134	137	1.97
	High	140	160	2.18
No-till	Medium	155	147	1.57
	High	160	141	1.89
LSD (P≤0.05)				
Tillage		ns	25	ns
Nutrition		ns	ns	ns
Tillage × Nutrition		ns	ns	ns

Tillage treatment did not affect the grain yield of Commander barley in this trial with an average grain yield of 4.25 t/ha. Tillage treatment also had no effect on grain quality parameters test weight, screenings and retention. Grain protein was significantly higher for the strategic treatments however, this can be attributed to the poor crop emergence and growth in this treatment in 2013. These findings support the general conclusion from the previous 14 years of this trial, which is no one tillage/seeding system consistently yields higher than another.

Table 2. Grain yield (t/ha), protein (%), test weight (kg/hL), screenings (%) and retention (%) for nutrition and tillage treatments in 2014. There was no significant interaction between tillage × nutrition.

Tillage	Nutiriton	Yield t/ha	Protein %	Test weight kg/hL	Screenings %	Retention %
Strategic	Medium	4.44	12.9	67.9	11.1	53.5
	High	3.85	15.0	65.6	26.8	23.4
Disc	Medium	4.54	11.9	69.5	6.5	68.5
	High	3.96	13.9	65.8	24.1	31.8
No-till	Medium	4.69	11.1	70.1	5.9	71.8
	High	4.04	14.1	66.4	28.2	29.2
LSD (P≤0.05)						
Tillage		ns	1.0	ns	ns	ns
Nutrition		0.2	0.8	1.4	ns	12.6

Nutrition treatment affected grain yield and all quality parameters measured (Table 2). The medium nutrition treatment yielded 0.61 t/ha more compared to the high nutrition treatments. In general the medium treatment had better test weight, screening, retention and protein levels (within 9-12% for malt classification) compared to the high nutrition treatment. This can be attributed to the above average rainfall early in the season setting yield potentials high (see Yield Prophet® article on page 90) followed by below average rainfall from August onwards. This led to a situation of too much N in the high nutrition treatment for the yield potential, increasing protein levels and screenings at the same time.



Photos: (L-R) Commander barley sown with a disc seeder into stripper front stubble, no-till treatment and strategic tillage treatment taken on 18th June, 2014.

Acknowledgements

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Seeding into stubble
Trial 1: a comparison of seeding systems, pre-emergent herbicides and stubble height in barley

Sarah Noack and Peter Hooper, Hart Field-Site Group

Key findings

- Hindmarsh barley grain yield was unaffected by stubble or seeding systems averaging 3.3 t/ha.
- Of all pre-emergent herbicides trialled a grain yield reduction was observed for Sakura (average reduction 0.18 t/ha). A split application of Boxer Gold (IBS/POST) was slightly safer compared to the full rate IBS.

Why do the trial?

It is estimated that less than 20% of growers use a full stubble retention system due to risks (eg. pests and disease) and costs associated with the practice, which limit its adoption. The outcomes of recent research are conflicting. Various reports have shown yield decline from full stubble retention, due to reduced interception of sun light, lower soil temperatures and increased pest activity. Other research has shown that stubble retention may increase grain yields by improving crop growing conditions, availability of water, nitrogen or a combination of these factors. The actual outcome, however, depends on the management of stubble (level and timing of ground cover), soil type, and interactions with rainfall, soil nitrogen and fertiliser management.

In order to improve no-till cropping system performance, a better understanding of residue management and its impact on crop production is needed. The trial data presented here is the second year of a three year project investigating the effect of full stubble retention compared with other stubble management methods and seeding technologies.

How was it done?

Plot size	10.2 m x 12.0 m	**Fertiliser**	Urea/DAP (22:14) @ 100 kg/ha
Seeding date	20th May 2014		Urea (46:0) @ 100 kg/ha on 11th July
Location	Hart	**Crop**	Hindmarsh barley @ 80 kg/ha

The trial was established as a randomised complete block design with three replicates and four stubble × two seeding × four pre-emergent herbicides. The baled, short and medium treatments were cut on 27th of November and stripper front treatments on 14th of December. Stubble treatments including height and biomass are outlined in Table 1.

Table 1. Summary of wheat stubble treatments in the 2014 Hart trial.

Stubble treatment	Standing stubble biomass (t/ha)
Baled – stubble cut with stripper front, slashed and removed.	1.3
Short – stubble retained cut to height of 15 cm.	1.9
Medium – stubble retained and cut to height of 30 cm.	2.4
Stripper front – stubble retained and cut using stripper front, height 60 cm.	3.4

Each stubble treatment was sown using two seeding systems. The disc treatment was sown using a John Deere 1890 Disc Machine 15.2 cm (6") row spacing. The tyne treatment was sown using a standard knife-point press wheel system was used to sow the remaining plots on 22.2 cm (8.8") row spacing.

All herbicides incorporated by sowing (IBS) were applied on 19th May and the post-emergent treatments were applied at the 2-3 crop leaf stage on the 15th of July. The herbicides trialled included;

1. Trifluralin 1.5 L/ha and tri-allate 1.6 L/ha IBS
2. Sakura 118 g/ha IBS
3. Boxer Gold 2.5 L/ha IBS
4. Boxer Gold 1.0 L/ha + tri-allate 1.6 L/ha IBS + Boxer Gold 1.5 L/ha POST (crop 2-3 leaf stage)

Plant establishment was assessed by counting 4 x 1 m sections of row across each plot. All plots were assessed for grain yield, protein, test weight, screenings with a 2.2 mm screen and retention with a 2.5 mm screen.

Soil surface temperature was logged using individual tiny tag loggers in each stubble treatment. Wind speed was assessed using seven anemometers position along a 2 m stand. Soil moisture was assessed using a Sentek Diviner 2000 moisture probe and access tubes cored up to 100 cm prior to seeding.

Results and discussion

Crop establishment, grain yield and quality

Stubble height (and therefore biomass) had no effect on crop establishment. Between the seeding systems the tyne seeder had better establishment compared to the disc. However, as seen in Table 2 this had no effect on grain yield which only varied by 0.2 t/ha across all treatments.

Grain quality parameters ranged from 11.3-12.7 % for protein, 64.9-67.0 kg/hL for test weight, 18.5-35.2% for screenings and 13.1-37.0% for retention. Despite the variation in these measurements, there was no consistent trend for any one stubble height or seeding system.

Previous stubble trials at Hart and Pinery (Hart trial results book 2013) showed greater crop growth and yield differences among stubble treatments in lentils. For example, plant height and pod height increased with increasing stubble height. In the current trial, barley growth was not consistently affected by stubble height or seeding system.

Table 2. Summary of crop measurements establishment (plants per square metre), grain yield (t/ha), protein (%), test weight (kg/hL), screenings (%) and retention (%) for Hindmarsh barley in 2014.

Seeder	Stubble	Establishement plants/m2	Grain yield t/ha	Protein %	Test weight kg/hL	Screenings %	Retention %
Tyne	Baled	179	3.4	12.3	66.0	32.8	14.0
	Short	165	3.3	11.3	67.0	23.6	24.5
	Medium	165	3.3	12.1	65.2	30.8	15.1
	Stripper	145	3.3	12.6	64.9	30.9	13.1
Disc	Baled	105	3.3	12.7	65.8	32.6	18.5
	Short	92	3.3	12.3	65.1	35.2	13.1
	Medium	91	3.2	11.8	66.9	18.5	37.0
	Stripper	96	3.2	12.2	65.7	23.4	27.2
	LSD (P≤0.05)	21	ns	0.7	1.5	11.8	11.4

Pre-emergent herbicides

The use of pre-emergent herbicides in disc seeding systems has received a lot of attention due to crop safety concerns. In the current trial there were no differences in pre-emergent herbicide activity on crop establishment or grain yield for any of the stubble treatments (Table 3). However, there were differences in final grain yield for the different herbicide treatments and among herbicide treatments (Figure 1).

Table 3. Average plant establishment for stubble × herbicide treatments (P>0.05).

Stubble	Trifluralin + Triallate	Sakura	Boxer Gold IBS	Boxer Gold Split IBS/POST + Triallate IBS
	plants/m^2			
Baled	144	136	139	154
Medium	143	127	101	140
Short	135	127	101	148
Stripper	138	98	119	127

Previous work from Kleemann et al. (2013) has shown generally disc seeders displace too little soil from the seed row to make trifluralin a safe option for use. However, the amount of stubble also needs to be taken into consideration as trifluralin will bind to stubble and become less effective. In the current trial we suspect a large portion of trifluralin was bound in the stubble treatments meaning it was unable to cause significant crop damage or yield reduction (Figure 1). The stripper front treatment contained 3.4 t/ha stubble and at the opposite end the baled treatment had 1.3 t/ha of standing stubble remaining (Table 1).

As trifluralin-resistant ryegrass populations are becoming more prevalent grower reliance on Sakura and Boxer Gold will continue to increase. The grain yield reduction for Sakura can be explained by the application onto moist soil (22.4 mm rainfall in May prior to application) and the amount of rainfall after seeding. Within 21 days after sowing the trial received 19.6 mm (Table 4) which washed Sakura (medium water solubility) into the row. For Boxer Gold (also medium solubility) splitting the 2.5 L/ha rate as IBS and POST application resulted in greater crop safety. Trifluralin and tri-allate (lower solubilities) would have still been bound to the stubble and did not result in the same grain yield reduction.

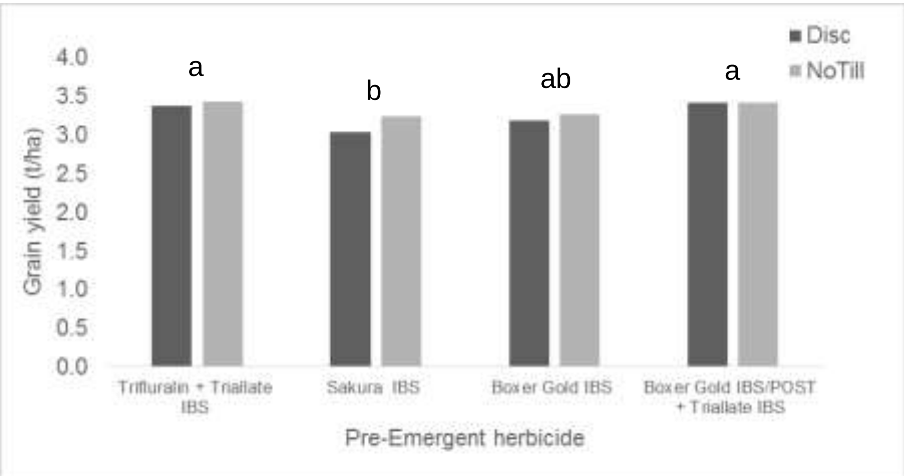


Figure 1. Average barley grain yield for different pre-emergent herbicides and seeding systems. Herbicide columns appended by a different letter are significantly different (l.s.d 0.20, P≤0.05).

Table 4. Rainfall at the Hart trial 7 and 21 days after herbicide applications.

	Rainfall (mm)	
Application Date	7 Days after application	21 Days after application
IBS 19 May	0.8	19.6
PSPE 15 July	8.6	23.4

Soil moisture

Differences in soil moisture between the stubble treatments were low in 2014 (Figure 2). Early summer rainfall (105 mm in February and March) meant that the typical differences seen in moisture retention under taller standing stubble were not observed in this trial. In addition, early growing season rainfall would have further contributed. Across all stubble treatments there was a similar trend in soil moisture draw down towards the end of the season (Figure 2c).

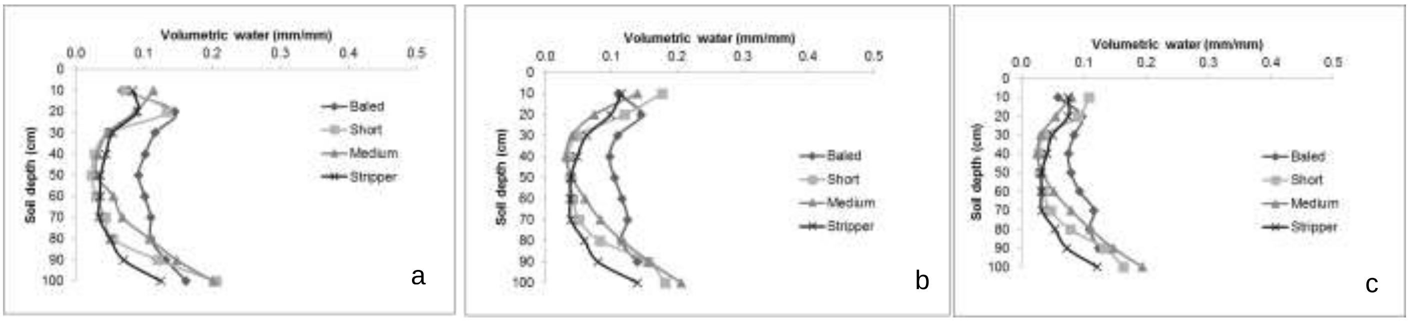


Figure 2. Soil volumetric water content (mm/mm) under the different stubble treatments samples at (a) 23rd May (b) 6th August and (c) 24th October.

Wind speed and temperature

All data displayed for the wind speed are the average data for one sampling time. For the medium, short and baled stubble treatments there was a much greater distance from the soil surface required to reduce wind speed (Figure 3). In contrast the stripper front stubble significantly reduced wind speed 80 cm above soil surface and had decreased relative wind speed to less than 20% at 40 cm. This data shows that wind speed in the zone of plant growth will be affected by stubble height and taller stubble treatments offer plants greater protection. The results also show there is little variation in wind speed reduction between stubble 15 cm high through to 60 cm high.

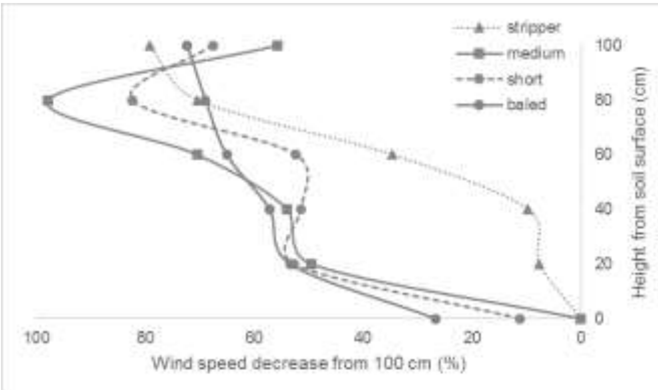


Figure 3. Wind measurements taken on a light wind speed morning (average 8 km/hr).

Soil surface temperature measurements showed a similar trends across all stubble treatments (Figure 4). Interestingly early in the season (June) the medium and stripper front stubble treatments had the highest daily temperature on average by 1-2°C. Prior to the end of June there was a shift in temperature among the stubble treatments and the baled, short and medium treatments were slightly warmer (2-3°C) compared to the stripper front stubble.

Differences in minimum daily temperature were small, except when the temperature dropped below 5°C. Below this temperature the medium and stripper front stubble tended to drop the temperature lower compared to the short and baled treatments.

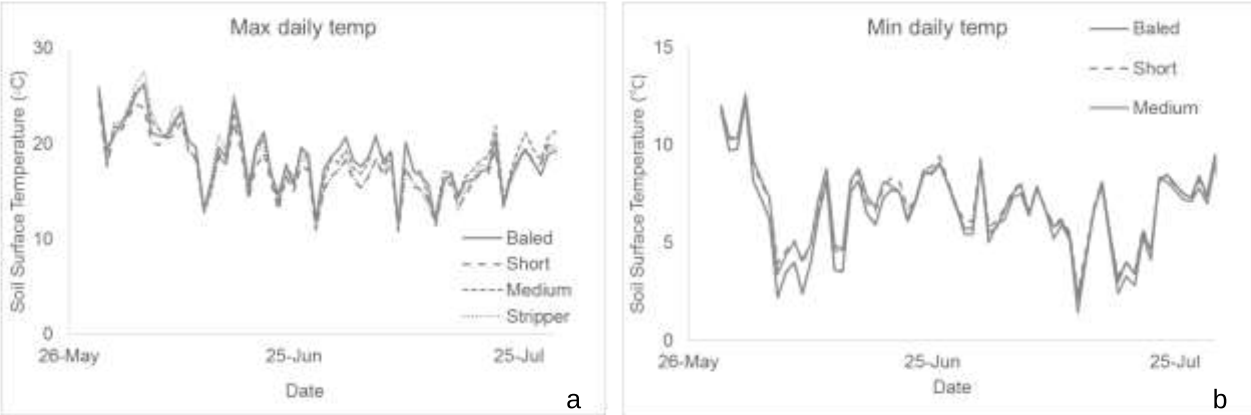


Figure 4. Maximum (a) and minimum (b) daily temperature at the soil surface for all stubble treatments.

Acknowledgements

The HFSG thank the South Australians Grains Industry Trust (H0113) for providing funding to support this research. We also thank all the growers who assisted with trial seeding, spraying, harvesting and providing land for this trial.

References

Kleemann, S., Desbiolles, J., Gill, G. and Preston, C. (2013) Disc seeders and pre-emergent herbicides. GRDC Adviser Update Manual Adelaide pg 69-73.

Seeding into stubble
Trial 2: the effect of stubble height on lentil growth

Sarah Noack and Peter Hooper, Hart Field-Site Group

Key findings

- There were no significant differences in lentil grain yield among stubble treatments.
- As seen in 2013, stripper and conventional stubble treatments resulted in taller and more erect lentil plants.

Why do the trial?

Refer to 'why do the trial' in the previous article.

How was it done?

Plot size	21.3 m x 50.0 m	**Fertiliser**	N:P:S (13:19:7) + 1% Zn @ 100 kg/ha
Seeding date	22nd May 2014	**Crop**	Jumbo lentils @ 55 kg/ha
Location	Pinery		

The trial was established as a randomised complete block design with three replicates and five barley stubble treatments. The stubble treatments included

1. **Baled** – stubble cut with stripper front, slashed and removed.
2. **Slashed** – stubble cut with stripper front, slashed and spread across the plot.
3. **Short** – stubble retained cut to height of 15 cm.
4. **Medium** – stubble retained and cut to height of 30 cm.
5. **Stripper front** – stubble retained and cut using stripper front.

The barley paddock was harvested using a stripper front in late November 2013. The baled, short and medium treatments were cut on 10th of February.

Plant establishment was assessed by counting 4 x 1 m sections of row across each plot. All plots were assessed for plant height both early in the season and maturity and pod height from soil surface at maturity.

Soil surface temperature was logged using individual tiny tag loggers in each stubble treatment. Soil moisture was assessed using a Sentek Diviner 2000 moisture probe and access tubes cored up to 100 cm prior to seeding. Gravimetric water content was also assessed at the time of access tube installation.

Crop establishment plant growth

There was no significant difference in crop establishment (plants per square metre) among stubble treatments for lentils in this trial (Table 1). Plant and pod height was highest for the medium and stripper front stubble treatments (Table 1). This was followed by the short and baled/slashed stubble treatments. Plant height was assessed both early and later in the season as previous work (Lines et al. 2012 unpublished) has shown there are differences in plant growth among lentil varieties. In particularly, Jumbo was shown to be least effected by stubble treatment. Results presented here and seen for Blitz lentils in 2013 have shown they were both effected by stubble height.

The shorter plant height for the baled and short stubble treatments may be attributed to the lack of stubble to support the growth of lentil plants. Evidence for this was also the higher lodging score for these treatments (Table 1). The medium stubble height had a slightly better lodging score compared to the stripper front treatment. This can be attributed to the fact that by the end of the season majority of the stripper front barley straw was no longer standing (fallen flat on the soil surface) and plants were showing signs of lodging. Similar observations were seen in 2013 for Blitz lentils at Hart however, at the end of the season the wheat stubble was still standing in all plots and had not fallen on the soil surface. Overall the stripper and medium stubble treatments resulted in taller and more erect plants with higher pods improving harvestability.

Table 1. Summary of crop measurements establishment (plants per sq metre), plant and pod height (cm), lodging and grain yield (t/ha).

Stubble	Establishment plants/m^2	Early plant height cm	Late plant height cm	Pod height cm	Lodging*	Grain yield t/ha
Slashed	74	5.5c	22.7c	13.3	3-4	1.83
Baled	76	4.9c	22.1c	12.3	3-4	1.71
Short	71	5.8c	25.1bc	13.8	4-5	1.79
Medium	76	7.8b	28.6a	14.7	8-9	1.79
Stripper	76	9.6a	28.1ab	15.7	6-7	1.77
LSD ($P\leq0.05$)	ns	1.4	3.0	ns		ns

**Crop lodging scored as 9 equals erect to 1 completely flat on the ground*

Grain yield

There were no differences in lentil yield between stubble treatments. Grain yield ranged from 1.71 – 1.83 t/ha with baled stubble having lowest yield and slashed stubble having the highest yield. These results are in agreement with the Hart trial 2013 which found no difference in Blitz lentil yield for any stubble height.

Soil surface temperature and soil moisture

Prior to seeding the soil moisture underneath the stubble treatments varied by 1-3% across all soil depths. In the top 0-20 cm layer soil moisture increased with stubble height (Table 2). However, this trend was not consistent across all soil depths. The volumetric soil moisture contents also reflect small, inconsistent shifts in soil moisture (Figure 1). As outlined in the article above the amount of summer rainfall and early season growing rainfall may have contributed to the lack differences between stubble treatments observed in 2014.

Table 2. Gravimetric soil water content (%) sampled prior to seeding on 16th of April.

Soil depth cm	Baled	Short	Medium	Stripper
	% soil moisture			
0-20	15.8	15.5	16.4	17.5
20-40	16.8	16.2	15.0	15.7
40-60	17.1	13.9	14.1	15.3
60-80	14.0	14.7	14.0	14.3

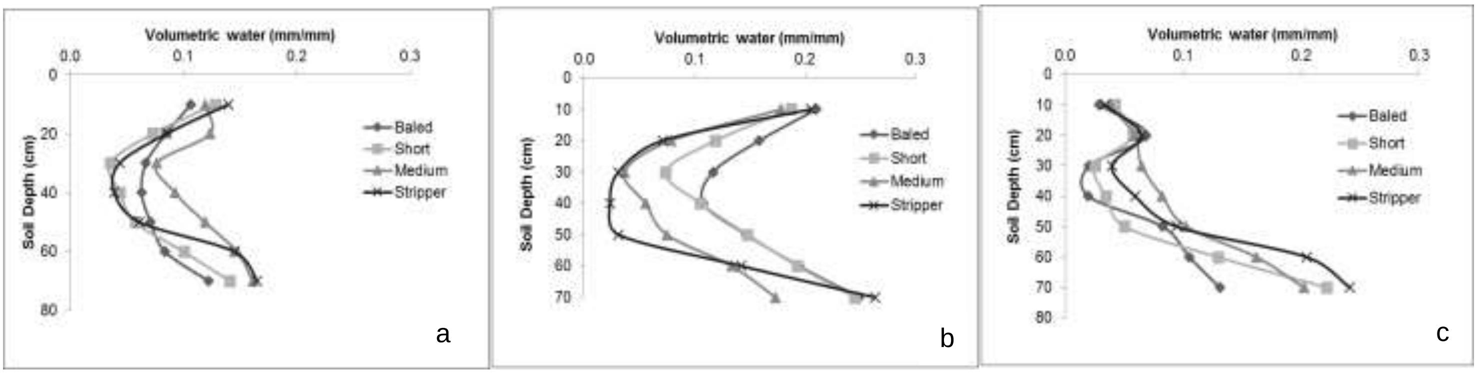


Figure 1. Soil volumetric water content (mm/mm) under the different stubble treatments samples at (a) 25th April (b) 22nd May and (c) 23rd October.

The average maximum daily temperature (Figure 2a) from start of season until end of August was 21.1°C (baled), 23.3°C (medium) and 25.6°C (stripper front). Similarly the stripper front stubble had the highest minimum temperature compared to the medium and baled treatments (Figure 2b). At the end of August there was a re-ordering in soil surface temperature for all stubble treatments. The baled treatment had the highest surface temperature followed by medium and stripper front. This could be attributed to the lentils in the baled treatment becoming lodged and trapping more heat.

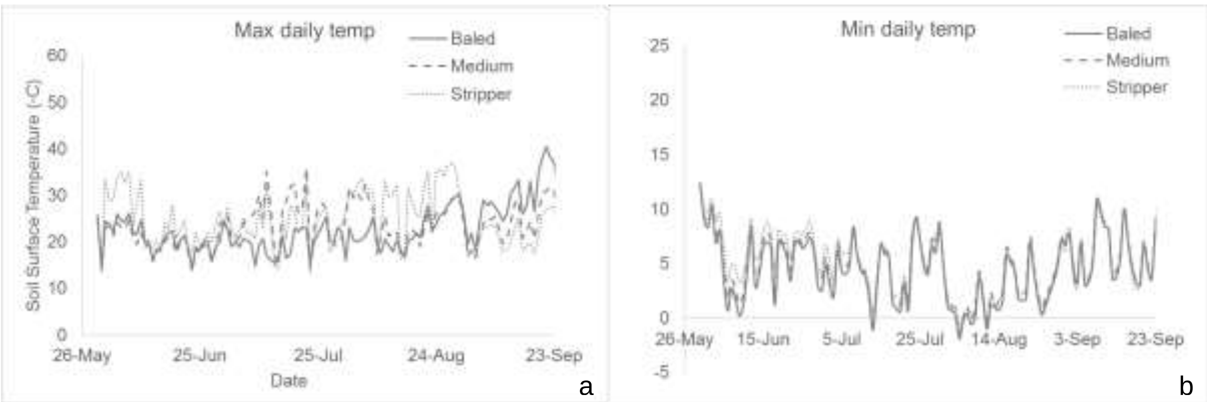


Figure 2. Maximum (a) and minimum (b) daily temperature at the soil surface for all stubble treatments.

Acknowledgements

The HFSG thank the South Australians Grains Industry Trust (H0113) and Caring For Our County (CLG-1206319-906) for providing funding to support this research. We also thank the grower who assisted with trial seeding, spraying, harvesting and providing land for the lentil trial.

Yield Prophet® performance in 2014

Sarah Noack, Hart Field-Site Group

Key findings

- Yield prophet® closely predicted a final grain yield of Mace at 5.5 t/ha in the Hart area.
- Good season rainfall meant the difference between 20% and 80% of years started at 0.8 t/ha in late June and was only 0.1 t/ha by mid-October.

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 2014	**Fertiliser**	30 kg N/ha 1st May 46 kg N/ha 15th 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

The actual grain yield for Mace wheat sown on the 8th May at Hart in 2014 was 5.01 t/ha. This final grain yield was 0.5 t/ha below the Yield Prophet® prediction (Figure 1) of 5.5 t/ha.

At the first simulation, 19th June 2014, the Yield Prophet® simulation predicted that Mace wheat sown on the 1st May would yield 4.9 t/ha in 50% of years. The predicted grain yield increased by 0.6 t/ha by the 16th July due to an increase in rainfall of 80 mm. This yield was closely maintained up until mid-October. Interestingly all other sites (expect Kybunga) had a yield prediction decrease between September and October of 0.8 – 1.4 t/ha compared to Hart which was only -0.1 t/ha (see Hart Beat Newsletter no. 31).

The Yield Prophet® simulation on the 13th October for grain yield, given an average (50%) finish to the season, was 5.5 t/ha as was the finish for 80% of years. Early in the season up until September the Hart rainfall ranged from decile 8 to 9 which meant the variation in grain yield between 20%, 50% and 80% was small. As the season dried out the variation in grain yield for the Hart site was even smaller (Figure 1).

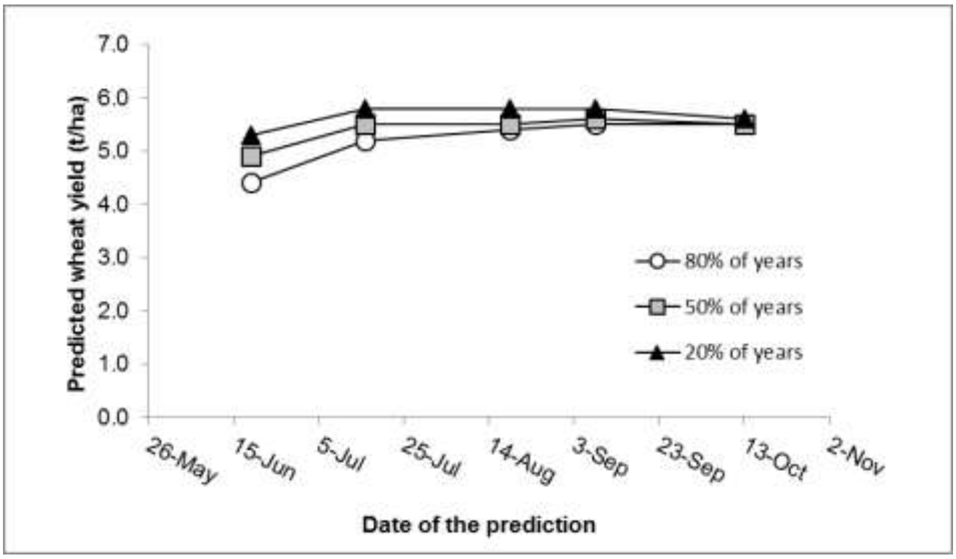


Figure 1. Yield Prophet® predictions from 19th June to the 13th October for Mace wheat sown on the 1st May, 2014. 80%, 50% and 20% represent the chance of reaching the corresponding yield at the date of the simulation.

Plant available water (PAW) (0-90cm) when the first simulation was run at the beginning of June was 98 mm. Plant available water had increased significantly when the second Yield Prophet® simulation was run on 16th of July (Figure 2). Plant available water slowly decreased until mid-August and from then on decreased faster due to lack of rainfall towards the end of the season. At the final simulation date of 13th of October there was still 28 mm of PAW (Figure 2). The 2014 season favoured earlier districts resulting in above average yields and grain quality. Additional rainfall in many of the later districts was required to finish the season and reduce screening levels, although generally grain yield and quality were good in areas unaffected by frost damage.

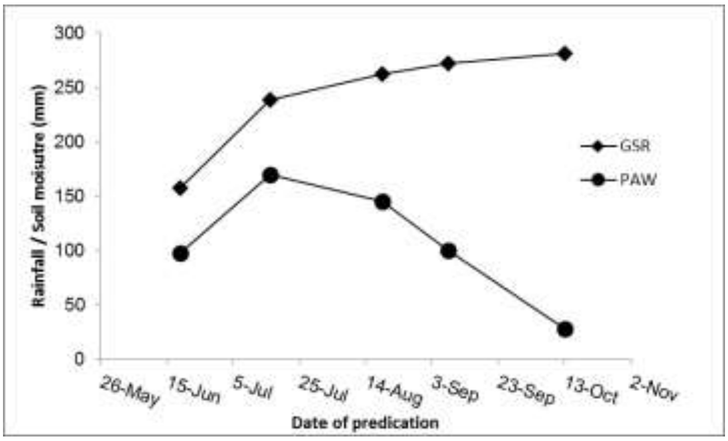


Figure 2. Predicated plant available water (PAW) and recorded cumilative growing season rainfall from 19th of June to 13thht of October at Hart in 2014.

Spring Twilight Walk 2014

Harvest 2014

Aerial photos 2014

We spent some time exploring robotics in agriculture this year and got some amazing aerial photos of the Hart site in the process.

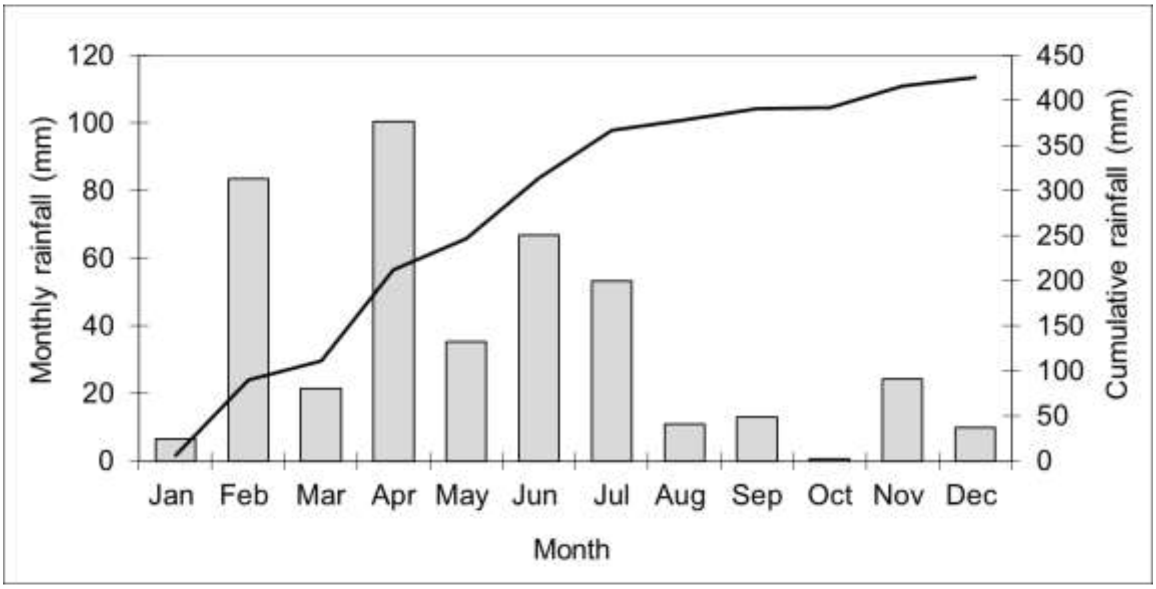
Photo credits: Trevor & Kathy Fischer & Joe Koch

Hart rainfall chart 2014

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1						2.2	1	4.4	2.4		2.6	
2					9.8	1.8		2	0.6			
3	0.6				5.4	2.8			0.4			0.4
4							0.4					
5							0.4					
6							2					
7							0.2					
8				4.4								
9				48.4			10		3.2			
10				20.4	7.2		18.2		0.8			
11				2.6			1					7.6
12							3					
13		1.6				0.2				0.6		
14		6.8				12						
15	0.2	72	1.4			2.4					3.4	
16		2.4	0.2			1.2	0.2	0.2	2.6		1	
17							5.6	3	0.2			
18	0.6						2.8	1.4				
19					0.2							
20		0.8			0.6						0.4	
21						0.4					17	
22												
23						0.4						1.8
24	4.6					10.2	8.2		0.8			
25	0.6						0.2		2			
26			1.8			0.2						
27					5.6							
28			17.8		2.2	18.2						
29			0.2	23		13.8						
30				1.8		1						
31					4.2							
Monthly total (mm)	6.6	83.6	21.4	100.6	35.2	66.8	53.2	11.0	13.0	0.6	24.4	9.8
Running total (mm)	6.6	90.2	111.6	212.2	247.4	314.2	367.4	378.4	391.4	392.0	416.4	426.2

Photo: Canola time of sowing.

Hart rainfall graph 2014



Average GSR (Apr-Oct)	**305 mm**	**Average rainfall**	**400 mm**
2013 GSR (Apr-Oct)	303 mm	2013 total rainfall	377 mm
2013 GSR (Apr-Oct)+summer	336 mm		
2014 GSR (Apr-Oct)	280 mm	2013 total rainfall	426 mm
2014 GSR (Apr-Oct)+summer	392 mm		

Hart site – soil test 2014

Northern quarter

Depth (cm)	**0 - 10**
Sampled 30/5/2013	
Phosporus (ppm) (Cowel P)	59
DGT – P (µg/L)	89
Phosphorus buffering index	102
KCl 40ºC (Sulphur) (mg/kg)	1.6
Soil nitrogen (0-60 cm) (kg/ha)	**48**
Sampled March 2010	
Potassium (ppm)	579
Salinity (EC dS/m)	0.14
Organic carbon (%)	1.80
pH (calcium chloride)	7.4
pH (water)	8.2

Notes

agfert
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DAP ZinCote 1%

1% Zinc evenly applied to every granule

DAP ZinCote 1% is Agfert Fertilisers first premium compound product to be released as part of its Premium Cropping Range. New technology allows Agfert to get 1% zinc evenly applied to every granule, ensuring even and consistent distribution of Zinc throughout the furrow. The Zinc used in DAP ZinCote 1% is in a controlled release form supplying zinc to the plant gradually throughout the growing season.

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