GRAINS RESEARCH UPDATE

STRATEGIC STEPS – ENDURING PROFIT

Campbell Town

Friday 13th July

9.00am to 1.00pm

The Grange Meeting & Function Centre,

4 Commonwealth Lane, Campbell Town

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Contents

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AGRICULTURE VICTORIA

Program

9:00 am	**Welcome**	***ORM***
9:05 am	**GRDC welcome and update**	***GRDC***
9:15 am	**High rainfall wheat & barley review – tailored agronomic packages**	***Jon Midwood,*** *Southern Farming Systems*
9:55 am	**Hyper yielding cereal project and Septoria tritici research update**	***Tracey Wylie,*** *FAR Australia*
10.35 am	***Morning tea***	
11:05 am	**The effect of stubble on nitrogen tie-up and supply**	***Tony Swan,*** *CSIRO*
11.45 am	**Yield and economic potential of high input cropping systems in the high rainfall zone**	***Malcolm McCaskill,*** *Agriculture Victoria*
12:25 pm	**Dealing with herbicide resistance in the high rainfall zone**	***Gurjeet Gill,*** *The University of Adelaide*
1.05 pm	***Close and evaluation***	***ORM***
1.10 pm	***Lunch***	

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Southern Farming Systems

"sustainable farming systems for the high rainfall zone"

www.sfs.org.au

The beginnings

Southern Farming Systems (SFS) was formed in 1995 by a group of farmers who came together to find ways of making farming in the higher rainfall zone (HRZ) more profitable. SFS now has nearly 500 members in five branches; Geelong, Streatham, Hamilton, Gippsland and northern Tasmania. SFS maintains international affiliations and has a strong link with the Foundation for Arable Research (FAR) in New Zealand.

Who and what is SFS?

SFS is one of the largest farming system groups in Victoria, recognised as a premier source of grower driven independent research, centred on the high rainfall zones of southern Victoria.

Our objectives are to research, develop and communicate the best use of resources, new techniques and technologies for more profitable agriculture; with a specific mission to increase farm profitability and sustainability. SFS will achieve its mission by developing more efficient and better adapted farming systems.

While SFS maintains strong partnerships with research and extension agencies and with agribusiness, the information provided to members is highly valued for its quality and independence.

What we produce

AgriFocus is the major field day event run by SFS, considered a "must attend" technical event for the HRZ cropping region. Held annually in October over two days; SFS showcase a range of research trials, technical tours and demonstrations. Visitors can talk directly to some of the leading researchers, plant breeders and technical experts in the HRZ, as well as see tractors, crop sprayers, tillage and sowing equipment from our sponsors.

SFS Annual Results Conference meetings are held during March in Southern Victoria, Gippsland and Tasmania, where the release of the much acclaimed SFS Trials Results book is made available to SFS members.

"Innovative, relevant & profitable cropping research for HRZ farmers"

Value for you

SFS membership packages are flexible & offer great value; including regular newsletters & updates of current research projects, copies of our Annual Trial Results book, Free entry to all SFS field days, local crop walks & workshops, as well as access to our exclusive Members Only area of the SFS website for branch specific updates, previous trial report data, SFS weather station data, plus much more!

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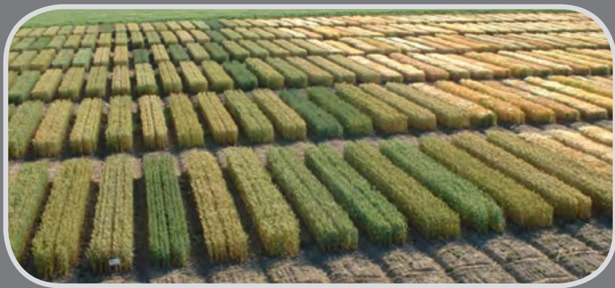

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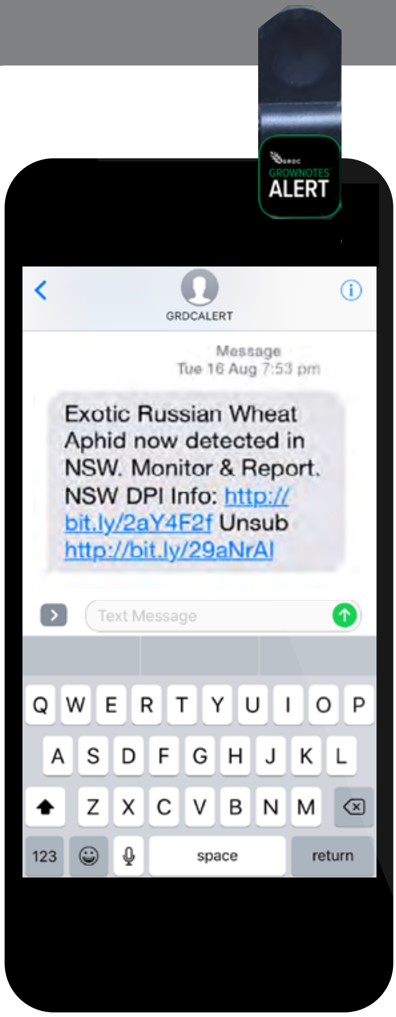

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AGRICULTURE VICTORIA

GRDC GROWNOTES ALERT

High rainfall wheat and barley review

Jon Midwood and Claudia Gebert.

Southern Farming Systems.

Keywords

- wheat, barley, varieties, agronomy, management, yield, high rainfall zone (HRZ).

Take home messages

- The final yields and gross margins in 2017 of wheat and barley were strongly influenced by key weather events.
- Delayed sowing of wheat by nearly three weeks at one site significantly improved establishment and average yields by 1.5t/ha by avoiding a 56mm rainfall event a day after sowing.
- Minimum temperatures at Westmere on four consecutive days of 0°C or less, during flowering and grain fill at the beginning of November, affected the yield and quality of both barley and wheat.
- In 2017, the additional cost of the fully managed strategy in the early sown wheat trials did not provide an improvement in financial return on average.
- Wheat varieties, LRPB Trojan⦻, LRPB Beaufort⦻ and Longsword⦻ all gave significantly ($p<0.05$) greater yields at both trial sites under the fully managed strategy.
- RGT Planet⦻ was the highest yielding barley variety overall ($p<0.05$) at the Inverleigh site and in the early sown trial at Westmere.
- Fully managed input treatments yielded significantly ($p<0.05$) higher than standard input treatments in all Southern Farming Systems (SFS) barley variety trials in 2017.

Background

Grain producers have become more proficient atWith limited wheat and barley varieties suited to the high rainfall zone (HRZ), it is important that there are agronomy packages available that suit each variety to maximise production and profitability. In the 2017 season, SFS created a new system of running variety trials, and now creates tailored agronomic packages for varieties with different levels of input management across existing and upcoming wheat and barley varieties, that are grown in the HRZ, including Tasmania. These trials, along with other GRDC projects such as DAN0017 Barley Agronomy, are helping to build a strong database of knowledge for targeted variety management, which will give advisers and growers confidence to try new varieties as they come to the table.

To determine input levels for the agronomy packages, pre-set yield targets were created for standard and fully managed input treatments:

- barley trials were aiming for 9t/ha yields in fully managed input treatments, and 6t/ha for standard input treatments; and
- in the wheat trials, 10t/ha was the target for fully managed treatments, and 7t/ha was the target for standard input treatments.

Once yields were determined, inputs such as fertiliser, fungicide and plant growth regulators (PGRs) were altered accordingly. Treatments that received higher inputs were pushing for maximum yield potential, while standard management input decisions were based on the likelihood of receiving an economic return.

Table 1. SFS wheat variety TOS dates.				
Location	Inverleigh		Westmere	
Time of Sowing	TOS1	TOS2	TOS1	TOS2
Date	23/04/2017	12/05/2017	2/05/2017	16/05/2017

This paper utilises the data from these management trials in 2017 with some references to SFS and GRDC NVT trial results from the Western districts in 2016.

Wheat trials

Trial setup

In the 2017 season, SFS ran a number of wheat variety management trials consisting of both existing and upcoming varieties that are suited to the HRZ. The trials were repeated at two times of sowing (TOS) at SFS sites across the Western district. Trials varied in design, depending on entries, either split plot factorial which included two different levels of management or randomised complete block with a single management level.

Table 2. Complete list of wheat varieties tested.

Variety	Supplying company
ADV 11.9419	DOW
LRPB Beaufort⦶	Grainsearch
Beckom⦶	AGT
Coolah⦶	AGT
Cutlass⦶	AGT
DS Pascal⦶	DOW
EDGE06-18b-10	Edstar
Jet	Edstar
LRPB Kittyhawk⦶	AGF
Manning⦶	Grainsearch
Longsword⦶	AGT
SQP Revenue⦶	Grainsearch
RGT Accroc⦶	Seed Force
SF Adagio	AGF
Sunlamb⦶	AGT
LRPB Trojan⦶	AGF
Zircon	Edstar

Nitrogen management

The previous crop at both the Westmere and Inverleigh sites was faba beans which were brown manured at late flowering. Available nitrogen (N) at sowing in the top 60cm at Inverleigh was 188kg N per hectare, and 80kg N per hectare at the Westmere site. Nitrogen (N) applications were applied at GS31 with a further application post GS32 for fully managed input treatments.

Varietal performance

SQP Revenue⦶ followed on its strong performance at the Westmere site in 2016 by being the top yielding variety in the early sown Westmere trial in 2017 under both management strategies, with an overall yield of 8.35t/ha. It was, however, not significantly ($p<0.05$) higher yielding at this site in 2017, under the standard management, or 2016 than RGT Accroc⦶ or ADV 11.9419 under the full management and 2016. Only four varieties in the fully managed strategy gave a significant ($p<0.05$) yield improvement over the standard approach — LRPB Trojan⦶, LRPB Beaufort⦶, Longsword⦶ and LRPB Kittyhawk⦶.

Results for the early sown trial at Inverleigh were affected by significant soil wash from a 56mm rain event one day after sowing, but RGT Accroc⦶ still yielded 9.55t/ha under the fully managed strategy and only 0.25t/ha less under the standard management. DS Pascal⦶ yielded considerably better at the Inverleigh site, which may suggest it was adversely affected by the frost at Westmere. Only four varieties in the fully managed strategy gave a significant ($p<0.05$) yield improvement over the standard approach — LRPB Trojan⦶, Beaufort⦶, Longsword⦶ and Zircon. Interestingly, the three varieties LRPB Trojan⦶, Beaufort⦶ and Longsword⦶ were the only varieties in the fully managed strategy that gave a significant ($p<0.05$) yield improvement over the standard approach at both sites suggesting something in the additional inputs was producing additional yield.

Table 3. Wheat variety yield results TOS 1 Inverleigh and Westmere, including 2016 results from Westmere.

Variety	Westmere 2017 Fully managed	Westmere 2017 Standard	Westmere 2016 (t/ha)
SQP Revenue⁽ᵈ⁾	8.35 a	8.35 a	9.4 a
Zircon	8.35 a	8.05 ab	6.9 de
ADV 11.9419	8.03 ab	7.73 b-e	8.7 ab
LRPB Trojan⁽ᵈ⁾	7.95 abc	7.23 fgh	Not entered
Sunlamb⁽ᵈ⁾	7.95 abc	7.95 abc	Not entered
Beaufort⁽ᵈ⁾	7.83 bcd	7.15 gh	8.4 abc
Manning⁽ᵈ⁾	7.83 bcd	7.93 abc	Not entered
RGT Accroc⁽ᵈ⁾	7.70 b-f	8.10 ab	9.2 a
Longsword⁽ᵈ⁾ (RAC2341)	7.63 b-g	6.88 hi	Not entered
Jet	7.50 c-g	7.38 d-g	9.1 a
SF Adagio	7.28 e-h	7.30 e-h	Not entered
LRPB Kittyhawk⁽ᵈ⁾	6.45 ij	5.95 kl	7.15 cde
EDGE06-18b-10	6.23 jk	6.18 jk	7.4 be
DS Pascal⁽ᵈ⁾	5.53 l	5.58 l	Not entered
LSD	0.49	0.49	1.4
p-value	0.04	0.04	0.0002

**Treatments with same letter do not significantly differ when p=0.05*

Table 4. Wheat variety yield results TOS 1 Inverleigh and Westmere, including 2016 results from Westmere.

Variety	Inverleigh 2017 Fully managed	Inverleigh 2017 Standard	Inverleigh 2016(t/ha)
SRGT Accroc⁽ᵈ⁾	9.55 a	9.30 ab	10.37 a
ADV 11.9419	8.85 bc	8.40 cd	Not entered
DS Pascal⁽ᵈ⁾	7.90 def	8.18 de	Not entered
Beaufort⁽ᵈ⁾	7.88 d-g	7.13 h-m	Not entered
Manning⁽ᵈ⁾	7.68 e-h	7.48 f-i	9.73 abc
LRPB Kittyhawk⁽ᵈ⁾	7.63 e-i	7.23 g-k	Not entered
Zircon (EDGE06-039-13	7.53 e-i	6.46 mno	Not entered
SF Adagio	7.40 f-j	7.63 e-i	9.27 b-e
Jet (EDGE06-025-03)	7.20 h-k	7.18 h-l	Not entered
Revenue⁽ᵈ⁾	6.98 i-n	6.60 k-n	9.03 c-f
LRPB Trojan⁽ᵈ⁾	6.76 j-n	5.25 q	9.10 cde
Longsword⁽ᵈ⁾ (RAC2341)	6.53 l-o	5.70 pq	Not entered
Sunlamb⁽ᵈ⁾	6.38 no	5.93 op	7.47 h
LSD	0.67	0.670.72	
p-value	0.02	0.02	0.0001

**Treatments with same letter do not significantly differ when p=0.05*

Table 5. Wheat variety yield results TOS 2 Inverleigh and Westmere 2017.

Variety	Westmere 2017 (t/ha)	Westmere 2016 (t/ha)	Inverleigh 2017 (t/ha)
Cutlass⁽ᵖ⁾	7.9 a	Not entered	8.6 bc
Jet	7.3 ab	Not entered	9.4 a
Zircon	7.3 ab	Not entered	8.4 c
Longsword⁽ᵖ⁾	6.8 bc	Not entered	8.4 c
LRPB Beaufort⁽ᵖ⁾	6.8 bc	9.2 b	9.3 ab
LRPB Trojan⁽ᵖ⁾	6.5 bc	8.6 bcd	9.2 ab
Coolah⁽ᵖ⁾	6.5 bc	Not entered	8.9 abc
Beckom⁽ᵖ⁾	6.3 cd	7.6 fg	8.6 bc
DS Pascal⁽ᵖ⁾	5.7 d	8.4 cde	9.5 a
HIL 049	Not entered	Not entered	8.4 c
EDGE06-18b-10	5.6 d	7.3 g	Not entered
LSD	0.8	0.7 0.725	
p-value	0.0001	0.0001	0.014

**Treatments with same letter do not significantly differ when p=0.05*

TOS effect

Earlier sowing time showed improvements in some varieties at the Westmere site due to flowering and grain fill being less impacted by frost events. At the Inverleigh site, large rain events prior to sowing meant that the earlier sown varieties experienced severe soil wash, resulting in a stronger yield performance in the later sown trial.

Fully managed and standard input results

Yield and protein

Where the two management strategies were used, fully managed input treatments yielded significantly ($p<0.05$) higher than standard input treatments in all trials in 2017. On average, proteins were higher in fully managed input treatments across all varieties, however as there was some spread of yield between fully managed and standard treatments, it seems that extra N that was applied to fully managed input treatments post GS32 has increased protein.

The input cost/ha for standard input treatments was $559, while input cost/ha for fully managed input treatments was $700. These prices include an identical herbicide regime, but different fertiliser, fungicide and PGR rates. A contract price for machinery was included per application.

Given these values and prices for feed and milling wheat per tonne from 2017, the extra yield per hectare required to cover the added cost of fully managed input treatments can be calculated. These costs have been outlined in Table 8.

Table 6. Yield performance of fully managed and standard management trials when all varieties are combined.

Management strategy	TOS 1 Westmere	TOS 1 Inverleigh
Fully managed	7.47 a	7.56 a
Standard	7.27 b	7.11 b
LSD	0.13	0.19
***p*-value**	0.0034	0.0001

**Treatments followed by same letter do not significantly differ when p=0.05*
Economic breakdown of fully managed and standard inputs

Table 7. Economic breakdown ($/ha) of fully managed and standard inputs Inverleigh wheat trials.

Grade	Trial	M'ment Strategy	Seed	Chem	Fert	Mach	Total cost	Income	Gross Margin $/ha
H2	TOS 1 WHT INV	Full	70	212	221	197	700	1892	1192
	TOS 1 WHT INV	Standard	70	183	137	169	559	1768	1209
	TOS 2 WHT INV	Standard	70	183	137	169	559	2216	1657
APW1	TOS 1 WHT INV	Full	70	212	221	197	700	1805	1105
	TOS 1 WHT INV	Standard	70	183	137	169	559	1686	1127
	TOS 2 WHT INV	Standard	70	183	137	169	559	2114	1555
FED1	TOS 1 WHT INV	Full	70	212	221	197	700	1607	907
	TOS 1 WHT INV	Standard	70	183	137	169	559	1502	943
	TOS 2 WHT INV	Standard	70	183	137	169	559	1882	1323

Table 8. Yield required to cover cost of fully managed inputs per hectare.

Cost difference between fully managed and standard inputs	**$141**	
Wheat price	$249 (H2)	$211.5 (Feed)
Additional yield required to cover cost of full inputs	$141/249 = **0.5t/ha**	$141/$211.5 = **0.6t/ha**

Table 9. SFS barley variety trial sowing dates.

Location	Inverleigh		Westmere	
Time of sowing	TOS1	TOS2	TOS1	TOS2
Date	7/05/2017	17/05/2017	2/05/2017	16/05/2017

When variety and input effects are combined, results show that economic benefits between fully managed and standard inputs are variety specific, however on average, the best returns were gained from the standard level of inputs.

Barley trials

Trial setup

In the 2017 season, SFS ran four barley variety trials consisting of nine existing and upcoming varieties that are suited to the HRZ. The trials were repeated at two TOS at the Westmere and Inverleigh trial sites, in the Western districts. Trials were a split plot design, and each variety was tested with two different levels of management as outlined earlier.

Table 10. Varieties tested in fully managed and low management variety trials.

Alestar$^{\phi}$	Edstar
Topstart$^{\phi}$	Edstar
Oxford	Edstar
Bottler	Grainsearch
Westminster$^{\phi}$	Grainsearch
IGB1305	Intergrain
Rosalind$^{\phi}$	Intergrain
Kiwi	Malteurop
RGT Planet$^{\phi}$	Seed Force

Nitrogen management

The previous crop at Westmere was faba beans that was brown manured, while at Inverleigh the previous crop was oaten hay. Available N in the top 60cm at Inverleigh was 121kg N per hectare and coincidentally, the same at the Westmere site. Nitrogen applications were split into two different timings — mid tiller and GS31. Fully managed input treatments received 20% of their total N requirement at mid tiller, and the remaining 80% at GS31. Treatments under the standard input program received 30% of their N requirement at mid tiller, and the remaining 70% at GS31.

Varietal performance

High yields were achieved, despite the Westmere trials being impacted by frost events in early November. Some varieties at Inverleigh achieved malting quality, but would currently be binned as F1 due to these varieties still awaiting malt-accredited status, apart from Westminster$^{\phi}$ which achieved a malt grade in the early TOS.

RGT Planet$^{\phi}$ was a standout variety in 2017, yielding the highest at Inverleigh across both TOS, and in the early TOS at Westmere. Rosalind$^{\phi}$ was also consistent and yielded the greatest in the second TOS at Westmere. The early maturing characteristic of Rosalind$^{\phi}$ allowed it to complete most of its grain fill before November frost events, meaning it had a heavier test weight at this TOS compared to all other varieties.

These results are consistent with NVT results in 2016, with RGT Planet$^{\phi}$ and Rosalind$^{\phi}$ holding the highest NVT site mean % at Inverleigh and RGT Planet$^{\phi}$ at Streatham. Results from Streatham in 2017 have not been included as they will be part of the frosted report.

TOS effect

At Westmere, the average yield of all varieties sown at the earlier sowing time was 0.4t/ha greater than when sown two weeks later, when management levels were combined. The results from Westmere follow on from data gained in the 2016 SFS variety trials at that site, where the earlier TOS averaged 1t/ha more yield on average. This result is also supported by a further TOS barley trial that was run at the Westmere site as a part of the GRDC Barley Agronomy Project (DAN000173), which achieved a significant result of 1.1t/ha more from early May sowing compared to mid-May in 2017.

Table 11. Variety yield results Inverleigh and Westmere (combining both management strategies) including 2016 results from Westmere.

Variety	Inverleigh		Westmere			
	2017 TOS1 (t/ha)	2017 TOS2 (t/ha)	2017 TOS1 (t/ha)	2016 TOS1 (t/ha)	2017 TOS2 (t/ha)	2016 TOS2 (t/ha)
RGT Planet(l)	10.0 a	9.9 a	8.6 a	Not entered	7.7 ab	9.0 a
Rosalind(l)	8.9 b	8.9 c	8.3 ab	8.3 ab	8.3 a	6.4 ef
Bottler	8.7 bc	9.1 bc	8.1 abc	Not entered	7.4 b	8.1 b
Oxford	8.5 bc	8.5 d	7.6 bcd	9.0 a	7.1 bc	8.0 b
Alestar(l)	8.7 bc	8.2 e	7.6 cd	7.8 bc	7.0 bc	6.7 de
Topstart(l)	8.9 b	9.4 b	7.2 de	Not entered	7.1 bc	Not entered
Kiwi	8.3 cd	8.5 de	7.1 de	Not entered	6.4 c	Not entered
IGB1305	8.3 cd	8.5 de	6.6 ef	7.4 cd	7.4 b	6.6 de
Westminster(l)	7.8 d	8.4 de	6.4 f	8.2 abc	5.5 d	7.0 cde
LSD	0.56	0.35	0.67	0.80	0.79	0.92
p-value	0.0001	0.0001	0.0001	0.0017	0.0001	0.0001

**Treatments with same letter do not significantly differ when p=0.05*

Fully managed and standard input results

Yield and protein

Fully managed input treatments yielded significantly ($p<0.05$) higher than standard input treatments in all barley trials in 2017.

Fully managed inputs were shown to significantly increase test weights in later sown trials and significantly increased protein across all trials (refer Table 8). Although proteins did increase with higher inputs, they did not indicate that excess N was utilised for grain protein rather than yield. With new feed barley varieties possessing strong yield potentials, there is merit in pushing N applications to achieve greater yields, rather than limiting N to contain protein within malting specifications. For further discussion on this topic, please refer to the SFS report 'Barley-Malt or Feed' available in the resources section.

The input cost for standard input treatments was $405/ha, while input cost for fully managed input treatments was $510/ha. These prices include an identical herbicide regime, but different fertiliser, fungicide and PGR rates. A contract price for machinery was included per application.

Table 12. Yield, test weight and protein performance of fully managed and standard management levels Inverleigh.

Management Strategy	TOS 1			TOS 2		
	Yield (t/Ha)	Test weight (kg/hL)	Protein (%)	Yield t/Ha	Test weight (kg/hL)	Protein (%)
Fully managed	8.9a	63a	11.1a	9.1a	63a	10.4a
Low	8.5b	63a	10.4b	8.5b	62b	9.7b
LSD	0.2	0.52	0.36	0.17	0.6	0.5
CV %	4.6 %	1.7 %	6.9 %	1.6 %	2.7 %	9.3 %
p-value	0.0002	0.4	0.0001	0.0001	0.0087	0.0018

**Treatments followed by same letter do not significantly differ when p=0.05*

Economic breakdown of fully managed and standard inputs

Table 13. Economic breakdown of fully managed and standard input treatments Inverleigh ($/ha)

Grade	Trial	Treatment	Seed	Chem	Fert	Mach cost	Total cost	Income	Gross Margin
Malt	TOS 1 INV	Full	85	164	174	187	610	$2,380	$1,770
F1	TOS 1 INV	Full	85	164	174	187	610	$1,988	$1,379
	TOS 1 INV	Standard	85	89	137	177	488	$1,857	$1,370
	TOS 2 INV	Full	85	164	174	187	610	$1,988	$1,379
	TOS 2 INV	Standard	85	89	137	177	488	$1,857	$1,370

Table 14. Yield required to cover cost of high inputs per hectare.		
Cost difference between standard and fully managed inputs	**$122**	
Barley price at two quality levels	$219 (Feed)	$262 (Malt)
Yield required to cover cost of high inputs (t/ha)	$122/$219 = **0.6 t/ha**	$122/$262 = **0.5t/ha**

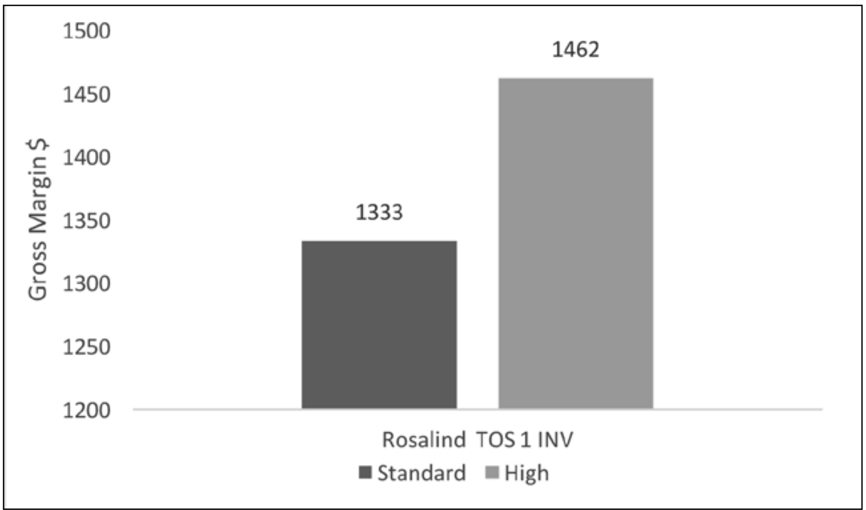

Figure 1. Rosalind⁽ᵖ⁾ margin in early sown trial Inverleigh.

Given these values, and prices for feed and malt barley per tonne from 2017, the extra yield per hectare required to cover the added cost of fully managed input treatments can be calculated — Table 10 below illustrates this.

When variety and input effects are combined, results show that economic benefits between fully managed and standard inputs are variety specific.

The varieties that achieved the strongest economic benefits between fully managed and standard input treatments were Rosalind⁽ᵖ⁾, Bottler, Westminster⁽ᵖ⁾ and Alestar⁽ᵖ⁾ across the Inverleigh site. An example of this is given in Figure 1, where Rosalind⁽ᵖ⁾ achieved an average yield of 1.2t/ha more with fully managed inputs in the earlier sown trial, resulting in an increase of $129 per hectare.

Useful resources

http://www.sfs.org.au/trial-result-pdfs/Trial_Results_2013/2013_BarleyMaltOrFeed_VIC.pdf

Acknowledgements

SFS would like to acknowledge the GRDC for its investment into the Barley Agronomy Project (DAN00173) trials referenced in this report, and the contributing breeders for co-funding the SFS trials. We would also like to thank our host growers — the Hamilton family of Inverleigh, the McCrow family of Westmere, and the Herrmann family of Tarrington.

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Return to contents

Notes

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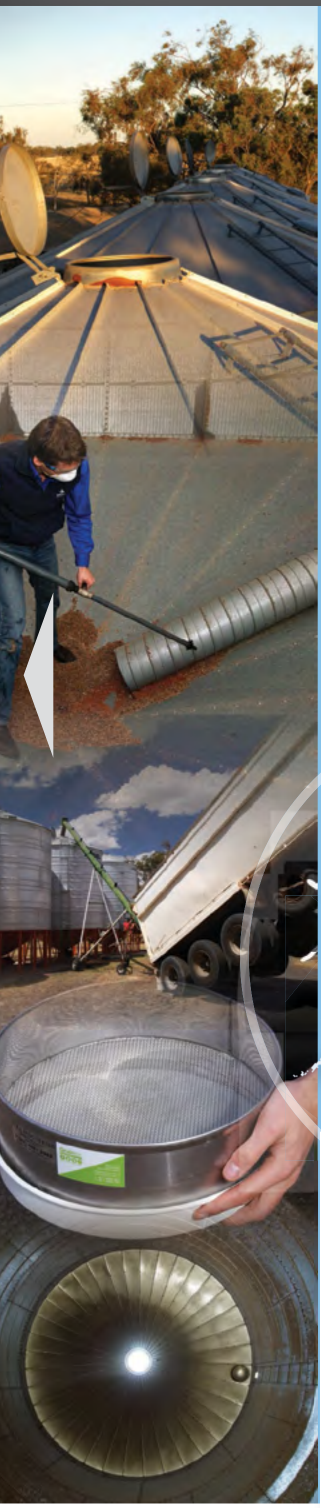

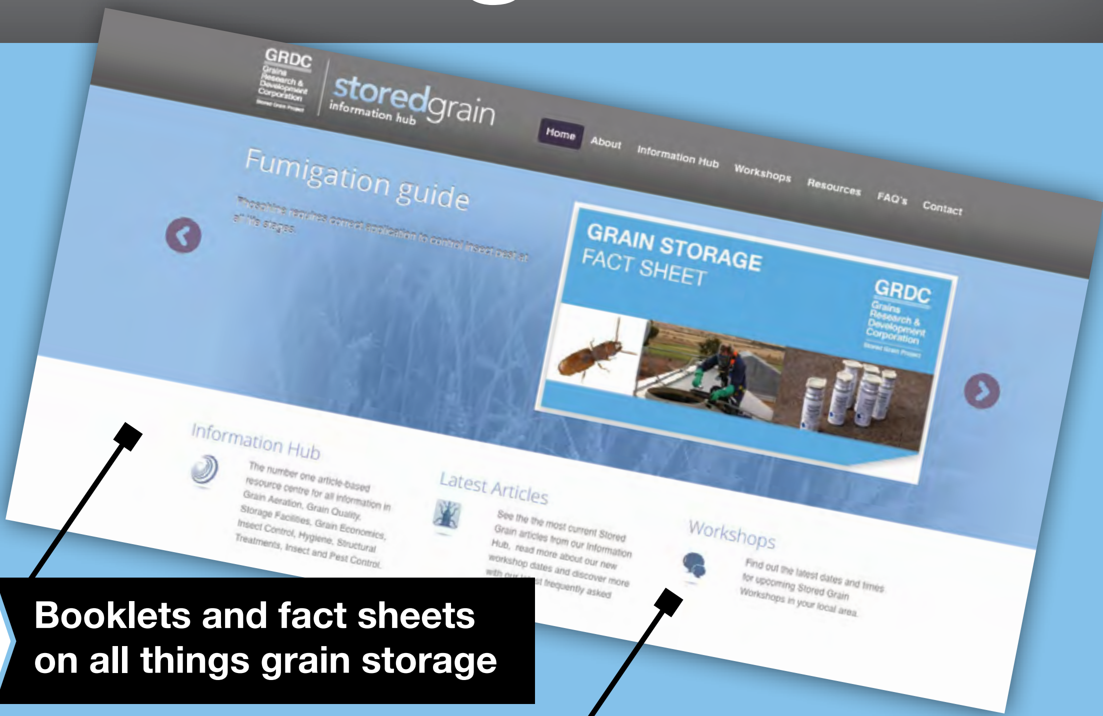

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Hyper Yielding Cereal Project - what has performed well over two contrasting seasons?

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[Φ]Extra technical comment by Protech Consulting Pty Ltd

GRDC project code: FAR00003

Keywords

- new feed wheat and barley germplasm, fungicide resistance, Septoria tritici blotch (STB), *Zymoseptoria tritici*, leaf rust, Puccinia triticina, lodging, flowering date.

Take home messages

- In 2017 second year research results from the Hyper Yielding Cereals (HYC) project produced maximum yields of wheat of 13t/ha with above average temperatures during grain fill and a generally harder finish.
- With the barley research, despite two contrasting seasons the same three cultivars topped the yield rankings, these were RGT Planet⦶, RGT Conquest and the faster developing cultivar Rosalind⦶.
- Shorter season wheat cultivars Annapurna and AGTW001 performed well irrespective of sowing date with similar or higher yields to last year's high fliers; RGT Relay, RGT Accroc, Genius, Conqueror and RGT Calabro at the first sowing date in early April.
- RGT Relay again showed good standing power and excellent Septoria tritici blotch (STB); *Zymoseptoria tritici* resistance but showed good yield responses to late fungicide control of leaf rust; *Puccinia triticina*.
- RGT Accroc has produced high yields in both 2016 and 2017 but again showed a weakness in straw strength.
- From the 2017 results it was difficult to establish a clear relationship between optimum flowering date and final yields since cultivars flowering from late October to mid November produced good yields. In part this may be related to the impact of irrigation which tends to assist cultivars that might otherwise be penalised in a dryland system because of their later development.

Background

Despite a more suitable climate for grain production than the mainland and a much higher yield potential, the average yield of red grain feed wheat in Tasmania is still around 5t/ha. While this has increased relatively more than the other states in the last 20 years (ABARES) it is still felt to be well below the potential. The Hyper Yielding Cereals (HYC) project funded by GRDC and led by FAR Australia in collaboration with Southern Farming Systems (SFS) aims to make Tasmania less reliant on grain supplied from mainland Australia through increased productivity of wheat and barley. Using the collaboration of international, national, local expertise and breeders, the five-year project is working to close the yield gap between actual and potential yields as well as using links with end users to promote the value of trading quality feed grains.

In 2017 the Hyper Yielding research centre at Hagley, Tasmania was composed of 1000 experimental research plots dedicated to identifying new cereal lines and agronomy strategies that could lift feed grain productivity.

In 2016 first year research results from the project set new benchmarks for the yield performance of feed wheat with plot yields in excess of 15t/ha. The soft finish and high rainfall experienced during 2016 was in stark contrast to 2017 when low rainfall, higher temperatures and late frosts affected the grain fill period. In many ways the contrast of the 2016 and 2017 seasons has been useful in determining which new cultivars and lines have performed well in both seasons.

2016 and 2017 climatic conditions

2017 differed in three principal ways from 2016 at the Hyper Yielding research centre; firstly, instead of warmer temperatures over autumn and early winter, cooler minimum temperatures prevailed (Figure 1a and 1b). One of the primary initial effects was to slow down growth from the late April sown crops (27 April) relative to those sown early in April (6 April). It also resulted in significantly less leaf rust infection (*Puccinia triticina*) in the early wheat sowings, a fact that appeared to indicate the importance of autumn infection in order to generate severe leaf rust infections in Tasmania. Despite the late leaf rust infection, the disease did not influence research results at the centre. Secondly, the temperatures for the grain fill period for the wheat crops in

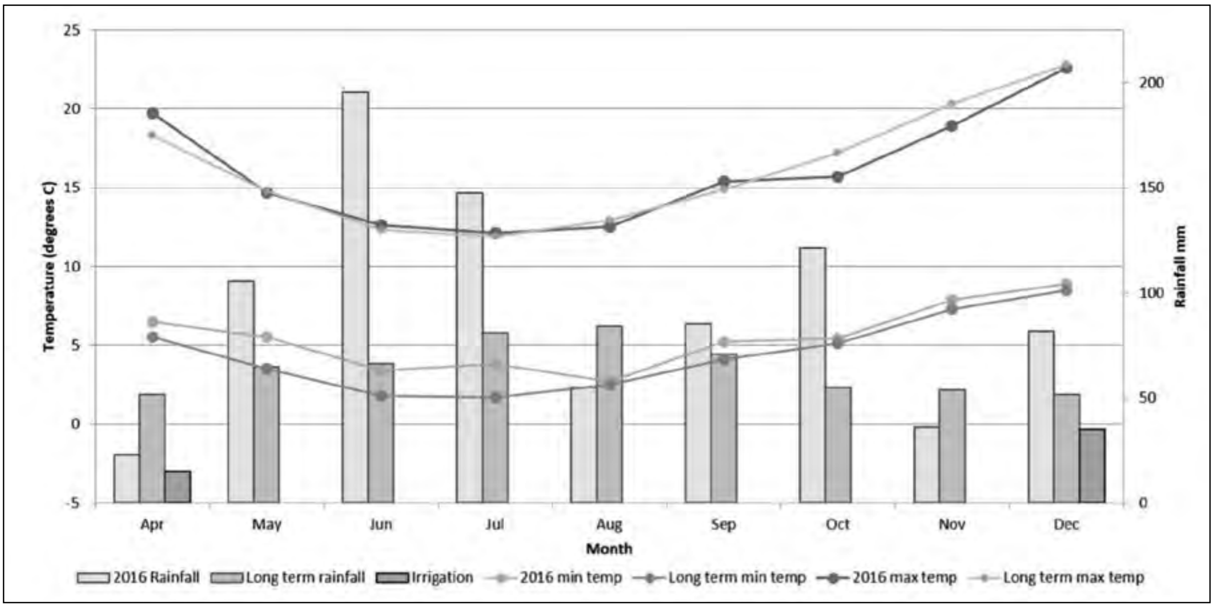

Figure 1(a). 2016 climatic data for the Hyper Yielding Cereal site at Hagley, Tasmania.

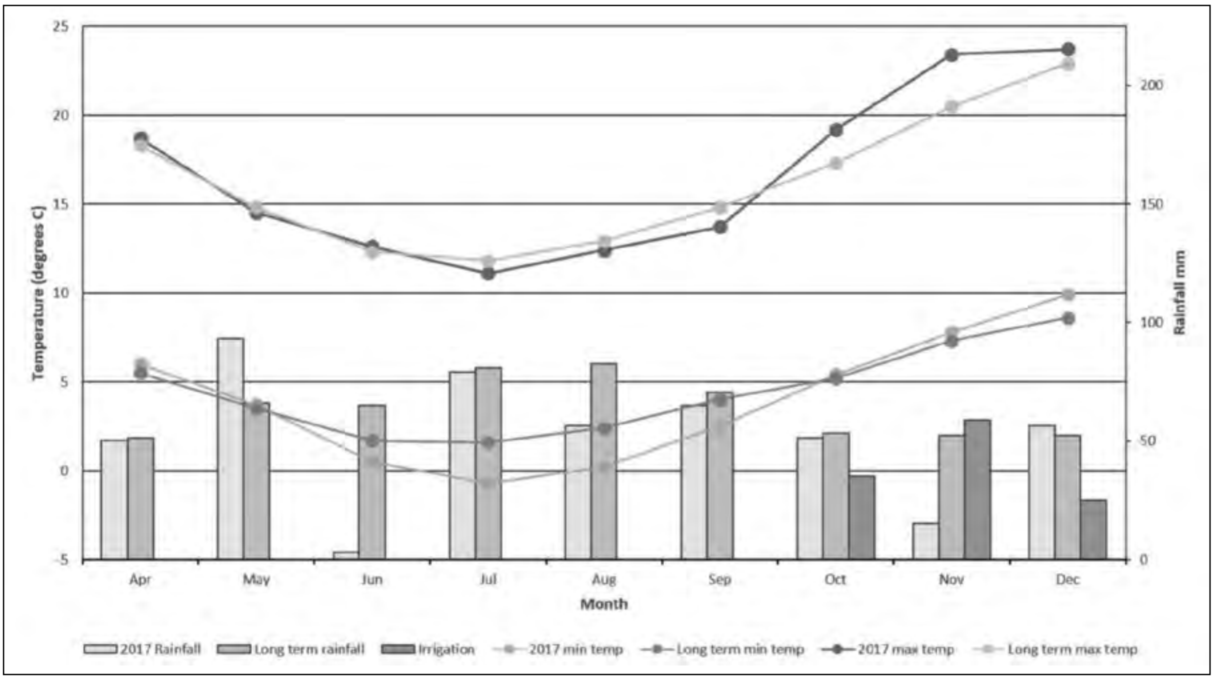

Figure 1(b). 2017 climatic data for the Hyper Yielding Cereal site at Hagley, Tasmania.

particular, was well above the long-term maximums for Tasmania. In November these high temperatures combined with below average rainfall, made it difficult for on-farm irrigation systems to keep up with soil water demand. Lastly, although regions were affected by frost during flowering and early grain fill, results were not severe at the research site as elsewhere in the state, although grain sample screenings were increased from an average of 1.5 to 2.0% in 2016 to between 4 to 6% in 2017.

Research conducted in 2017

A series of 10 field research trials covering 1000 plots were established in Year 2 to service germplasm screening and the agronomy objectives of the project. The initial 16 cultivars/lines provided by the breeders for the early sowing window (6 April) were narrowed down to four, with a further 16 cultivars that had not been sown early in 2016 tested at this sowing date for the first time. These 16 cultivars evaluated for the first time in 2017 either showed promise in the later sowing (27 April) last year or were thought to have been more suitable for early sowing due to longer season phenology (established in year 1). The four core elite cultivars plus the controls SQP RevenueⒹ and ManningⒹ were run under three different management approaches in order to further reveal their suitability

Table 1. Grain yield (t/ha), % Site Mean, Protein, test weight and screenings of the elite wheat germplasm under three management levels, sown 6 April, harvested 23 January.

Management Level		Grain Yield		Grain Quality		
	Variety	Yield (t/ha)	Site Mean (%)	Protein %	Test wt Kg/hL	Screenings %
High	ManningⒹ	11.50 ab	106.3	11.0 a-e	75.8 a	3.3 ab
	SQP RevenueⒹ	9.32 g	86.2	10.5 de	72.7 ab	4.6 a
	Genius	11.35 abc	105.0	10.9 a-e	71.4 ab	4.5 a
	Conqueror	11.53 ab	106.7	11.1 a-d	70.2 ab	3.8 ab
	RGT Accroc	11.66 a	107.8	10.9 a-e	75.5 a	3.2 ab
	RGT Relay	11.29 abc	104.5	11.2 abc	70.8 ab	3.8 ab
	Mean	**11.11 a**	**102.7**	**10.9 a**	**72.7 a**	**3.9 a**
Standard	ManningⒹ	11.28 abc	104.0	11.3 abc	74.8 a	3.9 ab
	SQP RevenueⒹ	8.75 h	80.9	10.7 b-e	75.2 a	3.4 ab
	Genius	11.32 abc	104.6	10.8 b-e	71.3 ab	4.5 a
	Conqueror	11.33 abc	104.5	11.5 a	75.2 a	3.6 ab
	RGT Accroc	10.59 e	97.8	11.3 ab	71.5 ab	2.5 b
	RGT Relay	11.45 abc	105.6	11.0 a-e	73.6 a	3.9 ab
	Mean	**10.78 b**	**99.6**	**11.1 a**	**73.6 a**	**3.7 a**
Grazed	ManningⒹ	10.82 de	99.8	10.6 cde	75.7 a	4.4 a
	SQP RevenueⒹ	9.81 f	90.5	10.5 de	71.4 ab	4.2 a
	Genius	10.02 f	92.6	10.4 e	70.2 ab	4.3 a
	Conqueror	10.60 e	97.9	11.1 a-d	72.5 ab	4.3 a
	RGT Accroc	11.07 cd	102.2	10.9 a-e	67.5 b	3.2 ab
	RGT Relay	11.18 bcd	103.3	11.1 a-d	69.9 ab	3.5 ab
	Mean	**10.58 b**	**97.7**	**10.7 a**	**71.2 a**	**4.0 a**
Mean (High)		11.11 **a**	102.7	**10.9 a**	**72.7 a**	**3.9 a**
Mean (Standard)		10.78 **b**	99.6	**11.1 a**	**73.6 a**	**3.7 a**
Mean (Grazed)		10.58 **b**	97.7	**10.7 a**	**71.2 a**	**4.0 a**
LSD Mgmt p = 0.05		**0.28**		0.4	4.5	0.7
LSD Variety p = 0.05		**0.23**		0.4	3.4	0.9
LSD Var x Mgmt P=0.05		**0.40**		0.7	5.9	1.6
P Val Mgmt		**0.011**		0.238	0.458	0.562
P Val Variety		**<0.001**		0.011	0.116	0.080
P Val Var x Mgmt		**<0.001**		0.841	0.456	0.861
CV		**2.6**		4.4	5.8	29.5

Notes: Figures followed by different letters are considered to be statistically different (p=0.05)
*Letters following mean figures in **bold** are only comparable to other **bold** letters in the same column/row.*

Table 2. Detail of management levels applied to the Management x Cultivar trial – sown 6 April

Sowing date:		6-April		
Plant population:		Target of 180 plants/m^2 (mean of 116 plants/m^2 established)		
Sowing Fertiliser:		100kg MAP		
Management:		High	Standard	Grazed
Grazing:		----	----	17-May & 14-Aug
Nitrogen:	27 July	46kg N	46kg N	46kg N
	31 August	160kg N	92kg N	92kg N
	19 September	92kg N	92kg N	92kg N
PGR:	9 August	Moddus Evo 200ml & Errex 650ml	----	----
	19 September	Experimental 1	Moddus Evo 200ml & Errex 1300ml	Moddus Evo 200ml & Errex 1300ml
	3 October	Experimental 2	----	----
Fungicide:	9 August	Opus125 500ml		
	6 September	----	Opus125 500ml	Opus125 500ml
	19 September	Prosaro 300ml & Hasten[Φ] 1% v/v	----	----
	20 October	Radial 840ml	Radial 840ml	Radial 840ml
	11 November	Prosaro 300ml	Prosaro 300ml	Prosaro 300ml
Insecticide:	15 May	Karate Zeon 0.04L/ha + Kontrace 3.0L/ha		
	5 June	Karate Zeon 0.04L/ha + Kontrace 2.4L/ha		
Irrigation:	23 October	18mm		
	30 October	17mm		
	9 November	25mm		
	29 November	18mm		
	30 November	16mm		
	20 December	25mm		

[Φ]Trial purposes only as label states that Hasten is only for use with Prosara at 150ml. In commercial situations please adhere to label recommendations

or otherwise for the early April sowing date. The three management levels of input were i) grazed (mechanically defoliated twice) with standard input ii) standard input alone and iii) high input where extra nitrogen, plant growth regulators (PGRs) and fungicide input were applied. The trial resulted in a significant ($p=<0.001$) interaction between cultivar and management applied (Table 1 and 2), meaning that cultivars responded differently to the management regimes imposed. The yields of the four elite cultivars selected from 2016 yielded between 10.02 to 11.66t/ha. The top yield of 11.66 t/ha (RGT Accroc) was 2.78t/ha less than the highest yield achieved in 2016 when RGT Relay yielded 14.44t/ha at the early sowing date. RGT Accroc was significantly higher yielding where it was grazed or treated with higher input, a result principally correlated to lower lodging in these two management regimes. In contrast, in the stiffer strawed, slower developing, more disease resistant variety RGT Relay there were no significant differences in yield amongst the three management regimes applied, with less than 0.3t/ha difference in the three strategies. In part the slower development resulted in reduced dry matter removal from the 'grazed' plots and extra PGR input was not required.

At the early sowing date in 2017 Relay yielded 3t/ha less than 2016. SQP Revenue(D) was the only cultivar to give significantly higher yields under grazing management, a result that correlated to lower levels of lodging and lower disease pressure in these defoliated crops. Protein levels were mainly in the range of 10.7 to 11.1% suggesting that yield was optimised for the site with the nitrogen levels applied. There were no significant effects of management strategy on the quality parameters of protein, test weight or screenings, but results on test weight were very variable and indicated some possible frosting damage.

The input levels for the three management regimes for the 6 April sowing date are outlined in Table 2.

In neighbouring trials looking at the 16 cultivars sown at the same early April sowing, yield results and phenology data revealed some surprising results with more rapid developing cultivars, such as AGTW001 and Annapurna either outperforming or giving comparable performance to the longer season elite lines selected from 2016 (Table 3), even though the flowering phenology of the cultivars was far earlier. Only RGT Accroc, Annapurna and

AGTW001 had passed the mid flower point (GS66-71) on 1 November. All other cultivars in Table 3 were at various stages of head emergence (GS51-59) with the exception of RGT Relay that was still at the late booting stage and did not start flowering until 17 November. RGT Calabro was at GS59 (full head emergence) on 1 November. The poor quality of the samples is part a reflection of partial frosting and partially the particular plot header. One of the major considerations for the early sowing window is stiff straw and good disease resistance when sowing early. Since many of the cultivars tested on 6 April 2017 had not been tested at this sowing date in 2016 the varieties were also grown in an untreated screen with no PGR and fungicide applied. Only the cultivars that lodged in this screen or in the yield trials sown at the same time are featured in Figure 2.

Table 3. Grain yield (t/ha), % Site Mean, % grain protein and % screenings

Cultivar/Line	Yield (t/ha)		% Site Mean	Protein (%)		Screenings (%)		Lodging index (0-500)	
Annapurna	13.01	a	112.5	11.3	bcd	5.4	bcd	16	de
AGTW-001	12.66	ab	109.6	11.3	bcd	4.8	cd	2	e
RGT Calabro	12.47	abc	107.9	11.7	a-d	5.1	bcd	40	cde
Genius	12.44	abc	107.6	12.3	ab	5.7	a-d	0	e
Manning⁽ᵇ	12.25	bc	106.0	10.8	d	5.6	bcd	15	de
RGT Accroc	12.17	bcd	105.3	11.8	a-d	7.4	abc	68	cde
Conqueror	11.99	b-e	103.7	12.6	a	6	a-d	0	e
JB Asano	11.86	c-f	102.6	12.0	abc	5.4	bcd	0	e
Einstein	11.78	c-f	101.9	11.5	bcd	4.1	d	1	e
BA 26.35	11.49	def	99.4	11.5	a-d	4.7	d	0	e
Mercedes	11.46	ef	99.1	11.3	bcd	7.6	ab	83	cd
RGT Relay	11.44	ef	98.9	11.3	bcd	6.2	a-d	0	e
Viscount	11.20	fg	96.9	11.7	a-d	7.5	ab	64	cde
Oakley	10.52	gh	91.0	11.0	cd	6.5	a-d	113	c
Hereford	10.51	gh	90.9	11.3	bcd	5.1	bcd	1	e
Xi 19	10.36	h	89.6	11.3	bcd	4.2	d	20	de
SQP Revenue⁽ᵇ	9.95	h	86.0	11.6	a-d	4.7	d	205	b
Cordiale	9.87	h	85.4	11.2	bcd	8.2	a	293	a
Mean	11.522		**100**	11.51		5.79		50.97	
LSD p = 0.05	0.704			1.13		2.62		78.38	
P value	<0.001			0.285		0.054		<0.001	

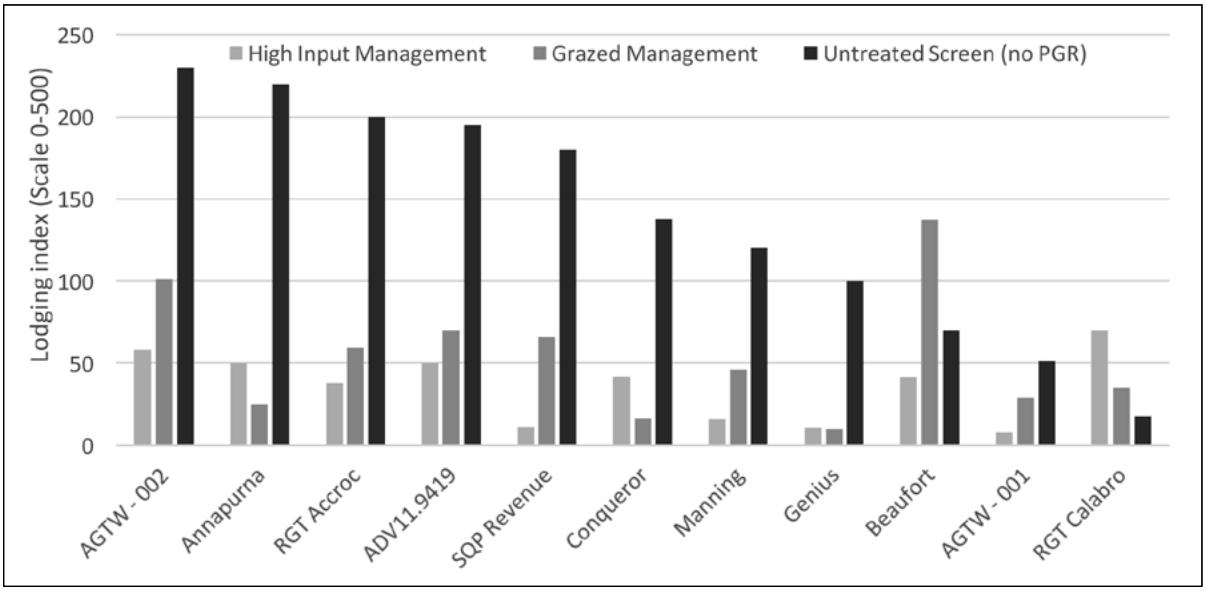

Figure 2. Lodging index (severity x extent – 0 to 500 scale) of cultivars trialled under both the standard and high input management and in the untreated screening trial (with PGR or fungicide) assessed on the 23-24 January just prior to harvest (GS99). Note. Other varieties not shown did not suffer lodging.

Disease resistance when sowing early

The same untreated screen gave an excellent insight into Septoria tritici blotch, *Zymoseptoria tritici* susceptibility when cultivars were sown in the highest risk sowing window (Figure 3). The screen was less reliable in 2017 for generating good leaf rust differences, however there was one exception to this general observation. This concerned RGT Relay that provided excellent STB resistance and stiff straw but did succumb to a very late infection of leaf rust that was not apparent in mid-December 2017, which resulted in significant yield reduction when not controlled (Table 5). Samples of the pathogen on RGT Relay did not reveal a new pathotype as the sample sent was not viable, but both yield and green leaf area were affected by the new year infection timing. At the same time (Jan 5) RGT Accroc, RGT Calabro and Annapurna had in the main, reached physiological maturity. This is an important observation for RGT Relay grown under irrigation, since later cultivar development combined with irrigation may make it particularly responsive to late fungicides for leaf rust control. Similar findings have been observed in New Zealand for similar cultivars grown under irrigation.

Yield potential of early versus late April sowing (6 April versus 27 April) – which was higher yielding in 2017?

In 2016 the late (27 April) sown wheat trials were 2 to 3t/ha higher yielding than the early (6 April) sown wheat trials, with yields in excess of 16t/ha at the later sowing date. A soft finish and higher leaf rust pressure affecting the early sowings appeared to be two primary considerations in 2016 affecting yield. This raises the question whether under a shorter growing season in 2017 with a hotter grain fill period in November was there any advantage to 6 April sowing compared with 27 April sowing growing irrigated wheat at the research centre? Although trials were in the same paddock the following results cannot be statistically compared but represent the best yields from both sowing dates (Table 4). The differences between the two sowing dates in 2017 was relatively small (0.3t/ha) with 13t/ha achieved in both sowing date blocks, and in both cases the same shorter season wheat cultivars were the optimum performers despite the differences in estimated flowering dates between the two sowings. Unfortunately, AGTW001 has been discontinued by the breeder since its stem rust resistance was very poor and not acceptable for the mainland, however Annapurna has been carried through for more detailed agronomy evaluations at the site for 2018/19.

At both sowing dates it was difficult to suggest a strong relationship between flowering date and final yield since at the first sowing date Genius and RGT Calabro performed similarly to AGTW001 in terms of yield, but were considerably later to flower than AGTW001. At the second sowing date the differences between flowering dates was much smaller however AGTW001 and Annapurna performed significantly better than RGT Accroc and RGT Calabro (Table 4). The exact timing of the late frosts interacting with both flowering date and

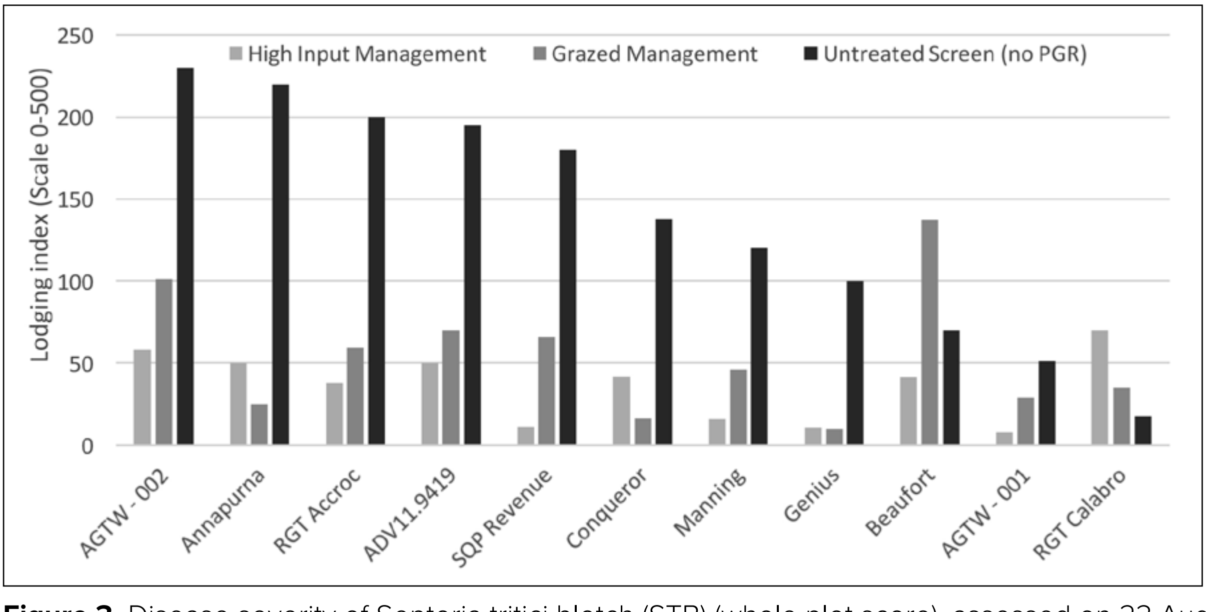

Figure 3. Disease severity of Septoria tritici blotch (STB) (whole plot score), assessed on 23 August (GS26-32), 21 September (GS31-51) and 01 November (GS47-71)

cultivar may help explain some of these differences but it is worth indicating that irrigation itself may obviate some of the differences that might be commonly seen with regard to optimum flowering dates and the relationship with yield in dryland crops. That stated the Tasmanian NVT results for wheat sown in late April/early May concur with the Hyper yielding performance results indicating high yields from RGT Accroc and RGT Calabro.

The lack of a relationship between flowering date and yield in these irrigated trials was further

Table 4. Grain yield (t/ha), % Site Mean, % grain protein and % screenings of the top five cultivars sown in trials on 6 and 27 April.

Cultivar/Line	Yield (t/ha)	% Site Mean	Protein (%)	Screenings (%)	Estimated Flowering (GS65)
Sowing date 1 (6 April)					
Annapurna	13.01	113	11.3	5.4	L.Oct
AGTW-001	12.66	110	11.3	4.8	L.Oct
RGT Calabro	12.47	108	11.7	5.1	E.Nov
Genius	12.44	108	12.3	5.7	M.Nov
ManningⓅ (control)	12.25	106	10.8	5.6	M.Nov
RGT Accroc	12.17	105	11.8	7.4	L.Oct
Conqueror	11.99	104	12.6	6	E.Nov
SQP RevenueⓅ (control)	9.95	86	11.6	4.7	E.Nov
Mean	**12.1**		**11.7**	**5.6**	
Sowing date 2 (27 April)					
AGTW - 001	13.10	116	12.7	3.3	M.Nov
Annapurna	12.81	113	12.3	3.5	E.Nov
RGT Accroc	12.14	107	12	3.3	M.Nov
AGTW - 002	12.03	107	12.6	3.8	E.Nov
RGT Calabro	12.01	106	12.4	2.8	M.Nov
Conqueror	11.53	102	12.3	2.7	M.Nov
ManningⓅ (control)	10.80	96	12.3	3	L.Nov
SQP RevenueⓅ (control)	10.00	89	11.8	4.2	M.Nov
Mean	**11.8**		**12.3**	**3.3**	

Table 5. Grain yield (t/ha), % Site Mean, % grain protein, test weight (kg/hl) and % screenings (selected treatments from larger trial)

Fungicide product, rate (mL/ha) & timing			Yield	Mean	Protein	Test wt.	Screenings
GS31-32	GS39	GS61-65	(t/ha)	(%)	(%)	(kg/hL)	(%)
Cultivar : RGT Accroc							
Untreated			10.23 de	102.3	11.4 a	71.9 a	4.8 bcd
Hornet 145	Opus 500	Hornet 145	10.83 c	108.3	11.6 a	71.2 ab	4 cde
Aviator Xpro 420	Radial 840	Prosaro 300	10.94 c	109.4	11.8 a	72.3 a	3.6 e
Cultivar : RGT Relay							
Untreated			10.51 cd	105.1	10.8 b	67.1 b-e	3.7 e
Hornet 145	Opus 500	Hornet 145	11.67 b	116.7	10.7 b	70.7 ab	3.3 e
Aviator Xpro 420	Radial 840	Prosaro 300	12.62 a	126.2	10.6 b	68.9 abc	3.7 de
Cultivar : SQP RevenueⓅ							
Untreated			8.09 g	80.9	10.4 b	63.1 e	5.7 ab
Hornet 145	Opus 500	Hornet 145	9.15 f	91.5	10.4 b	65.6 cde	5.2 b
Aviator Xpro 420	Radial 840	Prosaro 300	9.84 e	98.4	10.5 b	63.8 de	5.4 ab
LSD 0.05			0.486		0.523	4.57	1.06
P Val			<0.001		<0.001	0.001	<0.001

confounded by the performance of RGT Relay in the early sown fungicide and nitrogen research trials. These trials produced maximum yields of 12.5 to 13.0t/ha, despite a mid-November flowering date (Table 5). As stated earlier RGT Relay while being very resistant to STB, succumbed to a late leaf rust infection in the new year. Samples sent for pathotying were not viable so it remains to be seen whether this is a new issue, however it was not observed in 2016 when early leaf rust pressure was much higher. In 2017 control of late leaf rust gave significant benefits to fungicide programmes based on triazoles, SDHI and strobilurin as opposed to triazole alone.

Higher barley yields compared to 2016

Unlike the wheat trials where yields during 2017 were back to 13t/ha from maximums of 16 to 17t/ha in 2016, the shorter growing season with a hotter grain fill period favoured barley performance at the site. In 2016 the highest yields were generated by RGT Planet⦹, RGT Conquest, and Rosalind⦹ in a soft finish. In 2017 despite a season in stark contrast to 2016 the same three cultivars topped the performance charts but this time with a harder finish and higher yields overall. The different rotation position of ex pyrethrum may have helped, compared to process peas in 2016, however the results were very encouraging not only because of the consistency of variety performance but also the production of yields in excess of 11t/ha.

In the 2018/19 season the HYC project will undertake in depth, agronomic research on the following wheat cultivars: Annapurna, DS Bennett and the RGT lines Accroc, Calabro and Relay (sown 5 April and 26 April, 2018). With the barley component of the research, new winter germplasm sown at the same time is being tested alongside RGT Planet⦹, RGT Conquest and Rosalind⦹ for the very first time.

Come and view the research on Thursday November 15, 2018!

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Return to contents

Notes

The effects of stubble on nitrogen tie-up and supply

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GRDC project codes: CSP186, CSP174

Keywords

- nitrogen, soil organic matter, immobilisation, crop residue, stubble retention.

Take home messages

- Cereal stubble should be thought of as a source of carbon (C) for microbes, not as a source of nitrogen (N) for crops. In no-till systems, only approximately 6% of the N requirement of crops is derived from the stubble.
- Nitrogen tie-up by cereal residue is not just a problem following incorporation — it occurs in surface-retained and standing-stubble systems and can reduce wheat yields by 0.3t/ha to 0.4t/ha.
- Management is reasonably straightforward — supply more N (5kg N for each t/ha of cereal residue) and supply it early to avoid impacts of N tie-up on crop yield and protein.
- Deep-banding N can improve the N uptake, yield and protein of crops, especially those in stubble-retained systems.

Background

Most dryland growers in Australia retain all, or most of their crop residues (wherever possible) to protect the soil, retain soil moisture and maintain soil fertility in the long term. However, a pro-active and flexible approach to stubble management that recognises and avoids situations in which stubble can reduce productivity or profitability makes sense, and has been promoted as part of the GRDC Stubble Initiative (Swan *et al.*, 2017a). One such situation is where large amounts of retained stubble, especially high C:N ratio cereal stubble, 'ties-up' soil N leading to N deficiency in the growing crop that may reduce yield. The timing, extent and consequences of N tie-up are all driven by variable weather events (rainfall and temperature) as well as soil and stubble type, so quite different outcomes may occur from season to season and in different paddocks. In this paper, the process of N tie-up or immobilisation as it is known is reviewed in simple terms, to understand the factors driving it. The results from a series of recent experiments in southern NSW (both long-term and short-term) that serve to illustrate the process are then provided, and the ways in which the negative consequences can be avoided while maintaining the benefits of stubble are discussed.

The process of 'N-tie up' (immobilisation) — put simply

Growers are always growing two crops – the above-ground crop (wheat, canola, lupin, etc.) is obvious, but the below-ground crop (crop roots and the microbes) are always growing as well; and like the above-ground crop they need water, warm temperatures and nutrients to grow (there's as much total nutrient in the microbes/ha as in the mature crop, and two-thirds are in the top 10cm of soil!). There are two main differences between these two 'crops' — firstly the microbes can't get energy (carbon) from the sun like the above-ground plants, so they rely on crop residues as the source of energy (carbon). Secondly they don't live as long as crops — they can grow, die and decompose ('turnover') much more quickly than the plants — maybe two to three cycles in one growing season of the plant. The microbes are thus immobilising and then mineralising N as the energy sources available to them, come and go. In a growing season it is typical for the live microbial biomass to double by consuming C in residues and root exudates — but they need mineral nutrients as well. Over the longer-term the dead microbe bodies (containing C, N, phosphorus (P) and sulphur (S)) become the stable organic matter (humus) that slowly releases fertility to the soil. In the long-term, crop stubble provides a primary C-source to maintain that long-term fertility, but in the short-term the low N content in the cereal stubble means microbes initially need to use the existing soil mineral N (including fertiliser N) to grow, and compete with the plant for the soil N.

A worst-case scenario

That simplified background helps to understand the process of immobilisation, when and why it happens, and how it might be avoided or minimised. Imagine a paddock on the 5 April with 8t/ha of undecomposed standing wheat stubble from the previous crop after a dry summer. A 30mm storm wets the surface soil providing a sowing opportunity. Fearing the seeding equipment cannot handle the residue, but not wanting to lose the nutrients in the stubble by burning, the residue is mulched and incorporated into the soil. A canola crop is sown in mid-April with a small amount of N (to avoid seed burn) and further N application is delayed until bud visible due to the dry subsoil.

In this case, the cereal stubble (high C and low N – usually at a C:N ratio of approximately 90:1) is well mixed through a warm, moist soil giving the microbes maximum access to a big load of C (energy) — but not enough N (microbe bodies need a ratio of about 7:1). The microbes will need all of the available N in the stubble and the mineral N in the soil, and may even break-down some existing organic N (humus) to get more N if they need it. The microbes will grow rapidly, so when the crop is sown there will be little available mineral N - it's all 'tied-up' by the microbes as they grow their population on the new energy supply. Some of the microbes are always dying as well but for a time more are growing than dying, so there is 'net immobilisation'. As the soil cools down after sowing, the 'turnover' slows, and so is the time taken for more N to be released (mineralised) than consumed (immobilised) and net-mineralisation is delayed. Meanwhile — the relatively N-hungry canola crop is likely to become deficient in N as the rate of mineralisation in the winter is low. This temporary N-deficiency if not corrected or avoided, may or may not impact on yield depending on subsequent conditions.

Based on the simple principles above, it's relatively easy to think of ways to reduce the impact of immobilisation in this scenario:

- The stubble load could be reduced by baling, grazing or burning (less C to tie up the N).
- If the stubble was from a legume or a canola rather than a cereal (crop sequence planning) it would have lower C:N ratio and tie up less N.
- The stubble could be incorporated earlier (more time to move from immobilisation to mineralisation before the crop is sown).
- Nitrogen could be added during incorporation (to satisfy the microbes and speed up the 'turnover').
- More N could be added with the canola crop at sowing (to provide a new source of N to the crop and microbes), and this could be deep-banded (to keep the N away from the higher microbe population in the surface soil to give the crop an advantage).
- A different seeder could be used that can handle the higher residue without requiring incorporation (less N-poor residue in the soil).
- A legume could be sown rather than canola (the legume can supply its own N, can emerge through retained residue and often thrives in cereal residue).

In modern farming systems, where stubble is retained on the surface and often standing in no-till, control-traffic systems, less is known about the potential for immobilisation. In GRDC-funded experiments as part of the Stubble Initiative (CSP187, CSP00174), the dynamics of N in stubble-retained systems are being investigated. Examples from recent GRDC-funded experiments in southern NSW are provided in this paper and the evidence for the impact of immobilisation are discussed and some practical tips to avoid the risks of N tie-up are provided.

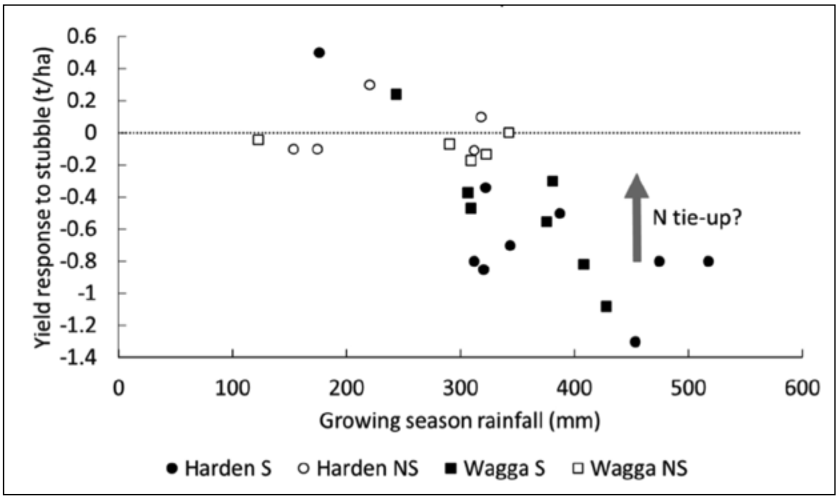

Figure 1. Effect of retained stubble on wheat yield is worse in wetter seasons at the Harden (circles) and Wagga (squares) long-term tillage sites. Open symbols indicated where difference between retained and burnt were not significant (NS), solid symbols indicated where difference between retained and burnt were significant (S).

Can stubble really reduce yield significantly in no-till systems — and is 'N-tie-up' a factor?

Harden long-term site

In a long-term study at Harden (28 years) the average wheat yield has been reduced by 0.3t/ha in stubble retained versus stubble burnt treatments, but the negative impacts of stubble were greater in wetter seasons (Figure 1). Nitrogen tie-up may be implicated in wetter years, due to higher crop demand for N and increased losses due to leaching or denitrification. But we rarely found significant differences in the starting soil mineral N pre-sowing. For many years, sufficient measurements were unavailable to determine whether N tie-up was an issue.

In 2017, two different experiments in sub-plots at Harden were implemented to investigate the potential role of N tie-up in the growth and yield penalties associated with stubble. A crop of wheat (cv. Scepter⁽ᴰ⁾) was sown on 5 May following a sequence of lupin-canola-wheat in the previous years. In both the stubble-retained and stubble-burnt treatments 50kg N/ha or 100kg N/ha broadcast as urea at sowing in one experiment were compared (Table 1), and in another experiment 100kg N/ha surface applied or 100kg/N deep-banded below the seed were compared (Table 2). The pre-sowing N to 1.6m was 166kg N/ha in retained and 191kg N/ha in burnt, but was not significantly different. Plant population, growth and N content at GS30 did not differ between treatments (data not shown) but by anthesis, the biomass and tiller density were significantly increased by the additional 50kg/ha of surface-applied N in the stubble-retained treatment, while there was no response in the stubble burnt treatment. At harvest, both stubble retention and increased N improved grain yield, but the increase due to N was higher under stubble retention (0.6t/ha) than stubble burnt presumably due to improved

Table 1. Effect of additional surface applied and deep-placed N on wheat response in stubble burnt and retained treatments at Harden in 2017.

Treatment		Anthesis		Harvest (@12.5%)	
Stubble	N	Biomass (t/ha)	Tillers (/m^2)	Yield (t/ha)	Protein (%)
Retain	50	7.1	324	4.3	8.8
	100	8.4	401	4.9	9.6
Burn	50	8.8	352	4.2	9.3
	100	8.7	372	4.5	10.5
LSD (P<0.05)	Stubble	0.9	ns	0.2	ns
	N	0.5	33	0.1	0.2
	Stubble x N	0.8	38	0.2	ns

water availability. The increase in yield with higher N, and the low protein overall (and with low N) suggests N may have been limiting at the site, but the water-saving benefits of the stubble may have outweighed the earlier effects of immobilisation.

Deep-banding the N fertiliser had no impact on crop biomass or N% at GS30, but increased both the biomass and N content of the tissue at anthesis more in the retained-stubble than in burnt stubble (Table 2). Retaining stubble decreased biomass overall but not tissue N. N uptake (kg/ha) at anthesis was significantly increased by deep-banding in both stubble treatments, however the increase was substantially higher in the stubble-retain treatment than in the burn treatment (38kg N/ha compared with15kg N/ha). The overall impact of deep-banding on yield persisted at harvest, but there was no effect, nor interaction with stubble retention, presumably due to other interactions with water availability. However the fact that deep-banding N has had a bigger impact in the stubble retained treatment provides evidence of an N-related growth limitation related to retained stubble. Its appearance at anthesis, and not earlier, presumably reflects the high starting soil N levels which were adequate to support early growth but the cold dry winter generated N deficiencies as the crop entered the rapid stem elongation phase. The increased protein content related to both burning and deep-banding and its independence from yield, suggest on-going N deficiencies generated by those treatments.

Temora site

At Temora, a nine-year experiment managed using no-till, controlled traffic, inter-row sowing (spear-point/press-wheels on 305mm spacing) in a canola-wheat-wheat system investigated the effects of stubble burning and stubble grazing on soil water, N and crop growth. In the stubble retained treatment, stubble was left standing through summer, and fallow weeds were strictly controlled. In the stubble grazed treatment weaner ewes were allowed to crash graze the stubble immediately after harvest for a period of seven to ten days and weeds were controlled thereafter. Stubble was burnt in mid-late March and the crop sown each year in mid-late April. Nitrogen was managed using annual pre-sowing soil tests whereby 5kg/ha N was applied at sowing and N was top-dressed at Z30 to attain 70% of maximum yield potential according to Yield Prophet® (Swan et al., 2017).

Burning

In un-grazed treatments, retaining stubble, rather than burning had no impact on the yield of canola or the first wheat crop over the nine years, but consistently reduced the yield of the second wheat crop by an average on 0.5t/ha (Table 3). This yield penalty was associated with an overall significant reduction in pre-sowing soil mineral-N of 13kg/ha, while there was no significant difference in pre-sowing N for the first wheat crop (Table 4).

Table 2. Effect of surface-applied and deep-banded N on wheat response in stubble-burnt and stubble-retained treatments at Harden in 2017.

Treatment		Anthesis			Harvest (@12.5%)	
Stubble	100 N	Biomass (t/ha)	Tissue N (%)	N Uptake (kg N/ha)	Yield (t/ha)	Protein (%)
Retain	Surface	8.1	1.1	91	4.5	9.3
	Deep	9.1	1.4	129	5.1	10.2
Burn	Surface	8.9	1.2	104	4.5	10.3
	Deep	9.5	1.3	119	5.0	10.8
LSD (P<0.05)	Stubble	0.6	ns	ns	ns	0.8
	N	0.2	0.1	8	0.2	0.4
	Stubble x N	0.6	0.2	12	ns	ns

Table 3. Effect of stubble burning on grain yields at Temora in Phase 1 and 2. Crops in italics are canola, and bold are the 2nd wheat crops.

Phase	Treatment	2009	2010	2011	2012	2013	2014	2015	2016	2017
Phase 1	Retain	1.7	*4.2*	4.6	**4.4**	*0.7*	3.8	**4.1**	*3.2*	3.7
	Burn	1.7	*4.0*	4.6	**5.0***	*1.0*	3.8	**4.6***	*3.2*	3.2
Phase 2	Retain	-	6.3	*3.4*	4.5	**2.0**	*2.0*	5.5	**5.2**	*2.1*
	Burn	-	6.2	*3.5*	4.8	**3.4***	*2.0*	5.3	**5.7***	*2.4*

** indicates where yields are significantly different*

Grazing

Grazing stubbles never reduced the yield of any crop at the site, but increased the yield of the second wheat crop by 1.2t/ha in 2013 (Phase 1) and by 1.0t/ha in 2015 (Phase 2) (Table 5). This was unrelated to pre-sowing soil N in 2013 (both had approximately 85kg N/ha at sowing) where suspected increased frost effects in the ungrazed stubble were expected. While in 2015, the yield benefit was related to pre-sowing N with an extra 61kg/ha N at sowing in the grazed plots. Overall, grazing increased the pre-sowing N by 13kg/ha in the first wheat crop and by 33kg/ha in the second wheat crop (Table 4).

Deep N placement

In an adjacent experiment at Temora in the wet year of 2016, deep N placement improved the growth, N uptake and yield of an N-deficient wheat crop but this occurred in both the stubble retained and the stubble removed treatments and there was no interaction suggesting N availability was not reduced under stubble retention (Table 6). However it was thought that the level of N loss due to waterlogging in the wet winter and the significant overall N deficiency may have masked these effects which were more obvious at Harden in 2017.

Post-sowing N tie-up by retained stubble

The evidence emerging from these studies suggests that even where cereal crop residues are retained on the soil surface (either standing or partially standing) and not incorporated, significant N immobilisation can be detected pre-sowing in some seasons. The extent to which differences emerge are related to seasonal conditions (wet, warm conditions) and to the time period between stubble treatment (burning or grazing) and soil sampling to allow differences to develop. However, even where soil N levels at sowing are similar between retained and burnt treatments (which may result from the fact that burning is done quite late) ongoing N immobilisation **post-sowing** by the microbes growing in-crop is likely to reduce the N available to crops in retained stubble as compared to those in burnt stubble. This was demonstrated in 2017 at Harden where the additional 50kg N/ha applied at sowing completely removed the early

Table 4. Mean effect of stubble burning or grazing across years and phases on soil mineral N (kg N/ha) to 1.6m depth prior to sowing either 1st or 2nd wheat crops at Temora. LSD for interaction of treatment and rotational position where P<0.05.

Rotation position	Stubble treatment		Grazing treatment	
	Retain	Burn	No graze	Graze
1st wheat	117	110	107	120
2nd wheat	102	115	92	125
LSD (P<0.05)	13	13		

Table 5. Effect of grazing stubble on grain yields at Temora in Phase 1 and 2. Crops in italics are canola, and bold are the 2nd wheat crops.

Phase	Treatment	2009	2010	2011	2012	2013	2014	2015	2016	2017
Phase 1	No graze	1.7	*4.2*	4.6	**4.4**	0.7	3.8	**4.1**	3.2	3.7
	Graze	1.7	*4.3*	4.5	**4.8**	0.9	3.7	**5.3***	3.3	3.3
Phase 2	No graze	-	6.3	*3.4*	4.5	**2.0**	*2.0*	5.5	**5.2**	*2.2*
	Graze	-	6.2	*3.3*	4.8	**3.0***	*2.2*	5.6	**5.6***	*x*

** shows where significantly different (P<0.05)*

Table 6. Effect of deep banding vs surface applied N (122kg N/ha as urea) at seeding, at Temora NSW in 2016 (starting soil N, 58kg/ha). The crop captured more N early in the season which increased biomass and yield in a very wet season. (Data mean of three stubble treatments).

Treatments	Z30			Anthesis			Grain Yield (t/ha)
	Biomass (t/ha)	N%	N-uptake (kg/ha)	Biomass (t/ha)	N%	N-uptake (kg/ha)	
Surface	1.4	3.8	51	7.8	1.3	103	4.0
Deep	1.4	4.4*	60	9.2*	1.5*	136*	5.2*

**indicates significant differences (P<0.01). (Data source: Kirkegaard et. al., CSIRO Stubble Initiative 2016 CSP00186).*

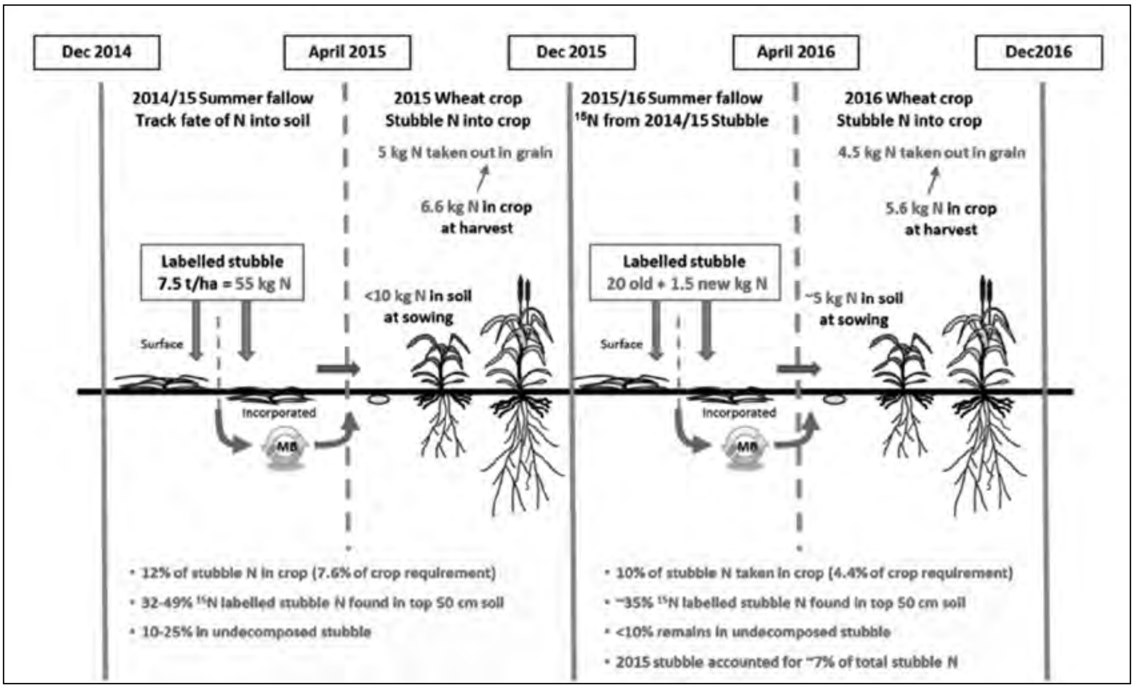

Figure 2. The fate of the N contained in retained wheat stubble over two years in successive wheat crops following the addition of 7.5t/has of wheat stubble containing 55kg/ha N. The successive crops took up 12% (6.6kg N/ha) and 10% (5.6kg N/ha) of the N derived from the original stubble representing only 7.6% and 4.4% of the crops requirements. Most of the stubble N remained in the soil (35%) or was lost (33%).

growth reduction observed in the stubble-retained treatment, although due to the overall water limitation at the site, this did not translate into yield.

Cereal stubble isn't a good source of nitrogen for crops

Studies at three sites in southern Australia (Temora, Horsham and Karoonda) have tracked the fate of the N in stubble to determine how valuable it is for succeeding wheat crops under Australian systems. Stubble labelled with ^{15}N (a stable isotope that can be tracked in the soil) was used to track where the stubble N went. At Temora (Figure 2), of the 55kg/ha of N contained in 7.5t/ha of retained wheat residue retained in 2014, only 6.6kg/ha N (12 %) was taken up by the first crop (representing 12 % of crop requirement); and 5.6kg/ha N (10%) was taken up by the second wheat crop (4.4% of crop requirement). The majority of the N after two years remained in the soil organic matter pool (19.1kg N/ha or 35%) and some remained as undecomposed stubble (10% or 5.5kg N/ha). Thus we can account for around 67% of the original stubble N in crop (22%), soil (35%) and stubble (10%) with 33% unaccounted (lost below 50cm, denitrified). In similar work carried out in the UK which persisted for four years, crop uptake was 6.6%, 3.5%, 2.2% and 2.2% over the four years (total of 14.5%), 55% remained in the soil to 70cm, and 29% was lost from the system (Hart *et al*., 1993). The main point is that the N in cereal stubble represented only 6% of crop requirements over two years (7.6% Year 1; 4.4% Year 2) and takes some time to be released through the organic pool into available forms during which losses can occur.

Conclusion

These studies have confirmed a risk of N-tie up by surface-retained and standing cereal crop residues which may occur in-season, rather than during the summer fallow, and so may not be picked up in pre-sowing soil mineral N measurements. Yield penalties for retained residues were significant, but confined to successive cereal crops, and could be reduced by reducing the stubble load or by applying more N (approximately 5kg N per t/ha of cereal residue) and applying it earlier to the following crop. Deep placement of the N improved N capture by crops irrespective of stubble management, but was especially effective in stubble-retained situations.
In summary, N tie-up is an easily managed issue for growers with suitable attention to the management of stubble and N fertiliser.

Useful resources

http://www.farmlink.com.au/project/maintaining-profitable-farming-systems-with-retained-stubble

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Return to contents

Notes

Filling the yield gap – Optimising yield and economic potential of high input cropping systems in the HRZ

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GRDC project code: DAV00141

Keywords

- fertiliser, waterlogging, nitrogen (N), phosphorus (P), potassium (K), sulphur (S), economics, wheat, canola.

Take home messages

- Under-fertilising appears to be a major cause of yield gaps in cropping systems in the high rainfall zone (HRZ).
- Yield gaps need to take into account seasonal risk and relative crop and fertiliser prices.
- Soil test critical values should be higher than commonly used because of the higher yield potential of the HRZ.
- Return on investment in nitrogen (N) fertiliser is maximised if phosphorus (P), potassium (K) and sulphur (S) are non-limiting.
- The project has produced three Excel-based decision support tools to determine the economic optimum application rate of N, P, K and S under a range of conditions.

Background

In the HRZ of southern Australia, commercial wheat and canola yields are well below their water-limited potential (Yield Gap Australia 2018). The yield gap in this case was defined as the difference between actual yields reported by growers to the Australian Bureau of Statistics (ABS), and a potential yield calculated for each region and cropping year using the Agricultural Production Systems sIMulator (APSIM) model supplied with non-limiting nutrients. Since nutrient limitations are one of the most common causes of yield gaps, a plant nutrition component was incorporated into the DAV00141 project. One of the questions posed was whether the soil test interpretation guidelines developed in the low and medium rainfall areas were appropriate to the HRZ with its higher yield potential. The nutrition component comprised field experiments, crop modelling, economics, and the development of three Excel-based decision support tools to assist decision makers choose the most economic application rate of various nutrients for a given season.

Method

Experimentation

To determine which nutrients were responsible for crop responses, a series of nutrient omission experiments were conducted in the 2015 and 2016 growing seasons in the HRZ between Bool Lagoon in South Australia (SA) and Rutherglen in Victoria (VIC). At each site, one treatment was supplied with non-limiting rates of all the nutrients to which responses could be expected (P, K, S, copper (Cu), zinc (Zn)), while in other treatments, one or all of these nutrients was omitted. Nitrogen was applied at a minimal rate — 60% of estimated requirements or 100% of requirements. The experiments were conducted with either wheat (cv. Beaufort⫽) or canola (cv. Archer⫽) (Table 1). Soil samples were collected prior to sowing to develop yield relationships appropriate to the HRZ. These included soil N and available K to a depth of 1.4m, and Colwell, DGT-P and KCl-40 available S to 10cm. Further details are given by McCaskill et al. (2016) and Pearce et al. (2017).

In the 2017 season, the experimental program was modified to examine a range of application rates for nutrients to determine the economic optimum nutrient application rate. Results are presented here for a canola P response experiment conducted on the Hamilton Long-Term Phosphate Experiment at five starting fertility levels, and sufficient N applied for it to be non-limiting. Background fertility ranged from a Colwell P of 14mg/kg where virtually no P fertiliser had been applied over the previous 40 years, and to a Colwell P of 143mg/kg where the annual application rate had averaged 27kg/ha.

Data presented here have been analysed in Genstat (18th Edition) using the restricted maximum likelihood (REML) and standard curve procedures, and are reported at the 5% significance level. However, as some of the data are from incomplete data sets, the findings must be considered preliminary.

Decision support

Utilising the experimental findings of this and previous projects, a series of Excel-based decision support aids were developed. Firstly, we utilised grain yield response relationships to soil tests for P, K and S from this project and the database of Better Fertiliser Decisions for Cropping in Australia (BFDC). Secondly, these were embedded in the Catchment Analysis Toolkit (CAT) model (Christy et al. 2013) to derive a series of predicted yields for wheat and canola in response to a range of fertiliser application strategies across multiple sites and years. CAT is a biophysical model that operates on a daily time-step, and has a dynamic N model. Scenarios of starting soil conditions and fertiliser application were developed through discussion with commercial agronomists in south-western VIC and southeast SA. Starting soil conditions were based on soil samples collected at the nutrient omission experimental sites. Thirdly, these scenarios were summarised into a series of coefficients for response functions showing diminishing marginal returns and incorporated into Excel look-up tables within the decision support tools. The spreadsheet tools use conventional marginal investment and return economics to calculate the economic optimum application rate of N, P, K and S for a given set of input conditions, grain and fertiliser prices and the user's required benefit/cost ratio or rate of return on the marginal dollar invested in fertiliser. The key risk factor is seasonal outcomes and production functions were determined for four season types — 'very poor', 'poor', 'good' and 'very good'. Three spreadsheet tools were developed from a common base and these address different questions — (i) an **awareness** tool showing likely response to in-crop N based on the initial P, K and S fertility, (ii) a **planning** tool to assist with pre-sowing applications of N, P, K and S and in-crop decisions based on climate forecasts, and (iii) an **evaluation** tool, to check whether the crop was under fertilised or over fertilised, post crop.

Results and discussion

Field experiments

Could full nutrient application close the yield gap?

Grain yields for the 'all' treatments were close to or exceeded the water-limited yield potential in six of the twelve experiments (Table 1). In four experiments, yields below potential were associated with prolonged waterlogging (Bool Lagoon in 2016 and 2017, and Rutherglen in 2016). For example, wheat at Bool Lagoon in 2017 was inundated continuously mid July until mid November, and yielded 2.6t/ha compared with a region-wide yield potential calculated by APSIM of 6.0t/ha for a rainfall decile of 10. In two experiments, yields below potential were associated with an exceptionally dry finish (canola at Francis and Inverleigh in 2015).

Which nutrients were required and what are the critical soil test values?

Statistically significant grain yield responses were found to N, P, K and S, but not to the micronutrients Cu and Zn (Table 1). The magnitude of the P response was related to the Colwell soil test. The data set from this project was supplemented by four previous trials in the HRZ in the BFDC database. An exponential curve described 64% of the variation, with the 90% critical value at a Colwell P of 30mg/kg (±SE 23 to 44mg/kg) (Figure 1). There was no significant difference between wheat and canola (for comparison, 90% critical values from the BFDC database from all trials in Australia are 24mg/kg for wheat and 20mg/kg for canola). Unlike most relationships in the BFDC database, which plateau at 100% of maximal yield, this relationship plateaued at 88% of maximal yield. This is the 'starter P' effect, whereby P banded just below the seed assists early crop establishment.

There were insufficient responses to K and S to derive similar relationships from this project alone. However, from the information collected to date from trials and the experience of crop agronomists, we suggest that the K response relationship for pastures be used for HRZ cropping. The pasture relationship has a 90% critical level at a Colwell

Table 1. Summary of nutrient omission and response experiments conducted under the project, including the decile of growing season rainfall (April to November inclusive), measured grain yield of the all-nutrients treatment, the yield potential estimated by APSIM for seasons of the same rainfall decile from the Yield Gap Australia website, and the relative yield (%) where particular nutrients are omitted (only reported where responses were statistically significant).

Location	Year	Crop	Rainfall decile	Yield of 'all' (t/ha)	Yield potential (t/ha)	Relative yield if a nutrient is omitted
Hamilton	2017	Canola	7	6.3	4.3	P (6%), N (24%)
Bool Lagoon	2017	Wheat	10	2.6	6.0	P (83%)
Hamilton	2016	Canola	10	6.2	3.7	K (83%), N (17%)
Tarrington	2016	Canola	10	5.3	3.7	P (61%)
Inverleigh	2016	Wheat	8	10.9	5.3	
Rutherglen	2016	Canola	10	0.7	2.3	P (78%), N (33%), S (68%)
Bool Lagoon	2016	Wheat	10	4.6	6.0	P (76%), S (78%), N (41%)
Bool Lagoon	2016	Canola	10	1.4	3.4	P (62%), N (59%), S (70%)
Francis	2015	Canola	1	0.9	2.5	N (78%)
Bool Lagoon	2015	Wheat	1	3.6	5.1	
Chatsworth	2015	Wheat	1	4.4	4.6	
Inverleigh	2015	Canola	1	1.8	3.8	P (83%), N (80%)

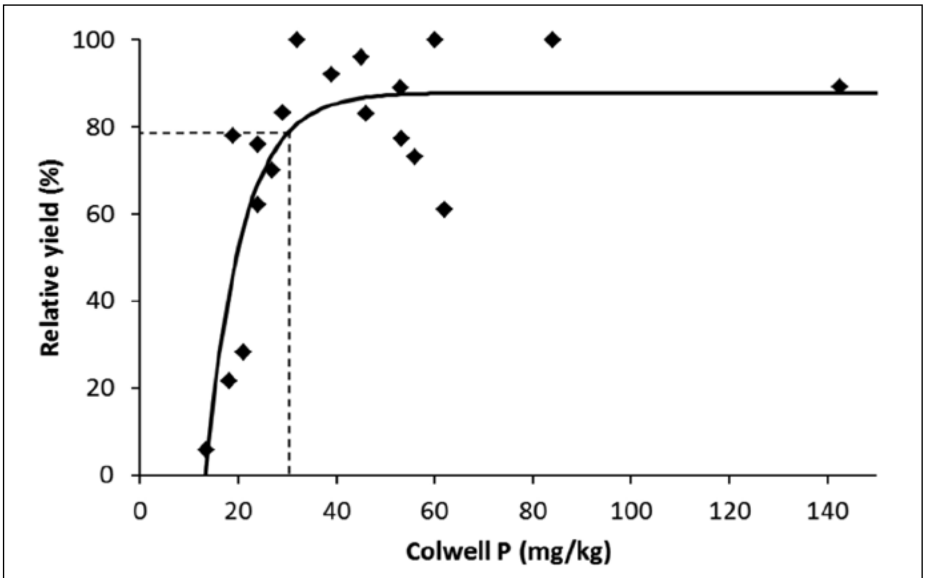

Figure 1. Relative grain yield response to Colwell P in wheat and canola for experiments in the HRZ in this project, and four previous trials in the BFDC database. Vertical line shows where fitted yield is 90% of the maximal value at a Colwell P of 30mg/kg. Note that because the relationship plateaued at 88% of the yield achievable when P is applied at sowing, the critical value is at 90% x 88% = 79%.

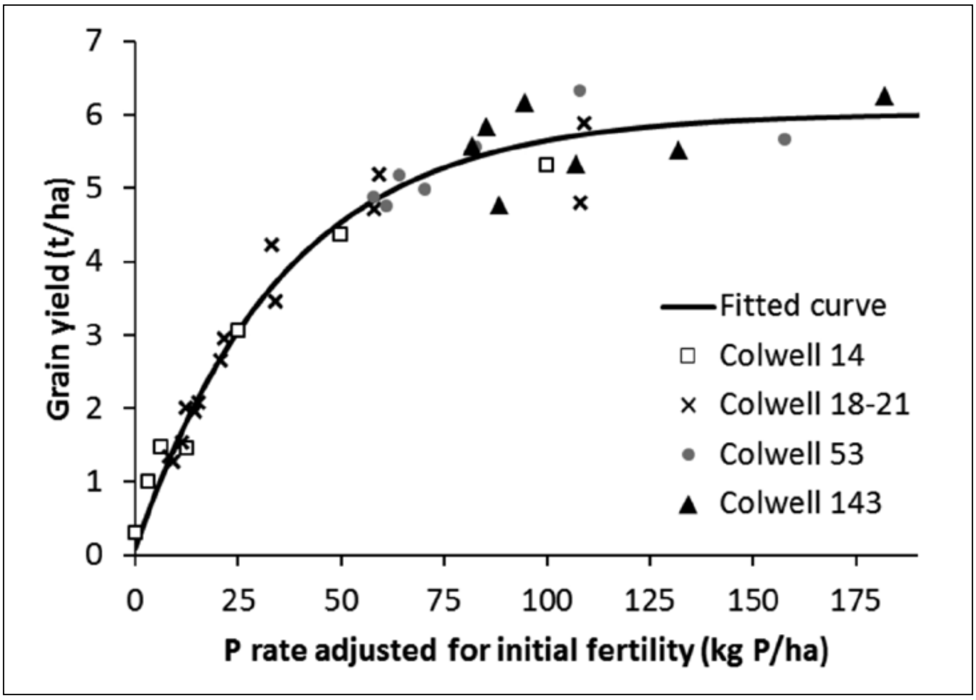

Figure 2. Canola grain yield response to applied P for a starting fertility of 14mg/kg Colwell, on the Hamilton Long-term Phosphate Experiment in 2017. Starting fertility ranged from 14mg/kg to 143mg/kg Colwell P, and P rates are adjusted so they are equivalent to the lowest starting fertility.

K of between 96mg/kg and 109mg/kg Colwell K depending on soil texture (Gourley et al. 2007) (this is much higher than 90% critical values from the BFDC database of 57mg/kg for wheat and 47mg/kg for canola based on trials in drier parts of Australia). For S using the KCl-40 extractant, a preliminary value of 8mg/kg appears to be more appropriate for both than the current BFDC values of 4.5mg/kg for wheat and 6.7mg/kg for canola.

A budgeting approach was used for N to determine application rates for the treatment where we aimed to provide 100% of N requirements. This approach involved calculating plant demand less soil N to a depth of 1m, less an allowance for mineralisation. The approach worked well for wheat but for canola it appeared much of the soil N was unavailable to the crop, despite the crop being highly responsive to fertiliser N. A parallel study (DAV00151 - Understanding how waterlogging affects water and nitrogen use by wheat) has shown that under waterlogged conditions, soil layers below approximately 5cm, become anaerobic. This would limit the capacity of roots to actively take up N and other nutrients, except where the roots have aerenchyma that allow oxygen diffusion. Wheat has aerenchyma in its adventitious roots, whereas canola lacks adventitious roots. This may explain why canola is much more dependent on fertiliser N application under waterlogged conditions than wheat.

How much nutrient was required?

While soil test response relationships describe the magnitude of response to a non-limiting amount of particular nutrient, they do not indicate the economic optimum amount to apply. This needs a fertiliser rate experiment such as that in Figure 2 (or equivalent model output such as from CAT). Here, seven rates of P were applied to fields with starting P fertility ranging from 14mg/kg to 143 mg/kg Colwell P. Canola grain yield followed a common relationship once adjustment was made for the starting fertility. For example, at a background P of 53mg/kg Colwell, yield of the nil P treatment was equivalent to a treatment receiving 58kg P/ha at a starting fertility of 14mg/kg Colwell.

Table 2. Background Colwell P of the response experiments on the Hamilton Long-term Phosphate Experiment, the long-term (40 year) annual P application that has produced the fertility level, the equivalent P application rate of the background P using the combined relationship in Figure 1, and the economic optimum P application rate at a 2:1 benefit cost ratio for canola at each background level.

Starting soil fertility	Economic optimum P application rate
P Colwell (mg/kg)	(kg P/ha)
14	88
18	79
21	80
53	30
143	6

Agricultural economists calculate the optimum fertiliser application rate as where $1 of extra grain is produced from $1 of extra fertiliser (Figure 3a), which is a 1:1 benefit cost ratio. A 1:1 benefit cost ratio is suitable if there is a high level of confidence in the response relationship, and no cost of capital. However, if there is some doubt whether a fertiliser investment will return sufficient additional yield despite seasonal variation and other possible crop growth constraints, a benefit cost ratio of 1.25:1 or 2:1 may be preferred, but the overall profits will be lower in the long term. In the example of P application to canola at Hamilton, the optimum P application rate at a 2:1 benefit cost ratio was 88kg P/ha less the allowance for background fertility (Table 2). Key factors that favour either high or low optimum application rates are:

Higher optimum fertiliser application rates	Lower optimum fertiliser application rates
High yields	Low yields
High crop prices	Low crop prices
Low fertiliser prices	High fertiliser prices
1:1 benefit cost ratio optimum	2:1 benefit cost ratio (or wider
Good seasons	Poor seasons

The yield factor is illustrated in Figure 3(b) by using the same curve as in Figure 2 scaled down to represent lower yield potentials in the Wimmera and Mallee. The 2:1 economic optimum occurs at 92% of yield potential in the HRZ, compared with 83% in the Wimmera and 66% in the Mallee. Soil tests are often interpreted in relation to a critical level at which 90% of maximum yield is achieved, whereas a higher threshold should be used in areas of greater yield potential.

The crop price factor is illustrated in Figure 3(c) by using the wheat price of $224/t in the canola yield response relationship, rather than the $495/t canola price. The economic optimum at a 2:1 benefit cost ratio declines to 55kg P/ha (from 88kg P/ha), less the allowance for background fertility.

It should be noted that this P response relationship was for a soil with a Phosphate Buffering Index (PBI) of 200, whereas the average PBI of commercial samples submitted in 2015 to the Nutrient Advantage laboratory from south-west VIC was only 108 (McCaskill et al. 2016 and unpublished). While a similar relationship would apply to all soils in the HRZ, the economic optimum application rate is likely to be lower than shown here.

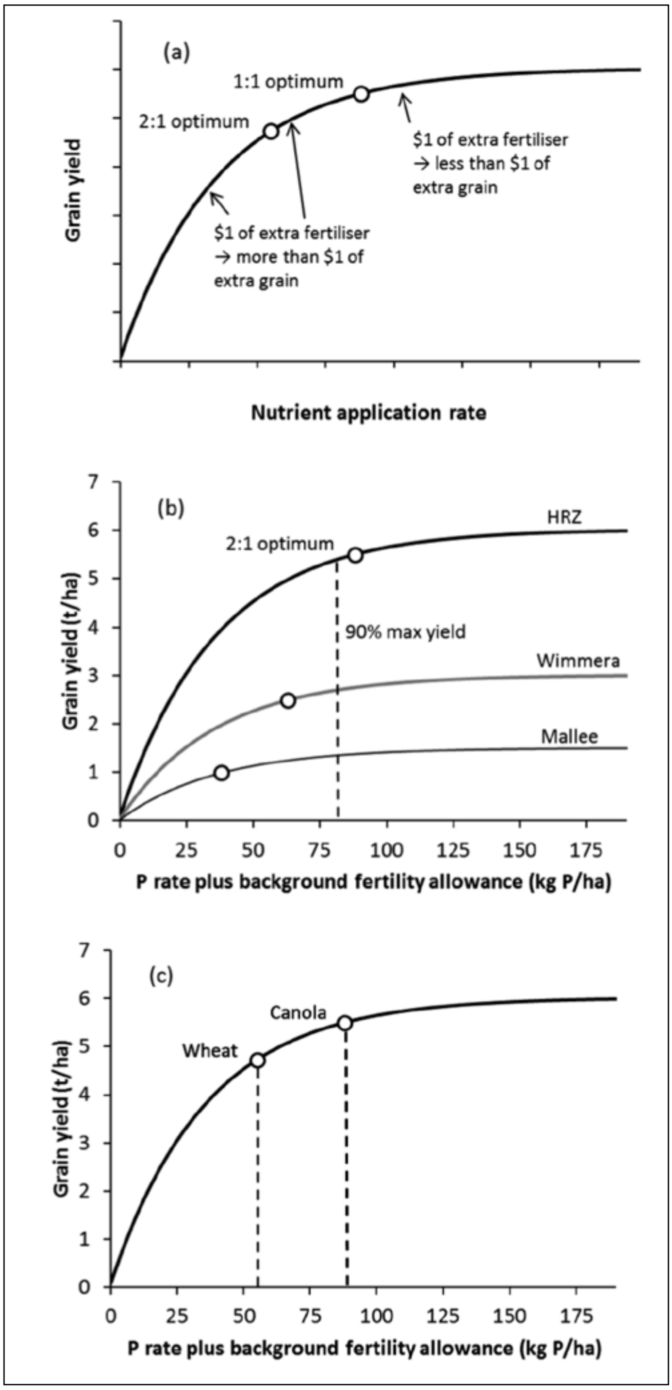

Figure 3. (a) Economic optimum nutrient application for a 1:1 and 2:1 benefit cost ratio; **(b)** economic optimum P application (circles) for a 2:1 benefit cost ratio for yield potentials representative of the HRZ, Wimmera and Mallee using the same curve as in Figure 2, and the fertility required for 90% of yield potential in all three environments; **(c)** economic optimum P application at a 2:1 benefit cost ratio for canola using the same curve as in Figure 2 and current prices, and for wheat if the yield response relationship also applied to wheat.

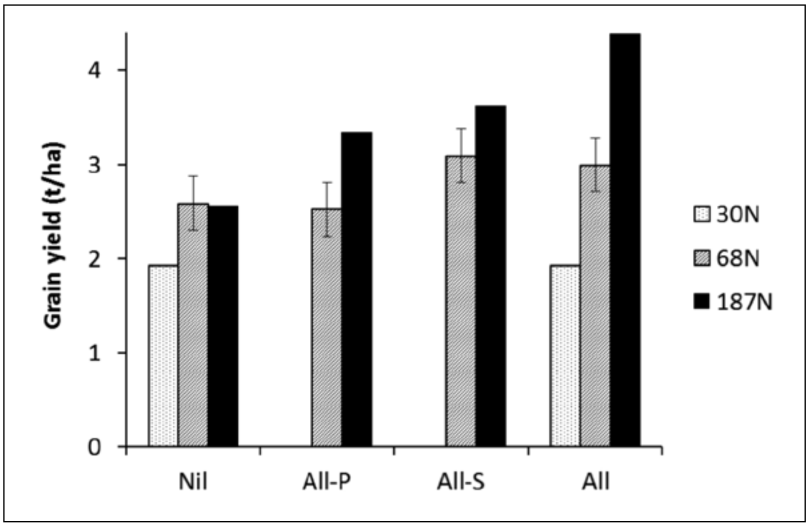

Figure 4. Wheat grain yield response to applied N at Bool Lagoon in 2016 as affected by the omission of all other nutrients at sowing, and the omission of P or S, at N application rates of 30kg, 68kg and 187kg N/ha. Error bars show the 5% least significant difference. Redrawn from Pearce et al. (2017).

What if two or more nutrients are limiting?

In the P rate experiment given above, non-limiting rates of N were applied, and N was not considered in the economic optimisation. In practice, most sites have an interaction between two or more limiting nutrients. This is illustrated from the 2016 wheat omission experiment at Bool Lagoon (Figure 4). There was a strong response to additional N where all the required other nutrients were applied, but there was a weaker response if P or S were omitted. Where both P and S were applied, each additional kilogram of N fertiliser between the mid and high rate of N produced 11.7kg of extra grain, compared with 6.8kg if P was omitted, 4.5kg if S was omitted and no additional yield if both were omitted. Correction of other nutrient limitations is the first step in obtaining a good response to applied N. Conversely, the P and S responses were only statistically significant at the high, but not the mid-rate of N. Similar findings were made from the other omission experiment sites. As cropping in the HRZ adopts varieties with higher potential yields and higher N rates are applied, we can expect more responses to P, K and S unless soil conditions are closely monitored.

4 YIELD POTENTIAL:		
Expected yield quartile	Quartile 3 (good)	
Modelled/experimental yield potential with unlimited nutrients	7.9	t/ha
Yield adjustment for your paddock	-10%	%
5 CROP PRICE AT FARM GATE:		
Price of crop at point of sale	260	$/t
Freight costs	15	$/t
Harvest costs	25	$/t
6 REQUIRED RETURN ON MARGINAL $ INVESTED IN FERTILISER:		
B/C ratio	1.25	:1
Equivalent marginal rate of return	25	%
7 FERTILISER DELIVERY AND SPREADING COSTS:		
Freight costs	15	$/t
Usual cost of fertiliser spreading, e.g. for ground application(s)	9	$/ha
Cost of topdressing final split application of N	9	$/ha
8 UREA COST (46-0-0-0) AT POINT OF SALE:	445	$/t

Putting it together — decision support

Since the economic optimum changes with input costs and product prices, economic information is better conveyed by calculation tools than static information. The tools combine well established production economics principles with relatively poorly developed (to-date) nutrient response relationships from the HRZ and are available on the eXtensionAUS website. The spreadsheet tools allow users to adjust prices for crops and inputs and reveal optimum nutrient ratios and fertilisation levels for the range of seasonal conditions. For limited capital and/or high risk situations, users are also able to specify their required benefit/cost ratio or rate of return on the marginal dollar invested in fertiliser. Simple graphs and tables were used to illustrate expected outcomes. A screen grab from the awareness tool (Figure 5) shows how limitations of P, K or S affect the optimal application rate of N.

The effect of season variability on the optimal fertiliser strategy is accommodated by a drop-down box of yield quartiles. At sowing, these yield outcomes have equal probability, and possible N, P, K and S fertiliser strategies can be tested under both good and poor seasonal conditions. As the season progresses, the probability of achieving a particular yield outcome becomes more certain because of rainfall received after sowing, and drought influences become apparent such as El Niño or a positive Indian Ocean Dipole (IOD). Much of this information is available in late August and can influence decisions on split N application in late winter and early spring. The planning tool allows users to test how these factors affect the probability of achieving a low or high final yield, and the economic optimum N application rate. We expect to conduct training and feedback sessions with the tools over the next year, leading to improved versions. Eventually the tools may be made available in other forms, through incorporation into existing decision support tools and possibly smartphone apps, but the current Excel form provides a way of prototyping in parallel with gathering more information on nutrient response relationships.

Conclusion

Through a series of nutrient response experiments, we have established that by providing sufficient nutrients, the yield of wheat and canola crops can be equal to or exceed the water-limited potential, except in cases of severe waterlogging or drought. The strongest responses were to P followed by N, S and K. The magnitude of these responses was related to soil tests, but with critical values at which 90% of maximal yield was achieved slightly higher than from previous trials in other parts of Australia. Economic analysis showed that the 90%

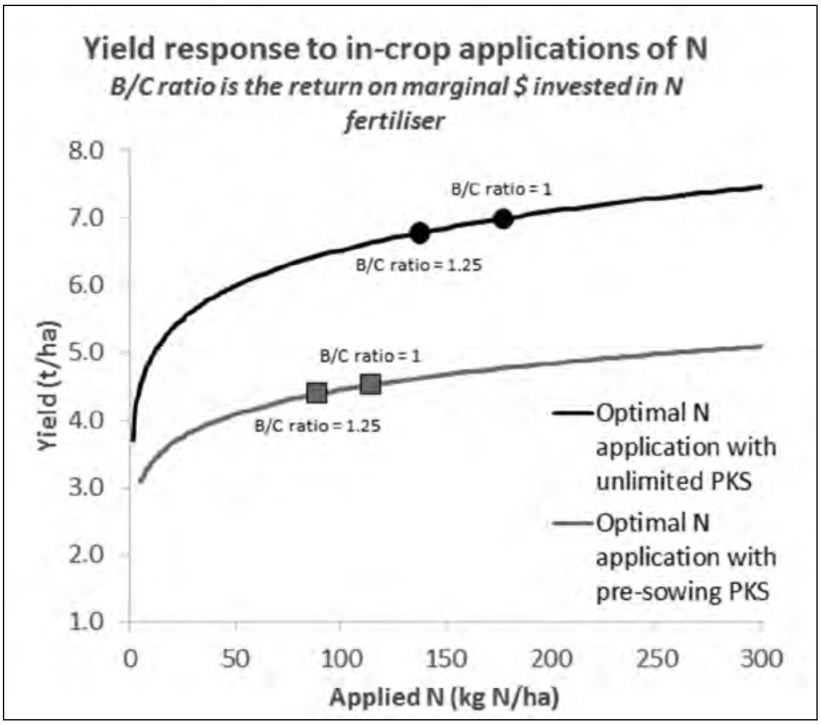

Figure 5. Screen grab from the awareness tool, showing some of the input data required, and a dynamic calculation of the economic optimum N application under conditions of limited P, K or S, and if these nutrients are fully supplied.

critical value underestimated the economic optimum because of the higher yield potential in the HRZ. Since the economic optimum fertiliser application rate is also dependent on input prices, product price and seasonal outlook, we have prepared three spreadsheets to calculate the optimum under a wide range of conditions. The spreadsheets are populated with yield and nutrient response data from a biophysical model, but allow modification to suit individual circumstances.

Useful resources

eXtensionAUS (http://extensionaus.com.au/)

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Return to contents

Notes

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Managing annual ryegrass in the high rainfall zone

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ΦExtra technical comment by Protech Consulting Pty Ltd

GRDC project codes: UCS00020, SFS00032, UOA1803-008RTX

Keywords

- herbicide resistance, annual ryegrass, crop competition, integrated weed management.

Take home messages

- Annual ryegrass has evolved resistance to most post-emergent herbicides in the high rainfall zone (HRZ).
- Individual pre-emergent herbicides tend to have variable efficacy making mixtures and sequences better.
- Crops mature later in the HRZ meaning that more than 50% of the annual ryegrass seed can shed prior to harvest. This makes harvest weed seed management practices less effective in the HRZ than other regions.
- Annual ryegrass can rapidly replenish the seed bank in the HRZ. This makes pre-sowing cultural tactics less effective unless they are coupled with stopping weed seed set.
- Double break crops in rotations are effective at reducing annual ryegrass population, due to the employment of crop topping.
- Moderate populations (less than 100 plants/m^2) of annual ryegrass do not greatly reduce crop yield, so strategies that drive annual ryegrass to low levels are not always the most profitable.

Herbicide resistance in Tasmania

Like most high rainfall cropping regions of Australia, resistance to the post-emergent herbicides is increasing in annual ryegrass in Tasmania. Random sampling shows resistance to Group A herbicides is common and resistance to Group B herbicides is increasing (Table 1). On the other hand, pre-emergent herbicides are mostly still effective. While the extent of herbicide resistance in annual ryegrass in Tasmania is lower than other high rainfall cropping regions on the mainland, increasingly pre-emergent herbicides will have to be relied on for annual ryegrass control with cereal production.

Table 1. Extent of resistance to herbicides in annual ryegrass in Tasmania from randomly collected samples in 2014 and 2019 (Data courtesy of Dr John Broster, Charles Sturt University).

Herbicide	Group	2014	2009
		Samples resistant (%)	
Diclofop	A	46	18
Clethodim (Select)	A	8	1
Sulfometuron (Oust)	B	16	24
Imazamox + Imazapyr (Intervix)	B	20	7
Trifluralin (TriflurX)	D	8	1
Prosulfocarb (Arcade)	J	0	-
Pyroxasulfone (Sakura)	K	0	-
Glyphosate	M	0	0

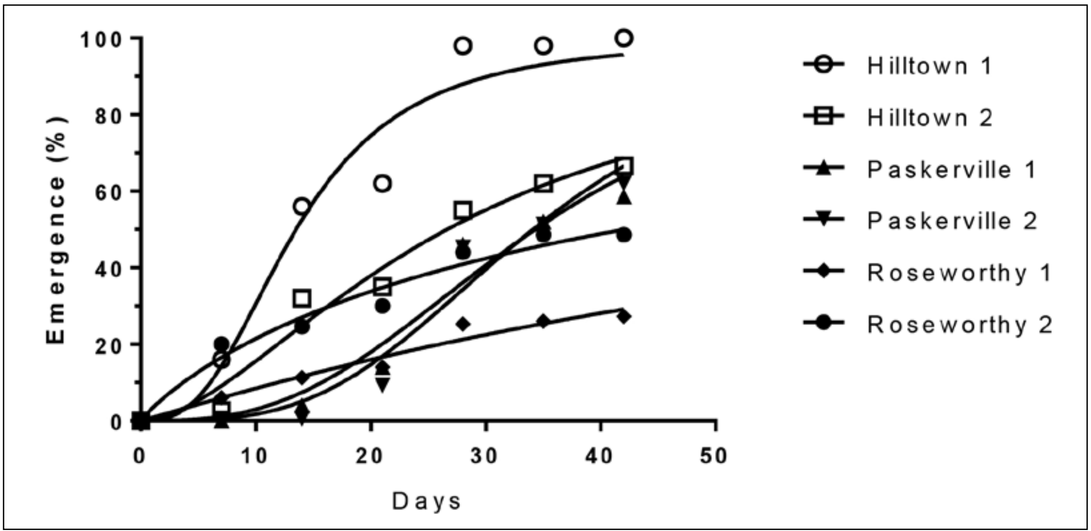

Figure 1. Emergence of annual ryegrass populations sourced from Hilltown (high rainfall), Paskerville (medium rainfall) or Roseworthy (medium rainfall) grown in the same environment.

Biology of annual ryegrass in the HRZ

There are anecdotal comments from growers and advisers that the ecology of annual ryegrass is different in the HRZ compared to other growing regions. Trial data from other regions suggests that annual ryegrass populations in continuously cropped regions have changed their emergence pattern to greater dormancy, with some of the population not emerging until after sowing. Where pre-emergent herbicides are the main control option, increased dormancy will reduce their efficacy. Some preliminary research from the University of Adelaide suggests that the changes in dormancy in annual ryegrass are less evident in higher rainfall regions than in medium rainfall regions (Figure 1).

Annual ryegrass populations tend to be larger in the HRZ and if seed dormancy has not changed, then later emergence of weeds is likely related to high weed seed banks and longer growing seasons. Rainfall tends to be higher in spring in the HRZ than in other growing regions and temperatures stay lower for longer. Both of these environmental conditions will encourage residual seeds in the seed bank to germinate. In addition, residual weeds in crops in the HRZ are able to take advantage of the extra moisture and cooler conditions to set more seed.

Pre-emergent herbicide performance in the HRZ

Trials and grower experience has consistently found that pre-emergent herbicide performance can decline quickly during the season in the HRZ. Activity of herbicides with short persistence in the environment, such as Boxer Gold® and Butisan®, can fall away quickly resulting in high weed populations later in the season. For this reason, products with longer residual activity are preferred.

Trial work conducted as part of GRDC project UA00113 examined the performance of various pre-emergent herbicide options for annual ryegrass control in 2011 and 2012 in six trials across higher rainfall districts of South Australia, Victoria and New South Wales. These trials showed that while all herbicides can perform adequately, single herbicide applications were more likely to fail than mixtures or sequences (Figure 2). The best performing options were mixtures of Avadex® Xtra with Sakura® and sequences of TriflurX® or Sakura® followed by Boxer Gold® early post. These are likely to be the best pre-emergent herbicide approaches for annual ryegrass control in wheat in the HRZ.

Harvest weed seed control in the HRZ

Harvest weed seed control (HWSC) is a set of practices that remove or destroy weed seeds that are collected by the harvesting operation. Some of these practices can be difficult to use in the HRZ because the biomass of cereal crops is often large, creating unacceptable fire risk for narrow windrow burning (form of HWSC). Frequently, the whole paddock will burn rather than just the windrows, producing a poor result.

Trial work conducted as part of GRDC project SFS00032 examined the applicability and use of HWSC in the HRZ. This work found that there were reductions in harvest efficiency with the Integrated Harrington Seed Destructor (iHSD) due to the amount of material going through the mill, resulting

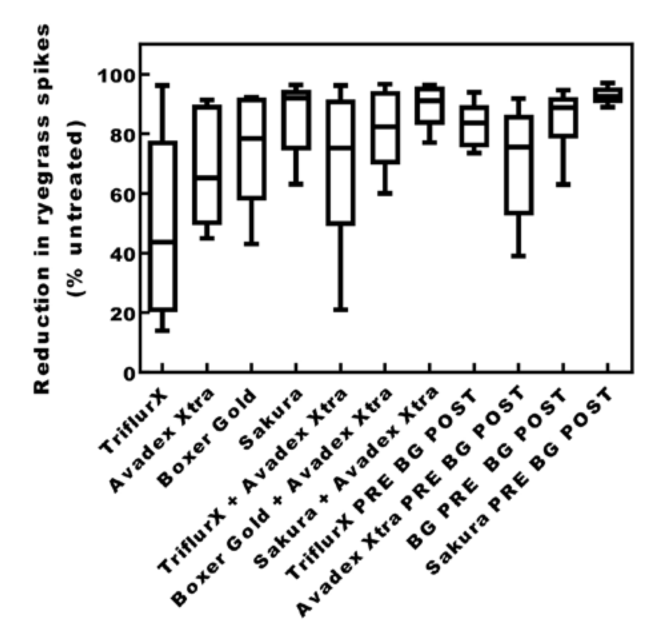

Figure 2. Performance of pre-emergent herbicides across six trials at Manoora, Yarrawonga and Wagga Wagga in 2011 and Saddleworth, Lake Bolac and Wagga Wagga in 2012. Data are presented as box and whisker plots. The line across the box is the mean of all trials. The top whisker is the best performing trial and the bottom whisker the worst performing trial. BG = Boxer Gold.

in greater fuel use. There was little impact of HWSC on annual ryegrass populations in fields with existing high annual ryegrass populations (Table 2). However, in these trials, annual ryegrass populations of about 100 plants/m^2 had little impact on crop yield.

Table 2. Annual ryegrass populations at 60 days after seeding/sowing (DAS) of the following crop after use of the iHSD at harvest in the previous crop.

Trial	Annual ryegrass at 60 DAS (plants/m^2)		
	2015	2016	2017
SFS Lake Bolac	145	115	
SFS Tasmania		259	
MFMG South Australia	218	144	74
FarmLink southern NSW		192	

In the HRZ annual ryegrass matures and substantial amounts of seed are shed before wheat maturity and this gets worse further south (Table 3). However, shedding of annual ryegrass seed can be reduced by later sowing and the amount of annual ryegrass seeds that are caught by HWSC can be increased by cutting lower. While still reducing weed numbers, the benefits of HWSC are not likely to be as great in the HRZ as they are in other regions.

Table 3. Amount of annual ryegrass seed shed in HWSC trials in the HRZ prior to harvest.

Trial	2015	2016	2017
Lake Bolac	50%	31%	0
Yarrawonga	-	57%	65%
Conmurra, SA		59%	65%

Crop competition for annual ryegrass management

Crop competition can help reduce seed set of annual ryegrass. There are several options for increasing crop competition against annual ryegrass. These include changing crop type, changing crop variety, reducing row spacing, increasing seeding rates, changing row orientation or changing planting times. Several of these tactics can vary greatly in efficacy in different environments.

Early sowing of wheat can reduce annual ryegrass seed production in medium rainfall zones; however, its value in the HRZ may be lower. A trial conducted at Lake Bolac in 2016 found no significant effect on annual ryegrass establishment in-crop or annual ryegrass seed head production between sowing times (Table 4). This demonstrates that competition practices effective in the medium and low rainfall zones may be less effective in the HRZ.

Table 4. Effect of time of sowing of wheat on annual ryegrass plant numbers and seed heads at Lake Bolac in 2016.

Time of sowing	Annual ryegrass plants (plants/m^2)	Annual ryegrass seed heads (spikes/m^2)
28 April	62	2418
15 May	53	1632
LSD	n.s.	n.s.

Long term Integrated Weed Management

A long-term trial at Lake Bolac has run since 2012. This trial initially examined the value of pre-sowing cultural tactics on annual ryegrass populations. These tactics were: retained stubble, burning stubble, incorporating stubble and a mouldboard plough operation followed by retained stubble. These were each followed by an in-crop treatment of either three different intensities of herbicide management (Table 5). The trial showed that the mouldboard plough operation reduced establishment of annual ryegrass by more than 95% in the year that it was implemented. However, in subsequent years the weed population continued to increase and by 2014 there was no difference in annual ryegrass populations between the pre-sowing cultural treatments.

Table 5. Herbicide and other treatments used as for the management strategies at Lake Bolac between 2012 and 2017.

Year and crop	Management strategy		
	MS 1 (low cost):	MS 2 (mid cost):	MS 3 (high cost)
2012 Wheat	Trifluralin 2L/ha + Dual Gold® 250mL/ha$^{\Phi a}$ IBS	Boxer Gold® 2.5L/ha IBS	Sakura® 118g/ha + Avadex® Xtra 1L/ha$^{\Phi a}$ IBS
2013 Barley	Trifluralin 2L/ha + Dual Gold® 250mL/ha$^{\Phi a}$ IBS	Boxer Gold® 2.5L/ha IBS	Boxer Gold® 2.5L/ha IBS, Boxer Gold® 1.5L/ha$^{\Phi a}$ @ GS11 ryegrass
2014 RT canola	Trifluralin 3L/ha IBS, Atrazine 900 2.2kg/ha$^{\Phi a}$ + Select® 0.5L/ha @ 4 leaf canola	Trifluralin 3L/ha IBS, Roundup Ready® 0.9 kg/ha @ cotyledon, Roundup Ready® 0.9kg/ha + Atrazine 900 1.1kg/ha @ 6 leaf canola	Trifluralin 3L/ha IBS, Roundup Ready® 0.9kg/ha @ cotyledon, Roundup Ready® 0.9kg/ha + Atrazine 900 1.1kg/ha @ 6 leaf canola, Weedmaster® DST 3.5L/ha @ crop top
2015 Wheat	Trifluralin 3L/ha + Avadex® Xtra 1L/ha$^{\Phi a}$ + Dual Gold 0.25L/ha$^{\Phi a}$ IBS	Sakura® 118g/ha IBS	Sakura® 118g/ha + Avadex® Xtra 2L/ha$^{\Phi a}$ IBS, Boxer Gold® 2.5L/ha$^{\Phi a}$ GS 11
2016 Faba beans	Terbyne® Xtreme 1kg/ha$^{\Phi a}$, Boxer Gold® 2.5l/ha IBS. Clethodim$^{\Phi b}$ 0.5l/ha, Factor® 0.18kg/ha @ GS13. Gramoxone® 0.8l/ha @ desiccation	Terbyne® Xtreme 1kg/ha$^{\Phi a}$, Boxer Gold® 2.5L/ha IBS. Clethodim$^{\Phi b}$ 0.5L/ha, Factor® 0.18kg/ha @ GS13. Gramoxone® 0.8L/ha @ desiccation	Terbyne® Xtreme 1kg/ha$^{\Phi a}$, Propyzamide 1.11L/ha IBS. Clethodim$^{\Phi b}$ 0.5L/ha, Factor 0.18kg/ha @ GS13. Gramoxone 0.8L/ha @ desiccation
2017 TT canola	Atrazine 900 1.1kg/ha IBS Atrazine 900 2.2kg/ha$^{\Phi a}$ + Clethodim 0.5L/ha$^{\Phi b}$ @ 4 leaf canola Weedmaster® DST 2.8L/ha crop top	Rustler® 500 mL/ha$^{\Phi a}$ + Atrazine 900 1.1kg/ha IBS Atrazine 900 2.2kg/ha + Clethodim 0.5L/ha$^{\Phi b}$ @ 4 leaf canola Weedmaster® DST 2.8L/ha crop top	Rustler® 500mL/ha$^{\Phi a}$ + Atrazine 900 1.1kg/ha IBS Clethodim 0.25L/ha + Factor® 60g/ha$^{\Phi a}$ @ 2 leaf canola Atrazine 900 2.2kg/ha + Clethodim 0.5L/ha$^{\Phi b}$ @ 4 leaf canola Weedmaster® DST 2.8L/ha crop top

Note: IBS = incorporated before sowing; $^{\Phi a}$Treatment listed are for trial purposes ONLY as rates and/or products are not as stated on the label for use within this crop, and therefore, are unregistered. For commercial use of products please adhere to label recommendations. $^{\Phi b}$Unspecified concentration of active.

Annual ryegrass seed head numbers increased in all management strategies between 2012 and 2016. They increased less with the most intensive management (MS 3) than with the other management strategies (Figure 3). Following crop topping of faba beans for all strategies in 2016, weed numbers were greatly reduced during 2017. Despite this, annual ryegrass seed head production was still substantially higher under the low intensity management strategy compared to the other management strategies.

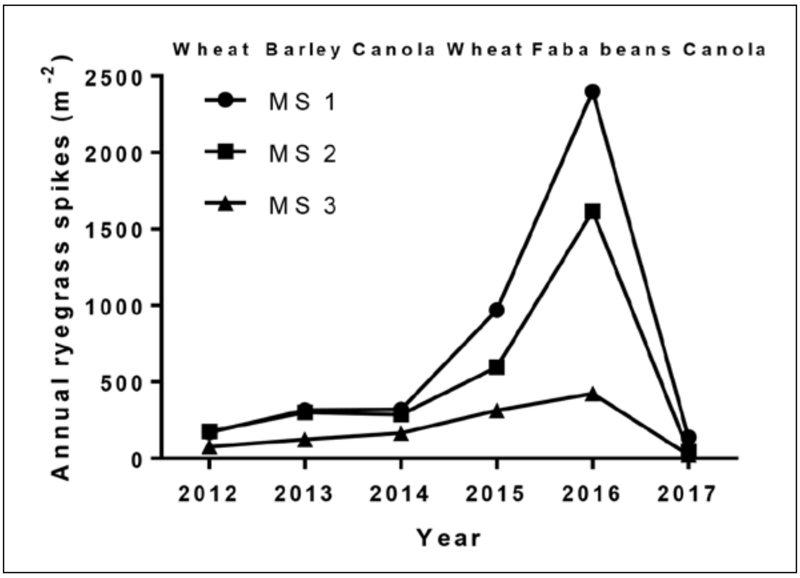

Figure 3. Annual ryegrass seed heads at harvest from 2012 to 2017 at Lake Bolac for the three different management strategies (MS1, MS2 and MS3) employed. See Table 5 for details of strategies.

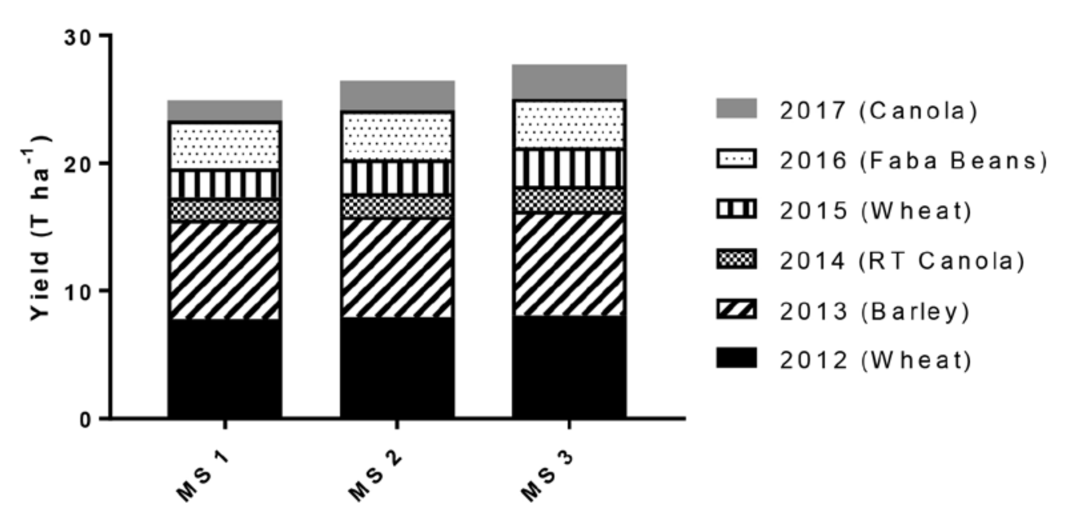

Figure 4. Effect of management strategy intensity on accumulated yield of crops at Lake Bolac between 2012 and 2017. MS1 was low intensity; MS2 medium intensity; and MS3 high intensity management.

Higher annual ryegrass populations in MS 1 resulted in lower crop yields at Lake Bolac (Figure 4). Yield over six years for MS 2 was 1.5t/ha more than MS 1 and for MS 3 was 2.8t/ha more than MS 1. These increases in yield were 6 to 12% of the yield of MS 1.

The GRDC has funded five demonstration trial sites across Victoria and South Australia in the HRZ to identify effective and profitable strategies for the management of annual ryegrass in the HRZ. Information about the trials and other information about management of herbicide resistant annual ryegrass in the HRZ can be found at: https://agwine.adelaide.edu.au/research/farming-systems/weed-science/hrz/

Useful resources

https://agwine.adelaide.edu.au/research/farming-systems/weed-science/hrz/

Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC — the authors would like to thank them for their continued support.

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Return to contents

Notes

Notes

THE 2017-2019 GRDC SOUTHERN REGIONAL PANEL

FEBRUARY 2018

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

CHAIR - KEITH PENGILLEY

Based at Evandale in the northern Midlands of Tasmania, Keith was previously the general manager of a dryland and irrigated family farming operation at Conara (Tasmania), operating a 7000 hectare mixed-farming operation over three properties. He is a director of Tasmanian Agricultural Producers, a grain accumulation, storage, marketing and export business. Keith is the chair of the GRDC Southern Regional Panel which identifies grower priorities and advises on the GRDC's research, development and extension investments in the southern grains region.

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DEPUTY CHAIR - MIKE MCLAUGHLIN

Mike is a researcher with the University of Adelaide, based at the Waite campus in South Australia. He specialises in soil fertility and crop nutrition, contaminants in fertilisers, wastes, soils and crops. Mike manages the Fertiliser Technology Research Centre at the University of Adelaide and has a wide network of contacts and collaborators nationally and internationally in the fertiliser industry and in soil fertility research.

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JOHN BENNETT

Based at Lawloit, between Nhill and Kaniva in Victoria's West Wimmera, John, his wife Allison and family run a mixed farming operation across diverse soil types. The farming system is 70 to 80 percent cropping, with cereals, oilseeds, legumes and hay grown. John believes in the science-based research, new technologies and opportunities that the GRDC delivers to graingrowers. He wants to see RD&E investments promote resilient and sustainable farming systems that deliver more profit to growers and ultimately make agriculture an exciting career path for young people.

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PETER KUHLMANN

Peter is a farmer at Mudamuckla near Ceduna on South Australia's Western Eyre Peninsula. He uses liquid fertiliser, no-till and variable rate technology to assist in the challenge of dealing with low rainfall and subsoil constraints. Peter has been a board member of and chaired the Eyre Peninsula Agricultural Research Foundation and the South Australian Grain Industry Trust.

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FIONA MARSHALL

Fiona has been farming with her husband Craig for 21 years at Mulwala in the Southern Riverina. They are broadacre, dryland grain producers and also operate a sheep enterprise. Fiona has a background in applied science and education and is currently serving as a committee member of Riverine Plains Inc, an independent farming systems group. She is passionate about improving the profile and profitability of Australian grain growers.

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JON MIDWOOD

Jon has worked in agriculture for the past three decades, both in the UK and in Australia. In 2004 he moved to Geelong, Victoria, and managed Grainsearch, a grower-funded company evaluating European wheat and barley varieties for the high rainfall zone. In 2007, his consultancy managed the commercial contract trials for Southern Farming Systems (SFS). In 2010 he became Chief Executive of SFS, which has five branches covering southern Victoria and Tasmania. In 2012, Jon became a member of the GRDC's HRZ Regional Cropping Solutions Network.

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ROHAN MOTT

A fourth generation grain grower at Turriff in the Victorian Mallee, Rohan has been farming for more than 25 years and is a director of Mott Ag. With significant on-farm storage investment, Mott Ag produces wheat, barley, lupins, field peas, lentils and vetch, including vetch hay. Rohan continually strives to improve productivity and profitability within Mott Ag through broadening his understanding and knowledge of agriculture. Rohan is passionate about agricultural sustainability, has a keen interest in new technology and is always seeking ways to improve on-farm practice.

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RICHARD MURDOCH

Richard along with wife Lee-Anne, son Will and staff, grow wheat, canola, lentils and faba beans on some challenging soil types at Warooka on South Australia's Yorke Peninsula. They also operate a self-replacing Murray Grey cattle herd and Merino sheep flock. Sharing knowledge and strategies with the next generation is important to Richard whose passion for agriculture has extended beyond the farm to include involvement in the Agricultural Bureau of SA, Advisory Board of Agriculture SA, Agribusiness Council of Australia SA, the YP Alkaline Soils Group and grain marketing groups.

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RANDALL WILKSCH

Based at Yeelanna on South Australia's Lower Eyre Peninsula, Randall is a partner in Wilksch Agriculture, a family-owned business growing cereals, pulses, oilseeds and coarse grain for international and domestic markets. Managing highly variable soil types within different rainfall zones, the business has transitioned through direct drill to no-till, and incorporated CTF and VRT. A Nuffield Scholar and founding member of the Lower Eyre Agricultural Development Association (LEADA), Randall's off-farm roles have included working with Kondinin Group's overview committee, the Society of Precision Agriculture in Australia (SPAA) and the Landmark Advisory Council.

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KATE WILSON

Kate is a partner in a large grain producing operation in Victoria's Southern Mallee region. Kate and husband Grant are fourth generation farmers producing wheat, canola, lentils, lupins and field peas. Kate has been an agronomic consultant for more than 20 years, servicing clients throughout the Mallee and northern Wimmera. Having witnessed and implemented much change in farming practices over the past two decades, Kate is passionate about RD&E to bring about positive practice change to growers.

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BRONDWEN MACLEAN

Brondwen MacLean has spent the past 20 years working with the GRDC across a variety of roles and is currently serving as General Manager for the Applied R&D business group. She has primary accountability for managing all aspects of the GRDC's applied RD&E investments and aims to ensure that these investments generate the best possible return for Australian grain growers. Ms MacLean appreciates the issues growers face in their paddocks and businesses. She is committed to finding effective and practical solutions 'from the ground-up'.

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2017–2019 SOUTHERN REGIONAL CROPPING SOLUTIONS NETWORK (RCSN)

The RCSN initiative was established to identify priority grains industry issues and desired outcomes and assist the GRDC in the development, delivery and review of targeted RD&E activities, creating enduring profitability for Australian grain growers. The composition and leadership of the RCSNs ensures constraints and opportunities are promptly identified, captured and effectively addressed. The initiative provides a transparent process that will guide the development of targeted investments aimed at delivering the knowledge, tools or technology required by growers now and in the future. Membership of the RCSN network comprises growers, researchers, advisers and agribusiness professionals. The three networks are focused on farming systems within a particular zone – low rainfall, medium rainfall and high rainfall – and comprise 38 RCSN members in total across these zones.

REGIONAL CROPPING SOLUTIONS NETWORK SUPPORT TEAM

SOUTHERN RCSN CO-ORDINATOR: JEN LILLECRAPP

Jen is an experienced extension consultant and partner in a diversified farm business, which includes sheep, cattle, cropping and viticultural enterprises. Based at Struan in South Australia, Jen has a comprehensive knowledge of farming systems and issues affecting the profitability of grains production, especially in the high rainfall zone. In her previous roles as a district agronomist and operations manager, she provided extension services and delivered a range of training programs for local growers. Jen was instrumental in establishing and building the MacKillop Farm Management Group and through validation trials and demonstrations extended the findings to support growers and advisers in adopting best management practices. She has provided facilitation and coordination services for the high and medium rainfall zone RCSNs since the initiative's inception.

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LOW RAINFALL ZONE CO-LEAD: BARRY MUDGE

Barry has been involved in the agricultural sector for more than 30 years. For 12 years he was a rural officer/regional manager in the Commonwealth Development Bank. He then managed a family farming property in the Upper North of SA for 15 years before becoming a consultant with Rural Solutions SA in 2007. He is now a private consultant and continues to run his family property at Port Germein. Barry has expert and applied knowledge and experience in agricultural economics. He believes variability in agriculture provides opportunities as well as challenges and should be harnessed as a driver of profitability within farming systems. Barry was a previous member of the Low Rainfall RCSN and is current chair of the Upper North Farming Systems group.

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LOW RAINFALL ZONE CO-LEAD: JOHN STUCHBERY

John is a highly experienced, business-minded consultant with a track record of converting evidence-based research into practical, profitable solutions for grain growers. Based at Donald in Victoria, John is well regarded as an applied researcher, project reviewer, strategic thinker and experienced facilitator. He is the founder and former owner of JSA Independent (formerly John Stuchbery and Associates) and is a member of the SA and Victorian Independent Consultants group, a former FM500 facilitator, a GRDC Weeds Investment Review Committee member, and technical consultant to BCG-GRDC funded 'Flexible Farming Systems and Water Use Efficiency' projects. He is currently a senior consultant with AGRIvision Consultants.

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HIGH RAINFALL ZONE LEAD: CAM NICHOLSON

Cam is an agricultural consultant and livestock producer on Victoria's Bellarine Peninsula. A consultant for more than 30 years, he has managed several research, development and extension programs for organisations including the GRDC (leading the Grain and Graze Programs), Meat and Livestock Australia and Dairy Australia. Cam specialises in whole-farm analysis and risk management. He is passionate about up-skilling growers and advisers to develop strategies and make better-informed decisions to manage risk – critical to the success of a farm business. Cam is the program manager of the Woady Yaloak Catchment Group and was highly commended in the 2015 Bob Hawke Landcare Awards.

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MEDIUM RAINFALL ZONE LEAD: KATE BURKE

An experienced trainer and facilitator, Kate is highly regarded across the southern region as a consultant, research project manager, public speaker and facilitator. Based at Echuca in Victoria, she is a skilled strategist with natural empathy for rural communities. Having held various roles from research to commercial management during 25 years in the grains sector, Kate is now the managing director of Think Agri Pty Ltd, which combines her expertise in corporate agriculture and family farming. Previously Kate spent 12 years as a cropping consultant with JSA Independent in the Victorian Mallee and Wimmera and three years as a commercial manager at Warakirri Cropping Trust.

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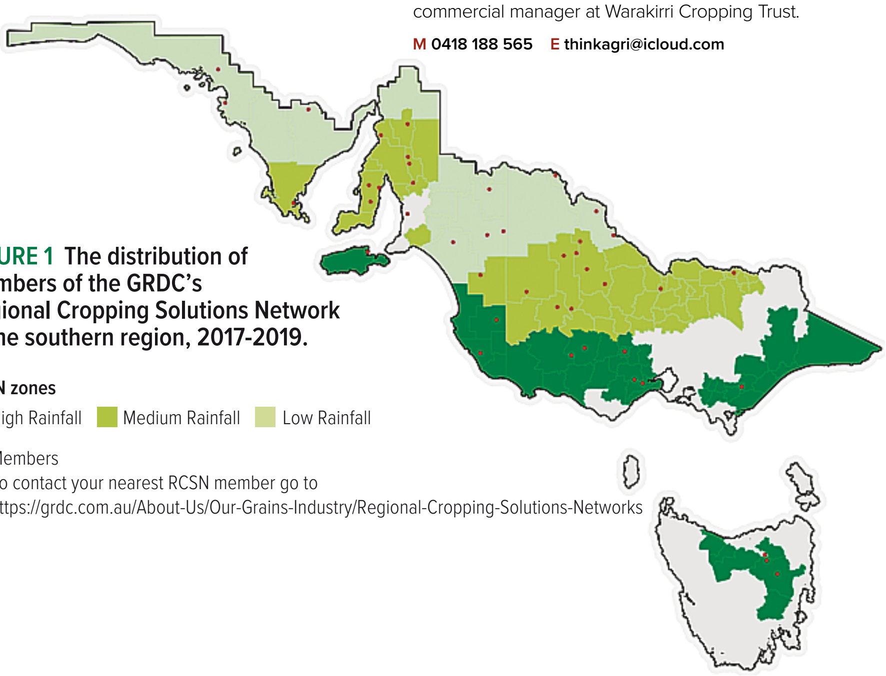

FIGURE 1 The distribution of members of the GRDC's Regional Cropping Solutions Network in the southern region, 2017-2019.

RCSN zones

High Rainfall | Medium Rainfall | Low Rainfall

Members

To contact your nearest RCSN member go to https://grdc.com.au/About-Us/Our-Grains-Industry/Regional-Cropping-Solutions-Networks

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- The local GRDC Grains Research Update planning committee that includes both government and private consultants and GRDC representatives.

- Partnering organisation: SFS

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

You can now provide feedback electronically 'as you go'. An electronic evaluation form can be accessed by typing the URL address below into your internet browser.

To make the process as easy as possible, please follow these points:

- Complete the survey on one device (i.e. don't swap between your iPad and Smartphone devices. Information will be lost).
- One person per device (Once you start the survey, someone else cannot use your device to complete their survey).
- You can start and stop the survey whenever you choose, **just click 'Next' to save responses before exiting the survey**. For example, after a session you can complete the relevant questions and then re-access the survey following other sessions.

www.surveymonkey.com/r/CampbellTown-GRU

2018 Campbell Town GRDC Grains Research Update
Evaluation

1. Name [ ]

ORM has permisssion to follow me up in regards to post event outcomes.

2. How would you describe your <u>main</u> role? *(choose one only)*

- ❑ Grower
- ❑ Agronomic adviser
- ❑ Farm business adviser
- ❑ Financial adviser
- ❑ Communications/extension
- ❑ Grain marketing
- ❑ Farm input/service provider
- ❑ Banking
- ❑ Accountant
- ❑ Researcher
- ❑ Student
- ❑ Other* (please specify) [ ]

Your feedback on the presentations

For each presentation you attended, please rate the content relevance and presentation quality on a scale of 0 to 10 by placing a number in the box (**10 = totally satisfactory, 0 = totally unsatisfactory**).

3. High rainfall wheat & barley review – tailored agronomic packages: *Jon Midwood*

Content relevance [ ] /10 Presentation quality [ ] /10

Have you got any comments on the content or quality of the presentation?

[ ]

4. Hyperyield cereal project and Septoria tritici research update: *Tracey Wylie*

Content relevance [ ] /10 Presentation quality [ ] /10

Have you got any comments on the content or quality of the presentation?

[ ]

5. The effect of stubble on nitrogen tie-up and supply: *Tony Swan*

Content relevance [ ] /10 Presentation quality [ ] /10

Have you got any comments on the content or quality of the presentation?

[ ]

6. Yield and economic potential of high input cropping systems in the high rainfall zone: *Malcolm McCaskill*

Content relevance ☐ /10 Presentation quality ☐ /10

Have you got any comments on the content or quality of the presentation?

7. Dealing with herbicide resistance in the high rainfall zone: *Gurjeet Gill*

Content relevance ☐ /10 Presentation quality ☐ /10

Have you got any comments on the content or quality of the presentation?

Your next steps

8. Please describe at least one new strategy you will undertake as a result of attending this Update event

9. What are the first steps you will take?

e.g. seek further information from a presenter, consider a new resource, talk to my network, start a trial in my business

Your feedback on the Update

10. This Update has increased my awareness and knowledge of the latest in grains research

Strongly agree	Agree	Neither agree nor Disagree	Disagree	Strongly disagree
❑	❑	❑	❑	❑

11. Overall, how did the Update event meet your expectations?

Very much exceeded	Exceeded	Met	Partially met	Did not meet
❑	❑	❑	❑	❑

Comments

12. Do you have any comments or suggestions to improve the GRDC Update events?

13. Are there any subjects you would like covered in the next Update?

Thank you for your feedback.