2014 UPDATE

New South Wales

Tuesday 11th and Wednesday 12th

February 2014

Temora Ex Services Memorial Club,
130 Baker St,
Temora

Share knowledge – accelerate adoption

GRDC
Grains Research & Development Corporation

Your GRDC working with you

Premier partners

NUSEED

Nufarm

Major sponsors

Incitec Pivot Fertilisers

syngenta

Grain Growers
Real benefits. Real results.

Bayer

Farmoz

Dow AgroSciences

agrimaster

Program management:
Matt McCarthy

Proceedings edited and compiled by:
Jane Crane

Design & Layout:
Peter Hoffmann - Lightning Designs

Additional copies ($60 + $15 postage including GST) available from:

www.orm.com.au

46 Edward Street
PO Box 189
Bendigo, Vic 3552

T 03 5441 6176
F 03 5444 4299
E admin@orm.com.au

Welcome

Welcome to the 2014 GRDC New South Wales Adviser Update. The theme of this year's Update; 'Share knowledge – accelerate adoption' is in line with one of GRDC's main objectives, which is the extension and adoption of technologies and project outcomes. With thousands of GRDC projects completed the industry needs to ensure that the process of sharing the knowledge occurs and as a result, accelerates the adoption of it.

This year's conference is again at Temora due to the success and positive feedback from 2013. The format has changed a little with an increase in concurrent sessions to allow more topics to be covered in smaller groups, which hopefully encourages greater audience/presenter interaction.

2013 dealt central and southern NSW a difficult hand. With a later than ideal break, wet mild winter and a dry spring, frost was the finish we did not want. For those that were lucky enough to dodge the frost, 2013 was a reasonable harvest, with modest commodity pricing. Those that suffered 30-60% frosting are back at the table; planning variety by sowing date, by ground cover, by nitrogen placement and timing, etc.

With the adoption of stubble retention, gains in WUE through ground cover, soil health and crop sequencing just to name few, we have all experienced gains in productivity and profitability through the years. This year's Update agenda covers a wide range of topics from pulse crops to slugs, from resistance and pre emergent herbicides to whole farm WUE strategies. Like never before, due to the luxury of social media and smart phones/tablets, growers can access "knowledge" faster, in greater amounts and where ever they like. The 2104 conference will update advisers with the necessary information to help our growers accelerate adoption of this knowledge, again increasing production, profitability and sustainability.

On a closing note I would like to thank GRDC for their continued involvement, support and input into the Adviser Updates across Australia, Matt McCarthy and his team at ORM Communications for the skills and professionalism in pulling the Updates together and finally the Update Planning Committee; who are the link between the advisers/ growers and GRDC/ORM. A lot of planning, discussion and effort go into each Advisor Update so I hope you get great value out of the 2014 NSW Adviser Update topics, speakers and networking opportunities.

Jim Cronin, *Chairman – southern NSW GRDC Adviser Update Planning Committee*

Grains Research Update 2014 planning committee

Chris Blanchard, *GRDC Southern Panel*
Rohan Brill, *NSW DPI*
Lachlan Caldwell, *Lachlan Fertilisers Rural*
Jon Cobden, *Farmlink Research*
Jim Cronin, *Earth Ag*
David Coddington, *Pioneer*
Neil Durning, *Ag 'n' Vet*
Rob Gill, *Griffith*
Barry Haskins, *Ag Grow Agronomy*
Angus Maclennan, *Bayer*
Matt McCarthy, *ORM*
Peter McInerney, *M.O.R.E*
Chris Minehan, *Rural Management Strategies*
Toni Nugent, *Charles Sturt University*
Tony Pratt, *Farmlink Research*
Andrew Rice, *GRDC*
Deb Slinger, *NSW DPI*

GRDC
Grains Research & Development Corporation
Your GRDC working with you

Grains Research UPDATE

Research partners

NSW Government | Industry & Investment

SARDI
South Australian Research and Development Institute

State Government Victoria
Departments of Primary Industries
Regional Development Victoria

EH Graham Centre for Agricultural Innovation
An alliance between Charles Sturt University and NSW Department of Primary Industries

The University of Sydney

Charles Sturt University

La Trobe University
Opportunity for excellence

The University of Melbourne
Australia

The University of Adelaide
Australia

SAGIT

AOF

Pulse Australia

CSIRO

GRDC values the contributions made by its research partners during the 2014 series of Grains Research Updates

GRDC
Grains Research & Development Corporation
Your GRDC working with you

Grains Research **UPDATE**

Supporters

Premier partners

NUSEED

Nufarm

Major sponsors

Incitec Pivot Fertilisers

syngenta

Grain Growers
Real benefits. Real results.

Bayer

Farmoz

Dow AgroSciences

agrimaster

Supporting the Australian Grains Industry through the

GRDC 2014

Grains Research Updates

- **VIC 5th & 6th February 2014 Ballarat**
- **NSW 11th & 12th February 2014 Temora**
- **SA 25th & 26th February 2014 Adelaide**

*** Networking time - refreshments - AGT**

GRDC
Grains Research & Development Corporation
Your GRDC working with you

RESEARCH PARTNER TO THE AUSTRALIAN GRAINS INDUSTRY

The GRDC plans, invests in and oversees research and development to benefit Australian graingrowers.

Find us at www.grdc.com.au

Contents

DAY 1

THEME – Share knowledge – accelerate adoption

Feeding the dragon – modernisation of China's food industry and what it means to the Australian grains industry?	***Ian Perry,*** *ANZ*	13
Strategies and tactics to extend whole-farm water use efficiency – sow on-time or early	***James Hunt,*** *CSIRO*	15

CONCURRENT SESSIONS

Pulses – new varieties and new management bring new options	***Eric Koetz,*** *NSW DPI*	29
The fundamentals of increasing nitrogen use efficiency	***Chris Dowling,*** *Back Paddock Company*	37
Improved slug management	***Michael Nash,*** *SARDI Entomology*	45
What's new with zinc – maybe just some critical reminders?	***Rob Norton,*** *IPNI*	51
Canola establishment – does size matter?	***Rohan Brill,*** *NSW DPI*	59
Biopesticides – fresh hope for the future	***Gavin Ash,*** *Charles Sturt University*	65
Is social media working for you?	***Prudence Cook,*** *DEPI, Vic*	69
Canola and pulse disease management – maintaining the vigilance in 2014	***Kurt Lindbeck,*** *NSW DPI*	73
Soil organic matter – what does it mean for you?	***Harm van Rees,*** *Cropfacts P/L*	81

FINAL SESSION

Students at work

Can canola meal be used to treat cancer?	***Saira Hussain,*** *Charles Sturt University*	89
Unlocking the potential of Australian chickpea – Improving functionality	***Christina Chin,*** *Charles Sturt University*	93
Accelerating adoption of innovative agronomy – experiences from Alberta, Canada	***Steve Larocque,*** *Beyond Agronomy*	99

INDUSTRY INFORMATION *101*

Nuseed	**Bayer**	**Farmoz**	**Syngenta**	**Grain Growers**
Nufarm	**Agrimaster**	**Incitec Pivot**	**Dow AgroSciences**	

Contents

DAY 2

THEME – Share knowledge – accelerate adoption

CONCURRENT SESSIONS

Crown rot – an update from the north	***Steven Simpfendorfer,*** *NSW DPI*	*131*
Maintaining flexibility and options with pre-emergents	***Chris Preston,*** *University of Adelaide*	*139*
Review of sulfur strategy to improve profitability in canola in the central west of NSW	***Maurie Street,*** *Grain Orana Alliance*	*145*
Dual–purpose wheat and canola – finding the best fit with experiments, experiences and modelling	***John Kirkegaard,*** *CSIRO*	*157*
To windrow or not to windrow in 2014? This is the question, but if so, when?	***Maurie Street,*** *Grain Orana Alliance*	*169*
New and potential malting barley variety update and agronomic developments	***Rick Graham,*** *NSW DPI*	*181*
Quantifying herbicide resistance in modern farming systems – Griffith region 2012/13	***Barry Haskins,*** *Ag Grow Agronomy*	*191*

FINAL SESSION

Robotics and intelligent systems for large scale agriculture	***Robert Fitch,*** *University of Sydney*	*199*
Maintaining market access – keeping it clean	***Ian Reichstein,*** *DAFF*	*203*

FURTHER INFORMATION

Establishing pastures – the trade-off between crop and livestock	***Evercrop***	*209*
Sustainable management of insect pests in grain crops	***ICAN workshop***	*212*
Non – herbicide weed control – not as sexy as a new herbicide but really important	***Peter Newman,*** *AHRI*	*213*

Evaluation 222

GRDC
Grains Research & Development Corporation
Your GRDC working with you

2014 UPDATE

Grains Research UPDATE

NEW SOUTH WALES

Share knowledge - accelerate adoption

Temora Ex-Services Memorial Club

Tuesday 11th February – Day 1

9.00am	**Welcome**	***Keith Pengilley,*** *GRDC Southern Panel and* ***Jim Cronin,*** *Planning Committee Chairman*
9.15am	**Feeding the dragon - modernisation of China's food industry and what it means to the Australian grains industry** - P13	***Ian Perry,*** *ANZ*
9.50am	**Strategies and tactics to extend whole farm water use efficiency** - P15	***James Hunt,*** *CSIRO*
10.30am	***Morning tea***	

CONCURRENT SESSIONS

(40 minutes including time for room change) *(R = session to be repeated)*

	Auditorium	*Narraburra Room*	*Bowling Room*	*Board Room*
11.00am	**Pulses - new varieties and agronomy provide new options (R)** - P29 ***Eric Koetz,*** *NSW DPI*	**The fundamentals of increasing N use efficiency (R)** - P37 ***Chris Dowling,*** *Back Paddock*	**Slug management practices - what is working? (R))** - P45 ***Michael Nash,*** *SARDI Entomology*	**Backchat session with** ***Ian Perry,*** *ANZ*
11.40am	**The fundamentals of increasing N use efficiency** - P37 ***Chris Dowling,*** *Back Paddock*	**Slug management practices - what is working?** - P45 ***Michael Nash,*** *SARDI Entomology*	**Pulses - new varieties and agronomy provide new options** - P29 ***Eric Koetz,*** *NSW DPI*	**Backchat session with** ***James Hunt,*** *CSIRO*
12.20pm	**New aspects on Zinc nutrition (R)** - P51 ***Rob Norton,*** *IPNI*	**Canola establishment in marginal conditions (R)** - P59 ***Rohan Brill,*** *NSW DPI*	**Bio-pesticides - fresh hope for future options (R)** - P65 ***Gavin Ash,*** *Charles Sturt University*	**Backchat session with** ***Chris Dowling,*** *Back Paddock*

1.00pm ***Lunch***

CONCURRENT SESSIONS

(40 minutes including time for room change) *(R = session to be repeated)*

	Auditorium	Narraburra Room	Bowling Room	Board Room
2.00pm	**Is social media working for you? (R)** - P69 ***Pru Cook,*** *DEPI Vic*	**New aspects on Zinc nutrition** - P51 ***Rob Norton,*** *IPNI*	**Canola establishment in marginal conditions** - P59 ***Rohan Brill,*** *NSW DPI*	**Backchat session with** ***Michael Nash,*** *SARDI Entomology*
2.40pm	**Diseases of pulses and canola - maintaining the vigilance (R)** - P73 ***Kurt Lindbeck,*** *NSW DPI*	**Stubble retention and nutrients to build organic matter (R)** - P81 ***Harm van Rees,*** *Cropfacts*	**Bio-pesticides - fresh hope for future options** - P65 ***Gavin Ash,*** *Charles Sturt University*	**Backchat session with** ***Rob Norton,*** *IPNI*
3.20pm	**Stubble retention and nutrients to build organic matter** - P81 ***Harm van Rees,*** *Cropfacts*	**Diseases of pulses and canola - maintaining the vigilance** - P73 ***Kurt Lindbeck,*** *NSW DPI*	**Is social media working for you?** - P69 ***Pru Cook,*** *DEPI Vic*	**Backchat session with** ***Rohan Brill,*** *NSW DPI*

4.00pm ***Afternoon tea***

4.30pm ***Students at work*** - P89 and 93

4.50pm **Accelerating adoption of innovative agronomy - experiences from Alberta, Canada** - P99 ***Steve Larocque,*** *Beyond Agronomy*

5.30pm **Close and evaluation**

5.40pm ***Drinks*** *(compliments of AGT)*

Premier partners

Major sponsors

GRDC Grains Research & Development Corporation

Your GRDC working with you

2014 UPDATE

Grains Research UPDATE

NEW SOUTH WALES

Share knowledge - accelerate adoption

Temora Ex-Services Memorial Club

Wednesday 12th February – Day 2

CONCURRENT SESSIONS

(40 minutes including time for room change)   (R = session to be repeated)

	Auditorium	*Narraburra Room*	*Bowling Room*	*Board Room*
9.00am	**Crown rot (R)** - P131 ***Steven Simpfendorfer,*** *NSW DPI*	**Commercial corner (R)** ***The latest services and products from the commercial sector***	**Maintaining flexibility and options with pre-emergents (R)** - P139 ***Chris Preston,*** *University of Adelaide*	**Backchat session with (R)** ***Steve Larocque,*** *Beyond Agronomy*
9.40am	**Maintaining flexibility and options with pre-emergents** - P139 ***Chris Preston,*** *University of Adelaide*	**Sulphur nutrition in canola - taking a second look (R)** - P145 ***Maurie Street,*** *Grain Orana Alliance*	**Commercial corner** ***The latest services and products from the commercial sector***	**Backchat session with** ***Steve Larocque,*** *Beyond Agronomy*
10.15pm	***Morning tea***			
10.50am	**Getting the best fit for wheat and canola dual purpose crops (R)** - P157 ***John Kirkegaard,*** *CSIRO*	**Crown rot** - P131 ***Steven Simpfendorfer,*** *NSW DPI*	**Sulphur nutrition in canola - taking a second look** - P145 ***Maurie Street,*** *Grain Orana Alliance*	**Backchat session with** ***Chris Preston,*** *University of Adelaide*

CONCURRENT SESSIONS

(40 minutes including time for room change)   (R = session to be repeated)

	Auditorium	Narraburra Room	Bowling Room	Board Room
11.30am	**Impact of canola windrow timing and direct heading (R)** - P169 ***Maurie Street,*** *Grain Orana Alliance*	**Barley - varieties, management and market specifications (R)** - P181 ***Rick Graham,*** *NSW DPI*	**Getting the best fit for wheat and canola dual purpose crops** - P157 ***John Kirkegaard,*** *CSIRO*	**Backchat session with** ***Steven Simpfendorfer,*** *NSW DPI*
12.10pm	**Barley - varieties, management and market specifications** - P181 ***Rick Graham,*** *NSW DPI*	**Central west weed resistance survey** - P191 ***Barry Haskins,*** *Ag Grow*	**Impact of canola windrow timing and direct heading** - P169 ***Maurie Street,*** *Grain Orana Alliance*	**Backchat session with** ***John Kirkegaard,*** *CSIRO*

12.45pm ***Lunch***

1.30pm **Robotics and intelligent systems for broad acre agriculture** - P199 — ***Salah Sukkarieh,*** *University of Sydney*

2.10pm **Maintaining market access - keeping it clean** - P203 — ***Ian Reichstein,*** *DAFF*

2.30pm **Herbicide resistance - fresh approaches** - P213 — ***Panel of experts including***
Peter Newman, *AHRI,*
Chris Preston, *University of Adelaide,*
Barry Haskins, *Ag Grow,*
Maurie Street, *Grain Orana Alliance and*
Greg Condon, *Grassroots Agronomy*

3.00pm **Close and evaluation**

Premier partners

Major sponsors

GRDC UPDATES SOUTHERN REGION

2014 UPDATE

GRDC Grains Research & Development Corporation — Your GRDC working with you

Grains Research UPDATE

ORM COMMUNICATIONS (03) 5441 6176

GRDC Research Updates for Advisers

5th & 6th February	**Ballarat VIC**	Ballarat Lodge
11th & 12th February	**Temora NSW**	Temora Ex-Servicemen's Club
25th & 26th February	**Adelaide SA**	Adelaide Convention Centre

GRDC Research Updates for Growers

Friday 7th February	**Lake Bolac VIC**	Lake Bolac Hall
Thursday 13th February	**Corowa NSW**	Corowa RSL Club
Thursday 27th February	**Crystal Brook SA**	Crystal Brook Football Club
Wednesday 12th March	**Wallendbeen NSW**	Wallendbeen Memorial Hall
Thursday 3rd April	**Bridgewater VIC**	Bridgewater Hall
Wednesday 23rd July	**Speed VIC**	
Thursday 24th July	**Nhill VIC**	
Tuesday 29th July	**West Wyalong NSW**	
Wednesday 30th July	**Griffith NSW**	
Thursday 31st July	**Moama NSW**	
Wednesday 13th August	**Waikerie SA**	
Wednesday 20th August	**Cummins SA**	
Thursday 21st August	**Minnipa SA**	
Wednesday 27th August	**Naracoorte SA**	

Register at www.orm.com.au

2014 UPDATE

GRDC Grains Research & Development Corporation — Your GRDC working with you

Farm Business UPDATE

ORM COMMUNICATIONS (03) 5441 6176

GRDC Farm Business Updates for Advisers

Wednesday 19th March	**Bendigo VIC**
Tuesday 12th August	**Launceston TAS**
Thursday 14th August	**Wagga Wagga NSW**
Thursday 13th November	**Adelaide SA**

GRDC Farm Business Updates for Growers

Wednesday 12th March	**Clare SA**
Wednesday 2nd April	**Naracoorte SA**
Friday 15th August	**Southern NSW**
Tuesday 9th September	**North East Victoria**
Wednesday 10th September	**Horsham VIC**
Thursday 2nd October	**Central West NSW**

Scan

scan.me/m609rv

For programs and to register head to www.orm.com.au

Feeding the dragon – modernisation of China's food industry and what it means to the Australian grains industry

Ian Perry,
ANZ

For information regarding this topic, please access the full report at http://www.anzbusiness.com/content/dam/anz-superregional/AgricultureInsightsChinaFood.pdf

Contact Details
Ian Perry
Ian.Perry@anz.com

Notes

Strategies and tactics to extend whole farm water use efficiency - sow on time or early!

***James Hunt*[1], *John Kirkegaard*[1], *Julianne Lilley*[1], *Susie Sprague*[1], *Tony Swan*[1], *Brad Rheinheimer*[1], *Dannielle McMillan*[2], *Alison Frischke*[2], *Paul Breust*[3] *and Tony Pratt*[3],**
[1]CSIRO Sustainable Agriculture Flagship, [2]BCG, [3]FarmLink Research

GRDC project codes: CSP00178, CSP00160, FarmLink Research and CSIRO stubble initiative project number TBA

Keywords

early sowing, slow maturing wheat, winter wheat, time of sowing, frost

Take home messages

- **Maximise wheat WUE by ensuring as much crop flowers during the optimal period as possible – sow on time or early!**
- **Early sown, slow maturing varieties (winter and spring) yield as well as, or better than faster maturing varieties sown later.**
- **Including an early sown variety in a cropping program can greatly increase whole-farm yield.**

Introduction

The dry autumn and frosty spring of 2013 continues the pattern of the last 17 years, and is likely to continue into the future (Cai *et al.* 2012). Getting wheat to flower during the optimal period in a given environment is a huge driver of yield and water-use efficiency, particularly with the recent pattern of late frosts, early heat and dry autumns making this very difficult to achieve. The majority of current wheat varieties need to be sown in the first half of May in order to flower during the optimal period for yield in most environments, which unfortunately coincides with the period of recent rainfall decline.

Growers wishing to maximise farm water-use efficiency need to adopt strategies that will allow them to get as much of their wheat crop as possible flowering during the optimal period in their environment. This means having the varieties, rotations, equipment and level of organisation required to take advantage of any sowing opportunity that arises from late summer onward. This article reports results from several experiments conducted across southern Australia and farmer experience investigating the potential for earlier sowing to increase wheat yields in the face of autumn rainfall decline.

Optimal flowering periods

Every production environment has an optimal period in which wheat crops need to flower in order for yield and water-use efficiency to be maximised (Figure 1). This period is defined by an optimal balance between temperature, radiation and water availability, and also decreasing frost risk and increasing heat risk. Optimal flowering periods vary for different locations e.g. the optimal flowering period for western NSW is early to mid September, whilst in the tablelands around Canberra it is the start of November. Growers and advisers should have a firm understanding of the optimal flowering period in their environment, and how to achieve it from different sowing dates with different varieties.

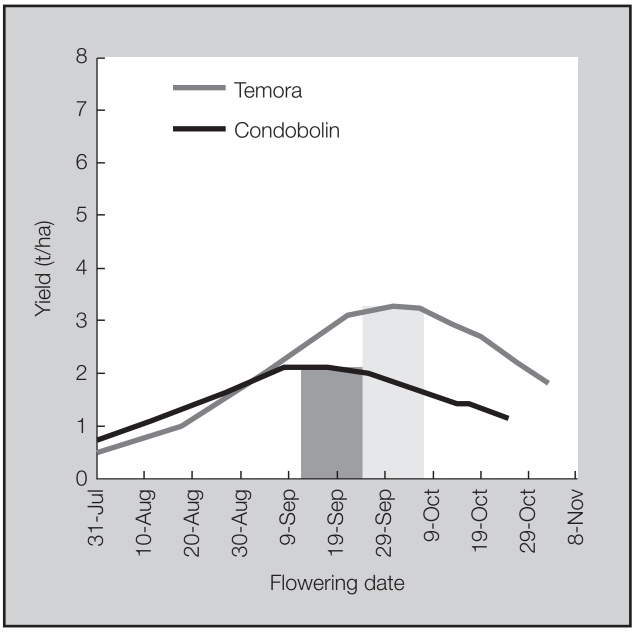


Figure 1. The relationship between flowering time and yield at Temora and Condobolin – optimal flowering periods are highlighted by light and dark grey boxes. Curves are derived from APSIM from 120 years of climate and with a yield reduction for frost and extreme heat events. Optimal flowering periods are mid-September at Condobolin, and late September-early October at Temora.

The key challenge for growers wanting to maximise whole-farm yield and WUE is to have as much of their wheat crop as possible flowering during the optimal period. This has become increasingly difficult for three reasons:

1. Autumn rainfall has declined significantly in the last 17 years, most likely as a direct consequence of anthropogenic climate change.
2. Recently released varieties for most environments have a very narrow range of maturities and unstable flowering times and only flower during the optimal period if sown between late April and late May.
3. Farm sizes and cropping programs are getting bigger.

For these reasons, growers increasingly need to be able to take advantage of whatever sowing opportunities they can get, and there are three strategies that can be employed in order to ensure as much wheat crop as possible flowers during the optimal period:

1. Sow winter wheats from late February through to April
2. Sow slower maturing spring wheats from mid-April to early May
3. Sow mid-fast wheats from late-April onward; including dry sowing if the break has not arrived by this time.

Currently most growers are comfortable with the third strategy, and this has been the principal adaption to the drying autumns. However, there is great potential for the first two strategies to complement May sowing and further increase farm yield.

Achieving optimal flowering periods – experiments 2013

February-March rainfall has not declined over the past 17 years, and in some areas it has increased (Hunt and Kirkegaard 2011). This rain can be used in lieu of the traditional autumn break to establish crops, but winter wheats are required to achieve this. Winter wheats have a vernalisation or cold requirement which means they will not develop beyond tillering until they have been exposed to

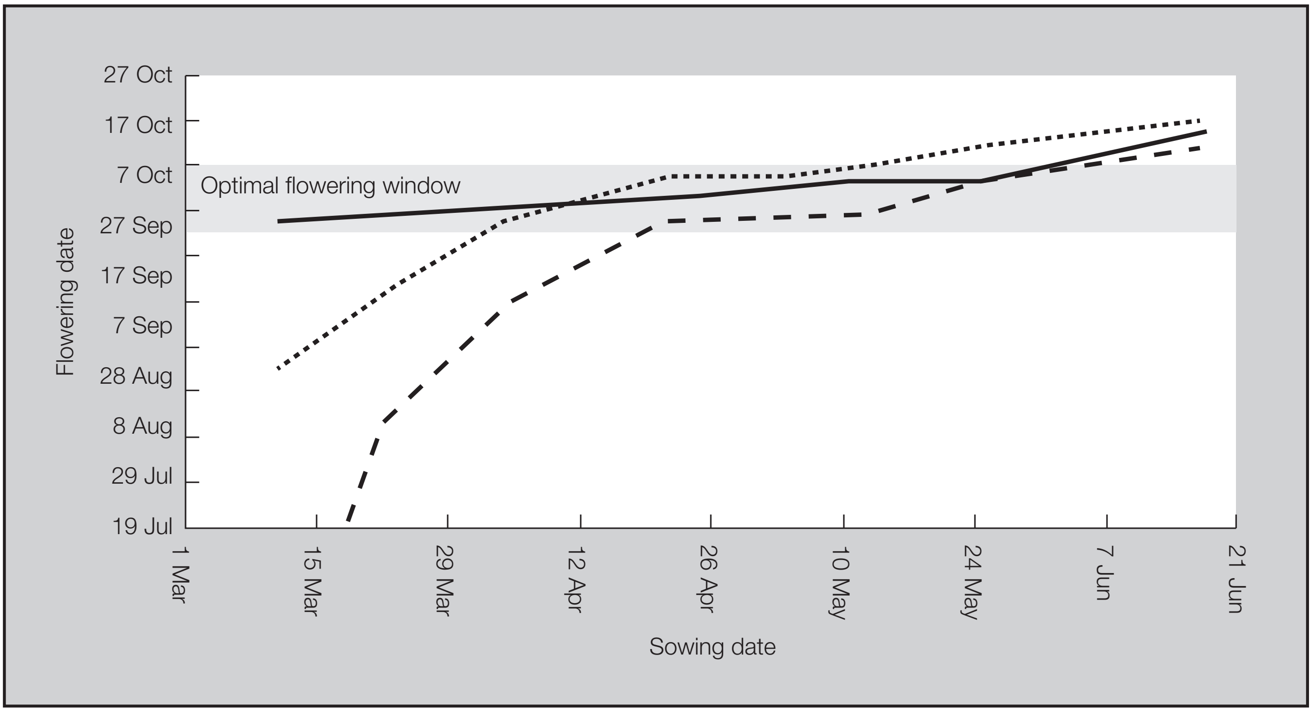


Figure 2. Flowering date of three wheat cultivars from sowings between March and June at Wagga Wagga in 2006 (GRDC, 2011). EGA Wedgetail⟮D⟯ (—) is a winter wheat with a moderate photoperiod requirement, EGA Eaglehawk⟮D⟯ (····) is a very slow maturing spring wheat with a strong photoperiod requirement and Janz (– –) is a mid-fast spring wheat with a minor photoperiod requirement (adapted from GRDC Southern Region Time of Sowing Fact Sheet using data from Peter Martin, NSW DPI).

a certain duration of low temperatures (~4-18 C). This gives them a very stable flowering date from a broad range of sowing dates (Figure 2). They can even be sown in summer, and not flower until the optimal flowering period in spring. They are often only thought of as 'dual purpose' (grain and graze) varieties, and have been undervalued as grain-only varieties, particularly in drier areas of the country. Unfortunately, Australian breeding programs stopped selecting for milling quality winter wheats early last decade. There are very few cultivars available, particularly for medium-low rainfall zones with alkaline soils. Commercial breeding companies have now resumed selection for winter wheats, and it is likely that they will play a greater role in our future farming systems as modern, adapted varieties are released.

Sowing winter wheats on summer rain

The Curyo district north of Birchip received 50 mm of rain in mid-February 2013. As part of their Grain and Graze II project, BCG took the initiative and planted an experiment (sown 26 February, 2013) which consisted of a range of winter wheat varieties from various sources planted on a chick-pea stubble. The farmer's paddock (Kord⟮D⟯ wheat sown 18 May) provided the experimental control.

The winter lines emerged successfully and survived one of the hottest and driest autumns on record. When rains finally came at the end of May, they regenerated rapidly and were able to flower during the optimal period for that environment (Table 1). Yields of the highest yielding lines (Table 2) were equivalent to that of the farmer's paddock sown in May (3.6 t/ha), despite most of the winter varieties having been released over a decade ago, and having no adaptation to the Mallee environment (CCN, salt or boron resistance).

Table 1. Growth stage of different varieties assessed on 12 September 2013. Mid-September is the optimal anthesis (flowering) period for wheat in the southern Mallee

Variety	Ungrazed		Grazed	
	Zadoks code	Growth stage	Zadoks code	Growth stage
YW443	46	Booting	39	Flag leaf emerged
Whistler	63	Early anthesis	51	Early heading
Wylah$^{\phi}$	61	Early anthesis	64	Mid anthesis
Wedgetail$^{\phi}$	66	Mid anthesis	61	Early anthesis
Rosella	60	Early anthesis	51	Early heading
Revenue$^{\phi}$	39	Flag leaf emerged	33	three nodes on main stem
CSIROW8A	53	Early heading	51	Early heading
CSIROW7A	67	Late anthesis	63	Early anthesis

Table 2. Ungrazed grain yield and quality of the winter wheat varieties in the BCG experiment planted at Curyo in 2013

Variety	Grain yield (t/ha)	Protein (%)	Screenings (%)	Test weight (kg/hl)
CSIROW7A	2.7	13.7	1.9	80
CSIROW8A	2.4	13.3	4.3	80
Revenue$^{\phi}$	3.4	11.5	4.6	76
Rosella	3.3	12.2	2.7	81
Wedgetail$^{\phi}$	2.8	12.4	2.5	77
Whistler	3.0	11.8	4.3	79
Wylah$^{\phi}$	2.8	13.1	2.6	76
YW443	1.7	15.4	3.7	74
P-value	*<0.001*	*<0.001*	*<0.001*	*<0.001*
LSD (P=0.05)	*0.3*	*0.9*	*1.2*	*3*
CV%	*6.5*	*4.6*	*24.1*	*2.3*

All lines produced useful amounts of forage for early grazing (0.2-0.5 t/ha), however grazing reduced yield across all varieties by an average of 0.3 t/ha (main effect P<0.001, LSD (p=0.05) = 0.1). See BCG 2013 Season Research Results for more details of this trial.

Whilst this experiment really pushes the boundaries of what is possible with winter wheats, yield of winter wheats is probably maximised if sown from early April onward. Temperatures are too hot during March for wheat to use water efficiently, and sowing this early is only an advantage if it is intended that crops be grazed, or the break ends up being very late.

This experiment really shows the possibilities which winter wheats could afford our modern farming systems, and southern NSW is exceptionally lucky to have well adapted milling quality winter wheats (Wedgetail⦶, Wylah⦶, and Whistler) available from the old NSW DPI Temora breeding program started by Ron Martin. However, Wedgetail is the most recently released of these varieties and it is now twelve years old. We desperately need breeding companies to provide us with modern, adapted lines.

Sowing opportunities – take them as they arise

In regions such as southern NSW, which is lucky to have adapted winter wheats and slow maturing spring wheats (Eaglehawk⦶, Bolac⦶, Lancer⦶) available, it has been repeatedly shown that there is a clear yield benefit from planting slower maturing varieties early (see GRDC update articles 2013). This was again the case in 2013, as demonstrated by a CSIRO and Kalyx trial comparing the grazing potential and grain recovery of winter and spring wheats sown at different times and with different grazing regimes. The experiment was located at Iandra north of Young on the SW slopes of southern NSW (571 mm median annual rainfall with equi-seasonal distribution). The site received 81 mm of rain from 24 February to 1 March 2013, which was followed by 14 mm on 23 March which made for ideal sowing conditions for a winter wheat (Wedgetail⦶) on 26 March. Another 13 mm fell on 29 March, and the crop emerged well and grew rapidly.

Like most of SE Australia, April was very dry and no further significant rain fell until mid May. Bolac⦶ was planted in its ideal window on 23 April, but into marginal seed-bed moisture, and only 30% of the crop emerged at this time. Gregory⦶ was sown dry on 8 May, and it and the remaining Bolac⦶ only emerged following 8 mm rain on 14 May. Winter was wet, but spring was dry, frosty and hot and the site received 280 mm for the growing season. The site was located on a hill and so largely avoided the black frost of 18 October which devastated crops in the region.

The yields very clearly show the benefit of using slower maturing wheats (winter and slow maturing spring) to take advantage of any establishment opportunity that arises early in the season (Table 3). Wedgetail⦶ and Bolac⦶ both had a 0.6-0.9 t/ha yield advantage over main season Gregory⦶.

Table 3. Crop yields from four treatments at the CSIRO and Kalyx experiment at Iandra, NSW comparing grazing potential and grain recovery of winter and spring wheats sown at different times and with different grazing regimes

Variety and sowing date	Yield (t/ha)	Standard error
Wedgetail⦶ - sown 26 March 2013		
Uncut	4.7	0.1
Z30 hard defoliation	4.4	0.2
Bolac⦶ - sown 23 April (30% emergence, remainder emerged following rain mid-May)		
Uncut	5.0	0.2
Z30 hard defoliation	4.9	0.1
Gregory⦶ – sown 8 May 2013		
Uncut	4.1	0.2
Z30 hard defoliation	4.0	0.1

Needless to say, the Wedgetail⟨PBR⟩ also provided significantly more forage (2.6 t/ha) than both the spring wheats (0.8 t/ha for Bolac⟨PBR⟩ and 0.4 for Gregory⟨PBR⟩), however grazing reduced yield. This (and the BCG data above) debunks a common misconception that winter wheats are only dual purpose varieties and have to be grazed in order to manage their canopy and achieve good yields. Winter wheats can be highly flexible grain-only varieties in their own right, and a very important tool for managing climate variability.

Farmer experience in 2013

The early sowing message has been rapidly adopted by farmers and advisers in southern NSW where suitable varieties are available, and the following case studies describe some successes and pitfalls of the approach.

Charlie and Lou Clemson, Ardlethan

The Clemson's farm south of Ardlethan received ~50 mm in a highly localised storm at the end of March. Charlie was understandably wary of the recent run of dry autumns, and not knowing when the next sowing opportunity was coming, decided to start planting wheat. He had Bolac⟨PBR⟩ seed from 2012; clean canola stubbles on their home block, and started planting on 4 April and finished by 11 April. Paddocks sown on 4 April emerged very quickly, those sown by 7 April were slower as things dried out, which probably turned out to be a good thing.

The start of April is a critical time for slow maturing spring wheats, as it is then that days just become short enough for the photoperiod sensitivity of slow maturing spring wheats to hold back their development (see how Eaglehawk⟨PBR⟩ and Janz development becomes slower at the start of April in Figure 3). That is why winter wheats are required for sowing before ~10 April, as their vernalisation requirement stops them from developing when days are long. The Bolac⟨PBR⟩ sown on 4 April was probably exposed to enough day length to speed its development, and it had started flowering on 5 August – a good month before the optimal period in that environment. It suffered 40% frost damage, probably from a frost on 16 August (-1.3°C recorded at West Wyalong AWS), but still averaged ~2.5 t/ha of H2 (Table 4). The Bolac⟨PBR⟩ sown 7 April flowered quite a bit later and only suffered ~10% damage, and averaged ~4.2 t/ha of H2. Average Bolac⟨PBR⟩ yield across the home farm was 3.7 t/ha.

On another two blocks further west, Bolac⟨PBR⟩ sown 12-18 April averaged 3-3.3 t/ha (26% of wheat crop) whilst main season varieties (74% of wheat crop) averaged 2.0 t/ha. Across all three farms, Bolac⟨PBR⟩ sown 4 to 18 April averaged 3.5 t/ha whilst main season wheats (Gregory⟨PBR⟩, Kord⟨PBR⟩) sown 1 May to 7 June averaged 2.1 t/ha. This reflected the results of the CSIRO, FarmLink and NSW DPI experiments showing the yield advantages of slow maturing wheats sown early.

Charlie and Lou were generally pretty pleased with the result, and next year will trial some different slow maturing spring wheats and winter wheats on their farm, and depending on results look to use winter wheat if they get a sowing opportunity in early April again.

Table 4. Hand harvest yields, frost induced sterility and machine harvest paddock averages for Clemson's Bolac⟨PBR⟩ sown in early April. Numbers in brackets are standard error of the mean – if standard errors overlap then means are unlikely to be significantly different

Sowing date	Hand harvest yield (t/ha)	Frost induced sterility (%)	Paddock average yield (t/ha)
4 April	3.0 (0.4)	44 (10)	2.6
7 April	4.2 (0.2)	10 (2)	4.2
8 April	4.9 (0.5)	9 (3)	4.2

Figure 3. Lou and Charlie Clemson inspecting one of their early sown Bolac$^{\phi}$ paddocks just prior to starting harvest on 24 October.

Heidi and David Gooden, Osborne

The Osborne district got a sowing opportunity at the start of April, and Heidi and David replicated over hundreds of hectares on their farm the small-plot experiments that CSIRO, FarmLink and NSW DPI had done in the GRDC water-use efficiency project which demonstrated the yield advantages of early sowing (see GRDC adviser update papers from 2013 for results of these experiments). The strategy fitted well with their sowing operation; they planted Wedgetail$^{\phi}$ and Eaglehawk$^{\phi}$ from 12 April, then canola before switching to Bolac$^{\phi}$ and Lancer$^{\phi}$ around Anzac day and finishing with Gregory$^{\phi}$ and Lincoln$^{\phi}$ in early May. The winter at Osborne was exceptionally favourable, and all crops looked sensational… until the Black Frost of 18 October! Frost damage and yields were largely determined by elevation and position in the landscape. Hand-cuts taken on hills show that the findings from the small plot trials held true; early sown, slow maturing wheats yielded more (Table 5). However, across whole paddocks frost was huge driver of yield (Figures 4 and 5), and average paddock yields were not that different to each other and Gregory$^{\phi}$ sown later achieved better quality (Table 5).

Table 5. Yield and total frost damage (frost-induced sterility and damaged grains) from hand-harvests (4 x 0.9 m quadrats from each treatment), and paddock averages from header yield monitor at Gooden's farm in 2013. Numbers in brackets are standard error of the mean; if standard errors overlap then means are unlikely to be significantly different

Variety and sowing date	Grain yield (t/ha)		Total frost damage (%)		Paddock average yield and quality (t/ha)
	Hill	Flat	Hill	Flat	
Eaglehawk⟲ 12 April	6.2 (0.1)	1.7 (0.2)	16 (3)	92 (4)	2.9 (HPS1)
Wedgetail⟲ 12 April	5.5 (0.3)	-	9 (2)	-	3.5 (AUH2)
Bolac⟲ 23 April	5.7 (0.2)	3.2 (0.5)	1 (1)	61 (18)	2.9 (FED1)
Gregory⟲ 5 May	4.2 (0.2)	-	33 (3)	-	3.5 (APW1)

Whilst Gregory⟲ on the hill appears to have sustained more frost damage, the absolute number of first florets which were either sterile or contained damaged grain (5 per head) was similar to Eaglehawk⟲ on the hill (3 per head), but Eaglehawk⟲ had 23 spikelets per head whilst Gregory⟲ had only 17. So whilst the percentage damage was higher in Gregory⟲, in absolute terms (t/ha) the damage in both varieties was about the same.

The Gooden's are a little trepidatious about trying early sowing with slow maturing varieties again; they are unsure if the high biomass of early sown crops is appropriate for their environment and farming system, and in a frosty year the early sown crops showed no benefit over mid varieties sown later.

A word on frost

The black frost of 18 October 2013 was financially and psychologically devastating to growers across southern NSW and Victoria who were affected. However, one learning from the catastrophe was that delaying sowing (or flowering) is not an effective way of managing risk of late-season frosts. This was starkly illustrated by a grower (who shall remain nameless!) on the south west slopes of NSW who mixed up his seed silos and planted Spitfire⟲ on 22 April and Bolac⟲ in May. This generated a very broad range of flowering dates from 'too early' to 'too late', but all crops were equally affected.

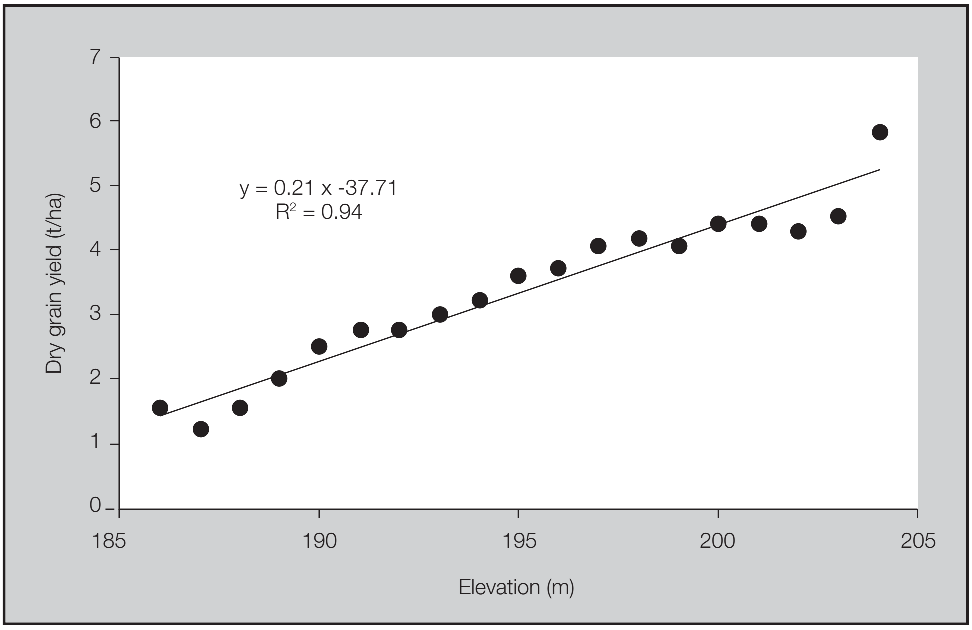


Figure 4. Relationship between elevation and yield for Bolac⟲ sown 23 April 2013 from Gooden's header yield monitor. Each data point on the graph is an average for each 1 m of elevation and represents thousands of datapoints. Elevation explains 94% of the variation in yield, and yield increased by 0.21 t/ha for every 1 m of elevation.

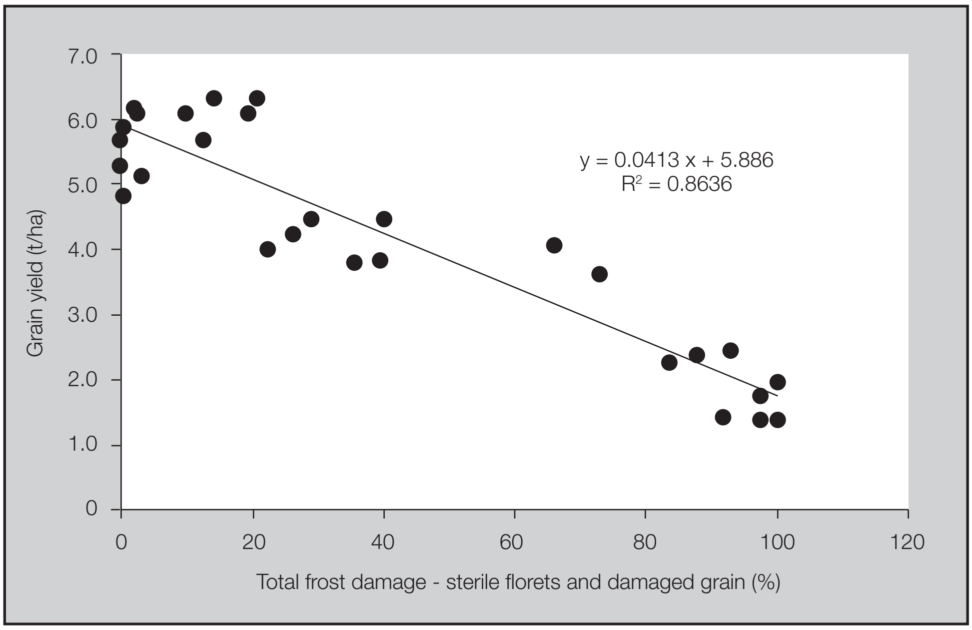


Figure 5. The relationship between frost damage (%) and grain yield from hand harvests at Gooden's farm in 2013.

Figure 6. Heidi, David and Adam Gooden stand in their crop of Eaglehawk⁽ᵇ sown 12 April 2013. This photo was taken at the end of August, the crop ended up being ~1.2 m tall!

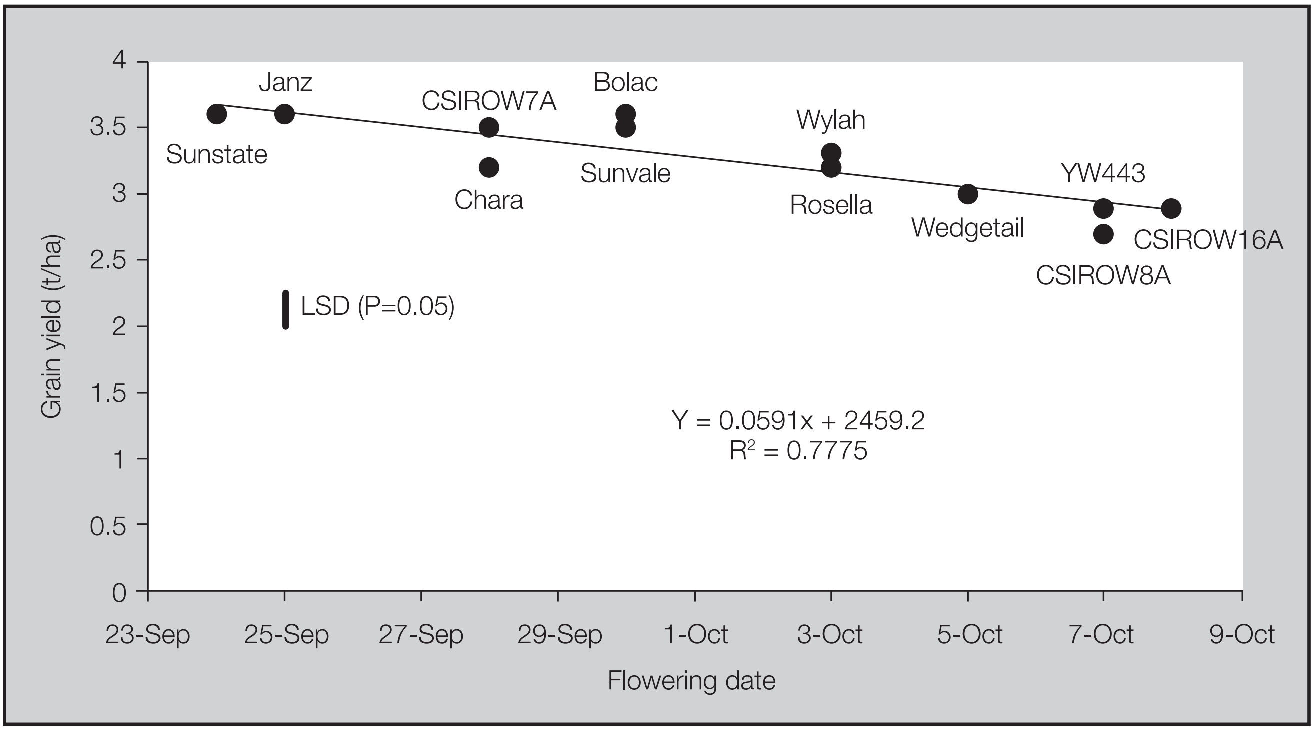


Figure 7. Relationship between flowering time and yield at a CSIRO experiment at Temora in 2013. The optimal flowering period in this environment is the first week of October.

Further evidence of this was provided by a CSIRO experiment in a frost-prone site south of Temora. The experiment was dry-sown on 23 April, but only emerged following rain on 8 May. It included varieties with a broad range of maturities, and flowering extended for a fortnight from ‘too early’ until ‘too late’. Air temperature fell to -3.6°C on the morning of 18 October, and despite all varieties suffering ~60% frost damage, yield still very clearly declined with flowering date (Figure 7). Varieties which flowered on time (or early!) yielded the most.

To have had crops flower after the 18 October frost would have required delaying sowing with main season wheats well into July, which in the majority of years is guaranteed to result in poor yields. Delaying sowing past the optimal date for a given variety is not an effective way of managing frost risk, and historically has probably cost more yield than frost itself.

There are more successful ways to manage frost risk than delaying sowing. Another result from a different experiment at the same Temora site (funded through the GRDC stubble initiative and run in conjunction with FarmLink Research) comparing grazed, burnt and retained stubbles; clearly demonstrated the insulating effect of stubble on the soil surface during frost events, and resultant increase in frost damage (Table 6). A similar yield result was observed in 2012, but whilst stubble retained treatments appeared visually to have more frost damage, frost scores showed no significant difference. These trials show the potential of burning stubbles in frost prone sites to reduce the risk of damage.

Table 6. Grain yield and frost damage for different stubble treatments applied prior to sowing at the FarmLink and CSIRO stubble initiative site at Temora

Treatment	2013 wheat yield (t/ha)		2013 canola yield (t/ha)		2012 wheat yield (t/ha)	
	Burn (30% frost damage)	Retain (59% frost damage)	Burn (43% frost damage)	Retain (59% frost damage)	Burn (10% frost damage)	Retain (10% frost damage)
Nil graze	3.3	2.2	1.0	0.7	5.0	4.4
Stubble graze	3.6	3.0	1.1	0.9	4.8	4.8
P value	<0.001		0.014		0.003	
LSD (P<0.05)	0.2		0.1		0.3	

Another observation from the 18 October frost and previous events was the strong effect of elevation (Figure 4). This means that frost is able to be managed spatially, and on the SW slopes, farms zoned according to how frost-prone different regions are, were able to avoid the worst of the damage. Frost sensitive crops are not planted in low lying or frost prone paddocks, and only pasture, hay crops, dual-purpose wheat or barley are grown in these areas.

The last obvious way to manage frost risk is through enterprise diversity. Farms in frost-prone areas should maintain enterprises not exposed to frost risk. These could be off-farm investments, or on farm such as livestock or hay.

Putting it into practice

Growers wishing to sow early in 2014 need to get themselves in a position to take advantage of early sowing opportunities should they arise? Early-sown wheat needs weed and disease free paddocks; a double break (e.g. pulse/legume pasture/hay crop followed by a canola crop) is an ideal set-up for early sown wheat, particularly in higher rainfall areas.

Growers also need to have a good idea of what their optimal flowering period is, and how to achieve it from different sowing dates with a range of varieties most suited to their environment. If growers keep two to three varieties (one winter and one or two spring wheats), they are able take advantage of

Table 7. Wheat maturity groups, sowing windows to achieve optimal flowering windows and examples of best-bet varieties within groups for southern NSW.

Winter wheats	Slow maturing spring wheat	Mid maturing spring wheat	Fast maturing spring wheat
Late February – late April	**Mid-April – early May**	**Late-April – mid May**	**Mid May onward**
Wedgetail$^{\phi}$, Wylah$^{\phi}$, Whistler	Bolac$^{\phi}$, Lancer$^{\phi}$, Eaglehawk$^{\phi}$	Suntop$^{\phi}$, Gregory$^{\phi}$ (both these varieties are competitive with fast spring wheats when sown later in May)	Spitfire$^{\phi}$, Wallup$^{\phi}$, Emu Rock$^{\phi}$, Lincoln$^{\phi}$, Livingston$^{\phi}$, Corack$^{\phi}$

any sowing opportunity that may arise over a three month period (Table 7). It does require growers to be tactical in how much of each variety they grow in a given year, but the potential yield benefits well outweigh the logistical hassles. In southern NSW, growers only need to keep two varieties (Wedgetail⟑ and either Suntop⟑ or Gregory⟑) in order to give themselves a very broad sowing window.

Early sown crops do require different management to later sown crops. In higher rainfall regions *Septoria tritici* is a very serious pathogen of early sown crops, and it is recommended that flutriafol in-furrow and earlier foliar sprays are used when sowing early. Barley yellow dwarf virus can be a threat in all environments, and it is recommended that seed be treated with imidicloprid, or crops closely monitored for aphid infestation and sprayed accordingly. Wheat streak mosaic virus is a very serious threat in the higher rainfall zones of SNSW, and there is no chemical control for this disease or its insect vector. The slow-maturing spring variety Forrest⟑ has tolerance to the virus, but is really only suited to mid-April sowing, at which time the risk of the virus affecting crops is greatly reduced. Forrest⟑ also appears to have a 'glass jaw' – it performs well in favourable seasons, but is not competitive with other slow maturing varieties in dry springs.

If planning to graze crops, higher seeding rates and up-front N will maximise early dry matter production. If crops are not to be grazed, then N fertiliser should be deferred until after Z30 to avoid excessive early growth, and if initial soil N is high sowing rates should be reduced (~50-80 plants/m^2). Yield effects of grazing are variable; sometimes positive and sometimes negative, but the effect size is rarely more than 0.5 t/ha if grazed in the safe window (prior to Z30). It is certainly not necessary to graze early sown crops to maximise grain production, but they can offer significant amounts of forage at a time when feed can be scarce.

References

Cai W, Cowan T, Thatcher M (2012) Rainfall reductions over Southern Hemisphere semi-arid regions: the role of subtropical dry zone expansion. Nature Scientific Reports 2.

Hunt JR, Kirkegaard JA (2011) Re-evaluating the contribution of summer fallow rain to wheat yield in southern Australia. Crop & Pasture Science 62, 915-929.

Contact details

James Hunt

GPO Box 1600 Canberra ACT 2601

02 6246 5066

james.hunt@csiro.au

New South Wales

Grains Research UPDATE

Concurrent Sessions

Australian Government

Australian Pesticides and Veterinary Medicines Authority

APVMA permits database goes mobile

The second release of the FREE APVMA mobile app is now available, providing on-the-go access to the APVMA's permits database.

The app provides a radically simpler, intuitive user interface with real-time access to the APVMA's agricultural and veterinary medicines chemical registration and permits databases and is of particular relevance for those reliant on minor use authorisations in the horticultural and minor grains industry.

Chemical users—farmers, vets, householders, industry, chemical manufacturers, environmental managers and researchers—are now able to:

- review product labels
- view off-label authorisations
- search by category, alphabetically, suspended or cancelled products and 'did you mean?' searches
- save searches and email results
- find information on product formulations, active ingredients, withholding periods, pack sizes, pests treated, hosts treated, states where the product is registered and poison schedule information.

To download, search 'APVMA' on the App Store. For more information, visit www.apvma.gov.au.

Available on the App Store

Pulses - new varieties and new management bring new options

Eric Koetz[1], Luke Gaynor[2,3], Eric Armstrong[2] and Gerard O'Connor[1],
[1]Technical Officer, NSW DPI Wagga, [2]Research Agronomists, [3]Reseach Leader Dryland, NSW DPI Wagga Wagga

GRDC project codes: DAN00151; DAV00113; DAV00118; DAV00119; DAN00157; DAW00181

Keywords

pulses, variety improvement, brown manuring, weed control, nitrogen fixation, winter crop rotations, farming systems, agronomy

Take home messages

- **Brown manures can be planted across the whole sowing window of winter crops in southern NSW.**
- **Vetch is the preferred "earlier" sowing option - April to mid May.**
- **Field pea is the preferred "later" sowing option - mid May onwards.**
- **Pulses assist weed control in southern NSW cropping systems by introducing wider herbicide options, brown manuring, crop topping and improved cultural practices.**
- **The brown manuring strategy in southern NSW is geared more to herbicide resistant weed control and weed seed bank reduction with nitrogen fixation the secondary benefit.**
- **Effective brown manure crops are not cost free, require careful planning and the use of some in-crop herbicides to maximise their competitiveness and avoid letting grass weeds get to a chemically uncontrollable size.**
- **Annual inoculation of pulses is essential on the acidic red-brown soils of southern NSW for effective nodulation and N_2-fixation.**
- **Pulse breeding and agronomy projects run by NSW DPI staff at Wagga actively support a Southern NSW cropping system.**

Utilising pulses in a southern NSW cropping system

Cropping systems in southern NSW are under constant pressure to maintain production, profitability and sustainability over seasons. Nitrogen use efficiency, weed control and moisture conservation are major obstacles central to achieving these goals. Pulses, when used wisely and strategically, assist with all of these.

The pulse research team at Wagga, supported by NSW DPI and GRDC, develop new varieties of field pea, lupin, chickpea, faba bean and lentil specifically targeting the unique environment of southern NSW. Agronomy projects associated with each pulse provide updated agronomy packages to support production of each pulse crop.

Brown manure cropping

Brown manuring in a cropping program is growing a legume to spray out using a non-selective knockdown herbicide, aiming to prevent weed seed set and maximise nitrogen fixation. Green manuring on the other hand utilises cultivation to kill the crop and weeds.

There are three key reasons for brown manuring pulses; to help manage weeds, particularly if there is herbicide resistance present, to boost soil nitrogen and to conserve soil moisture for subsequent crops. In southern NSW, controlling herbicide resistant weeds has now become the major objective behind brown manuring.

In order to understand the implications and proper management of brown manures in southern NSW cropping systems, experiments were conducted at Wagga in 2012 and 2013 to evaluate a range of pulse crops as potential brown manures over a wide range of autumn sowing dates. Field pea (Morgan⟑, PBA Percy⟑ and PBA Hayman⟑), vetch (Morava⟑), lupin (Rosetta⟑ and Mandelup⟑), faba bean (Fiord) and wheat (Lincoln⟑- a non-nitrogen fixing reference) were sown from early April to early June. Results have highlighted many issues and challenges and we have attempted to discuss and rank their importance and implications for southern NSW in this paper. Trials were situated in paddocks with either high annual rye grass (ARG) populations (2012) or low black oat numbers (2013). Weather conditions in both years are presented in Figures 1 and 2.

The 2012 season started with a full profile of soil moisture followed by a very dry, frosty growing season (Figure 1); the 2013 season started with almost no soil profile moisture but 100mm more growing season (Apr-Oct) rain, fewer frosts, much higher minimum temps (+2.00C) but an unusually cold October with damaging frosts (Figure 2).

2013 brown manuring experiment at Wagga Wagga

All pulse species and varieties were sown at three times – 12 April, 27 May and 11 June 2013. The first sowing was planted ‘dry’ without significant subsequent rain until 12 May. Certain treatments emerged better under these dry conditions. Each variety was duplicated for either brown manure or left for grain harvest, and replicated three times. Table 1 lists the varieties used and their specific trait which determined their inclusion.

Two DM cuts were taken, one coinciding with anthesis/early ‘milky-dough’ stage of self-sown black oats within each time of sowing treatment, the other at peak biomass of the pulse. The timing of the first cut was targeted to eliminate seed viability of black oats, and therefore, driven entirely by development of this weed. Consequently, the growth stage reached by each pulse varied slightly dependant on black oat development. The timing of the second cut was targeted at physiological maturity just prior to leaf drop, with the objective of estimating peak biomass production of each species. Only results of the first DM cut (black oat control) are reported here (Figure 3).

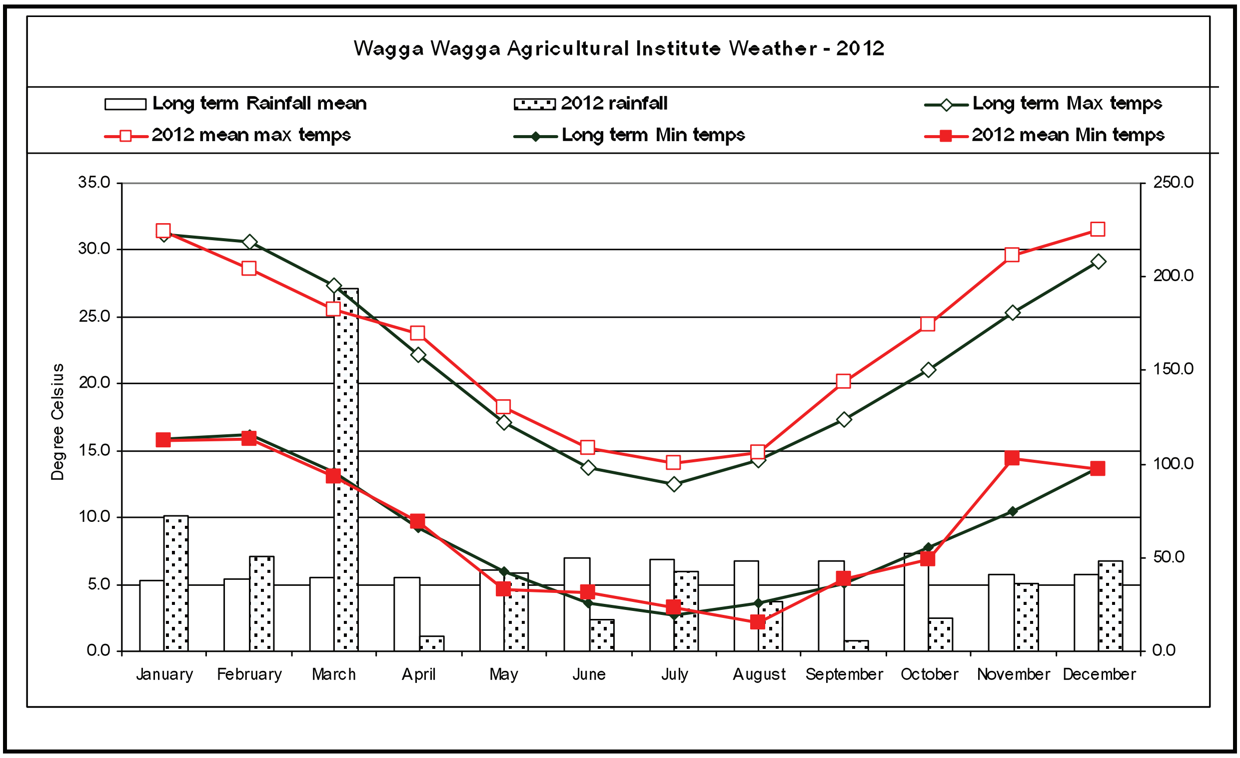


Figure 1. 2012 and the long term averages for rainfall, maximum and minimum temperatures for Wagga Wagga Agricultural Institute. GSR (April-Oct) were 52% below average. Maximum and minimum temperatures were 1.8°C above and 0.2°C below long term average temperatures, respectively.

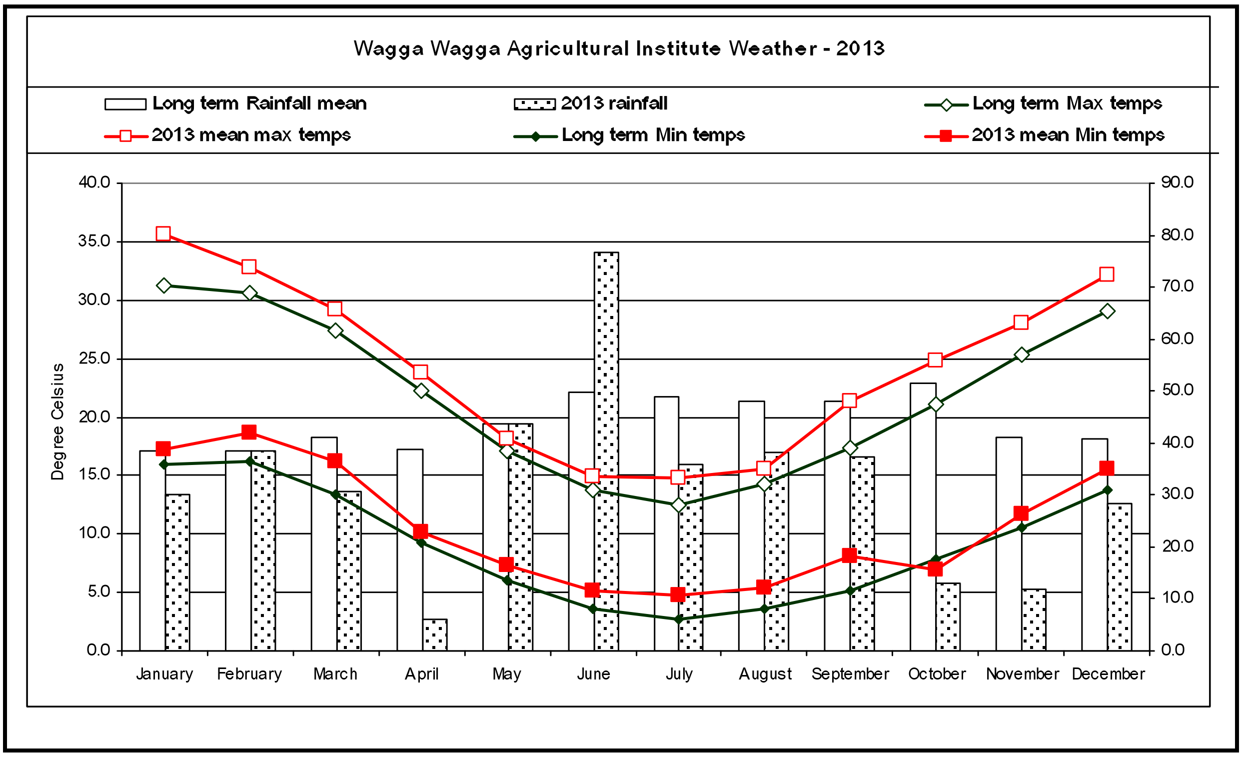


Figure 2. 2013 and the long term averages for rainfall, maximum and minimum temperatures for Wagga Wagga Agricultural Institute. GSR (April-Oct) was 24% below average, maximum and minimum temperatures were 2.1°C and 1.4°C above long term average temperatures, respectively. Extreme frost events occurred in mid October.

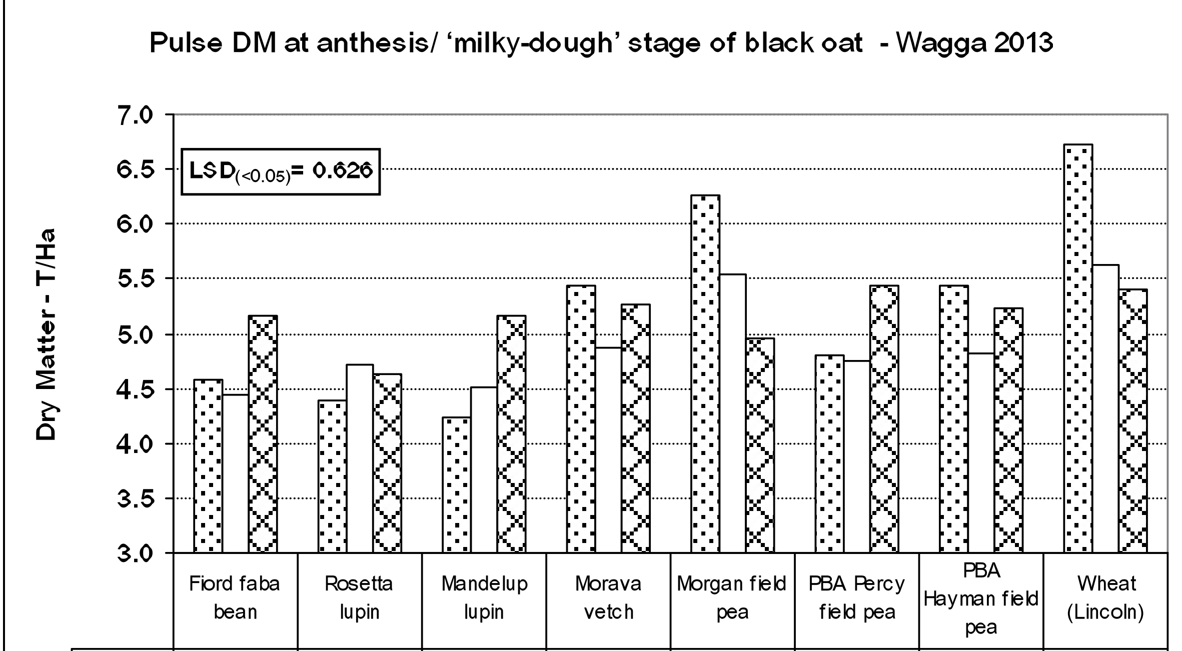
Table 1. Description and characteristics of pulse varieties used for potential brown manures at Wagga in southern NSW

Species	Phenology	Comments
Fiord	early flowering	small seeded type
Rosetta⟑	late flowering	high biomass
Mandelup⟑	early flowering	early vigour
Morava⟑	late flowering	high biomass, no hard seeds
Morgan⟑	late flowering	late type, high biomass
PBA Percy⟑	early flowering	conventional pea
PBA Hayman⟑	very late flowering	late type, forage type
Wheat (Lincoln⟑)	main season	non-nitrogen fixing control

All brown manure treatments were double knocked sprayed with 2L Ghyphosate + 100ml Lontrel®+100ml Striker® and then followed up with 2L Sprayseed®, seven to ten days later.

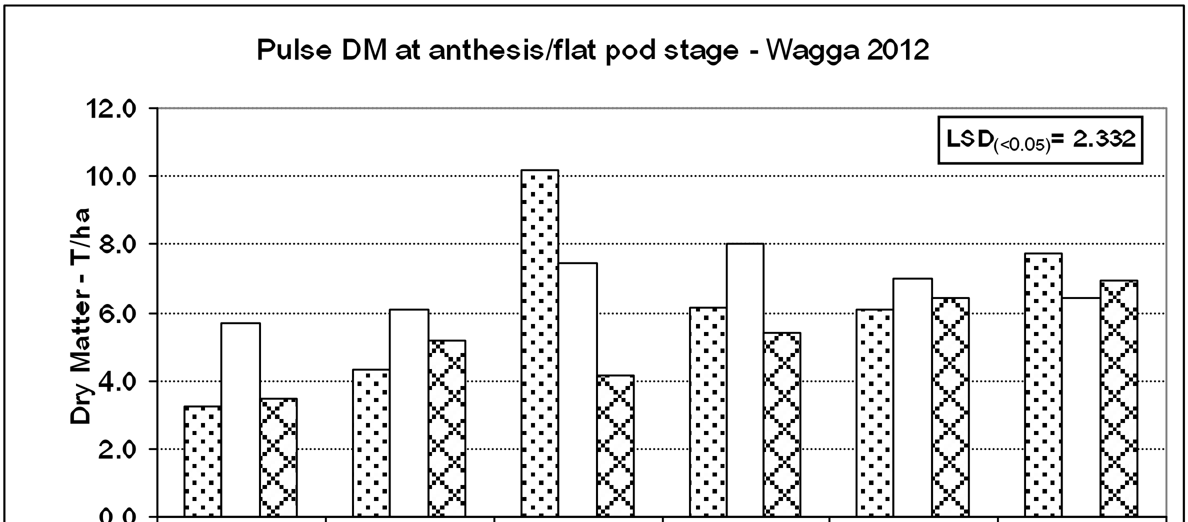
2013 discussion

- All plots received early in-crop grass herbicide sprays to give the pulse an opportunity to establish itself and compete against grass weeds. This was of greatest importance at the early sowing dates since no pre-sowing knockdowns were possible due to early and dry start. *Without early grass control the pulses would have been lost to ARG.*
- Pea and vetch produced more DM than faba bean and lupin and hence provided the best options for brown manuring.
- Morgan⟑, Morava⟑ and Hayman⟑ produced most DM at the earliest sowing. However, previous experience shows Morava⟑ to be the preferred option for early sowing (< mid May) since early sown peas become very susceptible to black spot and bacterial blight epidemics. DM of Morgan⟑ this season was greatly affected by sowing time, producing most when sown before the end of May. Hayman⟑ showed no advantage for forage or brown manuring over Morgan⟑ or Percy⟑ field pea for the second season in a row. Percy⟑ provided the best option for late sowing (end May onwards), producing most DM with the added flexibility of choosing brown manure, crop-topping or grain harvest.
- The first sowing (12 April) was sown dry and satisfactory emergence was only achieved in field pea, vetch and wheat. Lupin and faba bean failed to emerge until the next significant rain event (12 May). This result reflects mainly the differences in seed size, and a failure of larger-seeded species (lupin and faba bean) to imbibe moisture and germinate under marginal conditions. These implications become very relevant to pulse choice under dry autumns and marginal soil moisture at sowing.



	Fiord faba bean	Rosetta lupin	Mandelup lupin	Morava vetch	Morgan field pea	PBA Percy field pea	PBA Hayman field pea	Wheat (Lincoln)
12-Apr	4.57	4.39	4.24	5.44	6.26	4.80	5.44	6.73
27-May	4.44	4.71	4.51	4.88	5.54	4.74	4.82	5.63
11-Jun	5.16	4.64	5.17	5.27	4.96	5.44	5.24	5.41

Figure 3. 2013 dry matter accumulations of each pulse and cereal at anthesis of weed black oats present within trial and at each time of sowing.



	Mandelup Lupin	Rosetta Lupin	Morava Vetch	Morgan Field Pea	PBA Hayman Field Pea	PBA Percy Field Pea
10 Apr	3.22	4.34	10.18	6.16	6.10	7.76
9 May	5.71	6.06	7.47	8.03	7.01	6.41
2 Jun	3.46	5.18	4.16	5.38	6.44	6.93

Figure 4. 2012 dry matter accumulation at anthesis/early pod filling stage of each pulse species across three times of sowing.

2012 brown manuring experiment at Wagga

All pulse species and varieties were sown into good moisture at three times – 10 April, 9 May and 2 June. Each variety was duplicated for either brown manure or left for grain harvest, and replicated three times. Two DM cuts were taken, one coinciding with flowering/flat pod stage of each variety, the other at its estimated peak biomass. Peak biomass was taken closer to maturity just prior to leaf drop in an effort to measure potential biomass production of each species. Only results of the first DM cut (flat pod stage of the pulse) are reported here (Figure 4).

2012 discussion

- All plots received early in crop herbicide grass sprays to give the legume an opportunity to establish itself and compete against grass weeds. This was of particular importance for the early sowing dates as no pre-sowing knockdowns were possible due to early and dry start. *Without early grass control the pulses would have been lost to ARG.*
- Morava[ⓓ] vetch produced the most DM when sown early and is the preferred choice for an early (mid April) sowing. Early sown field peas suffered from disease in early winter, particularly black spot, reducing biomass.
- The new forage type PBA Hayman[ⓓ] performed no better than Morgan[ⓓ] or PBA Percy[ⓓ]. Any of the three field pea varieties were suitable for later (mid May onwards) sowing for either brown manuring or crop topping.
- Lupins produced the least biomass of all crops in this experiment, even when hare damage was not a factor. The poor competitive ability of lupins during early growth would further restrict their biomass production in the presence of weeds.

Key strategies for managing brown manure crops in southern NSW

Field pea and vetch are the preferred pulse for brown manuring in southern NSW cropping systems since they produced the most biomass at the correct timing for black oat control and or annual rye grass and were more competitive with weeds.

For practical reasons, growers prefer two main options for sowing a brown manure in this environment; either *sow early* before their main wheat and canola sowing window (April) or *delay sowing* till after this window (late May). The strategies, implications, pros and cons for both options are discussed below:

- *For April-mid May sowing*, vetch produced the most dry matter at the optimum time of spraying black oats and is considered the best early brown manuring option. This management strategy prevents both seed set in weeds (resistant ryegrass) and vetch, while maximising early DM and nitrogen fixation.
  - If planning to sow a brown manure pulse early, growers must be prepared to *use some selective herbicides to reduce the ARG numbers*, and maximise the competiveness and dry matter accumulation of the pulse crop. *At the brown out stage, a double knock is required* to ensure 100% of weeds are controlled prior to seed set to avoid potential selection of group "A" resistant weeds.
  - *Early sown* field peas are put at *high disease risk* (particularly ascochyta and bacterial blight) resulting in significant reductions in growth and biomass, and even death in some cases. *Therefore, peas should not be sown until mid May at the earliest.* Peas in particular are suited to late sowing and our results show no real production disadvantages of delaying sowing.
  - If no control of ARG is made with early sown brown manure crops, the ARG will out compete the legume crop (the very reason it is such a bad weed), reduce its biomass (and hence nitrogen fixation) and will become difficult to impossible to control by chemical knockdown alone. This could lead to greater pressure on ghyphosate resistance. The only option left then for control is full cultivation.

- ➢ Care needs to be taken when sourcing vetch seed. Hard seed carry over can cause issues in subsequent years. Whilst Movara⁽ᶲ⁾ is a soft seeded variety, non-pure seed can have off types mixed in that can have hard seeds if not pure.

- *For a late May sowing,* both vetch and field pea proved equally suited to brown manuring. This is the preferred timing for brown manuring, as it *allows for pre-sowing knock downs with non-selective herbicides* to be used prior to sowing. As can be seen from the data, the biomass accumulated does not vary a great deal with the correct variety selection. For a *June sowing, field pea was the most suited* with only minimal loss of dry matter.
  - ➢ In situations of considerable weed pressure and herbicide resistance, our data and grower experience over the past couple of seasons favours the late May sowing option (at the conclusion of the main crop seeding window), since weed burdens can be greatly reduced by then, allowing the legume to produce significantly more DM and fixed N.
  - ➢ Morgan⁽ᶲ⁾ produced equal or better DM than other field pea varieties for brown manuring. However, from a late May sowing onwards, PBA Percy⁽ᶲ⁾ showed superior DM production, with the additional advantage of being a high grain yielder if choosing to continue on to grain harvest, with or without spray-topping.
- Large amounts of DM (4-7 T/ha) were produced after the "flat pod' stage in all treatments (except Rosetta⁽ᶲ⁾ lupin). This illustrates the likely magnitude of losses of DM (and therefore N-fix equivalent to 100-175 kg /ha) when brown manuring early to prevent seed set in herbicide resistant weeds. Clearly if weeds are not a problem, brown manuring should be targeted as late as possible to maximise DM and the N fixation benefit.
- And remember, an early brown manuring is critical for weed control in early flowering species such as wild oats. For later flowering weeds, such as annual ryegrass, brown manuring can be delayed.

Inoculation, nodulation and N2 fixation of pulses in southern NSW

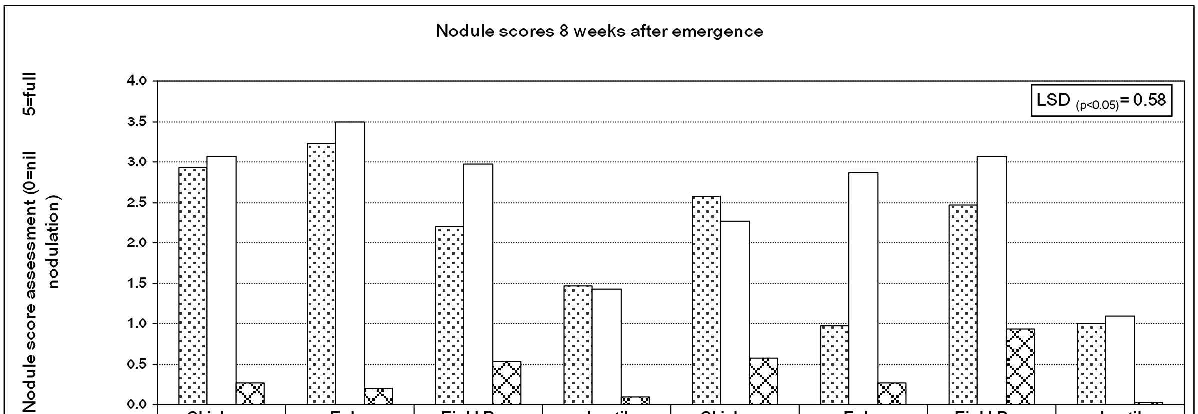
Annual inoculation of pulses is essential on the acidic red-brown soils of southern NSW for effective nodulation and N_2-fixation to occur. Each pulse has its own specific strain of rhizobia. Poorly nodulated pulses, not only require supplementary nitrogen fertilizer to maximise their own growth and yield, they also are unable to leave any fixed N for subsequent crops. Inoculants are living organisms, and therefore, they can be adversely affected by delays in sowing inoculated seed, exposure to air and sunlight, contact with fungicide seed dressings and contact with fertiliser at sowing.

Similarly, survival can be adversely affected by sowing into marginal soil moisture conditions in dry autumns, particularly when sowing early in March or April. Different formulations of inoculants may assist rhizobia survival under these conditions.

We established an inoculation experiment at Wagga Wagga in 2013 on an acidic (pH $CaCl_2$) red brown earth to compare a granular formulation alongside the standard peat-based formulation which was water-injected into the furrow at sowing. We included a third un-inoculated control. The experiment looked at four pulse species; field pea, faba bean, chickpeas and lentil and two sowings; either into a dry soil (sown 9 May) or moist soil (sown 7 June). While conditions were very dry at the first (9 May) sowing, 29mm of rain fell four to six days later.

We collected 10 plants from each plot eight weeks after emergence to assess nodulation, using a scoring system developed by Corbin et al. (1977). Preliminary results are presented in Figure 5 which clearly shows an inability of these pulses to effectively nodulate in our environment without inoculation.

There was very little difference between sowing into a dry soil or into a wet soil and very little difference between the two formulations under investigation. Nodulation was poorest in lentil, possibly reflecting its origin and a preference for alkaline soils.



	Chickpea	Faba	Field Pea	Lentil	Chickpea	Faba	Field Pea	Lentil
Granule	2.93	3.23	2.20	1.47	2.57	0.97	2.47	1.00
Liquid	3.07	3.50	2.97	1.43	2.27	2.87	3.07	1.10
Nil	0.27	0.20	0.53	0.10	0.57	0.27	0.93	0.03

Figure 5. Nodule scores for each pulse at two times of sowing and eight weeks after emergence at Wagga Wagga NSW in 2013. Scores of 0-1 are inadequate and reflect very low numbers; scores of 2-3 are adequate; and scores 4-5 high are very good (Corbin et al. 1977).

References

Corbin, E.J, Brockwell, J. and Gault, R.R. (1977). Nodulation studies on chickpea (Cicer arietinum). Australian Journal of Experimental Agriculture and Animal Husbandry, 17, 126-134.

Contact details

Eric Koetz

Wagga Wagga Agricultural Institute, Private Mail Bag, WAGGA WAGGA NSW 2650

02 69381954

eric.koetz@industry.nsw.gov.au

The fundamentals of increasing nitrogen use efficiency (NUE)

Chris Dowling,
Back Paddock Company

Keywords

denitrification, NUE, recovery, mineralisation, volatilisation, stranding

Take home messages

- **Improving NUE begins with identifying and measuring meaningful NUE indices and comparing them with known benchmarks and contrasting N management tactics.**
- **Potential causes of inefficiency can be grouped into six general categories. Identification of the most likely groups is useful in directing more targeted measurement and helping identify possible strategies for improvement.**
- **As result of seasonal effects, NUE improvement is an iterative process therefore, consistency in investigation strategy and good record keeping are essential.**

Introduction

Increasing nitrogen use efficiency (NUE) slips off the tongue easily as a noble goal for increasing profitability and sustainability of grain production, but a broad chasm still exists between the aspiration and reality in paddock.

The journey toward improved N use efficiency is notionally complex because of the large range of variables that impact yield, hence nitrogen (N) requirement. However, this journey can possibly be simplified by turning the challenge on its head and reinstating the goal in terms of 'identifying and then addressing sources of N inefficiency'.

It is critical in the journey to improving resource management of any type to ensure that the descriptive terms used are well defined and measured. In casual conversation farmers are frequently asked about the fuel usage efficiency of their family car and without hesitation give a prompt answer, and yet when I as the same question about nitrogen and water I get a sheepish look and the answer 'not sure or I don't know!' Therefore the first fundamental of increasing N use efficiency is to establish some standard metrics and establish as baseline what the paddock NUE situation is now?

Poor or ill-defined NUE measures can create both unrealistic goals and wasted effort. High efficiency in itself is not the ultimate goal as it must be balanced with profitable yield (Figure 1). Some of the inertia in measuring NUE comes from the general lack of definition of meaningful NUE indices useful to farmer's base N management strategies and tactics.

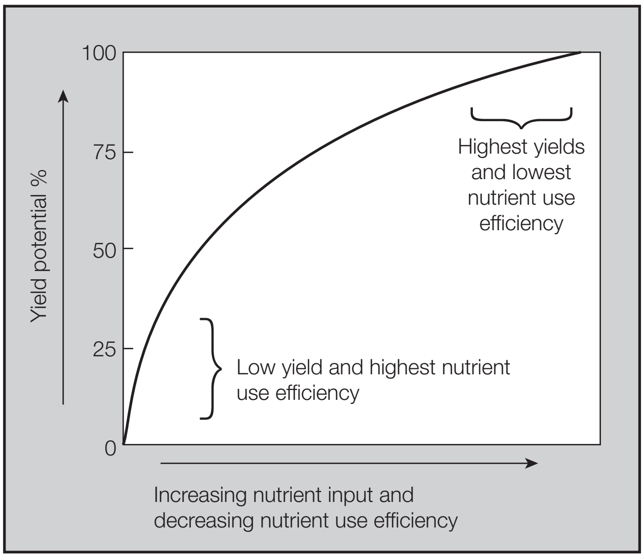


Figure 1. Understanding NUE in relation to yield potential is critical in assessing potential for improvement (Roberts 2008).

The most common measures of N use efficiency are outlined in Table 1.

The second fundamental of improving NUE is identifying and calculating the most useful indices and having consideration of them in formulation of rotation strategies and crop fertiliser tactics. For me AEN, $AEN and NTE are the most relevant and are reasonably easy to measure and calculate.

Fundament three is the identification of the likely causes of N use inefficiency (NUI). This will define the N strategy and tactics that are most relevant in addressing improvement in NUE in a particular situation.

Sources of N use inefficiency (NUI)

NUI has it origin both in the soil environment and within the plant. In both cases the interaction with growing season conditions make single season measurements of NUE unreliable without measurement of a contrasting management practice in the same season or as a longer term trend. Some of more common factors that increase NUI include:

Supply greater than demand - oversupply

Oversupply occurs where N availability is greater than crop/ grain demand. This decreases NUE from an annual perspective where the residual N is lost, however where losses are negligible (low fallow rainfall) rotation NUE may still be maintained. Oversupply frequently occurs as a result of over-estimation of yield potential, lack of consideration of soil N mineralisation potential and under- estimation of residual soil mineral N. The need for fertiliser N, stems from a decreasing contribution from soil organic pools both fresh (low legume frequency and duration in rotations) and ongoing rundown in labile and humic fractions (Figure 2). Where N mineralisation potential is ignored in any assessment of crop N requirements there is a possibility of fertiliser N over application, increased denitrification (Dn) loss (Harris 2013) and decreased NUE.

In southern grain production zones, mineralised N is calculated as a function of organic carbon % and growing season rainfall in-crop. However, the calculation may underestimate mineralisable N supply following pulse crops, legume rich pasture phases or where there has been recent addition of manures or composts. Alternatively, it may over-estimate available N following wet summer fallows where leaching or Dn has occurred.

Another potential link to low NUE from oversupply is failure to recognise the quantity and location of residual soil mineral N. Simple observations such as grain protein % in previous cereals crops is a good guide to likely existence of residual mineral N.

Inefficient nitrogen uptake

Poor efficiency from pre-sowing and at-sowing application is as a result of loss mechanisms such as volatilisation, denitrification and leaching or temporary unavailability due to soil processes such as immobilisation. In-crop applications of N (particularly those between Z31 and 37) reduce the

Table 1. Agronomic indices of N use efficiency and their typical ranges in cereals (adapted from Dobermann, 2005)

NUE Index	Definition	Common Values	Interpretation
PFPN - Partial factor productivity of applied N (often simply called nitrogen use efficiency or NUE) (kg harvest product per kg N applied)	PFPN = YN/FN	40–70 kg grain kg^{-1} N >70 kg kg^{-1} at low rates of N or in very efficiently managed systems	Most important for farmers because it integrates the use efficiency of both indigenous and applied N resources: PFPN = (Y0/FN) + AEN Increasing indigenous soil N (Y0) and the efficiency of applied N (AEN) are equally important for improving PFPN Limited potential for identifying specific constraints or promising management strategies.
AEN = Agronomic efficiency of applied N (kg yield increase per kg N applied)	AEN = (YN – Y0)/FN	10–30 kg grain kgv N >30 kg kg^{-1} in well managed systems or at low levels of N use or low soil N supply	AEN is the product of the efficiency of N recovery from applied N and the efficiency with which the plant uses each additional unit of N acquired: AEN = REN x PEN AEN can be increased by N, crop, and soil management practices that affect REN, PEN, or both.
REN = Crop recovery efficiency of applied N (kg increase in N uptake per kg)	REN = (UN – U0)/FN	0.30–0.50 kg kg^{-1} 0.50–0.80 kg kg^{-1} in well-managed systems or at low levels of N use or low soil N supply	REN depends on the congruence between plant N demand and the quantity of N released from applied N. REN is affected by the N application method (amount, timing, placement, N form) as well as by factors that determine the size of the crop N sink (genotype, climate, plant density, abiotic/biotic stresses).
PEN = Physiological efficiency of applied N (kg yield increase per kg increase in N uptake from fertilizer)	PEN = (YN – Y0)/(UN –U0)	30–60 kg kg^{-1} >60 kg kg^{-1} in well managed systems or at low levels of N use or low soil N supply	PEN represents the ability of a plant to transform N acquired from fertilizer into economic yield (grain). PEN depends on genotypic characteristics (e.g., harvest index), environmental and management factors, particularly during reproductive growth. Low PEN suggests sub-optimal growth (nutrient deficiencies, drought stress, heat stress,
Nitrogen Transfer Efficiency (NTE) (kg N in grain/kg total crop available N)	NTE= YN/ F0 + FN	40 - 60% 50 % general related to a target protein for optimum yield >60 % indicating likely yield penalty from insufficient N supply < 25 % generally related to high protein content in cereal grain, stranding of mineral N or over estimation of mineralisable N.	NTE integrates REN, PEN and total nitrogen supply (FN + Fo). Efficiency term most frequently used in determining crop N demand in N budgets. In some crops mathematical in relationship with grain protein content/oil % has been established.
$ Agronomic Efficiency ($AE)	$YN-Y0/ $F N	Optimum generally given as 1. >1 indicates increase in fertiliser cost is not being recovered in increase grain value.	Consideration also needs to be given to factors such as opportunity cost of money applied to fertiliser, interest cost and risk premium in determining acceptable $AE.

FN – amount of (fertilizer) N applied (kg ha^{-1})
Fo -amount of N available other than from fertiliser ((kg ha^{-1})
YN – crop yield with applied N (kg ha^{-1})
Y0 – crop yield ((kg ha^{-1}) in a control treatment with no N
UN – total plant N uptake in aboveground biomass at maturity (kg ha^{-1}) in an area that received N
U0 – the total N uptake in aboveground biomass at maturity (kg ha^{-1}) in an area that received no N

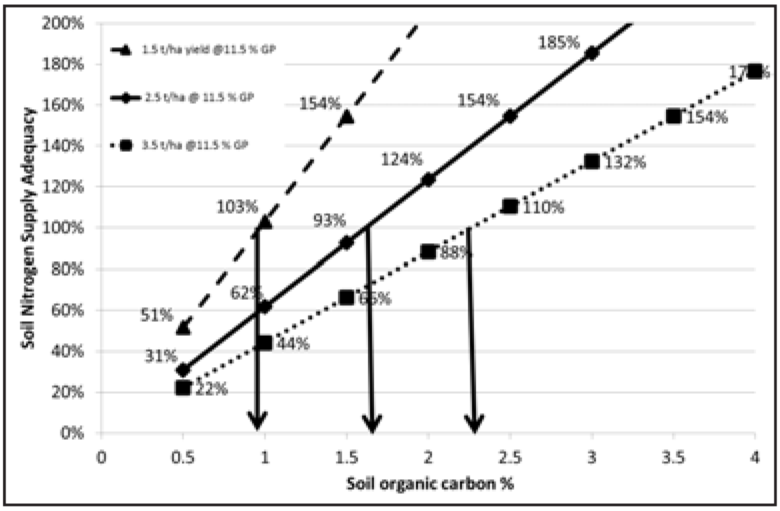


Figure 2. Ability of soil organic matter N mineralisation to meet crop yield and grain protein demand.

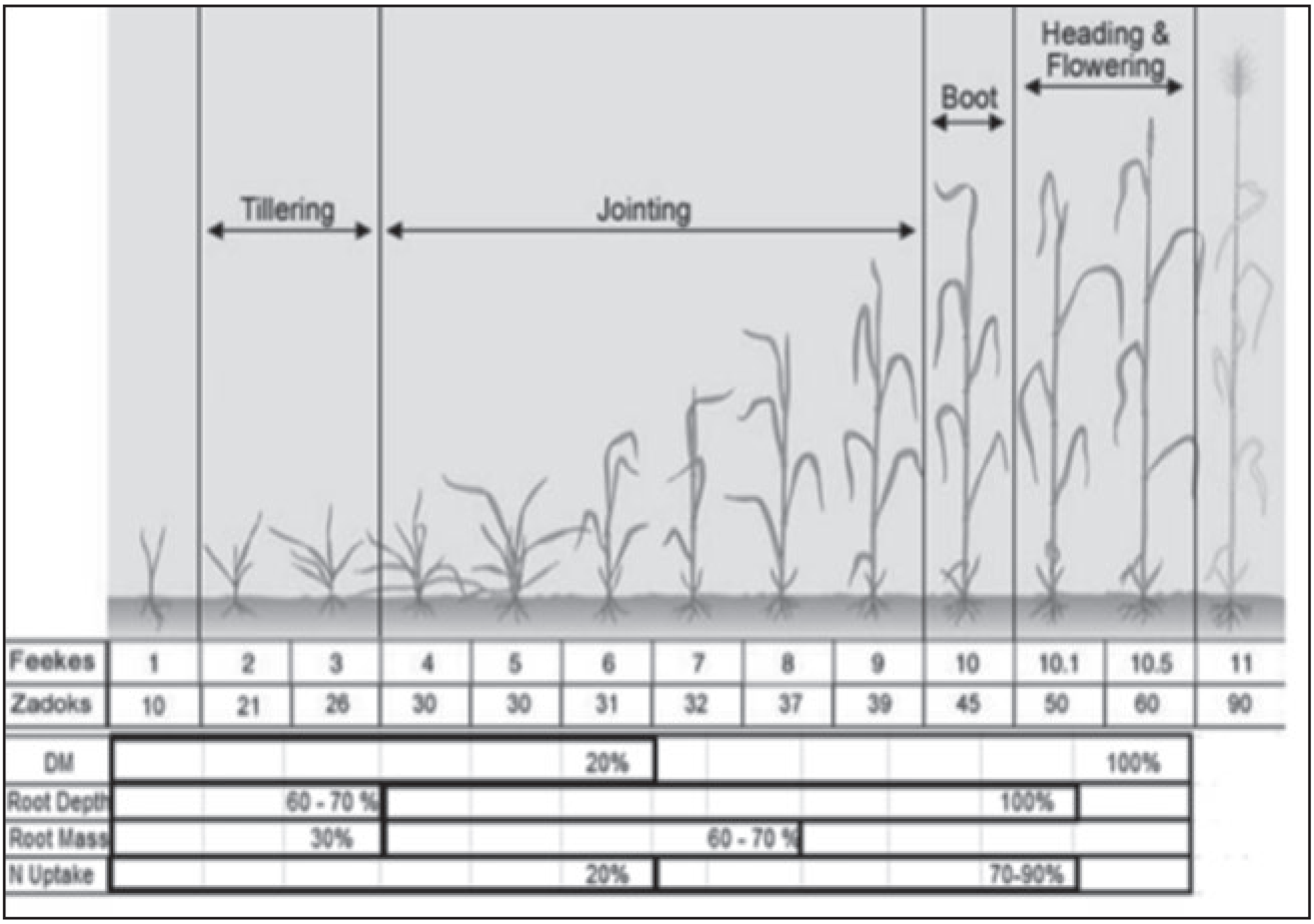


Figure 3. Generalised development of aboveground biomass and root activity in cereals at a range of growth stages.

time that applied N is subject to loss processes and increases the chance of interception when a significant root stricture is present and aboveground biomass demand is increasing rapidly (Figure 3).

Fertiliser N efficiency is also affected by the amount of soil available N at sowing that accumulates as residual N from the previous season and as mineralised N. High fertiliser efficiency is most common where soil residual N and the contribution from in crop mineralisation is low, loss processes are minimal and other management factors such as weeds, disease, sowing date, rate and cultivar selection are appropriate. There is no doubt that inappropriately high biomass production early in the season due to N availability may create poor efficiency (van Herwaarden 1996).

Applied but temporarily unavailable

- Inefficiencies occur if the process of immobilisation is significant and allowed to compete with a growing crop to the detriment of crop yield, and occurs parallel with nitrification. Net immobilisation reduces available N to the growing crop. Up to 18 kg of N/ tonne of cereal stubble can be consumed in the immobilisation process.

Applied or mineralised, but lost from soil due to:

- Leaching (summer mineralised N and residual mineral N) – at risk in sandy soils
- Ammonia volatilisation – generally a loss of N associated with applied N, particularly products that at some stage create ammonium-N after application e.g. urea, DAP, chicken manure. Under conditions favourable for loss, 10 – 20% of applied N may be lost in a 4 day period after application (Turner et al. 2010, Turner et al. 2012) but the effect on yield of this loss is not always expressed proportionally. Recent research has also indicated that urease inhibitors are able to reduce the rate of urea hydrolysis but saving N needs to be related to the reliability of producing higher yield or improved profitability (Suter et al. 2011).
- Denitrification – significant denitrification losses are mostly related to conditions of high soil moisture. Research in recent years suggests:
    - o Dry seasons – minimal waterlogging, mostly associated with nitrification of urea (Officer et al, 2013).
    - o Wet periods associated with water filled soil porosity (WFSP) >70% creates conditions for higher rates of Dn (Harris, 2013). Degree of loss primarily a function of the quantity of nitrate and labile carbon co-located in soil layers, soil temperature and duration of WFSP>40% (Chen 2010).
    - o Some nitrification inhibitors have shown potential for reducing losses but effects variables such as soil temperature (Chen et al. 2010) need to be further investigated to increase the reliability.
- Poor summer weed control – recent research (Table 2) suggests up to 36 % decrease in fallow N where weeds are not controlled.

Table 2. Controlling summer weed provides an increase in fallow N - total nitrogen levels (kg/ha) from 0-120 cm (Haskins et al. 2012)

Treatment	Nitrogen (kg/ha)
Complete spray	168.9
Delayed spray	143.3
Missed first spray	126.5
Nil spray	124.3
Average	140.7

Available in soil but not taken up due to:

- Positional unavailability - active root mass is at distance from mineral N sources for significant period of crop growth.
- Release synchronisation – timing of release or transformation of the applied product (organic matter, modified release N fertiliser) to a plant available mineral N form does not meet crop demand or is more exposed to losses.

- Limitation to root mass – root depth and density is restricted by chemical (e.g. phosphorus), physical (e.g. compaction) or biological (root disease) factors.

Taken up to biomass but not transferred to grain

The pathway of nitrogen to grain is a two part process, part one being the uptake from soil and incorporation into vegetative plant parts, part two being the mobilisation of N from vegetative parts and incorporation into grain proteins. Where nitrogen is taken up into above ground biomass (i.e. part one) but not relocated to grain, NUE indexes are affected (e.g. NTE and AE), but the cause can be uncertain. In comparison, those indices related to crop N uptake (REN and PEN) will generally highlight problems with remobilisation and transfer. Some of the factors that can influence NUE include:

- Genetics - generally the relationship between grain protein and yield is negative for a given quantity of available N in cereals. However among recently released varieties there appears to be some varieties that have consistently higher grain protein for a given grain yield (Figure 4). Whether this is a function of uptake efficiency or remobilisation efficiency is not yet clear.

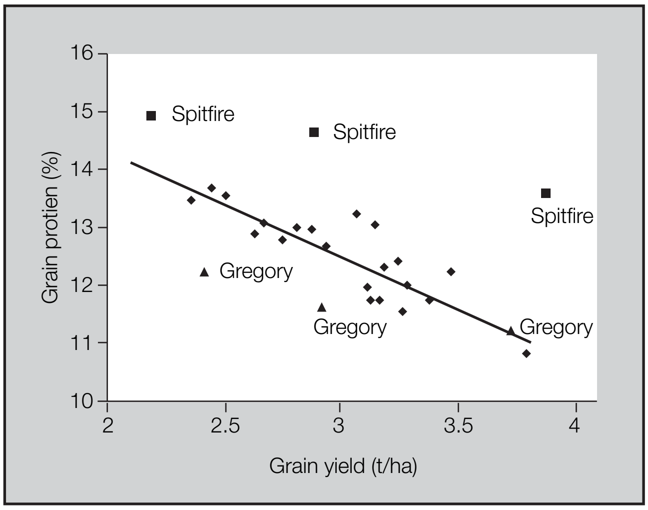


Figure 4. Grain yield and grain protein of 14 main season wheat varieties for three sowing dates at Condobolin, 2011. The trend line (excluding Gregory$^{\Phi}$ and Spitfire$^{\Phi}$) show that grain yield and grain protein were negatively correlated (R^2=0.74). LSDs were 0.3 (yield) and 0.27 (protein) (Fettell et al. 2012).

- Environmental conditions - remobilisation and translocation of nitrogen stored in stems and leaves to the grain during the grain filling period is influence by atmospheric temperature and soil moisture relationships. Extreme conditions, during grain fill can influence apparent NUE. The combination of grain size and grain protein% is generally a guide to an aberrant outcome.

References

Chen D, Suter HC, Islam A, Edis R (2010) Influence of nitrification inhibitors on nitrification and nitrous oxide (N2O) emission from a clay loam soil fertilized with urea. Soil Biology and Biochemistry 42(4), 660-664

Dobermann AR (2005) Nitrogen Use Efficiency – State of the Art", Agronomy & Horticulture - Faculty Publications. Paper 316 (http://digitalcommons.unl.edu/agronomyfacpub/316, accessed 31/12/13).

Fettell N, Brill R, Gardner M and McMullen G (2012) Grain protein – How important is variety choice? http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2012/02/Grain-protein-How-important-is-variety-choice, accessed 30/12/2013).

Harris R, Officer S, Hill P, Armstrong R, Fogarty K, Zollinger R, Phelan A, Partington D (2013) Can nitrogen fertiliser and nitrification inhibitor management influence N2O losses from high rainfall cropping systems in South Eastern Australia? Nutrient Cycling in Agroecosystems 95(2), 269-285.

Haskins B, McMaster C, Menz I and Muirhead T (2012) Report of Wheat fallow efficiency x nitrogen trial-Rankins Springs (http://n.b5z.net/i/u/10169267/f/Fallow_Trial_Rankin_Springs_2012.pdf, accessed 31/12/2013)

Officer SJ, Phillips F, Kearney G, Armstrong RD, Graham J, Partington DL (2013). Increased nitrous oxide flux in response to urea fertiliser in a semi-arid climate, identified by smoothing spline model. Soil Research (in press).

Roberts, TL (2008) Improving Nutrient Use Efficiency, Turk. J. Agric. For., 32,177-182

Suter, H., Pengthamkeerati, P, Walker, C and Chen, D (2011) Influence of temperature and soil type on inhibition of urea hydrolysis by N-(n-butyl) thiophosphoric triamide in wheat and pasture soils in Southeastern Australia, Soil Research 49; 315-319

Turner DA, Edis RE, Chen D, Freney JR, Denmead OT (2012) Ammonia volatilization from nitrogen fertilizers applied to cereals in two cropping areas of southern Australia. Nutrient Cycling in Agroecosystems 93(2), 113-126.

Turner DA, Edis RB, Chen D, Freney JR, Denmead OT, Christie R (2010) Determination and mitigation of ammonia loss from urea applied to winter wheat with N-(n-butyl) thiophosphorictriamide. Agriculture, Ecosystems & Environment 137(3–4), 261-266.

van Herwaarden AF (1996) Haying-off in wheat: enduring myth or current problem? “Agronomy - Science with its sleeves rolled up”. Edited by DL Michalk and JE Pratley. Proceedings of the 8th Australian Agronomy Conference, 30 January - 2 February 1996, The University of Southern Queensland, Toowoomba, Queensland.

Contact Details

Chris Dowling

Back Paddock Company P/L

PO Box 823, Cleveland, Qld, 4163

0407692251

cdowling@backpaddock.com.au

Notes

Improved slug management

Michael Nash,
SARDI

GRDC project code: GTA10475, DAS00127, DAS00134

Keywords

Integrated Pest Management (IPM), molluscicidal baits

Take home messages

- **Determine 'slug risk'.**
- **No one control option will work – develop a control strategy based on risk factors.**
- **Baits must be eaten to protect crop – slugs must be active.**
- **Sowing followed by rolling and baiting will protect emerging seedlings, but follow up baiting may be required if crop establishment is slow.**

Background

Slugs are significant pests of crops globally and are an increasing problem in Australia. There has been a 50% increase in expenditure on molluscicide in Australia over the last 10 years, with a total market value of $16.5 million for 2011/12. Agricultural expenditure is estimated between $10.2 million (Murray et al. 2013) and $13.5 million (Nash unpublished data), dominated by baits containing the active ingredient metaldehyde. Cultural controls cost a further $14.9 million annually. Assuming that slugs alone cost growers in excess of $25 million per annum, we must question the cost benefit of current control methods. GRDC projects (DAS00127, DAS00134) are aimed at the improved management of snails and slugs, with this paper presenting results specific to slugs. By understanding the biology of slug species and their interaction with farming systems and environmental factors, a management program can assess the likelihood of crop damage or 'slug risk', and thus implement well timed, integrated controls.

The first section presents results identifying the most problematic species within regions, whilst recognizing climatic factors that influence habitat suitability. Risk factors at the national and farm scale are indentified. The second section presents results from an ongoing project aimed at improved control of slugs using chemical options. Improved cultural control methods are also being investigated, but not presented here.

Indentifying slug risk - National level

The main pest species of slugs in Australia are the black keeled (*Milax gagates*) and the grey field slug *(Deroceras reticulatum*), however the brown field slug (*Deroceras invadens*) can also be a pest, with species often co-occurring. Recent survey work 2011-2013 across all of Australia has been completed. The Black Keeled Slug was rated by 62% of adviser respondants (at the 2013 GRDC updates) as causing problems and given its distribution is the focus.

Species distribution modelling is testing if different species have similar environmental requirements. The informative factors for grey field slug distribution models were temperature – (annual mean), moisture index (annual mean) and percentage soil clay, with cooler high elevation locations along the Australian escarpment providing the most suitable habitat. For brown field slugs, temperature (annual mean), moisture index (annual mean) and moisture index (warmest quarter mean) were informative factors and indicated suitable habitat across temperate / subtropical areas with >500mm rainfall. This species may have been widespread for a considerable time, however this survey indicated an increased prevalence. Moisture availability during the warmest quarter appears to have the most information that isn't present in the other variables. This result leads to the hypothesis that brown field slugs can breed in warmer conditions than grey field slugs where moisture is available. Thus, brown field slugs may become more of a problem with the predicted increased intensity of late summer rainfall (Cai et al. 2012, Cai & Cowan 2013). Modelling from the UK predicts that under warmer conditions brown field slugs will displace grey field slugs in southern regions of England (Willis et al. 2006). Survey results suggest changing climatic conditions are causing a shift of exotic slug species distributions in Australia, but this needs further testing.

Slightly different environmental factors seemed to influence the suitability of habitat for black keeled slugs; moisture index (annual mean) and moisture index (warmest quarter mean) being the most informative. The relatively low information provided to the predictive model by percentage clay suggests that heavy soils are an indirect factor for determining slug risk. Black keeled slugs were recorded from a range of broad acre crops and pastures, particularly soils with higher clay content in drier areas < 475mm. However, in wetter areas > 650mm the opposite was observed with this species found on sandy soils such as those between Mt Gambier and Portland. Heavy soils retain more moisture, and therefore, such areas are often prone to slug problems. It is the slug's response to moisture that is the key to understanding these pests. Slugs will continue to be pests in southern Australian high rainfall cropping areas due to growers improving their soil moisture holding capacity with practices such as stubble retention, no-till and raised beds, etc. Black keeled slugs are bio-indicators of excellent soil management that will help mitigate climate change.

Monitoring

A foundation dogma of integrated pest management is the monitoring of populations, yet monitoring of slugs is difficult to implement. Even current methods based on utilising surface refuges, such as terracotta paving tiles, are considered too labor intensive. A minimum of ten (10) 300mm by 300mm tiles per ten ha placed evenly across the entire area is recommended. However monitoring using four (4) refuges in areas where slugs have previously been a problem is better than nothing. Adequate replication is required due to their clumping behaviour and dependency on moisture. The problem with refuges is that they rely on individual slugs being active, and slugs will only be active when soil is moist. Thus, any decision support tool or thresholds based on refuge trap counts fail during dry periods, which is often before sowing when this data is needed to determine control strategies. Monitoring using surface refuges can only provide an estimate of what species are active (i.e. are unable to monitor species that are currently inactive)

Indentifying slug risk on farm - understanding biology

Understanding risk factors and biological differences between slug species is vital to an informed management of slugs, especially timing of bait applications. Being hermaphroditic and opportunistic breeders, slugs reproduce whenever temperature and moisture conditions are suitable. In Australia, black keeled slugs can have either a bi-annual or annual reproductive cycle. Observations from warmer areas of NSW indicate late summer breeding under moist conditions (2011) can occur with the new generation reaching maturity in late spring, however these individuals can delay breeding until the following season due to dry conditions.

In the colder regions of SW Vic, adults tend to breed in late winter with juveniles maturing the following season and breeding in late winter/spring, but if conditions are dry this is delayed until the next autumn. Observations (2013) of overlapping generations (adults and juveniles present) suggest that juveniles present in late autumn were from winter (2012) breeding adults but some of these adults delayed breeding. Despite eggs being laid 2-5cm into the soil, these eggs must remain moist in order to hatch in 40 days (at 18°C). Populations are adapted to survive harsh winter conditions in the Balkans by burrowing to avoid permafrost. The burrowing ability of juveniles and adults enable this exotic species to survive harsh Australian summers. Black keeled slugs have a much longer lifecycle compared to grey field slugs; approx. 300 days compared to 190 days. Differences in life history may explain why grey field slug populations return quicker after bait applications in winter. Further research is being conducted to understand factors such as crop type, soil management and weather conditions that affect breeding in the preceeding season.

Different behaviours may also explain varied species responses to bait applications. Grey and brown field slugs are mainly surface active, requiring moist refuges at the soil surface, such as volunteers and broadleaf weeds. Black keeled slugs are a burrowing species, thus better suited to drier environments and able to buffer temperature extremes. This behavioural difference may also influence activity in the autumn break. Dry autumn conditions in 2013 across western Vic and a late break resulted in canola being dry sown. Monitoring for slug activity indicated delaying bait application until rain occurred. This meant that baiting coincided with early crop establishment and provided improved control. Baits applied at sowing when the soil was dry, protected canola from grey field slugs, however where black keeled slugs occurred these emerged later and damaged canola at the four leaf stage. Control success requires monitoring to determine different species activity in response to environmental conditions.

Chemical control

Baiting is still the only effective chemical control worldwide, and the most commonly used active in Australia is 1.5% metaldehyde. A review of the literature indicates that active concentration must be increased above 3% in order to improve efficacy. Different species may be more tolerant of Metaldehyde; however these results may be confounded. Many factors influence the efficacy of baits, but put simply, slugs must encounter and consume a toxic dose of the active for it to kill them.

Chance of encounter is determined by:

a. slug activity,

b. attractiveness of bait; and

c. number of baits per unit area.

Consumption of a lethal dose is dependent on:

a. enough bait,

b. adequate concentration of toxicant; and

c. palatability.

Given these confounding factors, any data presented should be interpreted understanding the conditions and context of the trial. Following that caveat, current Australian trials support previous research, recommending the application of baits must be immediately after sowing and applied to the soil surface to protect emerging seedlings from active slug populations. Bait does kill juveniles that are active, but re-invasion from the soil and new hatchlings quickly return population levels often to greater than the initial population, hence the common observation that baits select for younger populations. Molluscicides do not limit slug populations when they are active for extended periods, they only protect the crop. Only climatic conditions can reduce populations in the long term. So far, no novel products tested provide better efficacy than those already registered.

Growers can protect crops from slugs if they take the effort to be proactive by monitoring slugs in preceding seasons to understand which areas

Table 1. Slug bait usage comparison 2014

Product	Active Ingredient	Rate	Rate kg / ha	Baits / kg	Baits / m^2	Active g / kg	A.I. /ha	Pellet	Rain Fast	Spreadability
Delica Sluggoff	Metaldehyde	label	**3**	100,000	**30**	30	90	flour	Yes	Fair
MetaKill (IPM Tech)	Metaldehyde	label	**4 - 8**	100,000	**40-81**	50	200-400	flour	Yes	Good
METAREX	Metaldehyde	farmer	3	60,000	18	50	150	flour	Yes	Good
METAREX		label	**5 - 8**	60-62,100	**30-50**		250-400			
METAREX (Ashley wakefield spread trials)			8	63,400	51		400			
META	Metaldehyde	label	5 - 7.5	26,000	13-20	15	75-112.5	bran	No	Poor
META (IPM Technologies data)			5	32,000	16		75			
META (Ashley wakefield spread trials)			7.5	32,000	24		112.5			
META (optimum)			**9.5-11.5**	26-32,000	**30**		143-173			
Slugger	Metaldehyde	farmer	5	22-23,000	11-12	15	75	bran	No	Poor
Slugger 2.5mm		farmer	5	27,000	13.5		75	bran	No	Fair
Slugger 4mm (Ashley wakefield spread trials)			8	7,500	6		120	bran		Poor
Pestmaster 4mm		farmer	5	8,000	4		75	bran	No	Poor
Pestmaster 2.5mm		farmer	5	26,000	13		75	bran	No	Fair
Bran based 2.5mm (optimal)			**11-11.5**	26-27,000	**30**		165-173			
SlugOut	Metaldehyde	farmer	**5**	85-93,000	**43-47**	18	90	granule	??	Good
SlugOut (IPM Technologies data)			10	112,000	112		180			
SlugOut (Ashley wakefield spread trials)			10	106,200	106					
Multiguard	Iron chelate	farmer	5	18 - 24,000	9-12	60	300	bran	No	Fair
Multiguard	Iron chelate	label	5 - **16**	18 - 24,000	9-**38**		300-960			
Multiguard (IPM Technologies data)			5	14,000	7		300			
Multiguard (optimum)			**15-17**	18 - 24,000	**31**		900-1020			
Mesurol bait	Methiocarb	label	5.5	30,000	17	20	110	bran	No	Poor

Products should always be applied as per label recommendations where these are available. This table is provided as a guide only.
Label recommendations for bran based baits can be misleading (e.g. Slugger rate 500 kg/ha) hence the rate used in broad acre is often 5 - 7.5 kg / ha.
Rates (kg / Ha) that result in optimal bait densities (>25 / m2) are highlighted. Bran bait rates results in sub optimal bait densities based on calcultaed values.
Data obtained from http://ipmtechnologies.com.au 29Oct2013 is indicated as IPM Technologies data.
Data obtained from Ashley Wakefield is indicated and presented as provided.
All other data is sourced from SARDI.

are at risk. A combination of control approaches needs to include current cultural controls such as burning, cultivation and consolidation of seedbeds with rollers, removal of summer volunteers and incorporation of sheep back into farming systems. Biological functions of farming systems also need to be recognized and priority given to farming practices that limit disruption to disease bearing nematodes and ciliates (that will infect slugs), and predatory beetles (Nash et al. 2008). New strategies, such as increased seedling resistance to damage (e.g. growing less susceptible crops), and early sowing with improved seedling management that provides quick establishment can achieve optimum plant densities.

To improve bait efficacy, growers need to apply when the crop is most susceptible and when the individuals are active and likely to feed on the baits. This is almost always at sowing prior to emergence. More expensive wet process flour based baits with 3-5% Metaldehyde will give better results for longer periods than dry process bran based products containing 1.5%, but still should only be considered as crop protectants lasting 3-6 weeks. Baits need to be evenly applied to the soil surface at 25-35 per m^2 to ensure encounter. Drilling baits increases the length of time before encounter for surface active individuals and increases the likelihood of microbial degradation of actives. To ensure even bait distribution, calibration of spreaders specifically for molluscicide baits is needed, with twin spinner or equivalent machines giving better results. Attempting to spread baits > 30m will give poor results.

Individuals often reinvade from the soil to feed over extended periods, so continue to monitor and check baits after application. Nil bait means they have all been eaten so you need to apply more. Do not wait until crop damage of susceptible crops such as canola to reapply baits to ‘problem’ areas. Applying baits early when conditions are warm seems to be most effective using metaldehyde, with multiguard more effective in cold wet conditions. However, multiguard is expensive and at the standard farmer rate of 5- 7.5 kg will lead to control failures due to either not enough baits points or because all the product is consumed. Consider the true cost of the product (Table 1) by including actual number of baits per kg and active concentration, field life and likelihood the pest you want to control will actually eat it. *‘The chief obstacle to improving chemical control of slugs is not the lack of molluscicidal materials but the difficulty of getting them into the animal’* (Briggs & Henderson, 1987).

Other sources of information

“Slug Control Fact Sheet: Slug Identification and Management” (GRDC March 2013) Nash, M. Brier, H. Horne, P. Page, J. Micic, S. Ash, G. Wang, A. https://www.grdc.com.au/~/media/412EEE56898A4AFB8B50409EC87FEBFE.pdf

HGCA Topic sheets 84, 85 & 88 http://adlib.everysite.co.uk/resources/000/102/346/HGCA_TS84.pdf http://adlib.everysite.co.uk/resources/000/102/346/HGCA_TS85.pdf http://adlib.everysite.co.uk/resources/000/102/346/HGCA_TS88.pdf

“Slug control in Australian canola: monitoring, molluscicidal baits and economic thresholds”. (2007) Nash MA, Thomson LJ, Hoffmann AA. *Pest Management Science* 63: 851-859

“Effect of remnant vegetation, pesticides and farm management on abundance of the beneficial predator Notonomus gravis (Chaudoir) (Coleoptera: Carabidae)”. (2008) Nash MA, Thomson LJ, Hoffmann AA. *Biological Control, 46, 83-93.*

References

Briggs & Henderson 1987 *Crop Protection* 6: 341-346.

Cai et al. 2012 *Scientific Reports* 2: 02

Cai & Cowan 2013 J. *Climate* 26: 189–205

Murray 2013 Aust. J. *Entomology* 52, 227-241.

Willis et al. 2006 *Global Change Biology* 12: 1643-1657.

Contact details

Michael Nash

1st Floor, East Wing, Waite Building, Waite Rd. Urrbrae SA 5064

Michael.Nash@sa.gov.au

Notes

What's new with zinc? Maybe just some critical reminders

Rob Norton,
International Plant Nutrition Institute

Keywords

4R nutrient stewardship, zinc

Take home messages

- **Low supply is typically associated with alkaline soils over a wide range of textures. The use of lime can reduce zinc availability.**
- **Zinc deficiency symptoms appear as oily grey green patches in the center of leaves. Young leaves are most affected.**
- **Critical soil test values (DTPA) are generally less than 0.5 mg/kg. However taken alone, test values are not a reliable predictor of zinc response.**
- **Tissue tests help guide diagnosis, and critical tissue concentrations in the youngest expanded blade of wheat is <14 mg/kg. However, the response curve is very steep.**
- **Zinc supplements can be applied with fertiliser as zinc oxide, chelated zinc or zinc sulfate. The latter products are soluble and can also be used for foliar applications. Product efficacy varies with the time and placement of application.**
- **No single source is a "silver bullet" to all situations**

Zinc in soils and plants

Zinc (Zn) is one of the 16 essential nutrients that plants need for growth and reproduction. Zinc is a micronutrient and is required in smaller amounts than some other nutrients, but it is essential. If Zn is limiting or in short supply, crop yields will suffer and crop utilization of water and nutrients will decrease. Grain Zn content is related to seedling vigor and there is also an important link to human health, with grains being a major source of dietary zinc for many in the world (http://www.harvestplus.org/content/crops).

Zinc was one of the first micronutrients recognised as essential and is considered the classic deficiency on alkaline soils such as Vertosols and Calcarosols. It is still the major micronutrient deficiency facing cropping systems in Australia, particularly since the change from single superphosphate (0.04% Zn impurity) to MAP and DAP (Holloway et al. 2008). Information from a range of researchers working in this area suggests that chronically Zn deficient sites are not common, and while Zn responses are often seen in terms of increased grain Zn concentration, significant yield benefits are less common (Peck et al. 2008).

Typically, zinc supply for susceptible can be low on many soil types, but common properties of Zn deficient soils are; pH>7.5, high sand content and soils that are cold, wet and compacted. Zinc can also bind to iron and manganese, so red acidic soils can be Zn responsive. Liming can alter root zone pH and so induce a zinc (and manganese) deficiency, if not applied well ahead of planting.

Plants growing on soils tested very high in phosphorus (P), commonly suffer Zn deficiency. This syndrome is sometimes mistakenly considered due to a P tie-up of Zn in the soil but competition for nutrient transporters is more likely. Applying P to a soil with sufficient Zn levels will not produce a Zn deficiency.

Much of the available Zn is associated with the organic matter in the topsoil. Land leveling and erosion can cause Zn deficiencies in crops by exposing subsoil low in organic matter, low in native Zn, and/or with a higher pH.

Zinc deficiencies tend to occur early in the growing season when the soils are cold and wet. This is due to slow root growth compared to rapid shoot growth. The slow growing root system is unable to take up enough Zn to supply the shoot. Plants some¬times appear to outgrow this defi¬ciency, but the damage has already been done, and yields can still be significantly reduced. Root pruning herbicides such as SU's can give a similar response.

A survey of soils from the NVT sites showed on a wide range of more intensively farmed soils, 15% of samples had low topsoil DTPA-Zn, and 15% of wheat grain samples had low grain Zn (<15 mg/kg), even though quite a few sites had supplementary zinc. A larger data set of soil tests indicated that about 30% of soils tested from New South Wales had DTPA Zn <0.5 mg/kg. Typical grain Zn concentrations for our cropping regions are around 20 mg/kg for wheat (Table 1), so off-take in a 4 t wheat crop is less than 100 g/ha. However, soil has a strong capacity to bind Zn and balancing removal is not a useful concept for this nutrient.

Based on this risk assessment, all soils evaluated seem to have a moderate to high risk of Zn deficiency, and wheat grain analysis does show low Zn concentrations. Soil tests are quite variable and show low Zn, but the relationship between grain Zn and soil test Zn is weak, even with the inclusions of other soil factors such as pH and organic C. Many of the Zn recommendations in the eastern states

Table 1. Mean values (± standard errors) of soil pH, Clay (%), Organic Carbon (OC%), DTPA extractable Zn in the top 10 cm, from NVT soil tests 2008-2012

ASC Order	pH ($CaCl_2$) (0-10 cm)	Clay % (L1)	OC%	Mean Critical Zn (mg kg^{-1})	DTPA Zn (0-10 cm) (mg kg^{-1})	Wheat Grain Zn (mg kg^{-1})
Calcarosol	7.3±0.1	18±9	1.7±1.6	0.25	1.1±0.7	18.6±0.9
Chromosol	5.6±0.1	14±7	2.1±1.3	0.20	2.1±0.3	22.6±1.1
Dermosol	6.8±0.1	29±9	2.5±1.5	0.26	0.8±0.6	16.7±3.0
Ferrosol	6.6±0.2	15±8	*		1.7±0.9	23.3±3.0
Kandosol	5.3±0.1	12±4	1.8±1.0	0.21	1.4±0.4	17.3±0.9
Sodosol	6.7±0.1	14±7	2.9±1.4	0.21	0.8±0.4	17.8±0.5
Tenosol	6.0±0.2	11±6	2.0±0.8	0.19	0.6±0.9	21.7±1.3
Vertosol (pH<7.0)	6.3±0.1	44±4	1.7±1.1	0.32	0.8±0.4	23.6±0.8
Vertosol (pH>7)	7.8±0.1	44±4	1.4±0.6		0.6±0.3	22.4±0.8
Means	**6.7±1.2**				**0.9±2.0**	**20.0±0.4**
% below Critical	**22%**				**15%**	**15%**

have been developed for alkaline cropping soils, and as yet there are few published reports of Zn responses in the high rainfall zones.

Soil tests to predict crop response

Soil tests for zinc and other micronutrients are available, most commonly either DTPA or EDTA extractable Zn. These two tests give similar numeric values (Norton, 2013). While soil tests have been correlated to crop responses in properly conducted trials, the trials have been limited and the confidence limits can be quite large. As a result the critical levels developed, which are often very low in absolute terms, are subject to sampling errors. Combined with poor analytical reliability, these critical levels are difficult to apply confidently. As with all soil testing, it is important to use accredited laboratories that use ASPAC accredited methods for assessing nutrients; these methods have critical values established for Australian conditions.

The current recommendations for critical DTPA Zn are variously given as 0.5 to 1.0 mg/kg, but this value is strongly influenced by soil pH, soil texture and soil organic carbon contents (Brennan 1992). Table 1 gives estimates of critical values for various soil types and in most cases these are between 0.2 and 0.4 mg/kg. Dang et al. (1993) proposed that including Zn buffering power of the soil in combination with DTPA-Zn values would improve the reliability of this soil test on Vertosols.

In general, these values are sufficient to meet Zn demands by crops, but recent research in the US has suggested that high yielding maize crops (Ciamoitti and Vyn 2013) may require higher levels. There is little evidence to support the idea that high yielding cereals in Australia have a higher critical DTPA-Zn value. On the other hand, there is genetic variation in zinc efficiency among wheat varieties but the detail of this interaction is not known. A comparison of grain Zn contents from NVT trials showed no differences among Elmore$^{\phi}$, Gregory$^{\phi}$, Gascoigne$^{\phi}$ and Scout$^{\phi}$, but an earlier survey showed that Yitpi$^{\phi}$ was more zinc efficient than Gladius$^{\phi}$ (Norton 2013).

It is uncertain how root associations such as the association with VA mycorrhizae may affect critical soil Zn value, as infected roots are more efficient at accessing Zn (and P) than poorly colonized roots. Ryan et al. (2002) showed that while VAM colonization did not affect early growth, P and Zn uptake to anthesis or grain yield, colonized plants that had higher grain Zn contents in one experiment.

Plant tissue tests

While soil tests provide a guide, the literature supports the use of tissue tests as a more reliable response diagnostic tool. It is critical to take the correct tissue at the correct time, as uptake and redistribution differs with time and tissues. Zinc has low mobility so the usual tissues to sample are the youngest fully expanded leaf (youngest expanded blade – YEB). Table 2 gives the critical values for zinc in a range of tissues. Younger more rapidly growing tissues are more responsive to changes in Zn supply so are better indicators of deficiency than older leaves or whole plants. Plant stage is also critical, as the plant matures Zn is redistributed and diluted, critical levels decline with plant age. YEB samples are also suitable for other micronutrient tissue tests.

Of all the tissue tests for micronutrients, Zn taken from the correct tissue at the correct time is one of the best diagnostics. Even so, there can be problems with positional unavailability of Zn in soil profiles or cold periods reducing uptake. These conditions need to be taken into account when interpreting the tissue test results.

Also included in Table 2 are values for Zn in grain. These can be used to track trends in paddock supply over time and have some diagnostic value within cropping systems. Grain Zn content is particularly important for seedling vigor; especially in cereals, and it is the seed content, not concentration, that is important. A supply of less than 500 ng Zn/seed is considered limiting, which in a 32 mg seed is a concentration of around 16 mg/kg (Rengel and Graham 1995). Larger seed could

Table 2. Critical tissue Zinc concentrations for a range of species (Reuter and Robinson, 1997). All values are from Australian research, except those marked with an asterisk

Species	Sampling Time	Tissue	Critical or deficient Value
Barley	5 leaf	Youngest expanded blade	<14 mg/kg
	Maturity	Grain	<8 mg/kg
Canola	3-5 leaf	Youngest mature leaf	<12 mg/kg
	3-5 leaf	Youngest open leaf	<27 mg/kg
	Start stem elongation	Youngest mature leaf	<8 mg/kg
	Start stem elongation	Youngest open leaf	<16 mg/kg
	Maturity	Grain	<29 mg/kg*
Chickpea	45 days after sowing	whole shoot	<34 mg/kg
	Vegetative	Youngest mature leaf	<22 mg/kg
	Maturity	Grain	<28 mg/kg
Faba bean	First flowers	Youngest open leaf	<19 mg/kg
	First flowers	Whole shoot	<26 mg/kg
	Maturity	Grain	<14 mg/kg
Field Pea	First flowers	Youngest mature leaf	<22 mg/kg
	Maturity	Grain	<20 mg/kg
Lupin	Pre-flowering	Youngest mature leaf	<13 mg/kg
	Maturity	Seed	<19 mg/kg
Sorghum	GS 3	Youngest mature blade	<10 mg/kg
	Maturity	Grain	<10 mg/kg
Sunflower	R2	Youngest mature leaf	<12 mg/kg
Wheat	23 days after emergence	Whole Shoot	<15-25 mg/kg
	Mid-Late Tillering	Youngest expanded blade	<14 mg/kg
	Mid-Late Tillering	Youngest emerged blade	<16 mg/kg
	Mid-Late Tillering	Whole shoot	<9 mg/kg
	Maturity	Grain	<15 mg/kg

have a lower concentration but still supply the 500 ng Zn.

Addressing zinc deficiency

If the indicators used, suggest zinc response is likely, there are several options available. Irrespective of the strategy, there are a couple of important aspects of using supplementary Zn.

- Roots move to zinc, and therefore, the distribution for drilled Zn needs to be even and banding with a product that has a reliable particle size and Zn content is important. Soil mixing (e.g. via cultivation) can dilute Zn concentration, and if placed too shallow, the Zn can be 'stranded' in dry soil if the season is slow to take up.
- Crops differ in their response to zinc, so within a rotation, it is more important to apply zinc ahead or onto responsive crops. In general, canola is relatively more efficient than cereals at accessing soil Zn (Brennan and Bolland 2002), while lupins, faba bean and chickpea have lower demands than wheat, and lentils have a higher demand (Brennan et al. 2001). Maize and sorghum have higher Zn demands than wheat or barley. So, in a crop rotation, address the Zn demand in the cereal phase rather than the pulse or oilseed phase.
- While foliar Zn can be used for rescue operations, it has little residual value. In comparison, soil applied Zn (with macronutrient) has a residual value of 2-5 crops depending on soil texture and pH.
- Yield increases with added zinc are less common than increases in grain Zn (Peck et al. 2008).

Right source of zinc

There are a large number of zinc products that can be blended with dry fertilisers, used to coat dry fertilisers, used as a seed dressing, and/or applied as an in-crop foliar application. The source can be inorganic, synthetic chelates or from natural organic complexes. The cost and efficiency of these different products varies significantly and the final decision is based around cost versus efficiency. Table 3 gives some properties for the different Zn sources.

Table 3. Selected Zinc fertilisers (Alloway 2008)

Compound	Zinc Content	Formula	Water solubility	Cost
Zinc Sulfate monohydrate	36%	$ZnSO_4.H_2O$	High	Low
Zinc Sulfate heptahydrate	22%	$ZnSO_4.7\ H_2O$	High	Low
Zinc Oxysulfate	20-50%	$xZnSO_4.xZnO$	Variable	Low
Zinc chloride	50%	$ZnCl_2$	High	Low
Zinc nitrate	23%	$Zn(NO_3)_2.3\ H_2O$	High	Medium
Zinc phosphate	50%	$Zn_3(PO_4)_2$	Low	?
Zinc fritts	10-30%	fritted glass	Very low	?
Ammoniated zinc sulfate	10%	$Zn(NH_4)SO_4$	Solution	High
Sodium Zinc EDTA	9-13%	Na.ZnEDTA	High	High

Source selection will depend on the desired solubility and the type of soil to which it is to be applied. For example, zinc sulfate is more effective than zinc oxide on alkaline soils but both sources are equally effective on acid soil (Brennan and Bolland 2006). Otherwise the agronomic value of the source depends on the solubility and concentration of Zn in the product, but it is important to note, that less soluble sources have lower residual value. The efficiency of sparingly soluble Zn sources such as ZnO, $ZnCO_3$, and zinc fritts in fine textured high Zn fixing soils was similar to highly soluble zinc sulfate heptahydrate. When sparingly soluble and soluble zinc sources are compared in coarse textured soils, soluble zinc sources give the best performance.

Cost is a major consideration, and the cost can vary ten-fold between products; especially with chelated products. To estimate the cost per kg of Zn supplied, use the formula:

$/kg zinc = Cost per tonne of product/%Zn/10

The uptake of zinc from compound fertilisers depends on the pH of the carrier (among other things). Mortvedt and Gilkes (1993) concluded from their literature survey that Zn incorporated into DAP based fertilisers is unlikely to be a fully effective Zn source, especially in neutral to alkaline soils. The coating of MAP granules with ZnO transforms all the applied ZnO to zinc ammonium phosphate, which limits expected Zn solubility and diffusion in soil. Coating of ZnO on urea granules reduced the solubility of Zn compared to coating on MAP granules (Milani et al. 2010). More recent research has showed that Zn diffuses more slowly from DAP than MAP because of the higher pH (stronger sorption), and there appears to be more Zn-P minerals precipitated from a DAP source compared to a MAP source (deGryse et al. 2012).

Other work has shown that distribution in the granule and then in the seed row is also important. Reduced rhizosphere pH due to root exudates or regions around acidic fertiliser granules is thought to assist with the solubilisation of soil Zn under alkaline conditions.

In some situations, (i.e. South Australia (Hollaway et al. 2008) and in the northern grains region (Bell, pers. comm)) there has been very good responses to deep-placed micronutrients. No more than three per cent Zn (as zinc sulfate heptahydrate) can be added to P fluid fertilisers (Holloway et al. 2008).

In terms of foliar sources of zinc, Brennan (1991) found zinc chelates 1.4 to 1.7 times more effective than zinc sulfate applied at GS14, but they were equally effective at GS23-24 on wheat. In the same experiment, zinc sulfate banded with the seed at sowing produced the highest grain yields.

Right time for zinc

In my opinion the best time to apply Zn is at seeding, mixed/blended with dry or fluid fertilisers. Using Zn fortified seed can also reduce the need for added zinc. However, under a moderate deficiency, crops are able to take up and respond to Zn applied before stem elongation. Later applications, up to flowering, can increase grain zinc content but will do little in terms of yield response.

As already mentioned, using soil applied zinc ahead of the most responsive crops seems a good strategy that balances cost and risk.

Conclusion

Use a soil test, paddock history, soil characteristics, crop demand, and tissue test to see if there is a likelihood of zinc responses. Soil tests get a 4/10 rating with regards to diagnosing the crops response to extra zinc, while tissue tests get a 7/10 rating. Water-soluble zinc content is a good indicator of agronomic effectiveness, but no formulation can provide more zinc than the amount supplied. In acidic soils, water insoluble fertilisers such as ZnO can be equally effective in improving plant growth when a soil is Zn deficient. When incorporated into acidic fertiliser, ZnO and $ZnSO_4$ can also be similarly effective in providing zinc to the plants.

References

Alloway BJ, 2008 Zinc in Soils and Crop Nutrition. http://www.fertiliser.org/ifa/HomePage/LIBRARY/

Bell R, Dell B. 2008. Micronutrients for Sustainable food, feed, fibe and bioenergy production. IFA. http://www.fertiliser.org/HomePage/LIBRARY/

Brennan RF, et al. 2001. Plant Nut.,

Brennan RF, Bolland MDA. 2002. Aust. J. Exp. Agric. 42, 985–993.

Brennan RF, Bolland MDA. 2006. Aust. J. Exp. Agric. 46: 1341–1347.

Brennan RF. 1991. Aust. J. Exp. Agric., 31: 831–834.

Ciampitti IA and Vyn TJ. 2013. Agronomy Journal, 106 (6), 1645-1657.

Dang YP, Dalal RC, Edwards DG, Tiller KG. 1993. Plant and Soil, 155/156, 247-250.

Degryse F et al. 2012. ASA meeting, October 2012, Cincinatti, USA. http://www.adelaide.edu.au/fertiliser/docs/ASA2012_Degryse_visualisation_new.pdf

Fernandez V et al. Foliar Fertilization: Scientifc principles and field practices. IFA http://www.fertiliser.org/ifa/HomePage/LIBRARY/

Holloway R, Graham RD, Stacey SP. 2008. Micronutrient Deficiencies in Australian Field Crops. In BJ Alloway (ed) Micronutrient deficiencies in Global Crop Production, Springer Science.

Milani, N et al. 2010. Proc of 19th world congress od soil science. http://www.iuss.org/19th%20WCSS/Symposium/pdf/1550.pdf

Mortvedt JJ. 1968. Journal of Agricultural and Food Chemistry. 16, 241-245.

Norton RM. 2013. Micronutrient survey and scoping study, Project 16. Grains Research and Development Corporation. 66 pp.

Peck AW, McDonald GK, Graham RD. 2008. Journal of Cereal Science, 47, 266-274.

Rengel Z, Graham RD 1995. Plant Soil, 173: 267–274.

Reuter DJ and Robinson JB (Eds), 1997. Plant Analysis: an interpretation manual. CSIRO Publishing.

Ryan MH, et al. 2002. Aust. J. Agric. Res. **53**, 1173-1181.

Tanner, P.D. and P.M. Grant (1973) Rhod. J. Agric. Res. 11: 69-75.

Contact details

Rob Norton
0428877119
rnorton@ipni.net
http://anz.ipni.net

Notes

Canola establishment – does size matter?

***Rohan Brill*[1], *Leigh Jenkins*[2] *and Matthew Gardner*[3],**
[1]NSW DPI Wagga Wagga, [2]NSW DPI Trangie,[3]AMPS Agribusiness (formerly NSW DPI Tamworth)

GRDC project code: DAN00129

Keywords

canola, establishment, seed size, phosphorus

Take home messages

- **Aim to sow large (>5 g/1000 seeds) canola seed to achieve adequate establishment rates from early sowing.**
- **Hybrid vigour (heterosis) has an indirect effect (larger seed size) and a direct effect (enhanced vigour) on canola establishment**
- **Avoid the application of high rates of phosphorus in direct contact with canola seed at sowing**

Introduction

Research in the southern region has almost universally shown a negative correlation between canola sowing date and grain yield. The challenge though is that earlier sowing of canola is generally (but not always) more risky for successful crop establishment. Therefore the overall aim of this research was not to improve canola establishment per se, but to increase the likelihood of achieving an adequate plant stand from sowing canola on time or early. The results reported here have greatest relevance for an early planting opportunity and a lesser relevance for canola that is dry sown or planted into moisture in May.

Sowing depth trials

Sowing depth trials were conducted at Coonamble, Nyngan and Trangie in 2012 and at Nyngan and Trangie in 2013. Each trial had six common varieties with a range in seed size (Table 1). Target seeding depths were 2.5 cm, 5 cm and 7.5 cm.

Table 1. Seed size and number of seeds sown in three canola variety sowing depth trials in 2012

Variety	Seed weight 2012 (g/1000 seeds)	Seed weight 2013 (g/1000 seeds)	Seeds sown/m²
AV-Garnet⦶	3.78	3.27	60
ATR-Stingray⦶	3.06	2.97	60
Pioneer 43C80 (CL)⦶	3.68	4.11	60
Pioneer 43Y85 (CL)	5.03	4.77	60
Pioneer 44Y84 (CL)	5.34	5.20	60
Hyola 555TT	4.26	4.00	60

In 2012, averaged across all trials and varieties, establishment (as a percentage of seeds sown) at the 2.5 cm target depth was approximately 66%, with no difference between varieties. All varieties had reduced establishment at the 5 cm sowing depth compared to the 2.5 cm sowing depth with the exception of Pioneer 44Y84 (CL) that had the largest seed (Fig. 1.). At the 7.5 cm sowing depth the difference between varieties and seed size became more marked as the largest seeded variety achieved 50% establishment compared to 20% establishment for the smallest seeded variety.

The effect of sowing depth on grain yield in 2012 was less marked than the effect on establishment. At Nyngan and Coonamble, the 7.5 cm target depth yielded approximately 250 kg/ha less grain than the 2.5 cm and 5 cm target depth. At Nyngan, Pioneer 44Y84 (CL) had no grain yield reduction at the 7.5 cm target sowing depth compared with the shallower sowing depths, however there was a significant grain yield reduction for all other varieties as a result of deep sowing. There was no effect of sowing depth on grain yield at Trangie.

In 2013 the overall establishment achieved was less than 2012. At the 2.5 cm sowing depth establishment was approximately 50% with no significant difference between varieties (Figure 2). All varieties had reduced establishment at the 5 cm sowing depth compared with the 2.5 cm sowing depth; however the reduction was less severe for the hybrids than for the open-pollinated (OP) varieties. Establishment was further reduced at the 7.5 cm sowing depth, with a similar hybrid advantage as occurred at the 5 cm sowing depth.

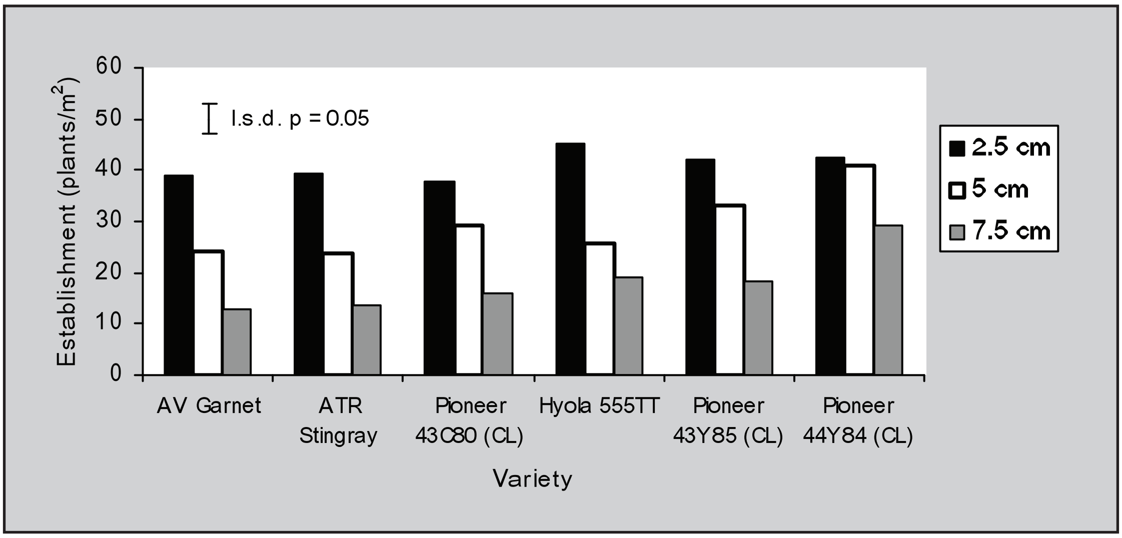


Figure 1. Establishment of six canola varieties at three sowing depths, averaged across three trials at Coonamble, Nyngan and Trangie in 2012.

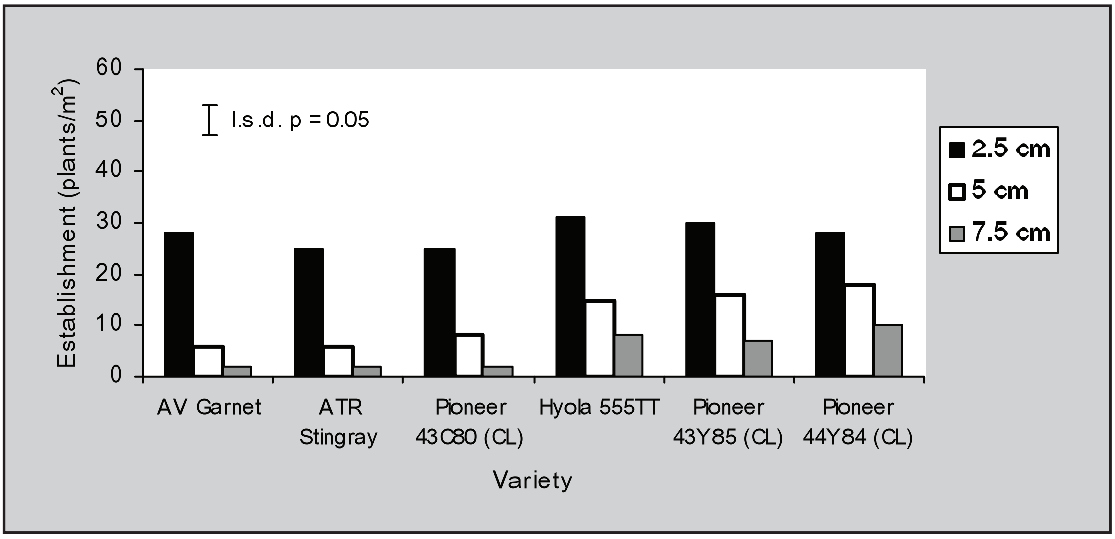


Figure 2. Establishment of six canola varieties at three sowing depths, averaged across two trials at Nyngan and Trangie in 2013.

The effect of sowing depth on grain yield was greater in 2013 than 2012 but was still of a lesser magnitude than the effect of sowing depth on establishment. At Nyngan, the grain yield of Pioneer 44Y84 (CL), AV-GarnetA and Hyola 555TT were all similar for the 2.5 cm sowing depth; however AV-GarnetA and Hyola 555TT both had a significant grain yield reduction at the 5 cm and 7.5 cm sowing depths, while Pioneer 44Y84 (CL) did not suffer a yield penalty from deeper sowing. At Trangie, all varieties suffered a grain yield penalty as sowing depth was increased but this reduction in grain yield was less severe for the larger seeded varieties.

Is seed size or plant type the key?

To determine if improved establishment is related to hybrid breeding or simply seed size the seed of each variety was graded into two size categories; large (2 - 2.4 mm diameter) and small (1 – 1.4 mm diameter). Twenty seeds of each variety and seed size category were sown at depths of 2.5, 5 and 7.5 cm in pots and placed in a glasshouse.

Similar to the field trial results the 2.5 cm planting depth had the highest establishment percentage and increasing planting depth to 5 and 7.5 cm significantly reduced establishment by 32 and 51% respectively, averaged across all varieties.

The small seeded OP varieties had the poorest establishment for each planting depth (Table 2). The large seeded hybrid and OP varieties had significantly better establishment compared to their respective small seeded varieties at both the 5 cm and 7.5 cm planting depths. Small seeded hybrids had significantly better establishment than the small seeded OP varieties (Table 2). This establishment data suggests that large seed as well as the heterosis advantage of hybrids contributes to improved establishment.

Dry matter of 100 plants was measured 15 days after emergence to give an indication of early plant vigour. The large seeded hybrids had the greatest dry matter accumulation at all sowing depths. Compared with the large seeded treatments,

Table 2. Plant establishment, days to emergence and 100 plant weights (15 days after emergence) for three hybrids (Pioneer 44Y84 (CL), Hyola 50 and Hyola 555TT) and three open pollinated (Pioneer 43C80 (CL), AV-Garnet and ATR-Gem) canola varieties segregated into large and small seed sown at three planting depths

Planting depth	Hybrid		Open-pollinated	
	Large seed	Small seed	Large seed	Small seed
Establishment				
2.5 cm	19.4a	19.8a	19.4a	16.3b
5.0 cm	18.8ab	12.8c	17.4b	8.8d
7.5 cm	15.9b	3.8e	8.7d	1.0f
Days to emergence				
2.5 cm	5.0a	5.1a	5.1a	5.2a
5.0 cm	5.9ab	6.7b	6.8b	7.2b
7.5 cm	7.4b	11.3e	8.7c	10.0d
100 Plant weight 15 days after emergence				
2.5 cm	56.9a	31.5d	45.7c	29.7d
5.0 cm	51.8b	24.5e	44.9c	23.5e
7.5 cm	49.5b	10.3g	45.8c	13.0f

***Numbers within each section (e.g. Establishment) designated with a different letter are significantly (P=0.05) different.*

the small seeded treatments (hybrid and OP) accumulated less dry matter and had a greater reduction in establishment where planting depth was increased. The early vigour advantage hybrids displayed over OP varieties that was observed for the large seeded treatments was not observed for the small seeded treatments, with hybrid and OP varieties accumulating similar dry matter per plant.

These glasshouse findings indicate that the establishment and early vigour advantage of hybrids is mostly due to their larger seed size, but also partly due to the heterosis advantage of hybrid breeding.

Starter fertiliser trials

At each trial site in 2012 a phosphorus rate trial was also sown. The phosphorus product used was triple super which does not supply any nitrogen with the phosphorus. The phosphorus rates applied were 0, 5, 10 and 20 kg/ha, with the fertiliser being placed directly with the seed.

There was no effect of phosphorus rate on canola establishment on the cracking clay (Grey Vertosol) soil at Trangie. In contrast, increasing P rate significantly reduced the establishment of all varieties on the lighter textured soils at Nyngan (Red Chromosol) and Coonamble (Brown Chromosol) (Figure 2). All varieties experienced a similar reduction in establishment, regardless of seed size or plant type.

Grain yield responded positively to phosphorus application at Trangie and Nyngan, which highlighted that the complete exclusion of phosphorus in order to improve crop establishment is not reasonable.

Two further phosphorus trials were conducted in 2013, with the Trangie trial planted on a lighter textured soil (Red Chromosol) compared with a heavy (Grey Vertosol) soil in 2012. There was a significant establishment reduction at both sites as phosphorus rate (applied as triple super) increased (Figure 3). Further product comparisons at a common P rate showed that all major phosphate fertilisers (MAP, DAP, Single Super, Triple Super, Supreme Z) affected establishment to a similar degree. Despite the effect on establishment, grain yield still responded positively to phosphorus at Nyngan, with the 5 kg/ha P rate yielding 0.25 t/ha more than the nil P treatment but with no further yield increase beyond this rate.

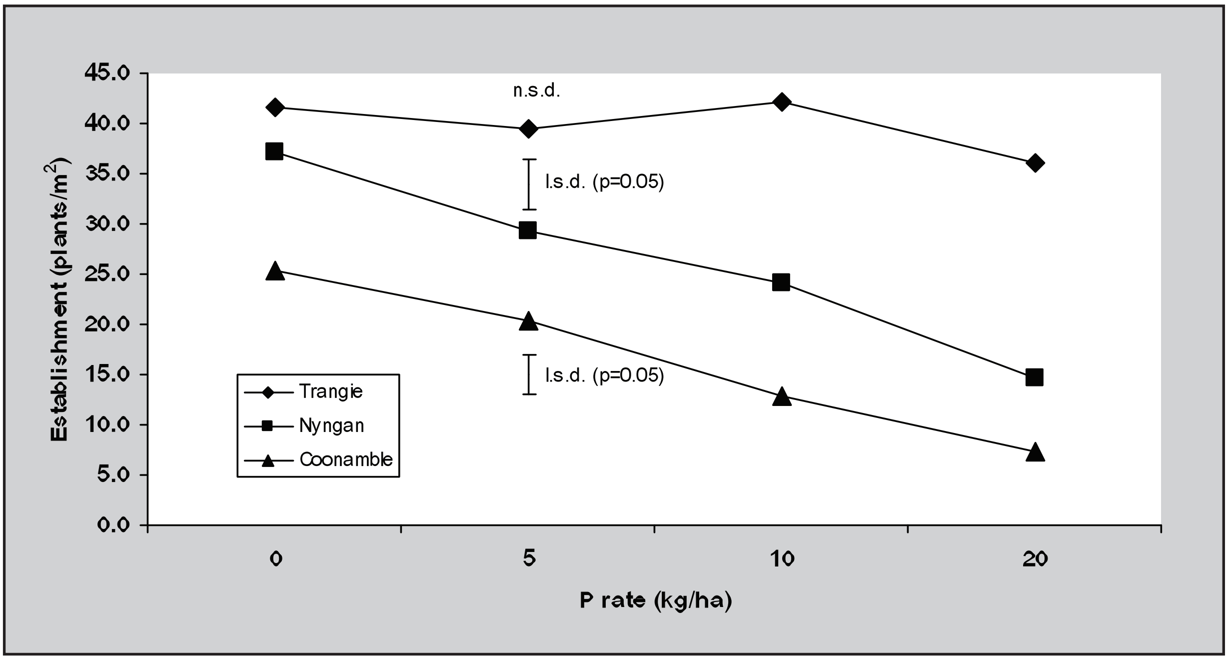


Figure 3. Average establishment of four canola varieties sown with four rates of phosphorus at Trangie, Nyngan and Coonamble in 2012.

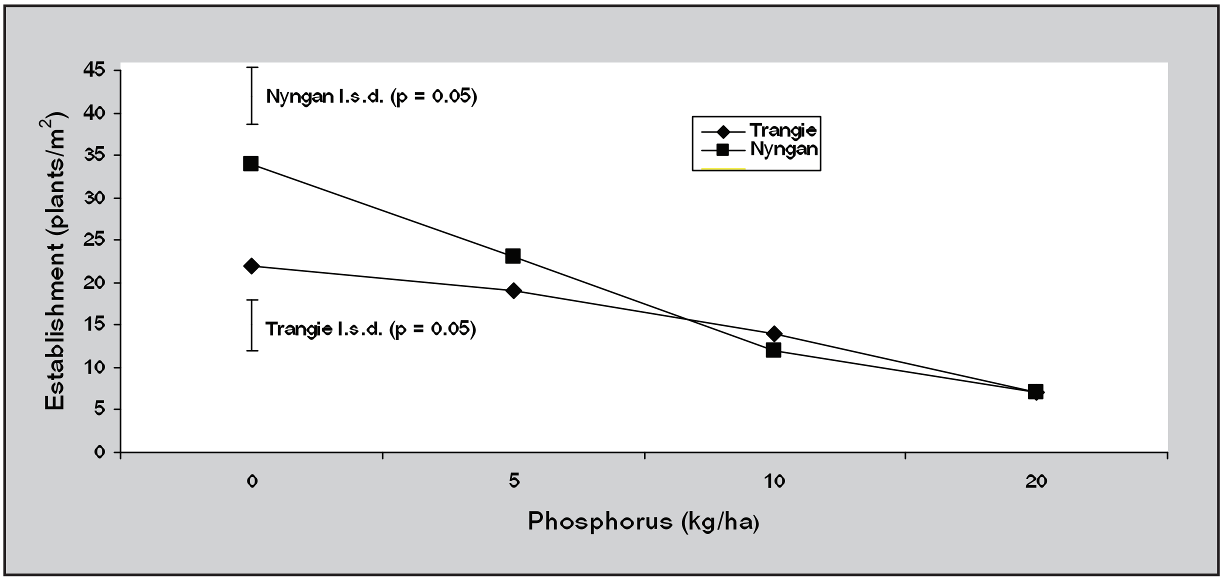


Figure 4. Average establishment of two canola varieties sown with four rates of phosphorus at Trangie and Nyngan in 2013.

For growers using a tine seeder it is generally possible (and recommended) to separate seed and fertiliser to avoid the negative effects of starter fertiliser. For growers with a disc seeder (or considering a disc seeder), there are several management options available such as:

- Planting on relatively narrow crop rows to reduce fertiliser concentration in the furrow.
- Plant canola early allowing greater root exploration, with potentially less phosphorus application required.
- Pay strict attention to closing devices. The firmer/heavier the closing device, the greater the negative impacts of phosphorus fertiliser.

Conclusion

To maximise grain yield potential canola needs to be planted early. This requires careful attention to detail in relation to crop establishment. Since the soil surface dries out more rapidly in early-mid April compared to mid-May, seed may need to be planted slightly deeper than optimal (up to 5-6 cm deep). In this early planting situation, pay strict attention to seed quality. Sowing large seed (> 5 g/1000 seeds) results in an increased likelihood of achieving an adequate establishment. For growers who wish to purchase seed, hybrid seed is generally larger than open pollinated seed. For growers who retain open-pollinated seed on farm for their own use, aim to clean seed with a 2 mm screen.

Phosphorus is essential for canola growth, but starter fertiliser may have an effect on crop establishment. Avoid high rates of phosphorus in direct contact with canola seed at sowing. Further research is required on phosphorus nutrition of canola, especially on the interactions between P application and sowing time and the effect that liquid phosphorus products may have on canola establishment.

Contact details

Rohan Brill

Wagga Wagga Agricultural Research Institute

02 6938 1989

rohan.brill@dpi.nsw.gov.au

Notes

Biopesticides - fresh hope for the future

Gavin J. Ash, B.A. Wilson, J.A. Pattemore, K. Crampton and A. Wang.,
Graham Centre for Agricultural Innovation, Charles Sturt University

GRDC project code: UCS00013; UCS00016; LUN00001

Keywords

biological control, insects, weeds, diseases, nematodes, molluscs

Take home messages

- **Biopesticides have been commercialised in Australia.**
- **They offer another avenue for managing recalcitrant insects, diseases and insects.**
- **Success with biopesticides depends on choosing the right target as well as the right agent.**
- **There are a large number of potential biopesticide agents but their commercial success depends on long term industry investment.**

Introduction

Biopesticides offer an innovative approach to the management of pests in farming systems using formulated microbial agents as the active ingredient. Microbes that have been used in this approach include fungi, bacteria, viruses and nematodes. Biopesticides are a viable adjunct to synthetic pesticides in a number of crops. The development of microbial biopesticides relies on agent discovery and selection, development of methods to culture the pathogen, creation of formulations that protect the organism in storage as well as aid in its delivery, studies of field efficacy, and methods of storage. Each microbial biopesticide is unique, in that not only will the organism vary but so too will the host, the environment in which it is being applied, and economics of production and control.

There are a large number of commercial products now available in most regions of the world, where biopesticides are being incorporated into farming systems. It has been projected that the market potential for these so-called "green products" could triple by 2020 and be worth over $4 billion (USD) (Bayer, 2013). The most successful examples of biopesticides include Dipel (a formulation of *Bacillus thuringenesis* - Bt), Gemstar (containing a nucleopolyhedrovirus – NPV) and T22 *(Trichoderma harzianum)*. The development of biopesticides is being driven by market opportunities such as pesticide resistance, changing consumer demands and the difficulty and cost of finding new synthetic pesticides. In Australia there are registrations for products based on Bt, NPV, *Trichoderma*, *Metarhizium* and *Beauvaria*. However, the number of registrations are relatively small when compared to the synthetic pesticides.

The use of biopesticides as a strategy in pest management can be applied to both native and introduced pests. However, the success of this type of biocontrol revolves around the costs of production, the quality of the inoculum and, most importantly, the field efficacy of the product.

Biopesticides are usually developed through collaboration with commercial companies with an expectation that they will recoup their costs and make a profit through the sale of the product.

Currently, in the Graham Centre at Charles Sturt University, there are a number of projects, at various stages of development, examining biological control of disease, insects, molluscs and nematodes affecting broad acre crops. These projects are variously funded by GRDC and CSU and have some level of commercial involvement.

Biocontrol of diseases

Blackleg disease of canola is a fungal disease of global importance. It is difficult to control by the use of chemicals and to date the best control measures are the use of genetically resistant canola cultivars and good farming practices. These cultivars display incomplete resistance to the disease and resistance breakdown has occurred in Australia.

Recent studies in other crops like radish and cucumber have identified a plant mechanism known as induced systemic resistance (ISR). This mechanism involves the use of naturally occurring beneficial soil bacteria, which switch on and activate the plant's defence system. The bacteria act somewhat like a vaccination to trigger the plants immune system. Such bacteria grow adjacent to and colonise a plant root system, this zone is high in nutrients released by the root system and consequently is heavily colonised by bacteria and fungi. The beneficial effects of rhizosphere bacteria have most often been based on increased plant growth, better seed germination and seedling emergence. These types of bacteria are now commonly called plant growth-promoting rhizobacteria (PGPR). PGPR use different mechanisms to suppress plant pathogens which include competition (nutrients and space), antibiosis production and inducing a plant's resistance mechanisms. This defence affects treated areas but also extends into non-treated areas and often even into newly developing plant parts. Systemic protection does not confer absolute immunity against disease but may reduce the severity by reducing lesion number, size and the extent of sporulation. Disease can be reduced by up to 90%. The potential of such bacteria is enormous for the reduction of disease and may be developed as seed coatings, drenches and powder applications depending upon the target pathogens, crop and the type of bacteria involved.

At Charles Sturt University we have isolated bacteria from the roots of canola and wheat in the southern cropping area. Some of these bacteria were from the rhizosphere and others were endophytic. They have been characterised in terms of their effect on growth of both wheat and canola, their ability to produce antibiotics active against the fungus that causes blackleg, numerous biochemical tests as indicators of their ability to suppress root pathogens and their ability to induce systemic resistance in canola against blackleg. Their ability to suppress disease in the glasshouse and in the field has also been assessed. Selected bacteria have been shown to reduce blackleg by induced systemic resistance in both sterile and non-sterile situations. The bacteria have then been ranked on desirable characteristics and the top 14 isolates have been identified using fatty acid analysis. This group includes endophytes and rhizobacteria, *Bacillus* and some *Pseudomonads* and all are plant growth promoters. Initial field results indicate that these bacteria are having positive effects on growth in the field. Furthermore, other species of bacteria have been isolated which have effects on other canola diseases and are comparable in efficacy to synthetic fungicides in field applications.

Biocontrol of molluscs

Four introduced Mediterranean snail species; *Cernuella virgata*, *Theba pisana*, *Cochicella barbara* and *Cochicella* acuta have become serious pests for the Australian grain industry in recent years. These pest snails cause heavy economic loss to farmers and the whole grain industry by contaminating the grain (wheat, barley, canola, lentil etc.), clogging harvesting equipment and downgrading the quality of grain. The lack of natural enemies of these pests in their distribution areas (most in SA, particularly in the Yorke Peninsula, some in VIC, TAS, WA and NSW) allow populations of these pest snails to increase rapidly.

This project was designed to investigate the possibility of developing a nematode based bioagent to control these pest snails in Australia. Nematodes have been successfully used for the management of slugs in over 14 European countries, and entomopathogenic nematode (EPN)-based bioinsecticides have been widely applied for the control of insect pests in Forestry, Horticulture and the turf industries.

In this project, a survey from south eastern Australia was used to isolate hundreds of indigenous potential EPNs from soil. From this collection, five nematode species with molluscicidal activities were selected and identified. The bacteria found associated with the nematodes were also isolated and identified. One of the bacteria, a strain of *Bt* molluscicidal activity (*Bacillus thuringiensis* DAR 81934), was found to be highly effective by itself and in combination with the nematode in killing the target snails. The complete genome of the *Bacillus* was sequenced and is a resource for further research. The nematodes were also found to be effective against slugs in the laboratory.

To be able to apply these organisms in the field, commercially available systems were used to produce the nematodes in Australia and internationally. Different systems were successful for different nematode species, allowing the production of concentrated nematode suspensions to be used in field trials conducted in South Australia over a number of years. It was found that the nematodes were best applied in the field in spring when the snails were laying eggs and moving on the soil surface. Unformulated nematodes caused up to 65% mortality in the field. However, synthetic snail baits provided up to 92% control.

This research has been discontinued as the cost of production of the nematodes was found to be too high for the use of the organism in broad acre agriculture in Australia.

Biocontrol of insects

Sucking insects like aphids can cause significant yield losses in agriculture due to the direct effects of feeding and the indirect effects associated with the spread of viruses. Current control of sucking insects relies on the use of chemical insecticides; however, these encourage the development of chemical resistance and suppress natural predator populations. Integrated Pest Management (IPM) programs that reduce the reliance on chemical pesticide therefore are likely to provide better management strategies for the future. As part of an IPM strategy GRDC have funded research into the discovery of biopesticides for the management of aphids in cereals and canola in Australia. The aim of the project was to develop pre commercialisation data for the registration of a biopesticide based on the fungus *M. anisopliae*.

A number of isolates of the fungus from Queensland and New South Wales have been isolated and cultured, with a number of the strains found to be highly pathogenic to a wide variety of aphid species common in Australia. Bioassays have been used to establish application concentrations and production efficacy of the strains is being established in the laboratory. All isolates are being compared to commercially available standards. Initial indications are that the Australian fungi are as efficacious as the internationally sourced commercial strains and are amenable to large scale manufacture.

Biocontrol of nematodes

At least four species of root lesion nematodes (RLN) in the genus *Pratylenchus* are considered serious pests of grain crops in Australia. *Pratylenchus neglectus* and *P. thornei* were chosen as the initial target species for this research project because of their prevalence and economic importance (recent estimates suggest losses due to RLN exceed $102M p.a. in Australia). Average incidence for both species across regions in Australia is 67-72% but with higher incidences recorded in the Northern and Southern regions (78-89%) compared to the Western region (43%). *P. neglectus* is more prevalent than *P. thornei* in the Western region but elsewhere the incidence levels are similar. It is important that the grains industry has robust control measures available to minimise the current and future losses from these nematode pests.

Currently, there are no nematicides registered for use in Australian cereal crops although some degree of management is possible with the use of resistant and/or tolerant crop cultivars, rotations incorporating poor host crops, manipulation of sowing time, provision of adequate nutrition and weed control within/between cropping phases. The cost of current control measures is estimated at $31OM p.a. for wheat and $81 M p.a. for barley.

The aim of this research project is to develop a bionematicide with activity against RLN on cereals. This strategy is based on the isolation and identification of naturally occurring beneficial microbes which are able to suppress the activity of the disease causing nematodes. The development of a new biological control product that is compatible with standard cereal cropping practices will provide growers with a wider range of disease management options for RLN and will add significant value to the grains industry.

The project has three initial research targets: the identification and evaluation of existing commercial biopesticides with potential suitability for this crop/pathogen system, the development of a *Trichoderma*-based bionematicide for cereal root lesion nematodes and the identification of indigenous strains of selected microbe groups that may have potential as bionematicides.

From initial surveys, a number of species of *Trichoderma* not previously recorded from Australia have been identified and their interaction with the organism responsible for crown rot and RLN are being evaluated in laboratory and glasshouse trials. A large screen of potential bacterial and fungal isolates have indicated that there are some which have potential as biological controls when compared with commercially available biopesticide formulations. Field trials in 2014 will establish whether these isolates can be used to manage nematodes in the field.

Conclusion

There are a number of advantages of the use of biopesticides over the use of conventional pesticides, including the minimal residue levels, control of pests already showing resistance to conventional pesticides, host specificity, and the reduced chance of resistance to biopesticides. This indicates an emerging, strong role for biopesticides in any integrated pest management strategy and an important involvement in sustainable farming production systems in the future. The main constraints to the production and use of biopesticides in Australia are the existence of facilities capable of producing the organisms economically and the systems for distribution and marketing of the products. These rely on the continued involvement of large corporations in the funding and development of these new management options.

Contact details

Gavin Ash

Graham Centre for Agricultural Innovation, Charles Sturt University, Locked Bag 588, Wagga Wagga 2678, NSW, Australia.

02 69332765

gash@csu.edu.au

Is social media working for you?

Prudence Cook,
Department of Environment and Primary Industries, Victoria

Keywords

social media, Twitter, Google +, LinkedIn, social media manager, access to information, networking, reputation management

Take home messages

- **Social media will become increasingly important to the workforce in the future.**
- **Social media channels can be used as sources of timely, relevant information.**
- **Using social media allows you to build networks outside of geographic boundaries.**
- **Having a professional online presence is crucial for reputation and brand management.**

Introduction

Some digital technologies; namely smart devices and apps, have been adopted rapidly in a short time frame with approximately 70 per cent of advisers now owning a tablet, despite the iPad only being commercially available since 2010. The benefit of these devices and their supporting applications are clearly apparent; you purchase a device and download the apps according to the functions you want it to perform. However, the benefits of social media, particularly for professionals who are not directly involved in marketing and communications, are much less obvious. Despite this, several benefits do exist, and having a grasp on these new media channels will become increasingly important as the Australian workforce incorporates more and more technological components.

Adopting social media, particularly from a professional standpoint, brings with it the need for many to develop new skills. Given that up-skilling can be a time consuming and costly exercise, you'd want to be certain that the skill will be needed in the long term. With that in mind, it's worth considering what core capabilities will be required in the workforce in the future. A report conducted by the Institute for the Future, looked at key drivers that will reshape the landscape of work and the key skills that will be needed in the next ten years. Ten key skills were identified:

- New media literacy: The ability to develop content online to communicate persuasively.
- Computational thinking: The ability to translate vast amounts of data.
- Transdisciplinary working: The ability to understand concepts across multiple disciplines.
- Cognitive load management: The ability to filter information depending on importance.
- Virtual collaboration: Work productively as a member of a virtual team.
- Sense making: The ability to determine greater significance from given information.

- Social intelligence: The ability to network and draw information from peers.
- Novel and adaptive thinking: The ability to find innovative solutions different to the norm.
- Cross cultural competency: The ability to work with an increasingly diverse workforce.
- Design mindset: The ability to develop tasks and processes for desired outcomes.

An understanding of social media can assist you in acquiring the above skill set through quickly accessing reliable information from a diverse range of sources and adapting that information into a local context. Staying abreast of happenings online will benefit continual professional development and ensure that your skill set remains aligned with an increasingly digital workforce.

In the short and medium term, there are still benefits to be gained for a grains adviser participating in social media. These are:

- Access to information,
- network building; and
- online presence and reputation.

Access to information

For any adviser considering using social media, the most immediate benefit is accessing information from all your preferred information sources. We're now at the stage where almost all agricultural media organisations, seed, chemical, fertiliser and marketing companies as well as grower groups and government organisations have a social media presence and are using it to distribute information the minute it comes to hand. This allows recipients of this information to be more proactive and timely with decision making as you're not waiting for a specific publication date, by which time, the information will not be as useful. It also allows you to receive the information most relevant to you, instead of having to flick through an entire publication.

In addition to the information sources listed above, a growing number of producers are using platforms like Twitter to share what's happening on their farm, while seeking information from others in industry. This includes seeking agronomic advice and troubleshooting machinery issues.

What's becoming increasingly important as more and more individuals and organisations contribute content to social media, is the filtering of that information to ensure it's relevant and easily accessed. There are a number of mechanisms that allow you to organise social media content to ensure you only get information that is relevant to you.

In order to sort incidental information, you may want to use a social media manager such as Tweetdeck (for Twitter only) or Hootsuite (for Twitter and other platforms such as Facebook and LinkedIn). A social media manager allows you to sort tweets into columns according to people or topics you're interested in. Some twitter hashtags (a hashtag is a way of categorising tweets) you may want to follow include: #tweetsfromthetractorcab, #harvest13, #plant14, #ausag, #agronomy, #grdcupdates and #agchatoz.

If you're after specific information from a particular source, you can often alter your settings within various social media platforms to ensure you are alerted whenever new information becomes available. For example, I receive a text message to my phone any time my local Country Fire Authority Twitter account puts out information regarding an incident. Another mechanism for ensuring you're alerted when new information becomes available is Google Alerts (you need a Gmail account to use this). This will allow you to select keywords that interest you. When new content that contains those keywords appears online, you'll receive an email. You have the ability to choose the type of content received and the frequency of emails received. I have set several Google Alerts. Some of these include “Agricultural Apps” and “Social media in Australian Agriculture”.

Network Building

As the amount of information available increases, so does the complexity of decision making. This means that, in the future, it will be unreasonable to expect that an individual adviser will be an expert in all areas. However, an individual will be expected to leverage on their professional and personal networks, to tap into people and resources that may be able to assist.

Local networks will always remain crucial, as producers will look to their adviser for issues relating to their region. However, as grain production is increasingly impacted by happenings on the other side of the state, country and even the world, building networks outside immediate geographic boundaries is important. Being involved in social media is a good way to start building those networks. In addition to accessing information, strong online networks can present professional opportunities and business leads.

For the Australian grains industry, following the hashtags mentioned above on Twitter is a great place to start networking with farmers, advisers, grain marketers, researchers, seed/chemical/fertiliser companies, industry bodies, agricultural media and consumers. Twitter is also useful for a global perspective, but you may also be interested in Google+. Google + has a series of communities centered on a common theme such as “Agricultural Innovators” and “Extension” that allow members to seek advice from professionals all around the world. Google + is free and accessable to anyone who has a Google account.

Online Presence and Reputation

Your professional reputation is an incredibly important asset. You work hard to ensure that you have a good presence in the area you service and that clients know to come to you with an issue that relates to your area of expertise. But what does your online presence look like?

If you don’t have one; you need one. Increasingly, the Internet is the first place many people will visit when seeking information or looking for someone to help them. If you don’t have an online presence, you run the risk of missing out on potential clients as well as business, media, career and funding opportunities.

Do you have a personal online presence instead of a professional one? Clean it up (no inappropriate photos or opinions); lock down your privacy settings for personal accounts so only those you choose can access it. Treat anything you post like a personal press release.

In addition to a Twitter and Google + presence, which allows you to network with others in your area of interest, consider a LinkedIn profile. This will allow you to have a ‘virtual resume’ as well as allow prospective clients, employees, employers or business partners to view not only your capabilities, but also your networks.

Conclusion

Social media is what you make of it. It can be used as entertainment or as a professional business tool, a time waster or a way of keeping up with the latest information. At present, return on investment from social media is difficult to calculate, particularly from an adviser’s perspective, as often it’s not used directly as a marketing tool. However, placing a value on access to information, networks and your reputation is also difficult, yet no one denies their importance in any business. Social media has the potential to aid these three areas, and will only become more important in the future as we move into a more online reliant workforce.

Please see the next page for a checklist of considerations when posting content on social media channels.

References

Cook, P. (2012) Keepad Evaluation from I.T. Starter Guide presentation, GRDC Farm Business Updates, Pineroo, Jamestown, Nhill, Echuca and Hamilton, October 2012.

Future Work Skills 2020. Institute for the Future for the University of Phoenix Research Institute, 2011.

The Do's and Don'ts of posting online

Do:

- ✓ Be human
- ✓ Be helpful and educating
- ✓ Ask questions
- ✓ Post consistently (try to stick to a few key themes)
- ✓ Respond to comments
- ✓ Post images and links
- ✓ Be relevant when joining conversations
- ✓ Maintain your account
- ✓ Understand your audience
- ✓ Pay attention to the reasons why you use different platforms
- ✓ Proofread your posts
- ✓ Remember that once it's online, it's permanent

Don't:

- ✗ Self promote excessively
- ✗ Post too often
- ✗ Pick fights and troll
- ✗ Give out personal information or too much information
- ✗ Post links you haven't read
- ✗ Drink and post!
- ✗ Post something you wouldn't want your mother to read

Contact Details

Prudence Cook
Private Bag 260 Horsham 3400
(03) 5362 2111
Prudence.cook@depi.vic.gov.au
Twitter: @DEPI_Grains

Canola and pulse disease management – maintaining the vigilance in 2014

Kurt Lindbeck[1], Stephen Marcroft[2], Angela Van de Wouw[2, 3], Vicki Elliott[2] and Barb Howlett[3],

[1]NSW - Department of Primary Industries, Wagga Wagga, [2]Marcroft Grains Pathology P/L, Horsham [3]The University of Melbourne.

GRDC project codes: DAN177, UM0051

Keywords

canola, blackleg, sclerotinia, disease management, blackspot

Take home messages

- **Elevated levels of internal blackleg infection were detected across southern NSW at blackleg monitoring sites in all varieties evaluated in 2013.**
- **Early flowering canola crops in combination with wet weather conditions were conducive to sclerotinia stem rot development in 2013.**
- **Consider the past frequency of sclerotinia stem rot outbreaks and yield potential when deciding to apply a foliar fungicide in 2014.**
- **Make informed decisions about blackleg and sclerotinia stem rot management. Monitor crops during the growing season to understand the impact of these diseases on production.**
- **Consult the Sclerotinia Stem Rot in Canola factsheet and Blackleg Management Guide for further information. These publications are available from the GRDC website.**
- **Early sown pulse manure crops are more prone to developing disease.**

Blackleg of Canola

Blackleg – the challenge continues

The blackleg fungus, *Leptosphaeria maculans* is sexually reproducing, resulting in enormously diverse populations, and therefore, a high propensity to overcome resistance in *Brassica napus* (canola) cultivars. Therefore, the fungal population evolves very rapidly and responds quickly to selection pressures such as wide-scale sowing of cultivars with specific resistance genes. This will lead to resistance being overcome when cultivars of the same resistance gene are sown for three or more years. Cultivar resistance has been overcome in many regions around Australia, the most recent being Hyola®50 which went from a rating of resistant to susceptible on the Eyre Peninsula in 2012.

There is a very strong relationship between the intensity of canola production within a region and the level of blackleg development within commercial crops. The blackleg pathogen survives and reproduces on the previous season's canola stubble, therefore the 500,000 ha canola crop in NSW in 2013 will result in 500,000 ha of blackleg infested stubble in 2014 releasing windblown spores every time it rains.

Blackleg – the warning signs for southern NSW

Cultivars representing each of the blackleg resistance groups were sown at 32 National Variety Trial sites across Australia (ten sites were located in NSW) and monitored for levels of blackleg development in 2013. Each site contained a representative cultivar of each of the six blackleg resistance groups, Groups A, B, C, D, E and G. There was no fungicide applied to seed, fertiliser or the growing plot (foliar) at these blackleg monitoring sites. These data indicate which resistance groups have higher levels of disease compared to the national average at each of the regionally based NVT canola yield sites and serve as a monitoring tool of local blackleg pathogen populations.

Overall blackleg severity increased across all cultivars at blackleg monitoring sites in 2013 in southern NSW (see Table 1). Blackleg severity increased from 26% average internal infection level in 2012 to 38% in 2013. The blackleg severity in NSW in 2013 was twice as high compared to infections levels in Victoria and South Australia. This increase in disease severity is likely due to the increasing area sown to canola in NSW since 2010.

In addition to overall increased blackleg severity, the Group D monitoring cultivar had a marked increase in blackleg severity. When similar increases in blackleg severity in Group D were detected on the Eyre Peninsula in South Australia in 2011, the Group D cultivars showed increased susceptibility to blackleg in the following season (2012). This situation could potentially occur in some regions of NSW in 2014.

Use the appropriate management strategy to minimise yield loss

Spores of the blackleg fungus are released from the previous year's canola stubble, so an increased area of canola results in increased disease pressure. *The most effective blackleg management tool is to keep a 500 m distance from this season's crop and last year's canola stubble.* However, as more canola is grown this control measure is becoming harder to achieve, particularly in tight wheat/canola rotations.

Blackleg can be minimised by a number of factors including the sowing of cultivars with high blackleg resistance, avoiding last year's stubble and applying the appropriate fungicides (see 2014 Blackleg Management Guide for details - www.grdc.com.au). An additional method for minimising disease is rotating cultivars with different resistance genes.

All canola cultivars are now classified into different resistance groups. Refer to the current Blackleg Management guide (www.grdc.com.au) for individual cultivar groups.

Remember to monitor the level of blackleg development in canola crops during the growing season as a basis for selecting appropriate management strategies in the future.

Sclerotinia Stem Rot – the new disease challenge

How does the disease develop?

The fungal pathogen that causes sclerotinia stem rot is called *Sclerotinia sclerotiorum*. This fungus can infect over 300 plant species, mostly broadleaf plants, including many crop, pasture and weed species. This includes plants like canola, lupin, chickpea, sunflower, lucerne, cape weed, and shepherds purse. The main features of the disease are:

1. Airborne spores of the fungus are released from apothecia (a small, golf tee shaped structures, 5 – 10 mm in diameter) which germinate from sclerotia in the soil. For this to occur prolonged moist soil conditions in combination with moderate temperatures of 15°C to 25°C are considered ideal. Most sclerotia will remain viable for up to 3 – 4 years then survival slowly declines.
2. Spores of the sclerotinia pathogen cannot infect canola leaves and stems directly. They require petals as a food source for spores to germinate grow and colonise the petal. When the infected petal eventually drops, it may become lodged onto a leaf, within a leaf axil or at branch junctions along the stem. If conditions are moist the fungus grows out of the petal and invades healthy plant stem tissue which will result in a stem lesion and production of further sclerotia within the stem which will be returned to the soil after harvest.
3. Sclerotia also have the ability to germinate in the soil, produce mycelium and directly infect canola plants in close proximity, causing a basal infection.

Table 1. Summary data of all Australian blackleg monitoring sites for levels of internal infection

Cultivars representing each of the resistance groups were sown adjacent to canola National Variety Trial sites across Australia and monitored for levels of blackleg. These data indicate which resistance groups have high levels of disease compared to the national average at each site. For more detail consult the individual site summaries and recommendations on the NVT online website.

Site	Resistance Group						Comments
NSW	**A**	**B**	**C**	**D**	**E**	**G**	
BECKOM	**H**	**H**	M	M	L	L	High blackleg severity in groups A, B. Moderate in C, D.
BELLATA	L	L	L	L	L	L	Low blackleg severity in all groups.
COOTAMUNDRA	**H**	**H**	L	L	L	L	High blackleg severity in groups A and B.
CUDAL	**H**	**H**	**H**	**H**	L	L	High blackleg severity in groups A, B, C and D.
GEROGERY	L	L	L	L	L	L	Low blackleg severity in all groups.
GRENFELL	**H**	M	L	L	L	L	High blackleg severity in group A. Moderate in group B.
LOCKHART	**H**	**H**	L	M	L	L	High blackleg severity in groups A and B. Moderate in group D.
MULLALEY	L	L	L	L	L	L	Low blackleg severity in all groups.
PARKES	**H**	**H**	M	L	L	L	High blackleg severity in groups A and B. Moderate in group C.
WAGGA WAGGA	**H**	**H**	**H**	**H**	L	L	High blackleg severity in groups A, B, C and D.
SA	**A**	**B**	**C**	**D**	**E**	**G**	
ARTHURTON	L	L	L	L	L	L	Low blackleg severity in all groups.
BORDERTOWN	L	L	L	L	L	L	Low blackleg severity in all groups.
MT HOPE	L	L	L	H	L	L	High blackleg severity in Group D.
RIVERTON	L	L	L	L	L	L	Low blackleg severity in all groups.
SPALDING	L	L	L	L	L	L	Low blackleg severity in all groups.
TURRETFIELD	H	M	L	L	L	L	High blackleg severity in group A. Moderate in Group B.
VIC	**A**	**B**	**C**	**D**	**E**	**G**	
CHARLTON	L	L	L	L	L	L	Low blackleg severity in all groups.
DIGGORA	L	L	L	L	L	L	Low blackleg severity in all groups.
HAMILTON	L	L	L	L	L	L	Low blackleg severity in all groups.
KANIVA	L	L	L	L	L	L	Low blackleg severity in all groups.
MINYIP	L	L	L	L	L	L	Low blackleg severity in all groups.
STREATHAM	L	L	L	L	L	L	Low blackleg severity in all groups.
WUNGHNU	L	H	M	L	L	L	High blackleg severity in Group B. Moderate in Group C.
YARRAWONGA	H	H	L	H	L	H	High blackleg severity in Groups A, B, D and G.
WA	**A**	**B**	**C**	**D**	**E**	**G**	
BADGINGARRA	L	L	L	L	L	L	Low blackleg severity in all groups.
CORRIGIN	L	L	L	L	L	L	Low blackleg severity in all groups.
GIBSON	L	L	L	L	L	L	Low blackleg severity in all groups.
KATANNING	L	M	L	L	L	L	Moderate blackleg severity in Groups A and B.
KENDENUP	L	M	L	L	L	L	Moderate blackleg severity in Group B.
KOJONUP	L	M	L	L	L	L	Moderate blackleg severity in Groups B.
S. STIRLING	L	L	L	L	L	L	Low blackleg severity in all groups.
WILLIAMS	L	M	L	L	L	L	Moderate blackleg severity in Group B.

Key	
	No data
L	Low blackleg severity compared to national average – continue with current management techniques.
M	Moderate blackleg severity compared to national average – Monitor crops for disease, see Blackleg management guide.
H	High blackleg severity compared to national average – high risk of yield loss, see Blackleg management guide.

4. *Weather conditions during flowering play a major role in determining the development of the disease.* The presence of moisture during flowering and petal fall will determine if sclerotinia develops. Dry conditions during this time can quickly prevent development of the disease, hence even if flower petals are infected, dry conditions during petal fall will prevent stem infection development.

Research findings in 2013

A number of commercial canola crops were monitored for the development of sclerotinia stem rot in 2013. These crops were around Cootamundra and south of Henty, in traditionally high disease risk districts. Results from observations within these crops found a very strong relationship between leaf wetness and stem rot development. While the level of stem rot development varied between the crops south of Henty and those at Cootamundra, it was found those extended periods of continual leaf wetness of at least 48 hours or longer were critical 'trigger' points for stem rot development in both regions.

There was also two distinct phases identified in the development of the disease. It was found that petal infection provided the first phase in the initial establishment of stem rot within the crop. The second phase occurred once canopy closure occurred and a humid microclimate was established, with the retention of infected plant tissue under the crop canopy providing opportunities for continued disease development later in the season. This tissue included lower leaves and senescent leaves that became colonised and later adhered to stems, causing stem lesion development and yield loss. This work will continue in 2014 to collect and collate data which will be used to develop a disease prediction model for NSW.

Where did the disease occur in 2013?

In 2013 epidemics of sclerotinia in southern NSW and northern Victoria were observed in traditionally high rainfall districts. These included districts east of Cootamundra, Young and Cowra, south of Henty, around Corowa and Howlong and districts along the Murray River. Infection levels observed in some crops were as high as 30 – 60%. In other districts, crop infection levels were generally low.

Why did we observe higher levels of sclerotinia stem rot in 2013?

The weather conditions during the winter of 2013 could be considered ideal for the development of sclerotinia stem rot. Mild winter temperatures resulted in many canola crops flowering 3 – 4 weeks earlier than would be considered 'normal' for southern NSW and northern Victoria. Canola crops were observed to be flowering as early as the middle of July. These flowering crops also coincided with good rainfall throughout late July and August, which provided ideal conditions for apothecia development and release of ascospores. Frequent rainfall events throughout August provided long periods of leaf wetness and ideal conditions for infected petals to drop into wet crop canopies and allow infection to occur.

What are the indicators that sclerotinia stem rot could be a problem in 2014?

- Epidemics of sclerotinia stem rot generally occur in districts with reliable spring rainfall and long flowering periods for canola.
- Use the past frequency of sclerotinia stem rot outbreaks in the district as a guide to the likelihood of a sclerotinia outbreak. Paddocks with a recent history of sclerotinia are a good indicator of potential risk, as well as those paddocks that are adjacent.
- The commencement of flowering can determine the severity of a sclerotinia outbreak. Spore release, petal infection and stem infection have a better chance of occurring when conditions are wet for extended periods, especially for more than 48 hours. Canola crops which flower earlier in winter, when conditions are cooler and wetter, are more prone to disease development.

If I had sclerotinia in my canola crop last year, what should I do this season?

The biggest challenge in managing sclerotinia stem rot is deciding whether or not there is a risk of disease development and what will be the potential yield loss. Research in Australia and Canada has shown that the relationship between the presence of the pathogen (as infected petals) and development of sclerotinia stem rot is not very clear due to the strong reliance on moisture for infection and disease development.

Important management options include:

1. *Sowing canola seed that is free of sclerotia.* This applies to growers retaining seed on farm for sowing. Consider grading seed to remove sclerotia that would otherwise be sown with the seed and infect this season's crop.
2. *Separate this season's paddock away from last year's canola stubbles.* Not only does this work for other diseases such as blackleg, but also for sclerotinia.
3. *Rotate canola crops.* Continual wheat/canola rotations are excellent for building up levels of viable sclerotia in the soil. A 12 month break from canola is not effective at reducing sclerotial survival. Consider other low risk crops such as cereals, field pea or faba bean.
4. *Follow recommended sowing dates and rates for your district.* Canola crops which flower early, with a bulky crop canopy are more prone to developing sclerotinia stem rot. Bulky crop canopies retain moisture and increase the likelihood of infection. Wider row spacing's can also help by increasing air flow through the canopy to some degree until the canopy closes.
5. *Consider the use of a foliar fungicide.* Weigh up yield potential, disease risk and costs of fungicide application when deciding to apply a foliar fungicide.
6. *Monitor crops for disease development and identify the type of stem infection.* Main stem infections cause the most yield loss and indicate infection events early in the growing season. Lateral branch infections cause lower levels of yield loss and indicate infection events later in the growing season.

When is the best time to apply a foliar fungicide?

Research in Australia and Canada has shown that an application of foliar fungicide around the 20% - 30% flowering stage (20% flowering is 14 – 16 flowers on the main stem, 30% flowering is approx. 20 flowers on the main stem) can be effective in reducing the level of sclerotinia infection. The objective of the fungicide application is to prevent early infection of petals while ensuring that fungicide also penetrates into the lower crop canopy to protect potential infection sites (such as lower leaves, leaf axils and stems). Timing of fungicide application is critical.

In 2013 some commercial crops which received an application of foliar fungicide still developed stem rot later in the season. This is not unexpected as the fungicide will have a limited period of protection during a time of rapid plant growth and the main aim of foliar fungicide applications is the prevention of main stem infections, which cause the greatest yield loss. Development of lateral branch infections later in the season is not uncommon, and will cause lower yield loss.

Consult the Sclerotinia Stem Rot in Canola factsheet for further information. This publication is available from the GRDC website.

Diseases of Pulse Crops in 2013

Disease issues which appeared in pulse crops in the southern region in 2013 include:

Phytophthora root rot of lupin: Wet winter conditions throughout July and August favoured the appearance of this disease in some districts. Lupin crops sown in lower lying paddocks or paddocks with a hard pan layer which favoured waterlogging, may have developed patches of dying plants in spring. The pathogens which cause phytophthora root rot (also known as sudden death in the past) only require a brief period (short as 8 hours) of waterlogging for infection of roots to occur.

Bacterial blight of field pea: This disease was not seen or reported in any commercial field pea crops in 2013. The mild winter temperatures experienced in 2013 did not favour development of bacterial blight, with a strong relationship between frost events and the development of the disease.

Powdery mildew of field pea: Mild winter temperatures and rapidly growing crops resulted in outbreaks of powdery mildew in some districts further west and north of Wagga Wagga. Traditionally this disease does not appear in crops till later in the season during late flowering and pod fill. Mild daily temperatures in combination with cool nights, which favour dew formation, are ideal for this disease to develop. There are a number of foliar fungicide options available and resistant varieties to manage this disease.

Manuring Pulse Crops and Disease Management – striking the balance

A number of disease issues developed in 2013 with the increasing trend toward using pulse crops as manure in southern NSW and northern Victoria, in particular blackspot (or ascochyta blight) of field pea. If pulse crops are to be used successfully for manuring purposes the balance has to be made between dry matter production and disease management. Essentially, many pulse crop species have not been developed as manure crops and the agronomy and disease management packages which accompany these crops traditionally focus on grain production.

Field pea is sensitive to early sowing. Early sown field pea crops are more prone to developing blackspot if conditions are wet in winter or developing bacterial blight if conditions are dry and frosty. The traditional sowing window for this crop in our region has been developed around maximising yield and avoiding disease, in particular avoiding spore release from old field pea stubble. The pathogens which cause blackspot can survive between seasons on seed, in soil and on stubble, which means an integrated approach must be taken to manage this disease. Effective disease management options include:

- ***Use of a fungicidal seed dressing:*** To reduce seed transmission of the disease and provide early seedling protection (products such as P-Pickle-T).
- ***Crop rotation:*** A break of at least three years to ensure adequate time between field pea crops for soil-borne spore populations to decease.
- ***Paddock selection:*** Do not sow this year's field pea crop adjacent to last year's field pea stubble which will release air-borne spores onto new season's crops. Leave a distance of at least 500m between last year's stubble and this year's field pea crop.
- ***Time of sowing:*** Do not be tempted to sow crops too early outside the recommended sowing window for your district. Early sowing will expose crops to early season spore showers and allow crops to develop a dense canopy by mid – late winter, which further favours disease development. Early sown crops are also more prone to bacterial blight by increasing exposure to frost events.

Why did we see high levels of blackspot last year?

High levels of blackspot were observed in field pea manure crops in several districts in southern NSW last year. These blackspot epidemics were due to a combination of factors which favoured development of the disease. These factors included:

- Crops sown extremely early.
- Field pea crops sown adjacent to the previous season's field pea stubble.
- Dry conditions over summer which did not allow any spore maturation or release to occur prior to sowing.

In previous seasons the wet conditions over summer had aided breakdown of field pea stubble and accelerated spore maturation and release in the field prior to sowing. This had allowed early sown field pea crops to effectively 'escape' early spore showers from the previous season's stubble and develop only low levels of disease.

Disease prediction using Blackspot Manager

Primary infection of blackspot can be reduced if field pea crops are sown after the majority of blackspot spores have been released from infected field pea stubble. Consequently pea growers have generally been advised to sow pea crops 2-3 weeks after opening rains so newly emerging crops can avoid these spores. However the timing of the spore release varies depending on seasonal conditions over summer and autumn.

For several years field pea producers in Western Australia have had access to 'Blackspot Manager', which is a computer based model which predicts the best time to sow new season field pea crops to avoid disease. Blackspot Manager calculates the timing of spore release from old stubble using seasonal rainfall and temperature data, and identifies whether the delay in sowing is necessary in the current season or whether it is safe for peas to be sown during the autumn. The optimum sowing dates calculated also consider agronomic factors, which may vary by region and season, and other production issues such as frost and yield penalties from late sowing.

In recent years this service has been extended to field pea producers in South Australia and Victoria. Over the past two years data from southern NSW has been supplied to researchers in DAFWA to validate the model for this region. It is hoped that this service will be available this coming season. For more information refer to *http://www.agric.wa.gov.au/cropdisease*

Choosing appropriate crops to manure

To overcome the issues relating to disease development in manure crops the choice of manure crop should be considered and how this fits within the farming system. For some producers time of sowing will be seen as an important consideration. For producers who prefer to sow manure crops early, crops such as lupin or high density legume species would be suitable. For a later sowing time, field pea or vetch would be appropriate. Even within some of these crop types there are varietal differences that can be exploited if dry matter production (and hence nitrogen fixation) is the objective. For example, within field pea, varieties such as MorganA or PBA HaymanA produce more dry matter, even when sown within the recommended sowing window, than other high yielding varieties.

Unfortunately there exists a conflict between dry matter production and disease development. Crops sown to maximise dry matter production will succumb to disease more readily and the manure crop fails to reach potential. Advisers and producers need to weigh up the potential risks, limitations and costs of the various manure crop options and choose a crop that best suits their particular farming system.

Contact details

Kurt Lindbeck

NSW Department of Primary Industries, Wagga Wagga Agricultural Institute

02 69 381 608

kurt.lindbeck@dpi.nsw.gov.au

Notes

Soil organic matter – what does it mean for you?

Harm van Rees[1], Brian Murphy, Enli Wang[2], Jeff Baldock[2], Frances Hoyle3, David Lawrence[4], Bhupinder Pal Singh[5] and Peter Thorburn[2],

[1]Cropfacts P/L, [2] CSIRO, [3] DAFWA, [4] QDAFF, [5] NSW DPI

GRDC project code: CRF00002

Keywords

soil organic matter, soil C, soil functions, soil organic matter fractions

Take home messages

- **Soil organic matter plays a critical role in maintaining the productive capacity of soils.**
- **The particulate, humus and resistant organic carbon fractions contribute to different functions in the soil.**
- **Increasing the soil organic matter content of soils takes time and requires higher levels of carbon inputs and reduced levels of carbon outputs.**
- **Soil organic matter plateaus at an equilibrium level for a given management system (decreases or increases are not continuous).**

Aims:

- To discuss the benefits of soil organic matter on the productive capacity of the soil; and
- To identify the importance of different fractions.

What is soil organic matter?

Soil organic matter (SOM) is derived from decaying plant and animal matter and according to fractionation methodology, consists of three carbon fractions:

1. Particulate Organic Carbon (POC) – decomposing plant and animal material (size: 0.05 to 2mm).
2. Humus Organic Carbon (HOC) – decomposed material found as large organic molecules attached to soil particles (size: <0.05mm).
3. Resistant Organic Carbon (ROC) – inert material, mostly charcoal.

The stability of each of these fractions is very different. Particulate Organic Carbon (POC) is the least stable fraction. It lasts only months or at the most one or two years before the carbon is either lost to the atmosphere as carbon dioxide (CO2), or is decomposed further into humus. Humus Organic Carbon (HOC) is a relatively stable fraction and can last in the soil for decades. Resistant Organic Carbon (ROC) is mostly charcoal and is very stable and may last 100s of years.

Soil type and vegetation management will affect POC and HOC levels, but ROC levels are historical and change very little.

Functions of soil organic matter

Soil organic matter (SOM) plays an essential role in maintaining the productive capacity of agricultural soils and higher levels of SOM can improve the physical, chemical and biological functionality of the soil.

- Physical: SOM improves aeration and soil structure, increases plant available water (PAW), lowers bulk density, and protects the soil against wind and water erosion by binding soil particles.
- Chemical: SOM contributes to the cation exchange capacity of the soil, acts as a buffer against acidification and maintains the availability of phosphorus (P); by binding to iron (Fe) and aluminium (Al).
- Biological: SOM provides energy for micro-organisms and releases plant available nitrogen in the form of nitrate and ammonium during its decomposition.

The importance of soil organic matter fractions

The three fractions of SOM have distinctly different functions in the soil. Understanding each of their functions will help to manage and possibly increase the POC and HOC fractions.

Table 1. Functions of Particulate (POC), Humus (HOC) and Resistant (ROC) organic carbon where √ = minor importance, √√ = moderately important, √√√ = very important and X = not important

Soil Function Organic Carbon (POC)	Particulate (HOC)	Humus Organic Carbon	Resistant Organic Carbon (ROC)
Physical properties			
Increased infiltration (better soil structure)	√√√ for sands and loams √ for clays	√ for all soil types	√
Tilth (improved structure, friability) X for clays	√√√ for sands and loams √√ for sands and loams	√ for clays	√
Lowering bulk density	√√ for sands and loams √ for clays	√ for all soil types	√
Increasing Plant Available Water	X	√ for all soil types	√
Chemical properties			
Improved Cation Exchange Capacity	X	√√√ for sands and loams X for clays	√ for sands and loams
Buffer against acidification (binds to Fe and Al)	X	√√√ for sands and loams X for clays	√
Biological properties			
Food source for micro-organisms	√√√ for all soil types	√√√ for all soil types	√ for all soil types
Release of nitrate and ammonium	√ for all soil types	√√√ for all soil types	√ for all soil types

How can SOM be increased? – with particular reference to the different fractions

Particulate Organic Carbon (POC): Stubble retention and reduced tillage results in an increase in this fraction within the total SOM pool. This fraction is unstable and during drought years with low crop or pasture production this fraction can decrease markedly.

Humus Organic Carbon (HOC): Current research indicates that the humus organic carbon content can be increased if sufficient nutrients are added to stubble for the soil microbial population to break-down the stubble into humus. The research undertaken by Clive Kirkby (CSIRO) and farmer demonstration projects are investigating management practices which can result in an increase in the humus fraction of the total SOM pool.

Quantifying functions of SOM

The quantification of the functions of soil organic matter forms the basis of a research program funded by GRDC ('Improved Management of Soil Organic Matter for Profitable and Sustainable Cropping'), which is also supported by DA (Federal Department of Agriculture). On the completion of the project it is envisaged that the functions of SOM and its component fractions will have been identified and quantified in relation to their importance to improve soil quality and crop production.

What is currently known of the benefits of increasing soil carbon content?

By using the simulation model APSIM, the impact of increasing SOM levels can be investigated.

Impact of SOM on yield

Increasing Soil Carbon from 0.8% to 1.8% (0-30cm soil layer) has a marked positive outcome on yield (APSIM simulation on a Temora Brown Chromosol soil (APSoil no. 179) – also known as a brown duplex soil; using 100 years of BoM Temora weather data) (Figure 1). Note: in the APSIM set up, 50kg of N was applied at seeding.

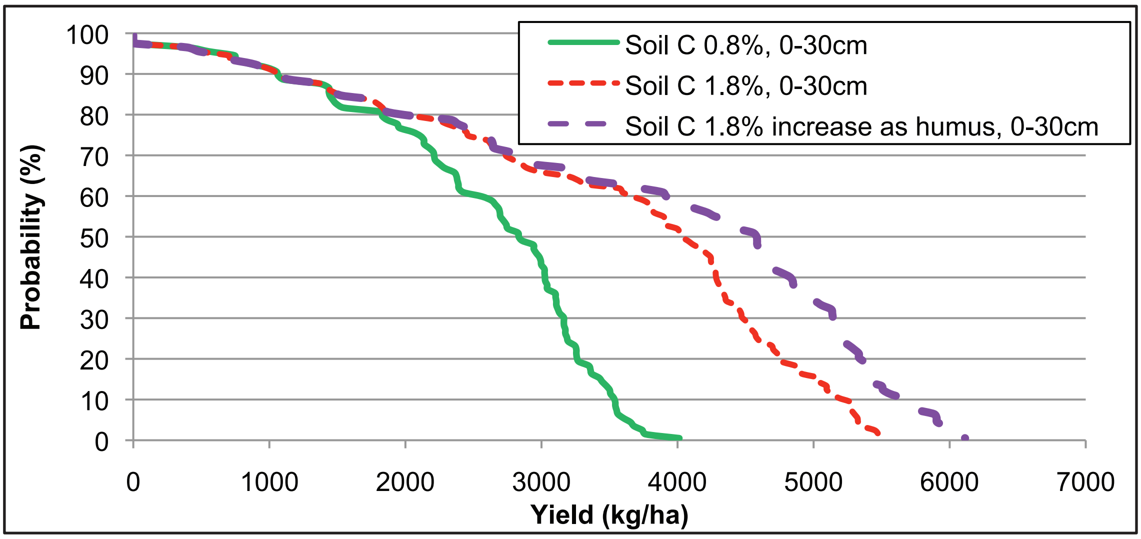


Figure 1. APSIM simulation of grain yield demonstrating the impact of increasing soil C, by increasing total soil carbon and by increasing the humus fraction only, on a Temora Brown Chromosol.

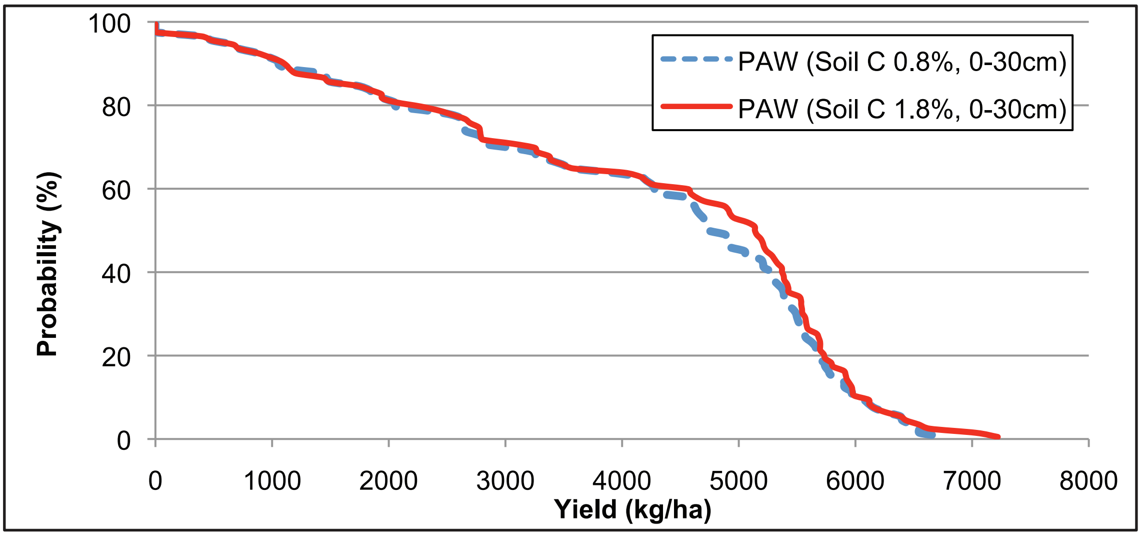


Figure 2. APSIM simulation of grain yield demonstrating the impact of increasing soil C resulting in a higher Plant Available Water (PAW) on a Temora Brown Chromosol (APSoil no. 179).

Impact of increased PAW on yield

Increasing soil carbon from 0.8% to 1.8% (0-30cm soil layer) resulted in a small increase in PAW, which in turn resulted in a very small potential increase in yield (Figure 2).

Impact of SOM on mineralisation of N

During the cropping season, SOM is mineralised to available N (nitrate and ammonium). The extent of N mineralisation was modelled, using APSIM, for baseline SOM (SOC 0.8%); increased SOC at 1.8%, and increased SOC at 1.8% but with the increased carbon attributed only to the Humus fraction (Figure 3). Increasing SOC by 1% resulted in an increase of 15 kg/ha of available N (at 50% probability) but if the increase in SOC was all attributed to the humus fraction then mineralisation was increased to 25 kg/ha of available N (Figure 3).

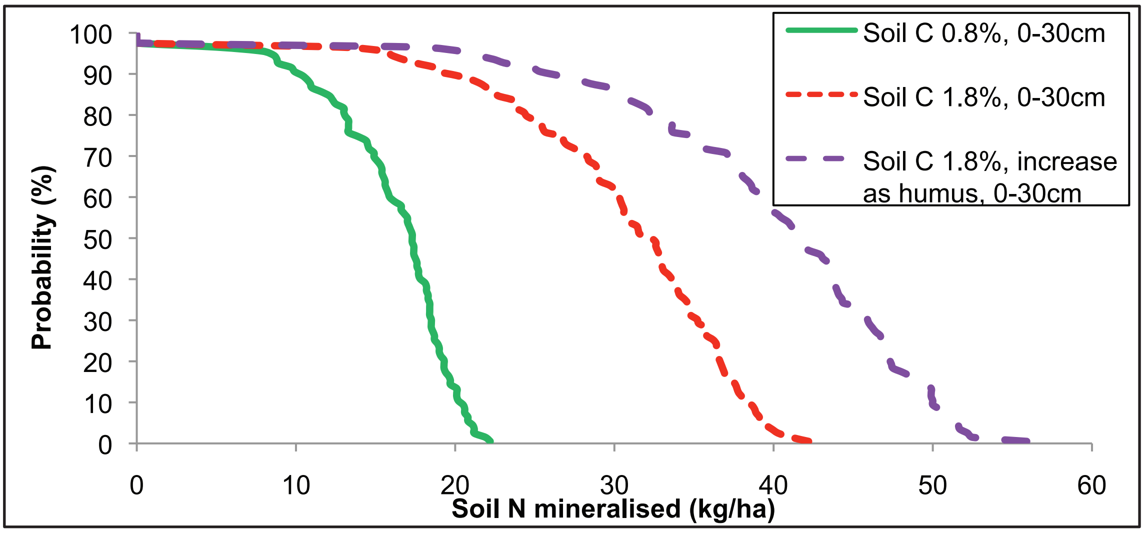


Figure 3. APSIM simulation of N mineralisation from a baseline SOC content (0.8% SOC), an increase of 1% in SOC, and an increase of 1.0% in the humus fraction only.

Summary

- Soil Organic Matter (SOM) can be separated into three distinct fractions (POC - Particulate Organic Carbon; HOC – Humus Organic Carbon; and ROC – Resistant Organic Carbon).
- Each of the fractions of SOM has different beneficial attributes, and these attributes are dependent on soil type.
- Increasing SOM results in a small increase in PAW. Correspondingly, the small increase in PAW results in a very small increase in yield (simulated using APSIM).
- The greatest benefit of increasing SOM to crop yield comes from increased N mineralisation and subsequent release of plant-available N. Most of the benefits from increased N mineralisation of SOM can be attributed to the Humus fraction.
- Research, funded by GRDC and the Federal Dept. of Agriculture, into the beneficial aspects of soil organic matter is ongoing.

Further reading

Hoyle (2013). 'Managing Soil Organic Matter – a practical guide' published by the GRDC.

Contact details

Harm van Rees
0419 325252
harm@cropfacts.com.au

Notes

New South Wales

Grains Research UPDATE

Students at work

Can canola meal be used to treat cancer?

Saira Hussain[1,2], Ata-ur-rehman[1], David Luckett[1] and Christopher. L. Blanchard[1],
[1]Graham Centre for Agricultural Innovation (an alliance between NSW Department of Primary Industries and Charles Sturt University), BSchool of Biomedical Sciences, Charles Sturt University

Keywords

topoisomerase, canola meal, cancer

Take home messages

- **Increased canola production is leading to an excess of the meal by-products.**
- **Canola meal is a relatively low value product compared to oil.**
- **Canola meal may contain high value compounds that could increase the value of canola.**
- **Preliminary results indicate that compounds in canola meal inhibit an enzyme highly active in cancer cells.**
- **Further research may reveal other high value compounds in canola with a range of health benefits.**

Introduction

The increased level of canola production in Australia has resulted in an excess of the by-product termed 'meal'. Canola meal is currently used as a low-value stock feed, however, if higher value applications can be developed, the profitability of canola production could be further increased. One option would be to investigate the presence of bioactive compounds which are high value biological molecules that have a physiological function.

Topoisomerase-1(Topo-1) is an important enzyme for cellular processes such as DNA replication. Higher than normal levels of Topoisomerase-1 are often found in human cancer cells, hence, they are an attractive target for anti-cancer therapy (Tabassum, Al-Asbahy, Afzal, Arjmand, & Bagchi, 2012). Compounds that reduce topoisomerase-1 levels either by 'poisoning' and/or 'suppressing' the enzyme may result in the premature death of these cells, forming an effective treatment for cancer (Bailly, 2000). Camptothecin is a natural alkaloid extracted from the stem tissue of the chinese tree *camptothcea acuminate* and has the ability to inhibit Topo-1. It is currently used as an anticancer agent in clinical research (Webb & Ebeler, 2003), suggesting other Topo-1 inhibitors could also function as anti-cancer agents.

Aim

1. Generate a range of canola meal extracts using different solvents.
2. Evaluate the Toposiomerase-1 poisoning and inhibition activities of the various extracts.

Materials and methods

- Canola breeding line Bln-3347 was used for all extractions. After extraction, residues were freeze-dried and stored at -20°C.

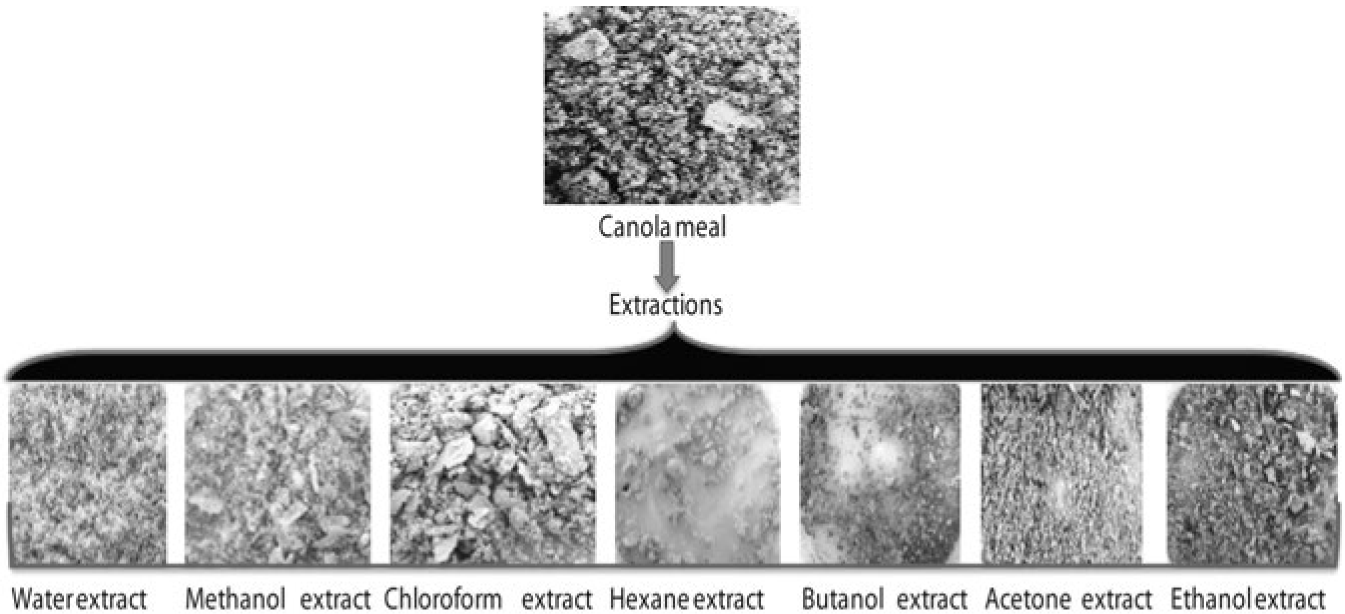


Figure 1. Canola meal extracts generated using various solvents.

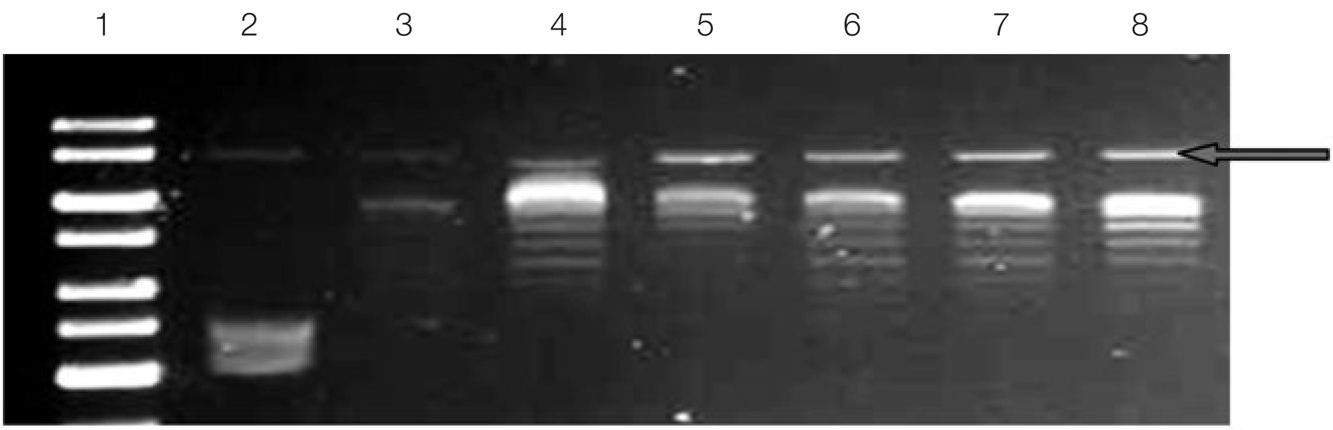


Figure 2. Agarose gel electrophoresis showing poisoning result by topoisomerase I (Topo I)-induced cleavage by canola meal extracts. Lane 1, Marker; Lane 2, Supercoiled DNA; Lane 3, Relaxed DNA; Lane 4 Supercoiled DNA +Topo 1 (10X); Lane 5, Relaxed DNA+10µM Camptothecin+ Topo 1 (10X), Lane 6-8, Relaxed DNA+Ethanol extract 100, 25 and 6.26ug/5ul+ Topo 1 (10X).

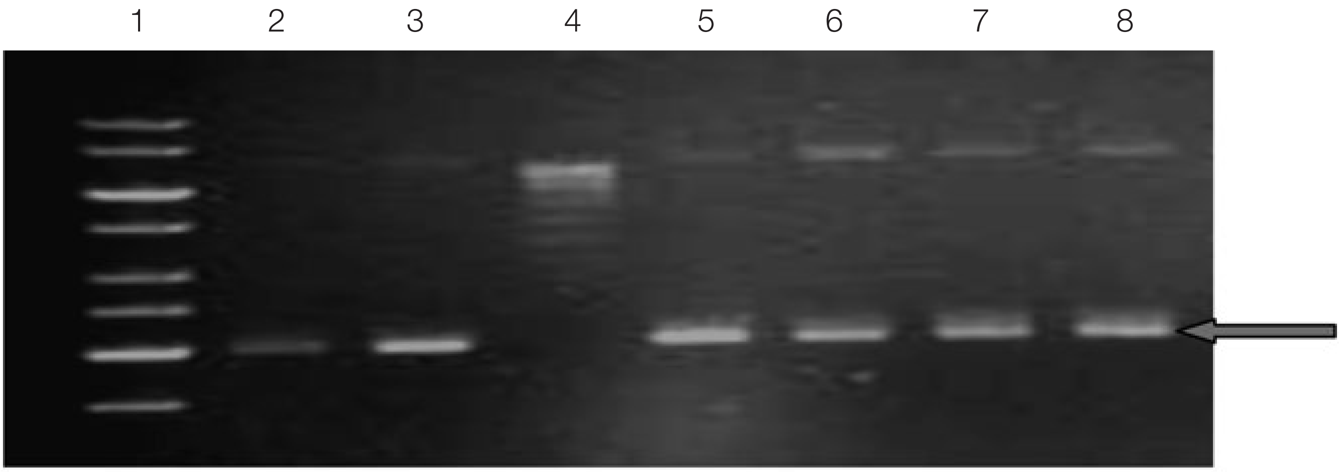


Figure 3. Agarose gel electrophoresis showing inhibition results. Lane 1, Marker; Lane 2, Supercoiled DNA; Lane 3, Supercoiled DNA+10µM Camptothecin+ Topo 1 (2X); Lane 4, Relaxed DNA; Lane 5, Supercoiled DNA+10µM Camptothecin+ Topo 1 (2X); Lane 6-8, Supercoiled DNA+ Ethanol extract 100, 25 and 6.26ug/5ul+ Topo 1 (10X)+ Topo 1 (2X).

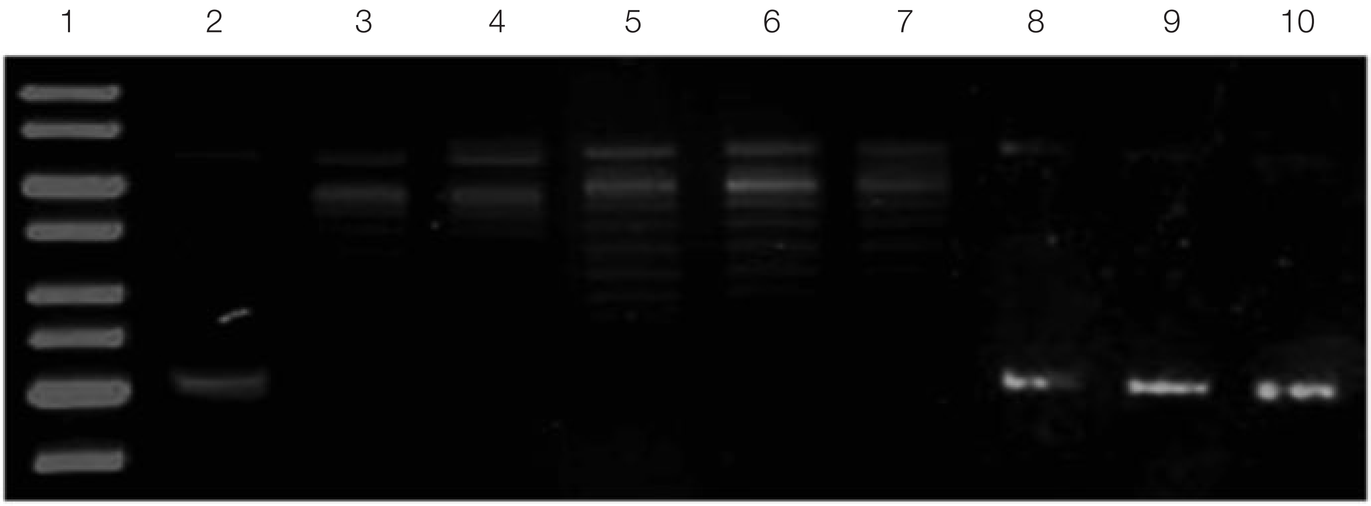


Figure 4. Agarose gel electrophoresis showing poisoning and inhibition results. Lane 1, Marker; Lane 2, Supercoiled DNA; Lane 3, Relaxed DNA; Lane 4, Relaxed DNA+10µM Camptothecin+ Topo 1 (10X); Lane 5-7, Relaxed DNA+ Acetone extract 100, 25 and 6.26ug/5ul+ Topo 1 (10X)+ Topo 1 (2X); Lane 8-10 Supercoiled DNA+ Acetone extract 100, 25 and 6.26ug/5ul+ Topo 1 (10X)+ Topo 1 (2X).

- The Poisoning assay was performed by adding canola meal extracts (100, 25 and 6.25µg) to relaxed DNA and incubated for 20 minutes. Toposiomerase-1 (10X) was then added and incubated for 1 hour. Reactions were stopped by the addition of Proteinase K. Reactions were electrophoresed on an agarose gel and DNA bands were visualized using Gel Star. A poisoning effect is indicated by a higher intensity in the nicked DNA band as shown by arrow (Figure 2, lane 8).
- For the suppression assay, canola meal extracts were added to supercoiled DNA and treated in a similar way as before, but toposiomerase-1 (2X) was added instead of toposiomerase-1 (10X). A suppression effect is indicated by the prevention of supercoiled DNA from being converted to relax DNA as indicated by arrow (Figure 3, lane 8). Agarose electrophoresis was also used for the characterization and quantification of 'suppression' activity of topoisomerase-1.
- Camptothecin was used as a reference compound.

Results and discussions

A range of extracts were generated using water and various organic solvents (Figure 1.)

Gel electrophoresis was used for the characterization and quantification of Topo-1 inhibition/poisoning activities of the canola meal extracts. All extracts were able to inhibit Topoisomerase-1 either through suppression or poisoning or both.

Poisoning activity is represented as an increased amount of nicked DNA. The ethanol extract showed poisoning activity (Figure 2, lanes 6-8) as, represented by arrow.

Ethanol extract also showed suppression activity (Figure 3, lanes 6-8), as represented by arrow.

Acetone extracts was also shown to have both poisoning (Figure 4, lanes 5-7) and suppression activity (Figure 4, lanes 8-10).

Conclusion

Canola meal extracts were shown to have the ability to inhibit topoisomerase-1, suggesting canola meal contains bioactive compounds that may act as anti-cancer agents. Further work is also underway to investigate other biological activities of canola meal extracts.

References

Bailly, C. (2000). Topoisomerase I Poisons and Suppressors as Anticancer Drugs. *Current Medicinal Chemistry*, 7(1).

Tabassum, S., Al-Asbahy, W. M., Afzal, M., Arjmand, F., & Bagchi, V. (2012). Molecular drug design, synthesis and structure elucidation of a new specific target peptide based metallo drug for cancer chemotherapy as topoisomerase I inhibitor. *Dalton Transactions, 41*(16), 4955-4964.

Webb, M. R., & Ebeler, S. E. (2003). A gel electrophoresis assay for the simultaneous determination of topoisomerase I inhibition and DNA intercalation. *Analytical biochemistry, 321*(1), 22-30.

Contact details

Saira Hussain

School of Biomedical Science, Charles Sturt University, Locked Bag 588, Wagga Wagga, NSW, 2650.

0469 818 885, 0420 364 496

shussain@csu.edu.au

Unlocking the potential of Australian chickpea – improving functionality

***C. Chin* [1], *J.A. Wood* [1,2], *A. Saliba* [1,3], *S. Agboola* [1], *P. Prenzler* [1] and *C. Blanchard* [1],**

[1] ARC Industrial Transformation Training Centre for Functional Grains (an initiative of the Graham Centre). Wagga Wagga NSW 2678 [2] NSW Department of Primary Industries, Tamworth Agricultural Institute, Tamworth, NSW 2340, Australia. [3] School of Psychology, Charles Sturt University, Wagga Wagga NSW 2678, Australia.

GRDC project code: DAN00139

Keywords

chickpea quality, pasting properties, cooking time, genotype, phosphorus addition

Take home messages

- **Genotype, environment and agronomic practices were shown to affect chickpea quality.**
- **PBA HatTrick⁽ᴰ⁾ is more efficient in phosphorus uptake and accumulation in seeds, resulting in quicker cooking time.**
- **The puffed chickpeas exhibited a defined beehive-like structure when viewed under SEM.**
- **An understanding of the structural and chemical factors that are controlled by chickpea genetics will be useful for breeding programs to improve chickpea quality.**
- **Phosphorus application and varietal selection may be a useful option for farmers to achieve premium quality chickpeas in the future.**

Introduction

The importance of pulses as a food crop, is well recognised to feed and provide proper dietary sources of protein, carbohydrates and minerals to many millions of people, particularly in developing countries (Jood et al , 1989). Food legumes, especially chickpeas, have made a significant contribution to Middle-Eastern and Indian subcontinent diets for many centuries. (Coskuner and Karababa, 2007; Siddique et al, 1993)

Chickpea cultivation, like other cultivated pulse crops, have the ability to reduce the incidence of plant diseases in subsequent crops and improve soil fertility through nitrogen fixation, particularly in dry land farming systems where they play an important role in crop rotation (Sharma and Jodha 1984; Suzuki and Konno, 1982). The adoption of the pulse crops in the development of a sustainable cropping system has subsequently become a significant aspect of pulse production during the evolution of farming systems in 1970s to 1980s in Australia (Siddique and Sykes, 1997). Chickpea production and export have increased rapidly over recent years (Agricultural commodity statistics 2013, ABARES). The saturation of the domestic chickpea market resulting from the continuous growth of chickpea production and a relatively small domestic consumption in Australia has created an opportunity for a profitable and sustainable farming system through international export.

Australia has been the largest exporter of chickpeas since 2008 (Pulse market outlook, 2013). Most of the Australian chickpeas, especially desi types, are exported to the Indian subcontinent to cater for their increasing population (Siddique 1993). Australian chickpeas are preferred over other exported chickpeas by Indian purchasers due to their high quality and competitive pricing (Market indicator report, 2009). Nonetheless, the potential to increase the market share of Australian chickpeas in this region is encouraging, due to the improving economic conditions of pulse consuming countries. The end use consumers from these countries may now have a higher buying power, and make more discerning choices based on quality, both in terms of sensory properties such as appearance, taste and mouth feel (Wood et al, 2013), and cooking quality.

The preparation methods for chickpeas include boiling, frying and puffing. Secondary products such as cotyledon splits and flour are equally important in the preparation of common Indian cuisines and daily staples. Each market segment based on the different preparation methods prefers different chickpea quality attributes. Good quality chickpeas attract a premium. This has encouraged the further study of the factors affecting chickpea quality in order to enhance the value and market share of Australian chickpeas globally. This study highlights the effect of genotypes on different chickpea quality attributes.

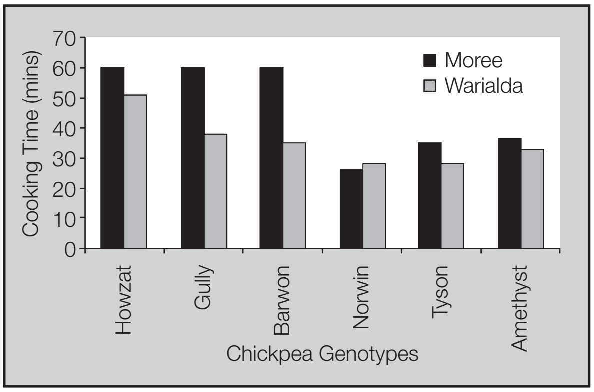


Figure 1. Cooking times of different chickpea genotypes grown in Warialda and Moree.

Study 1. The effect of genotype, environment and management on cooking time

Cooking time is one of the key parameters used in the evaluation of chickpea quality. A lengthy cooking time is inconvenient, utilises more energy in food preparation, and reduces the nutritional quality of pulses (Bakr et al., 1991, Walker et al., 1982). Several factors affect the quality of pulses including cultivar (Kaur et al., 2005, Bishnoi et al., 1993), environment (Wood et al., 2008, Gubbels et al., 1985, Bhatty et al., 1983) and their interactions (Wang et al., 2010, Balamaze et al., 2008). Our study supports previous research that demonstrated that both genotype and environment have a significant effect on cooking time (Figure 1) in Australian chickpeas.

We have also demonstrated the effect of agronomic management; particularly of phosphorus application at sowing, on cooking time of desi chickpea dhal. Two desi chickpea cultivars (Kyabra⊕ and PBA HatTrick⊕) were sown in 2011 at Tamworth. The seed was sown with four different phosphorus rates (0 kg/ha, 5kg/ha, 10kg/ha and 20 kg/ha) in a randomised block layout consisting of four field replicates. Our investigation demonstrated the dhal phosphorus content (averaged across genotypes) significantly increased with crop phosphorus application. The phosphorus content of dhal was higher in PBA HatTrick⊕ at all phosphorus application rates compared to Kyabra⊕, suggesting that PBA HatTrick⊕ was more efficient at phosphorus uptake and accumulation in seeds (Figure 2). Our results have also shown that higher phosphorus (P) content in the seed cotyledons was associated with quicker dhal cooking times (Figure 3).

a) b)

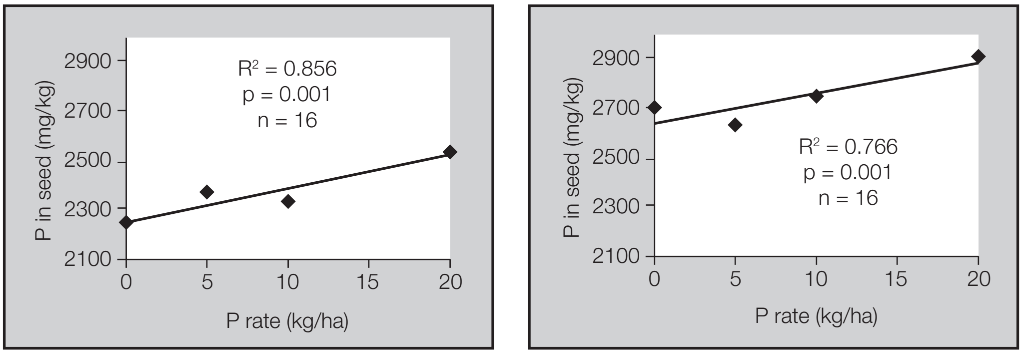


Figure 2. The effect of phosphorus applied at sowing on dhal phosphorus content in a) Kybra⊕ b) PBA HatTrick⊕.

a) b)

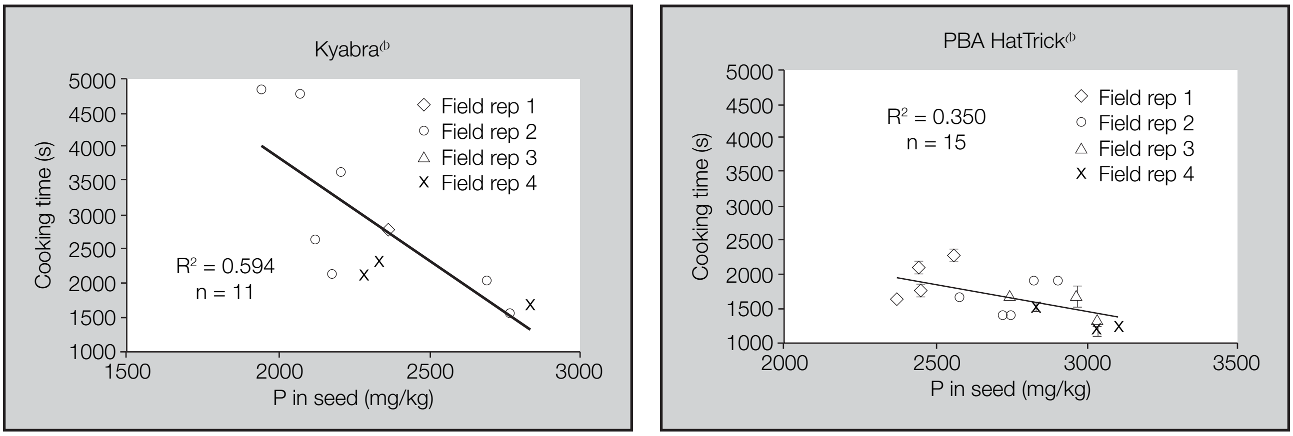


Figure 3. The effect of dhal phosphorus content on cooking time in a) Kyabra⊕, b) PBA HatTrick⊕.

Study 2. The effect of genotype on puffing quality – microstructure investigation

Puffing performance is an important attribute in defining the quality of chickpeas used to produce puffed chickpea products. Different genotypes have exhibited variation in puffing performance in Australian chickpeas (Mukhopadhyay et al 2013). Scanning Electron Microscope (SEM) images of transverse sections of chickpeas before and after puffing showed considerable structural difference (Figure 4). The starch granules could be clearly observed, varying in shape from ovoid to spherical and uniformly packed in the microstructure of different raw samples. The puffed chickpea showed a very porous matrix made up of numerous cavities of different sizes and separated by a very thin 'wall'. This phenomenon was not observed in raw and poorly puffed chickpeas. The poorly puffed chickpea exhibited a rather wrinkled surface. A higher magnification (1700x) showed that the microstructure of a poorly puffed chickpea does not have defined cavities. The absence of defined starch granules in poorly puffed chickpeas, may suggest that the starch granules in poorly puffed

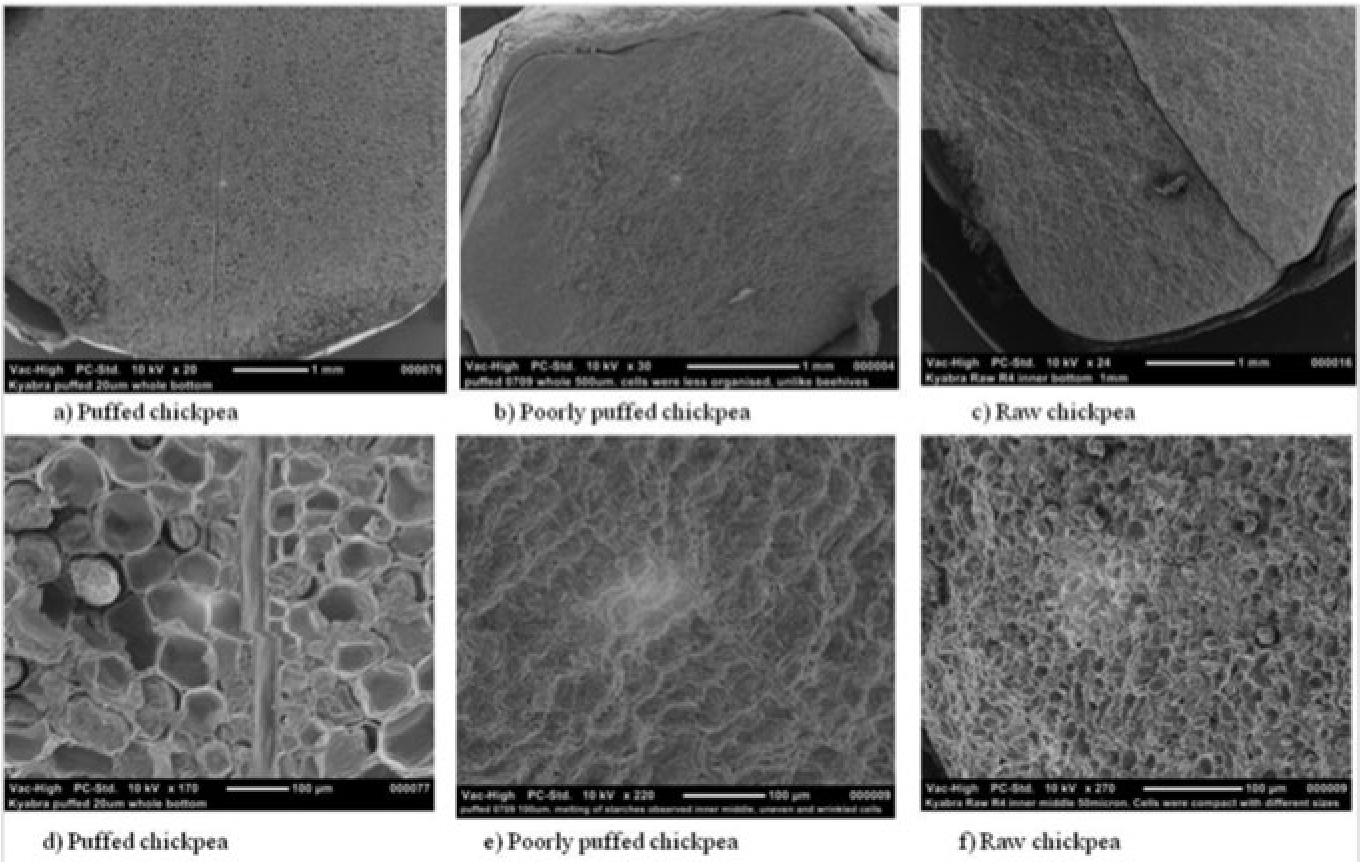


Figure 4. Scanning electron micrograph of puffed chickpea (a&d), poorly puffed chickpea (b&e) and raw chickpea (c&f).

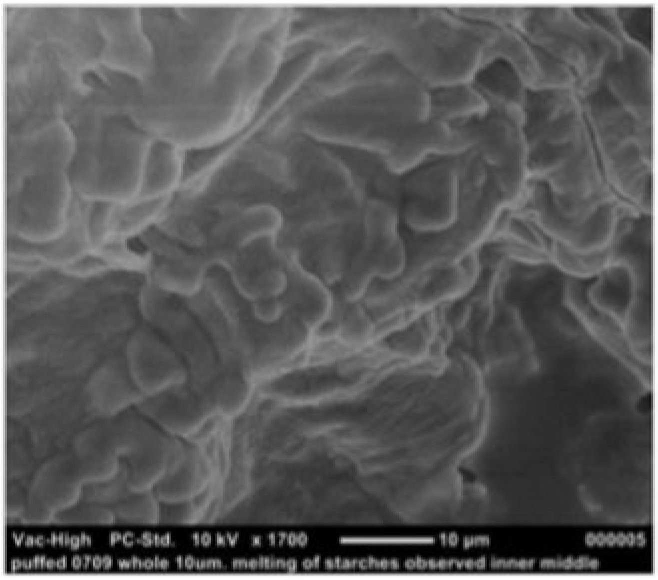


Figure 5. Scanning electron micrograph of poorly puffed chickpea under magnification 1700x.

chickpeas have undergone a 'melting' process, forming starch/protein complexes. This finding is particularly useful for us to understand the structural changes that occur during puffing. The distinct difference between raw, poorly puffed and puffed chickpeas shown in the micrographs suggests that SEM may be a useful tool to understand why some chickpea genotypes puff better than others.

Conclusion

Our study presents strong evidence that genotype and environment has a significant effect on chickpea quality. The variation in cooking time observed in samples from different trial locations may have implications for supplying markets with chickpeas that have consistent cooking times. A comparison of cooking times in samples from different locations indicated the genotypes vary in their response to the environment. The variation observed in dhal phosphorus content was due to differences in plant genetics and soil phosphorus levels. The rate of phosphorus uptake and assimilation into chickpea dhal differed between the two varieties analysed and was negatively correlated to cooking time. Chickpea puffing capability was shown to be influenced by plant genotypes which resulted in differences in the microstructure of the puffed product. An understanding of these findings will be useful for chickpea breeders, agronomists and farmers to make better decisions on phosphorus application and varietal selection to achieve premium quality chickpeas.

References

Agbola, F. W., T. G. Kelley, et al. (2002) Chickpea marketing in India: Challenges and Opportunities. Int Food Agrib. Mang.Rev., 5:7-21.

Bakr, A., & Gawish, R. (1991) Nutritional Evaluation and cooking quality of dry cowpea (*Vigna sinensis* L.) grown under various agricultural conditions. 1. Effect of soaking and cooking on the chemical composition and nutritional quality of cooked seeds. J. Food Sci. Technol. Mys., 28(5): 312-316.

Bishnoi, S., & Khetarpaul, N. (1993) Variability in physico-chemical properties and nutrient composition of different pea cultivars. Food Chem., 47:371–373.

Coskuner, Y. and E. Karababa (2004) Effect of location and soaking treatments on the cooking quality of some chickpea breeding lines. Food Rev. Int., 20(3): 257-274.

Jood, Sudesh, Chauhan, B. M., Kapoor, A. C. (1989) Protein digestibility (in vitro) of chickpea and blackgram seeds as affected by domestic processing and cooking. Plant Food Hum. Nutr., 149-154.

Kaur, M., & Singh, N. (2005) Physicochemical, cooking, textural and roasting characteristics of chickpea (Cicer arietinum L.) cultivars. Food Chem., 91(3): 403-411.

Market indicator report (2009) Consumer trends – Pulses in India. Agriculture and Agrifood in Canada. http://www.gov.mb.ca/agriculture/statistics/agri-food/india_pulses_en.pdf

Mukhopadhyay, S.P., Prenzler, P.D.,Wood, J.A.,Saliba, A.J., Blanchard, C.L. (2013) Improving the value of Australian pulses through puffing. Proc. GRDC update 2013.

Pulse market outlook (2013), Pulse workshop. Mercantile Consulting Venture Inc. http://www.saskpulse.com/uploads/content/Marlene_Boersch_-_Pulse_Market_Outlook.pdf

Sharma, D. and Jodha, N. S. (1982) Pulses production in semi-agrid regions of India: Constraints and Opportunities. Econ Polit Weekly, 135-137.

Siddique, K. H. M., Walton, G.H., Seymour, M. (1993) A comparison of seed yields of winter grain legumes in Western Australia. Aust. J. Exp. Agric., 33: 915–922.

Siddique, K. H. M.,and Sykes, Y. (1997) Pulse production in Australia past, present and future. Aust J of Expl Ag., 37(1): 103-111.

Suzuki, F. and Konno, F. (1982) Regional report on Grain Legumes Production in Asia. Tokyo,

Japan. Asian Productivity Org., pp 19-93.

Wood, J.A., Chin, C., Prenzler, P.D., Saliba, A.J., Blanchard, C.L. (2013) Unlocking the full potential of Australian pulses: research with a customer value focus. Poster presentation, PBA Conference Australia.

Walker, A. F., & Kochhar, N. (1982) Effect of processing including domestic cooking on nutritional quality of legumes. Proc. of the Nut. Society, 41: 41-51.

Wang, N., Hatcher D. W., Tyler, R. T., Toews, R., Gawalko, E. J. (2010) Effect of cooking on the composition of beans (*Phaseolus vulgaris L.*) and chickpeas (*Cicer arietinum L.*). Food Chem., 118 (1): 109-115.

Contact details

Christina Chin

School of Biomedical Sciences ,
Charles Sturt University, Locked Bag 588,
WAGGA WAGGA, NSW 2678

02 6933 2085

cchin@csu.edu.au

Notes

Accelerating adoption of innovative agronomy - experiences from Alberta, Canada

Steve Larocque,
Beyond Agronomy

Keywords

Keywords: nitrogen use efficiency, precision planting, abiotic stress, soil temperature, GreenSeeker®, NDVI mapping, controlled traffic farming

Take home messages

- **Focus on building a system that addresses abiotic stress (wind, cold, heat, flooding).**
- **Soil temperatures have a greater impact on yield than ambient temperatures.**
- **GreenSeeker® technology is a real time mapping and variable rate nitrogen tool.**
- **Controlled traffic farming (CTF) performs well in low rainfall environments – improved water use efficiency.**
- **Vacuum planters provide improved singulation and plant spacing in small grain crops.**
- **Inter-row side dress nitrogen in cereals reduces dependency on rainfall after application.**

The presentation offers a visual tour of the technologies and agronomy used by leading edge farmers in Western Canada.

Contact details

Steve Larocque
Box 1696, Three Hills, AB, T0M 2A0
1-403-321-0181
steve@beyondagronomy.com

Notes

GRDC on air

GRDC
Grains Research & Development Corporation
Your GRDC working with you

Did you know that the GRDC has a suite of audio programs to keep growers up to date with RD&E, locally and across the country.

Now in the GRDC audio library are:

GROUND COVER RADIO

An audio version of the main stories from the current issue of GRDC's bimonthly Ground Cover magazine.

DRIVING AGRONOMY

Weekly interviews covering nationally significant research projects with Australia's leading grains industry scientists and advisers.

GRDC RADIO UPDATES

Weekly regional audio programs that bring research down to the local level and include local grains news, information and events.

Listen to the programs on the GRDC website or as a podcast downloaded onto a device such as smartphone or MP3 player.

If you have an iPhone or iPad:

- go to iTunes and search for 'GRDC' and/or go to the Podcast app
- subscribe to the programs you want to hear; and
- the programs will automatically download to your phone or tablet as they become available.

For other devices:

- go to www.grdc.com.au/podcasts;
- click on the program you would like to hear; and
- follow directions for subscribing to the podcast of your choice.

Grains Research and
Development Corporation
Level 1, Tourism House | 40 Blackall Street,
Barton ACT 2600
PO Box 5367, Kingston ACT 2604
T +61 2 6166 4500 | **F** +61 2 6166 4599
E grdc@grdc.com.au

www.grdc.com.au

NVT

National Variety Trials

A GRDC INITIATIVE

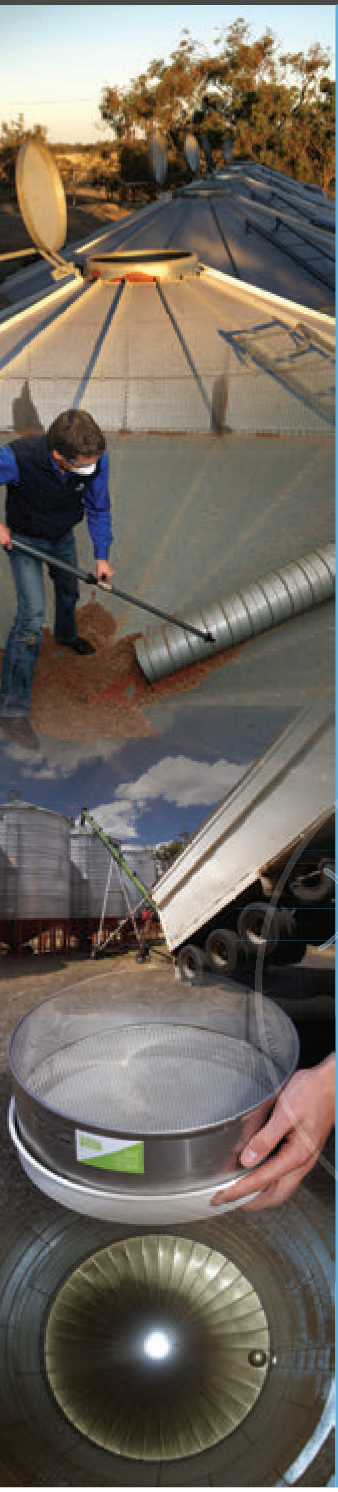
YOUR VARIETY FORM GUIDE

BELLATA 2397 COOLAH 2843 MERRIWA 2329 MULLALEY 2379 NORTH STAR 2408 SOMERTON 2340 SPRING RIDGE 2343 TAMWORTH 2340 WELLINGTON 2820
WONGARBON 2831 BULLARAH 2400 COONAMBLE 2829 GILGANDRA 2827 GOONUMBLA 2870 NYNGAN 2825 PARKES 2870 TRANGIE 2823 TULLOONA 2400 WALGETT 2832
ARIAH PARK 2665 BOOROWA 2586 BROCKLESBY 2642 CANOWINDRA 2804 COOTAMUNDRA 2590 COWRA 2794 CUDAL 2864 CUMNOCK 2867 GALONG 2585 GEROGERY 2642
GRENFELL 2810 HARDEN 2587 HENTY 2658 QUANDIALLA 2721 TEMORA 2666 WAGGA WAGGA 2650 BALRANALD 2715 BECKOM 2665 BOREE CREEK 2652 COLEAMBALLY 2707
CONDOBOLIN 2877 LOCKHART 2656 MAYRUNG 2710 MERRIWAGGA 2652 OAKLANDS 2646 WILLBRIGGIE 2680 BILOELA 4715 CAPELLA 4723 DUARINGA 4712 KILCUMMIN 4721
SPRINGSURE 4722 BROOKSTEAD 4364 JONDARYAN 4401 KINGSTHORPE 4400 MACALISTER 4406 BUNGUNYA 4494 DULACCA 4425 LUNDAVRA 4390 MEANDARRA 4422
MUNGINDI 2406 NINDIGULLY 4497 WESTMAR 4422 COCKALEECHIE 5631 CUMMINS 5631 GREENPATCH 5607 MT HOPE 5607 RUDALL 5642 UNGARRA 5607 WANILLA 5607
WHARMINDA 5603 YEELANNA 5632 CRYSTAL BROOK 5523 LAURA 5480 MINTARO 5415 RIVERTON 5412 SALTERS SPRINGS 5401 SPALDING 5454 TARLEE 5411 TURRETFIELD 5411
COOKE PLAINS 5261 GERANIUM 5301 LAMEROO 5302 NANGARI 5333 PALMER 5237 PARUNA 5311 PINNAROO 5304 WAIKERIE 5330 WANBI 5310 WUNKAR 5311
BORDERTOWN 5268 CONMURRA 5272 FRANCES 5262 KEITH 5267 MOYHALL 5271 MUNDULLA 5270 SHERWOOD 5267 WOLSELEY 5269 DARKE PEAK 5642 ELLISTON 5670
KIMBA 5641 LOCK 5633 MINNIPA 5654 MITCHELLVILLE 5602 NUNJIKOMPITA 5680 PENONG 5690 PIEDNIPPIE 5680 STREAKY BAY 5680 TOOLIGIE 5607 WARRAMBOO 5650
ARTHURTON 5572 BRENTWOOD 5575 BUTE 5560 MAITLAND 5573 MINLATON 5575 PASKEVILLE 5552 PORT CLINTON 5570 URANIA 5573 WAROOKA 5577 WILLAMULKA 5554
WOKURNA 5520 CRESSY 7302 BIRCHIP 3483 HOPETOUN 3396 MANANGATANG 3546 MERRINEE 3496 MURRAYVILLE 3512 QUAMBATOOK 3540 RAINBOW 3424 ULTIMA 3544
WALPEUP 3507 BALLIANG 3340 CHARLTON 3525 COLBINABBIN 3559 DIGGORA 3561 EASTVILLE 3463 MITIAMO 3573 DOOKIE 3646 RUTHERGLEN 3685 WUNGHNU 3635
YARRAWONGA 3730 HAMILTON 3300 STREATHAM 3351 TEESDALE 3328 BRIM 3391 CORACK 3480 HORSHAM 3400 KANIVA 3419 MINYIP 3392 TARRANYURK 3414
WONWONDAH 3401 BADGINGARRA 6521 CARNAMAH 6517 ERADU 6532 MINGENEW 6522 MORAWA 6623 NABAWA 6532 OGILVIE 6535 WALKAWAY 6528 BADGINGARRA 6521
BEVERLEY 6304 BINNU 6532 BUNTINE 6613 CALINGIRI 6569 COOROW 6515 CORRIGIN 6375 CUNDERDIN 6407 ENEABBA 6518 ERADU 6532 GOOMALLING 6460
KATANNING 6317 KULIN 6365 MILING 6575 MINGENEW 6522 NAREMBEEN 6369 PINGELLY 6308 WAGIN 6315 WICKEPIN 6370 WONGAN HILLS 6603 WONGAN HILLS R.S. 6603
ARTHUR RIVER 6315 COOROW 6515 FRANKLAND 6396 GNOWANGERUP 6335 KENDENUP 6323 KOJONUP 6395 MT. BARKER 6324 MULLEWA 6630 NARROGIN 6312
NYABING 6341 PINGRUP 6343 TOODYAY 6566 WILLIAMS 6391 YORK 6302 ARTHUR RIVER 6315 BENCUBBIN 6477 CADOUX 6466 DALWALLINU 6609 KATANNING 6317
KELLERBERRIN 6410 MERREDIN 6415 MOORINE ROCK 6425 MUKINBUDIN 6479 MULLEWA 6630 PINGELLY 6308 PITHARA 6608 WYALKATCHEM 6485 YUNA 6532
GRASS PATCH 6446 HOLT ROCK 6355 HYDEN 6359 JERRAMUNGUP 6337 LAKE GRACE 6353 MT. MADDEN 6356 SALMON GUMS 6445 SCADDAN 6447 WITTENOOM HILLS 6447
WONGAN HILLS 6603 ESPERANCE 6450 GIBSON 6448 MUNGLINUP 6450 NEWDEGATE 6355 HYDEN 6359 MERREDIN 6415 ESPERANCE 6450

Get the latest stored grain information online

GRDC
Grains Research & Development Corporation
Stored Grain Project

storedgrain.com.au



Booklets and fact sheets on all things grain storage

Workshops in all regions covering topics such as:

- Economics of on-farm storage
- Grain storage hygiene
- Aeration cooling or drying
- Managing high moisture
- Fumigation
- Insect pest management
- Managing different storages
- Storage facility design
- Storing pulses and oilseeds

Contact your regional specialist to arrange a workshop

SOUTHERN REGION

- **Peter Botta**
  pbotta@bigpond.com
  0417 501 890

GRDC
Grains Research & Development Corporation
Stored Grain Project

www.grdc.com.au | www.storedgrain.com.au | 02 6166 4500

Welcome to Day 2

2014 UPDATE

New South Wales

Tuesday 11th and Wednesday 12th

February 2014

Temora Ex Services Memorial Club, 130 Baker St, Temora

Share knowledge – accelerate adoption

GRDC
Grains Research & Development Corporation
Your GRDC working with you

Premier partners

NUSEED Nufarm

Major sponsors

Incitec Pivot Fertilisers syngenta GrainGrowers Real benefits. Real results.

Bayer Farmoz Dow AgroSciences agrimaster

GRDC
Grains Research & Development Corporation
Your GRDC working with you

Grains Research UPDATE

Supporters

Premier partners

NUSEED Nufarm

Major sponsors

Incitec Pivot Fertilisers · syngenta · Grain Growers

Bayer · Farmoz · Dow AgroSciences · agrimaster

Supporting the Australian Grains Industry through the

GRDC 2014

Grains Research Updates

- **VIC 5th & 6th February 2014 Ballarat**
- **NSW 11th & 12th February 2014 Temora**
- **SA 25th & 26th February 2014 Adelaide**

*** Networking time - refreshments - AGT**

Contents

DAY 2

THEME – Share knowledge – accelerate adoption

CONCURRENT SESSIONS

Crown rot – an update from the north	***Steven Simpfendorfer,*** *NSW DPI*	*131*
Maintaining flexibility and options with pre-emergents	***Chris Preston,*** *University of Adelaide*	*139*
Review of sulfur strategy to improve profitability in canola in the central west of NSW	***Maurie Street,*** *Grain Orana Alliance*	*145*
Dual–purpose wheat and canola – finding the best fit with experiments, experiences and modelling	***John Kirkegaard,*** *CSIRO*	*157*
To windrow or not to windrow in 2014? This is the question, but if so, when?	***Maurie Street,*** *Grain Orana Alliance*	*169*
New and potential malting barley variety update and agronomic developments	***Rick Graham,*** *NSW DPI*	*181*
Quantifying herbicide resistance in modern farming systems – Griffith region 2012/13	***Barry Haskins,*** *Ag Grow Agronomy*	*191*

FINAL SESSION

Robotics and intelligent systems for large scale agriculture	***Robert Fitch,*** *University of Sydney*	*199*
Maintaining market access – keeping it clean	***Ian Reichstein,*** *DAFF*	*203*

FURTHER INFORMATION

Establishing pastures – the trade-off between crop and livestock	***Evercrop***	*209*
Sustainable management of insect pests in grain crops	***ICAN workshop***	*212*
Non – herbicide weed control – not as sexy as a new herbicide but really important	***Peter Newman,*** *AHRI*	*213*

Evaluation *222*

GRDC
Grains Research & Development Corporation
Your GRDC working with you

2014 UPDATE

Grains Research UPDATE

NEW SOUTH WALES

Share knowledge - accelerate adoption

Temora Ex-Services Memorial Club

Wednesday 12th February – Day 2

CONCURRENT SESSIONS

(40 minutes including time for room change) (R = session to be repeated)

	Auditorium	*Narraburra Room*	*Bowling Room*	*Board Room*
9.00am	**Crown rot (R)** - P131 ***Steven Simpfendorfer,*** *NSW DPI*	**Commercial corner (R)** ***The latest services and products from the commercial sector***	**Maintaining flexibility and options with pre-emergents (R)** - P139 ***Chris Preston,*** *University of Adelaide*	**Backchat session with (R)** ***Steve Larocque,*** *Beyond Agronomy*
9.40am	**Maintaining flexibility and options with pre-emergents** - P139 ***Chris Preston,*** *University of Adelaide*	**Sulphur nutrition in canola - taking a second look (R)** - P145 ***Maurie Street,*** *Grain Orana Alliance*	**Commercial corner** ***The latest services and products from the commercial sector***	**Backchat session with** ***Steve Larocque,*** *Beyond Agronomy*
10.15pm	***Morning tea***			
10.50am	**Getting the best fit for wheat and canola dual purpose crops (R)** - P157 ***John Kirkegaard,*** *CSIRO*	**Crown rot** - P131 ***Steven Simpfendorfer,*** *NSW DPI*	**Sulphur nutrition in canola - taking a second look** - P145 ***Maurie Street,*** *Grain Orana Alliance*	**Backchat session with** ***Chris Preston,*** *University of Adelaide*

CONCURRENT SESSIONS

(40 minutes including time for room change) *(R = session to be repeated)*

	Auditorium	Narraburra Room	Bowling Room	Board Room
11.30am	**Impact of canola windrow timing and direct heading (R)** - P169 ***Maurie Street,*** *Grain Orana Alliance*	**Barley - varieties, management and market specifications (R)** - P181 ***Rick Graham,*** *NSW DPI*	**Getting the best fit for wheat and canola dual purpose crops** - P157 ***John Kirkegaard,*** *CSIRO*	**Backchat session with** ***Steven Simpfendorfer,*** *NSW DPI*
12.10pm	**Barley - varieties, management and market specifications** - P181 ***Rick Graham,*** *NSW DPI*	**Central west weed resistance survey** - P191 ***Barry Haskins,*** *Ag Grow*	**Impact of canola windrow timing and direct heading** - P169 ***Maurie Street,*** *Grain Orana Alliance*	**Backchat session with** ***John Kirkegaard,*** *CSIRO*

12.45pm ***Lunch***

1.30pm **Robotics and intelligent systems for broad acre agriculture** - P199 — ***Salah Sukkarieh,*** *University of Sydney*

2.10pm **Maintaining market access - keeping it clean** - P203 — ***Ian Reichstein,*** *DAFF*

2.30pm **Herbicide resistance - fresh approaches** - P213 — ***Panel of experts including***
Peter Newman, *AHRI,*
Chris Preston, *University of Adelaide,*
Barry Haskins, *Ag Grow,*
Maurie Street, *Grain Orana Alliance and*
Greg Condon, *Grassroots Agronomy*

3.00pm **Close and evaluation**

Premier partners

nuSEED® Nufarm

Major sponsors

Incitec Pivot Fertilisers syngenta. Grain Growers Real benefits. Real results.

Bayer Farmoz Dow AgroSciences agrimaster®

Winter Cereal Nutrition App

GRDC
Grains Research & Development Corporation
Your GRDC working with you

Winter Cereal Nutrition: The Ute Guide is designed to assist growers to easily identify cereal nutritional disorders.

It covers both nutrient deficiencies and toxicities and environmental, chemical and physiological disorders which can give similar symptoms to nutrient disorders.

The app contains prominent images, detailed descriptions of the issue and its contributing factors.

Application features:

- Predictive search topics for disorders
- Enables user to compare photos of different nutritional disorders side-by-side for correct disorder identification
- Opt to download content updates containing the latest research on nutritional disorders for winter cereals
- Receive notifications of winter cereal news from GRDC

Visit www.grdc.com.au/apps for GRDC's full suite of apps

Grains Research and Development Corporation
Level 1, Tourism House | 40 Blackall Street, Barton ACT 2600
PO Box 5367, Kingston ACT 2604
T +61 2 6166 4500 | **F** +61 2 6166 4599
E grdc@grdc.com.au

Available on the App Store

GET IT ON Google play

New South Wales

Grains Research UPDATE

Concurrent Sessions

Crown rot – an update from the north

Steven Simpfendorfer,
NSW DPI, Tamworth

GRDC project code: DAN00175

Keywords

stored soil water, inoculum, PreDicta B, yield loss, variety tolerance, root lesion nematodes

Take home messages

- **Impact of crown rot on yield and quality is a balance between inoculum levels and soil water.**
- **The balance is heavily tipped towards soil water yet most management strategies tend to focus solely on combating inoculum, sometimes to the detriment of soil water.**
- **Cultivation (even shallow) distributes infected residue more evenly across paddocks and into the infection zones which is below ground for crown rot. This IS NOT good!**
- **Some of the newer wheat varieties appear promising; in that they provide improved tolerance to crown rot.**
- **PreDicta B is a good technique for identifying the level of risk for crown rot (and other soil-borne pathogens) prior to sowing within paddocks. However, this requires a dedicated sampling strategy and IS NOT a simple add on to a soil nutrition test.**

Introduction

Crown rot, caused predominantly by the fungus *Fusarium pseudograminearum* is a significant disease of winter cereals in the northern region. The incidence of crown rot also appears to have increased in southern NSW in recent seasons. Infection is characterised by a light honey-brown to dark brown discolouration of the base of infected tillers, while major yield loss from the production of whiteheads is related to moisture stress post-flowering. It is critical that growers understand that there are three distinct and separate phases of crown rot, namely ***survival, infection*** and ***expression***. Management strategies can differentially effect each phase.

Survival: the crown rot fungus survives as mycelium (cottony growth) inside winter cereal (wheat, barley, durum, triticale and oats) and grass weed residues, which it has infected. The crown rot fungus will survive as **inoculum** inside the stubble for as long as it remains intact, which varies greatly with soil and weather conditions as decomposition is a *very slow* process.

Infection: given some level of soil moisture, the crown rot fungus grows out of stubble residues and infects new winter cereal plants through the coleoptile, sub-crown internode or crown tissue which are all below the soil surface. The fungus can also infect plants above ground *right* at the soil surface through the outer leaf sheathes. However, with all points of infection, direct contact with the previously infected residues is required and infections can occur throughout the whole season given moisture. Hence, wet seasons favour increased infection events by the crown rot fungus and when combined with the production of greater stubble loads significantly build-up inoculum levels.

Expression: Yield loss is related to moisture/temperature stress around flowering and through grain-fill. This stress is believed to trigger the crown rot fungus to proliferate in the base of infected tillers, restricting water movement from the roots through the stems, and producing whiteheads that contain either no grain or lightweight shrivelled grain. The **expression** of whiteheads in plants infected with crown rot (i.e. still have basal browning) is restricted in wet seasons and increases greatly with increasing moisture/temperature stress during grain-fill.

What is the balancing act?

Figure 1a and 1b summarise collaborative work conducted by the Northern Grower Alliance (NGA) and NSW DPI across 11 sites in 2007 which illustrate the relative impact of both crown rot inoculum level and moisture stress on the extent of yield loss.

Figure 1a represents the average yield loss in cv. Lang⁽ᐩ⁾ across the 11 sites in 2007 compared to plots where no crown rot inoculum (0 g/m) was added. Even though artificially introduced, the trial looks at the impact of starting inoculum levels on yield loss with the levels roughly representing a high risk (2 g/m), medium risk (1 g/m) or low risk (0.5 g/m). Extended lines represent the maximum yield loss at each inoculum level at an individual site in 2007, which was either Millie or Cryon where very hot/dry conditions during grain-fill were experienced which exacerbated the **expression** of crown rot. With a high level of crown rot inoculum (2 g/m), cv. Lang⁽ᐩ⁾ averaged 25% yield loss with up to 55% yield loss occurring under hot/dry conditions during grain-fill. Halving the level of crown rot inoculum (1 g/m) resulted in an average yield loss of 14% with losses topping out at 35% under moisture stressed conditions during grain-fill. Even the 'low' inoculum risk level (¼ of the top inoculum level, 0.5 g/m) resulted in an average yield loss of 9% with maximum yield loss of 25% still occurring under a 'tough' seasonal finish. Reducing crown rot inoculum levels within a paddock decreases the potential for yield loss but the actual extent of yield loss is very sensitive to the level of moisture stress during grain-fill. Up to 25% yield loss can still occur with a 'low' starting inoculum level if the crop becomes severely stressed during grain-fill.

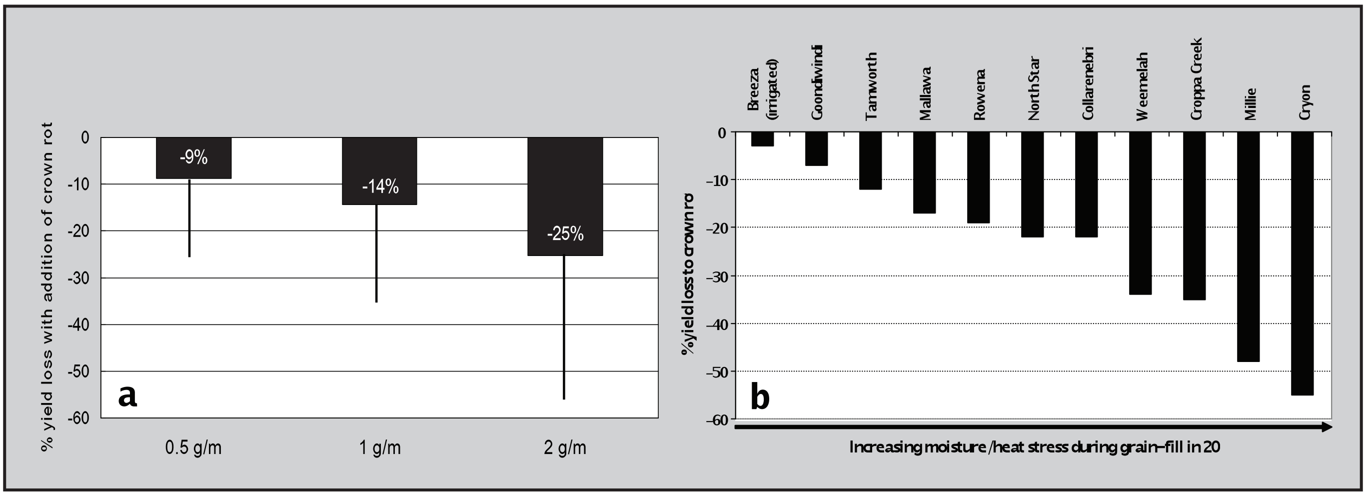


Figure 1. Impact of crown rot inoculum load (a) and moisture stress during grain-fill (b) on yield loss to crown rot in 2007.

Figure 1b further re-enforces the balance between soil moisture and inoculum by looking at the yield loss from crown rot averaged across five bread wheat varieties at 11 sites in 2007. Moisture stress during flowering/grain-fill clearly dictates the extent of yield loss from crown rot infection. Sites ranged from minimal moisture stress at Breeza, which was irrigated, through to Millie and Cryon where there were very dry and hot finishes in 2007. All inoculated plots at each site had the same source and 'high' rate of crown rot added at sowing. Hence, the seasonal finish, even under high crown rot infection, can mean 3% (no moisture stress) to 55% yield loss (hot/dry finish) in bread wheat (Figure 1b) or 13% to 90% yield loss in the durum variety EGA Bellaroi⊕ (data not shown).

Inoculum level is important in limiting the potential for yield loss from crown rot but the overriding factor dictating the extent of loss is moisture/temperature stress during grain-fill. Thus, the balance is heavily tipped towards soil water.

Some management strategies however, focus heavily on trying to combat crown rot inoculum, sometimes without full consideration of their impact on soil water. Any management strategy that limits storage of soil water or creates constraints which reduce the ability of roots to access this water, increases the probability and/or severity of moisture stress during grain-fill, and therefore, exacerbates the impact of crown rot.

What is the effect of cultivation?

Growers may cultivate their stubble for a range of reasons e.g. to reduce trash load prior to sowing. However, the effect of cultivation on crown rot is complex as it potentially impacts on all three phases of the disease cycle.

Survival: stubble decomposition is a microbial process driven by temperature and moisture. Cultivating stubble in theory increases the rate of decomposition as it reduces the particle size of stubble and buries these particles in the soil where microbial activity is greater and the soil environment maintains more optimal moisture and temperature conditions, compared to the soil surface or above ground. However, cultivation also dries out the soil in the cultivation layer, which immediately limits the potential for decomposition of the incorporated stubble. Decomposition of cereal stubbles is a *very slow* process that requires adequate moisture for an extended period of time to occur completely. A summer fallow (even if extremely wet and stubble has been cultivated) is **not** long enough!

Infection: as covered earlier, the majority of infection sites with crown rot are below ground and physical contact between an infected piece of residue and these plant parts is required to initiate infection. Cultivation of winter cereal stubble harbouring the crown rot fungus effectively breaks the inoculum into smaller pieces and spreads them more evenly through the cultivation layer across the paddock. Consequently, the crown rot fungus has been given a much greater chance of coming into contact with the major infection sites below ground, as the next winter cereal crop germinates and develops. In a no-till system the crown rot fungus becomes confined to the previous cereal rows and is more reliant on infection through the outer leaf sheathes at the soil surface. This is why inter-row sowing with GPS guidance has been shown to provide around a 50% reduction in the number of plants infected with crown rot when used in a no-till cropping system. Cultivation or harrowing negates the option of inter-row sowing as a crown rot management strategy.

Expression: extensive research has shown that cultivation dries out the soil to the depth of cultivation and reduces the water infiltration rate due to the loss of structure (macro pores, etc.). The lack of cereal stubble cover can also increase soil evaporation. With poorer infiltration and higher evaporation, fallow efficiency is reduced for cultivated systems compared to a no-till stubble retention system. Greater moisture availability has the potential to provide buffering against crown rot expression late in the season. Like crown rot management and all farming practices, cultivation is a balancing act between perceived benefits and costs.

Is crown rot generally worse on worked or no-till paddocks in your region?

Soil type?

Soil type does not differentially affect the survival or infection phases of crown rot. However, the inherent water holding capacity of each soil type interacts with expression by potentially buffering against moisture stress late in the season. Hence, yield loss can be worse on red soils compared to black soils due to their generally lower water holding capacities. Any other sub-soil constraint e.g. sodicity, salinity or shallower soil depth, effectively reduces the level of plant available water which can increase the expression of crown rot.

Are there generally more whiteheads in red paddocks, red patches within black paddocks or rocky or shallow ridges in your region?

Rotations?

Growing non-host break crops remains an important tool for managing crown rot as they allow time for decomposition of winter cereal residues that harbour the crown rot fungus. The canopy density and rate of canopy closure can impact on the rate of decomposition and varies with the different break crops (i.e. faba bean and canola are better than chickpea). Row spacing and seasonal rainfall during the break crop also impact on decomposition and hence survival of the crown rot fungus. Break crops can also further impact on the expression of crown rot in the following winter cereal crop in terms of both the amount of soil water they use, and therefore, leave at depth and their impact on the build-up of root lesion nematodes.

Stubble burning?

Burning removes the above ground portion of crown rot inoculum but the fungus will still survive in infected crown tissue below ground so it is **not** a 'quick fix' for high inoculum situations. Removal of stubble residues through burning will increase evaporation from the soil surface and impact on fallow efficiency. A 'cooler' autumn burn is therefore preferable to an earlier 'hotter' burn as it minimises the negative impacts on soil moisture storage whilst still reducing inoculum levels.

Sowing time?

Earlier sowing within the recommended window of a given variety for a region generally brings the grain-fill period forward where the probability of moisture and temperature stress during grain-fill is reduced. Earlier sowing may also increase the extent of root exploration at depth that could provide greater access to deeper soil water later in the season, which buffers against crown rot expression. This has been shown in previous NSW DPI research across seasons to reduce yield loss from crown.

Do you generally have more whiteheads (i.e. expression) in early or late sown wheat crops?

Interaction with root lesion nematodes and variety tolerance?

A variety trial was conducted at Gurley in northern NSW in 2012. The site had faba beans in 2011, barley in 2010 and was cultivated using kelly-chains prior to sowing in 2012. The trial site was soil cored (0-30 cm) for PreDicta B testing of background pathogen levels at sowing in 2012. The site had high levels of the root lesion nematode *Pratylenchus thornei* (9.2 Pt/g soil) and a high risk of crown rot (2.1 log pg *Fusarium*/g soil). Ten bread wheat varieties and one durum variety were sown in replicated plots and evaluated for their relative tolerance to both *Pt* and crown rot. The tolerance and resistance rating of each variety to Pt or crown rot and yield outcomes are outlined in Table 1.

When looking at the yield of each variety it is difficult to determine the relative contribution of both diseases to the final outcome, as a lack of tolerance to Pt can also increase the severity of crown rot expression (yield loss). However, it is evident that varieties which have good levels of tolerance to *Pt* combined with some level of resistance to crown rot (even MS) had a significant improvement in yield in the presence of both of these diseases.

Within the bread wheat varieties Suntop⏀ was 1.54 t/ha (109%) higher yielding than Ellison⏀ which has poorer resistance/tolerance to both Pt and crown rot. Suntop⏀ and EGA Gregory⏀ are both moderately tolerant (MT) of Pt but the improved

Table 1. Pratylenchus thornei tolerance, crown rot resistance ratings and yield of ten bread wheat and one durum variety evaluated at Gurley in 2012. Yield values followed by the same letter are not different at the 95% confidence level

Variety	*Pt* tolerance	Crown rot resistance	Yield (t/ha)
Suntop⫯	MT	MS	2.95 a
Sunguard⫯	T-MT	MR-MS	2.64 ab
LongReach Spitfire⫯	MT	MS	2.51 ab
Baxter⫯	MT-MI	MS	2.38 b
Livingston⫯	MT-MI	MS-S	2.36 b
Ventura⫯	MT-MI	MS-S	2.27 bc
Longreach Crusader⫯	MI-I	MS	2.22 bc
EGA Gregory⫯	MT	S	1.90 cd
Sunzell⫯	MT-MI	S	1.56 de
Ellison⫯	I-VI	S-VS	1.41 e
Caparoi⫯	MT-MI	VS	0.89 f

resistance of Suntop⫯ (MS) to crown rot over EGA Gregory⫯ (S) appears to have provided a 1.05 t/ha (55%) yield advantage at this site in 2012.

Both *Pt* and crown rot had significant impact alone and in combination with the clear message that varieties which are very susceptible or intolerant of either of these two pathogens should not be grown in medium to high risk situations. This was painfully obvious with Caparoi⫯ which was the only durum variety in the trial which yielded only 0.89 t/ha and was the most susceptible (VS) to crown rot as evidenced further by around 60-70% whiteheads during grain-fill in mid-October.

In 2013, NSW DPI compared the yield of ten wheat and two durum varieties with and without added crown rot inoculum across 11 sites from central NSW into southern Qld. The 2013 season was very conducive to the expression of crown rot in the northern region with little rainfall in spring and hot grain-fill temperatures. EGA Gregory⫯ remains the dominant wheat variety across the region due to its high yield potential and flexibility in sowing time. However, in the presence of added crown rot Suntop⫯ was 0.42 t/ha, LRPB Lancer⫯ 0.52 t/ha, Sunguard⫯ 0.61 t/ha and LRPB Spitfire⫯ 0.64 t/ha higher yielding than EGA Gregory⫯ when averaged across the 11 sites in 2013. This reflects the improved levels of tolerance to crown rot and *Pt* in recently released varieties in the region, which can seriously impact on profitability in the presence of these disease constraints.

How do I know my level of risk for crown rot and RLN?

PreDicta B is a DNA based soil test which detects levels of a range of cereal pathogens that is commercially available to growers through the South Australian Research and Development Institute (SARDI). RLNs, being soil-borne, appear to be more flexible with sampling technique to obtain an accurate risk level prior to sowing. However, the crown rot fungus is stubble-borne, so detection is more sensitive to the sampling technique used to collect the soil samples. Punching 3-6 cores between the previous crop rows in a paddock, as with a soil nutrition test, may give a reasonable estimate of RLN levels but will provide a poor indication of the crown rot risk. Recent collaborative research in the northern region between SARDI and NSW DPI has demonstrated that the use of a smaller diameter soil core (e.g. Accucore) to collect 15-30 cores (depending on sampling depth) targeted at the previous cereal row if disease is evident, provides a good measure of both RLN and crown rot risk along with a range of other pathogens. This number of cores collected spatially across the paddock is required to account for the potential variability in the distribution of crown rot inoculum. An important change to sampling; is it's now recommended up to 15 short pieces of cereal stubble from previous cereal crops to be added to PreDicta B soil samples to enhance detection of the Fusarium spp that cause crown rot. Where stubble is present, add one piece of cereal stubble per sampling location. Each piece should be selected from the base of separate crowns and the stubble above the first node discarded.

Soil cores – collect up to three cores from 15 different locations within the target area; take cores from the previous cereal rows and retain any stubble collected by the core. The number of cores per location will vary depending on core diameter and depth. Maximum sample weight should not exceed 500g.

If you are not willing to follow the recommended PreDicta B sampling strategy, then DO NOT assess disease risk levels prior to sowing.

Do fungicides have a role?

A replicated field trial at Garah in northern NSW in 2013 was conducted on two wheat varieties (EGA Gregory⍉ and Suntop⍉); with and without added crown rot inoculum at sowing (31st May). This trial aimed to take a step back in the approach of using foliar fungicides to determine if targeting application at the base of tillers might improve the level of crown rot control and provide more consistent control. The reduction of crop canopy through slashing at GS30 was also examined for its potential to impact on crown rot expression and yield.

The trial consisted of three in-crop application strategies, all at GS 30-31 being:

1. Above crop - foliar spray 50 cm above crop height (i.e. normal rust spray with most of product deposited on upper leaf surfaces).
2. On crop - boom dropped to crop height and nozzles moved between wheat rows (i.e. product hitting base of plant and soil).
3. Droppers - solid rod from boom down to below canopy height then two nozzles angled at ~45 degrees toward base of tillers on opposite crop rows (i.e. all of product targeted at base of plants).

Two slashing treatments using a cutter bar at GS30-31 were also examined being:

1. Leave - plot slashed and cut leaf material left on soil surface.
2. Remove – plot slashed and cut leaf material raked off plot.

Prosaro® (prothioconazole + tebuconazole) was used in this study as it is known to have improved efficacy in the control of Fusarium head blight (FHB) compared to other fungicides. However, the control of crown rot infection is a quite different prospect compared to FHB which has a defined infection area (anthers) and much narrower window of infection (flowering to soft dough). In contrast, crown rot infection occurs through the coleoptile, sub-crown internode, crown and outer leaf sheathes at the soil surface. Infection can also occur throughout crop growth. This trial was not designed as a product evaluation trial; rather it was primarily a proof of concept as to whether targeting fungicide application at the base of plants could potentially improve the control of crown rot.

The use of droppers with nozzles angled at the base of tillers provided a 5% yield benefit (+0.17 t/ha) in the no added crown rot treatment and a 10% (+0.21 t/ha) yield benefit in the added CR treatment. However, the level of benefit provided even with this best fungicide treatment in the presence of high crown rot levels (added CR) was 0.98 t/ha lower

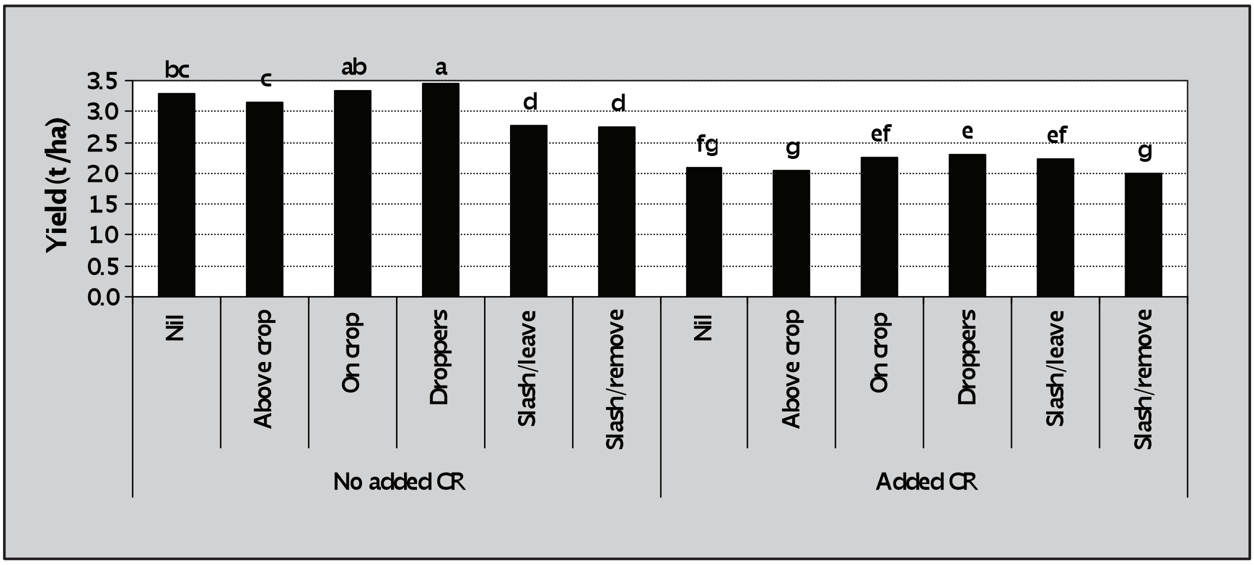


Figure 2. Effect of fungicide application or slashing at GS30 on grain yield with or without added crown rot inoculum - Garah 2013.

yielding then no fungicide application in the absence of added crown rot (no added CR). At best, the impact of fungicides targeted at the base of plants in still relatively minor but is an improvement over a normal foliar application above the crop canopy which did not provide any yield benefit.

Slashing at GS30 to reduce canopy size and hence reduce soil water usage for a short period, had a negative impact on yield in the absence of added CR but no impact on yield in the presence of added CR. There was a slight but significant yield advantage to leaving the cut biomass on the soil surface rather than removing (e.g. through grazing) in the presence of added CR only. Slashing also reduced grain protein levels by nearly 1% compared to other treatments. The negative impact of slashing on yield was more pronounced in Suntop ɸ than EGA Gregory ɸ while the fungicide benefit on yield was greater in EGA Gregory ɸ than Suntop ɸ.

Targeting the in-crop application of fungicides at the base of plants provided a minor (5-10%) yield improvement but is far from a complete control measure under high crown rot levels. However, it may be a useful addition to an integrated control strategy for managing crown rot.

Acknowledgments

This paper includes some older information conducted in collaboration with Northern Growers Alliance as acknowledged in the text. This information has been presented in greater detail at previous GRDC Updates with full reports available at www.grdc.com.au. Technical assistance provided by Robyn Shapland, Finn Fensbo, Karen Cassin, Kay Warren, Rod Bambach, Peter Formann, Stephen Morphett and Jim Perfrement are gratefully acknowledged.

Contact details

Steven Simpfendorfer
NSW DPI
0439581672
steven.simpfendorfer@dpi.nsw.gov.au

Notes

Maintaining flexibility and options with pre-emergents

Christopher Preston, Peter Boutsalis, Rupinder Saini, Sam Kleemann and Gurjeet Gill,
School of Agriculture, Food & Wine, University of Adelaide

GRDC project codes: UA00113, UA00121, UA00144

Keywords

annual ryegrass, brome grass, clethodim, Sakura®, Boxer Gold®

Take home messages

- **Understanding the behaviour of pre-emergent herbicides in relation to rainfall and soil type is essential for obtaining the best results.**
- **Controlling herbicide resistant brome grass with pre-emergent herbicides is difficult and other strategies will have to be employed.**
- **A combination of pre-emergent herbicides with clethodim plus Factor® provides the best control of clethodim resistant annual ryegrass in canola.**

Understanding pre-emergent herbicides

With the release of Boxer Gold® and Sakura®, farmers now have the choice of several pre-emergent herbicides for the control of annual ryegrass in cereals. The important factors in getting pre-emergent herbicides to work effectively while minimising crop damage are: to understand the position of the weed seeds in the soil; the soil type (particularly amount of organic matter and crop residue on the surface); the solubility of the herbicide; and its ability to be bound by the soil. Managing all these factors is complex, but some rules of thumb are:

1. The more water-soluble herbicides will move more readily through the soil profile and are better suited to post sowing pre-emergent applications than the less water soluble herbicides. They are also more likely to produce crop damage after heavy rain.
2. Soils with low organic matter are particularly prone to crop damage from pre-emergent herbicides (especially sandy soils) and rates should be reduced where necessary to lower the risk of crop damage.
3. If the soil is dry on the surface, but moist underneath there may be sufficient moisture to germinate the weed seeds, but not enough to activate the herbicide. Poor weed control is likely under these circumstances. The more water soluble herbicides will work more effectively under these conditions.
4. Pre-emergent herbicides need to be at a sufficient concentration, and at or below the weed seed (except for Avadex®Xtra which needs to be above the weed seed) to provide effective control. Keeping weed seeds on the soil surface will improve control by pre-emergent herbicides.

5. Many pre-emergent herbicides can cause crop damage. Separation of the product from the crop seed is essential. In particular care needs to be taken with disc seeding equipment in choice of product and maintaining an adequate seeding depth.
6. High crop residue loads on the soil surface are not conducive to pre-emergent herbicides working well as they keep the herbicide from contact with the seed. More water soluble herbicides cope better with crop residue, but the best solution is to manage crop residue so that at least 50% of the soil surface is exposed at the time of application.

Table 1 provides a comparison of water solubility and strength of binding to organic matter of several common pre-emergent herbicides. A key facet to getting pre-emergent herbicides to work is to understand their solubility in water. Trifluralin and pendimethalin (Stomp®) are the least water soluble herbicides, whereas Boxer Gold® (containing prosulfocarb and S-metolachlor) is one of the most soluble. This means less moisture is required for activation of Boxer Gold® than for Sakura®. Our rule of thumb is that 5 to 10 mm of rainfall in the 10 days after sowing is fine for Boxer Gold®, but 10-15 mm is required for Sakurav.

Greater water solubility also means more mobility in the soil and higher risk of crop damage with heavy rain after sowing. Herbicide washing into the crop row can damage the emerging crop. This is particularly a problem in light soils with low organic matter. Movement of herbicides in the soil profile is strongly influenced by their binding to soil organic matter. Trifluralin and pendimethalin are strongly bound to organic matter in the soil. This means they will not move far from where they are applied. In contrast, Sakura® and S-metolachlor (in Dual Gold® and Boxer Gold®) are bound much less tightly and are prone to movement in soils with low organic matter. In such soils, consideration should be given to reducing rates to reduce the risk of crop damage.

Table 1. Water solubility and binding to soil organic matter (K_{oc}) for some common pre-emergent herbicides

Herbicide	Trade Name	Water solubility (mg L^{-1})*		K_{oc} (mL g^{-1})**	
Trifluralin	TriflurX®	0.22	Very low	15,800	Very high
Pendimethalin	Stomp®	0.33	Very low	17,800	Very high
Pyroxasulfone	Sakura®	3.9	Low	223	Medium
Triallate	Avadex® Xtra	4.1	Low	3000	High
Prosulfocarb	Boxer Gold®***	13	Low	2000	High
Atrazine		35	Medium	100	Medium
Diuron		36	Medium	813	High
S-metolachlor	Dual Gold®	480	High	200	Medium
Triasulfuron	Logran®	815	High	60	Low
Chlorsulfuron	Glean®	12,500	Very High	40	Low

**at 20 C and neutral pH; **in typical neutral soils; ***also contains S-metolachlor*

Most weed seeds are on or close to the soil surface after crop harvest. As most pre-emergent herbicides, except triallate (Avadex® Xtra), are absorbed by the roots or the mesocotyl (the part of the shoot emerging from the seed) the ideal situation is to have the herbicides concentrated immediately below the weed seed. No-till systems, where seed are maintained on the soil surface until the pre-emergent herbicide is applied are ideal for efficacy of pre-emergent herbicides.

Due to its different action in the soil profile, addition of Avadex® Xtra to other grass pre-emergent herbicides generally results in increased levels of control of annual ryegrass. Essentially, the mixture allows weeds germinating both at the top of the soil profile and below the soil surface to be controlled.

Pre-emergent herbicides for brome grass management

The increasing incidence of resistance in brome grass to post-emergent Group A and Group B herbicides in Victoria and South Australia is making brome management more difficult. Brome grass provides several challenges to management in the absence of post-emergent herbicides.

Firstly, brome grass tends to have extended dormancy providing staggered germination through the season. This means that all pre-emergent herbicides struggle to control brome, but those with low soil persistence, such as Boxer Gold®, are particularly poor. Also, if any brome grass has germinated prior to application of the herbicides, it will be less well controlled.

Secondly, brome grass tends to occur in low rainfall regions. These regions have less moisture to activate pre-emergent herbicides. In addition, crops tend to be less competitive and competition from crops is important in getting the best from pre-emergent herbicides.

We have been conducting a series of trials to determine the ability of various pre-emergent herbicides to control brome. Trials have been conducted at various sites in SA and Victoria and on both species of brome. Generally pre-emergent herbicides are much less effective on brome grass than they are on annual ryegrass.

Figure 1 shows a compilation of data from five trials as reduction in the number of brome panicles at the end of the season. The horizontal line in the centre of each column is the mean of the five trials. The bar is the standard error. Common product mixtures, such as trifluralin plus metribuzin only provided about 50% reduction in brome panicles. Sakura® on its own provided similar or less control. Sakura® plus high rates of Avadex® Xtra generally provided high levels of control, but this treatment was poor in one trial.

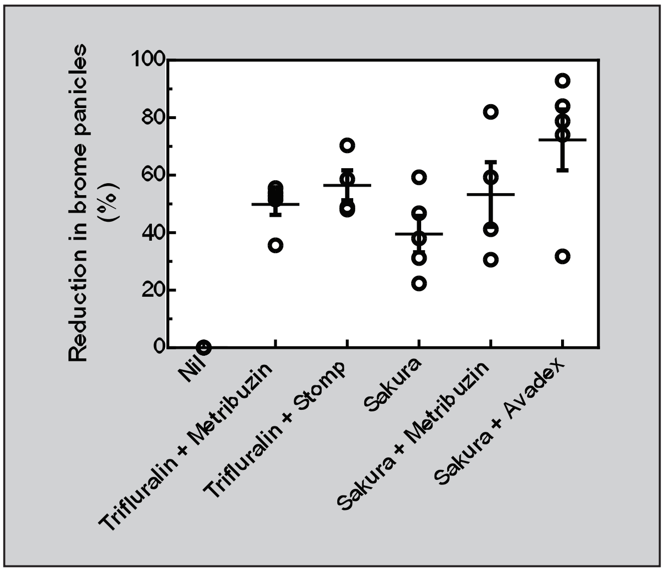


Figure 1. Average reduction in brome grass panicles with pre-emergent herbicide mixtures across 5 trials in southern Australia.

Control of brome grass in the absence of effective post-emergent herbicides will be difficult. Taking opportunities to reduce seed set of brome in non-cereal phases in the rotation will be important for the long-term management of this weed.

Control of clethodim resistant ryegrass

The increasing incidence of clethodim resistance in annual ryegrass is making weed management in break crops more difficult. We have conducted experiments to identify management practices that might be effective at managing clethodim resistant ryegrass focussing on novel pre-emergent herbicides. In 2013 we conducted a trial examining alternative strategies in both open-pollinated TT and

Table 2. Effect of alternative herbicide strategies for control of clethodim resistant annual ryegrass in TT canola on ryegrass seed heads and canola yield

Treatment	Ryegrass seed heads (spikes m^{-2})	Yield (T ha^{-1})
1.5 kg ha^{-1} Atrazine IBS fb 500 L ha^{-1} Clethodim POST	51	2.15
1.5 kg ha^{-1} Atrazine IBS fb 1.0 kg ha^{-1} Atrazine + 500 ml ha^{-1} Clethodim POST	33	2.15
1.5 kg ha^{-1} Atrazine IBS fb 500 ml ha^{-1} Clethodim + 80 g ha^{-1} Factor POST	60	2.20
Exp 1 IBS	326	1.62
Exp 2 IBS	231	1.68
Exp 2 IBS fb 500 L ha^{-1} Clethodim POST	79	2.02
Exp 2 IBS fb Exp 2 POST	178	1.77
Exp 3 IBS	477	1.30
Exp 3 + 2.0 L ha^{-1} Avadex Xtra IBS	308	1.65
Exp 3 IBS + 2.5 kg ha^{-1} Atrazine POST	103	1.99
1.5 kg ha^{-1} Atrazine IBS + Exp 4 POST	67	2.16
LSD	108.7	0.22

Table 3. Effect of alternative herbicide strategies for control of clethodim resistant annual ryegrass in Clearfield canola on ryegrass seed heads and canola yield

Treatment	Ryegrass seed heads (spikes m^{-2})	Yield (T ha^{-1})
2.0 L ha^{-1} Trifluralin + 2.0 L ha^{-1} Avadex X IBS fb 750 ml ha^{-1} Intervix + 500 ml ha^{-1} Clethodim POST	43.8	1.69
2.0 L ha^{-1} Trifluralin + 2.0 L ha^{-1} Avadex X IBS fb 750 ml ha^{-1} Intervix + 500 ml ha^{-1} Clethodim + 80 g ha^{-1} Factor POST	31.3	1.68
Exp 1 IBS	141.7	1.55
Exp 2 IBS	9.7	1.60
Exp 2 IBS fb 500 L ha-1 Clethodim POST	14.6	1.62
Exp 2 IBS fb Exp 2 POST	61.5	1.63
Exp 3 IBS	156.3	1.60
Exp 3 + 2.0 L ha^{-1} Avadex Xtra IBS	139.6	1.49
Exp 3 IBS + Exp 2 POST	100.0	1.65
2.0 L ha^{-1} Trifluralin IBS + Exp 4 POST	13.0	1.46
LSD	43.0	0.21

hybrid Clearfield™ canola. The ryegrass population had resistance to both clethodim and Intervix®, so these products were not very effective (Tables 2 and 3).

The growing conditions were above average rainfall during winter followed by much below average rainfall in spring. The Clearfield™ hybrid grew very rapidly in autumn and winter leading to lower ryegrass numbers, but the dry spring had a negative impact on yield. The wet winter conditions favoured the activity of atrazine in the TT canola, but worked against the activity of some of the novel pre-emergent herbicides. Failure to control ryegrass in TT canola with pre-emergent herbicides alone resulted in significant yield reductions of up to 40% (Table 2). There was less impact of weeds on yield in the more competitive Clearfield™ hybrid (Table 3). In addition, the competition from the Clearfield™ hybrid greatly improved the performance of some of the pre-emergent herbicides, particularly within experiment 2.

Even with clethodim resistance present in ryegrass, the best currently registered treatments still contained clethodim and Factor®. None of the alternative treatments were consistently more effective than the clethodim treatments.

Contact details

Christopher Preston

School of Agriculture, Food & Wine,
University of Adelaide

(08) 8313 7237

christopher.preston@adelaide.edu.au

Notes

Review of sulfur strategy to improve profitability in canola in the central west of NSW

Maurie Street,
Grain Orana Alliance (GOA)

GRDC project code3: GOA00001, DAN00129, NGA00003

Keywords

sulfur, canola, nutrition, sulfur deficiency, KCl-40, soil test, yield, oil

Take home messages

- **Three years of trialling by GOA has consistently failed to demonstrate a significant response to the addition of sulfur (S) in yield or oil%.**
- **Numerous trials by other organisations recently have also failed to demonstrate responses to sulfur in canola.**
- **Sulfur deficiency in canola, when it occurs, can be severe but not always. The frequency of such deficiency is most likely lower than thought and can be rectified early in crop without ongoing penalty.**
- **Unwarranted applications of 20kg/ha of S is reducing the profitability of many canola crops and rates should be reviewed to maintenance levels of 4 kg/t of grain removed. If soil levels are adequate this may be reduced even further.**
- **Canola is more frequently responsive to nitrogen applications and at least some expenditure on fertiliser may be better redirected from sulfur to nitrogen applications.**
- **Soil test critical levels are un-calibrated and are most likely too high and should be reviewed.**

Introduction

Canola has been generally accepted as having high requirements for sulfur (S), much higher than that of wheat. S deficiency was first identified in 1988 and 1989 but was only noted as a significant problem in 1990 (Coulton & Sykes, 1992). Literature from that time and since suggests that deficient situations lead to significant yield and oil penalties where it occurs.

In 2010 Grain Orana Alliance (GOA) established four trial sites investigating the effect of S fertiliser forms and timing on canola performance. In particular, final seed oil % was of interest. None of these trials resulted in any response to S fertiliser in yield or oil % regardless of form or timing.

Following on from this result, GOA questioned why responses were not seen despite prediction that three of the sites would respond. Was it because of changes in our farming systems, a vagary of the particular season; as one of the wettest on record, or because our understanding of S nutrition of canola and its occurrence was incorrect?

In 2011 and 2012 GOA established eight and four trials, respectively to improve our understanding and better identify situations where S deficiency or responses will occur. However, none of these trials responded to S in yield or oil % either.

In 2013 GOA established another four trials investigating aspects of canola nutrition including the responsiveness to S. No response to S was demonstrated in these trials either.

During this period a number of other agencies also conducted trials investigating S nutrition in canola. The results of these will be discussed in this paper and these too have not realised any S responses.

The results from these recent trials should challenge our understanding and approach to S nutrition in canola and a number of specifics listed below will be discussed in this paper such as;

1. The frequency and likelihood of deficiencies in the central west of NSW,
2. critical soil test levels,
3. grain removal rates and nutrient budgeting; and
4. new approaches to S nutrition in canola.

Background

Unreliable yields and crop failures of canola in the late 80's and early 90's were suspected of being due to S deficiency. With the identification of these deficiencies, a series of 14 trials were established in 1992 in collaboration with CSIRO, UNE, Incitec and NSW DPI. These trials investigated the interaction of N and S and if higher N rates were exacerbating S deficiency (Sykes, 1990).

It was quoted in a report by ACIL consulting (1998) that the trials' responses in 1992/3 were 'dramatic', particularly when following pasture. It also states that the trial collaborators, reported from the series of trials that 'applying 20-30kg/ha is sufficient to achieve maximum yields' and 'the best practice for maximising yield with the least risk versus cost trade off'. It is probable that all subsequent recommendations for S application in canola in most industry resources to current date are originally sourced from this one statement, albeit shortened without reference to the later part.

This recommendation was widely adopted and still accepted today as quoted in the 2009 BMP guide for canola;

> 'All paddocks sown to canola should receive 20kg/ha of sulfur in the form of available sulphate. On lighter soil with a history of deficiency symptoms increase rates to 30kg/ha.'

This practice will be referred to as Current Recommended Practice or CRP.

The adoption of this recommendation was rapid; it was estimated that even before the completion of the trials, 90% of canola was receiving the additional levels of S recommended. One of the key factors that supported this rate of adoption was the relatively low cost of S fertilisers at the time which was outweighed by the risk of penalty in deficient situations (ACIL, 1998).

During the same period in the early 90's the KCl-40 soil test for S was introduced and gained adoption as a more appropriate test method than the existing MCP method, however this superiority was demonstrated primarily on pasture sites. (ACIL, 1998)

The KCl-40 test was then widely used for estimating soil S levels particularly for canola. However there is very little evidence for NSW of yield performance against soil tests, until recently with Anderson *et al.* (2013) reviewing past trials. Therefore assumedly, soil critical levels were based upon values extrapolated from critical levels for pasture situations and/or simply on the base blanket recommendations of 20-30 kg/ha of S.

Local trial work by Mullen and Druce between 1993 and 1998, demonstrated that responses to S were not common on heavy grey soils of the region due to S contained in the subsoil. Through this work, S fertiliser applied on these soil types is not common but all other soils in the GOA region commonly still receive the standard 20kg/ha of S.

More recently, trial work by Khan *et al.* (2011) had questioned the suitability of gypsum as an S source for growing of canola compared to sulphate of ammonia (SOA). Gypsum is a commonly used fertiliser in the GOA region and it was questioned if this was contributing to lower oil % in our crops and/or suppressing yields due to S deficiencies.

Khan's findings were part of the basis of the first four trials run by GOA in 2010 investigating S sources and application timings. None of the trials responded to S in any form or timing despite predictions by soil analysis and experience to the contrary. This work is briefed in 'Sulfur Nutrition in Canola - Gypsum vs. SOA and Application Timings' (Street, 2011).

Following this outcome and other questions raised in above mentioned paper, GOA continued this work. Trial design was revised to better mimic the original trial work with the simple aim to quantify a response and also help build on the predictability of response.

Recent findings

Summarised below are the findings from recent trial work investigating S responses in canola. For specific trial detail, please refer to individual trial reports. Unless otherwise stated all statistics are analysed at the 95% confidence level.

GOA trials – 2010 (GOA1001-1004)

Four sites were selected in winter 2010 across the GOA region. Three sites were identified through recent KCl-40 soil tests as being low- moderate in S. The fourth site was deemed adequate in S by way of KCl-40 soil tests.

Treatments addressed three rates of S applied - 0, 15 or 30kg/ha, in two forms (gypsum or SOA), applied at five different timings from pre-seeding to early flowering.

Table 1. Canola yield and oil % performance to applied S fertiliser, GOA 2010

Site	Total S 0-60cm kg/ha #	Site Av. yield t/ha	Yield response to S	Oil % response to S
Nyngan	1.4kg	2.5	n.s.d	
Narromine	85kg	2.2	n.s.d	
Curban	39kg	2.8	n.s.d	
Wellington	23kg	2.2	n.s.d	

*# calculated S total = (KCl40 * bulk density * depth)*

There was no significant difference between any treatment and UTC at 95% confidence levels in yield or oil % as assessed by ANOVA.

GOA trials – 2011 (GOA1101-1104 plot sown trials) (GOA1110-1113 farmer sown trials)

Four plot sown sites and four farmer sown replicated trials were established in 2011. All sites were selected for low soil S with the details below.

The small plot sown trial protocol was changed in 2011 to a full factorial trial design with two nitrogen (N) rates (50 & 100kg N/ha) and five S rates (0, 5, 10, 20 & 30kg S/ha). All fertiliser treatments were predrilled immediately prior to sowing. S was supplied in the form of granular SOA (20% N, 24% S) and the N rates adjusted using urea (46% N).

Yield results were analysed by factorial analysis (ANOVA) with the outcome listed in the table 2.

There was no response to added S in yield or oil %. Three of the sites demonstrated strong positive and statistically significant responses to increased N rates from 50kg/ha of N to 100kg/ha. Yield responses were 18% increase at Geurie, 32% at Warren and 42% at Curban.

The four farmer sown trials were small plot replicated trials. The trials were established on farmer sown paddocks on soils of low S backgrounds. These trials were only designed to provide further support to the more comprehensive plot sown trials and treatments were reduced to basic plus and minus S.

The treatments were broadcast ahead of rain during the vegetative stage and were:

1. No N or S added or UTC
2. S added in the form of SOA at 100kg/ha (21kg/ha N & 24 kg/ha S)
3. N added as urea at 45kg/ha (21kg/ha N) to supply the equivalent amount of N contained in the SOA treatment

The outcomes analysed by ANOVA are listed in the table 3.

Table 2. Canola yield performance to increasing applied S or N fertiliser, GOA 2011

Site	Total N 0-70cm kg/ha #	Total S 0-70cm kg/ha#	Trial av. Yield	Yield response	
				Nitrogen	Sulfur
Geurie	62	35	1.68	+0.28 t/ha	n.s.d
Curban	37	40.4	0.84	+0.3t/Ha	n.s.d
Warren	39	30.1	0.97	+0.26 t/ha	n.s.d
Narromine	44	42	2.03	n.s.d	

*# calculated N/S total = (soil test value * bulk density * depth), NB- Oil % was not available for this set of trials*

Table 3. Canola yield and oil % performance to applied S or N fertiliser, GOA 2011

Site	Total Soil S kg/ha #	Trial Av. Yield t/ha	Yield Response	Oil % Response
Wongarbon	No S applied in 14 years	1.7	n.s.d	n.s.d
Coolah Black	33	0.9	Urea or SOA suppressed yield over UTC	n.s.d
Coolah Red	31	1.06	n.s.d	n.s.d
Arthurville	24	2.3	n.s.d	n.s.d

*# calculated S total = (soil test value * bulk density * depth) Soil sampled to 60cm depth*

As shown above, the only interaction achieved in these trials was a reduction in yield to applied S at Coolah. This reduction however was achieved with both urea and SOA which could indicate this was due primarily to the added N in both treatments, not the S. The resulting reduction in yield could be attributed to the dry conditions in late winter and spring experienced in 2011 at this site and over fertilisation with N, supported by the low average trial yield.

GOA trials – 2012 (GOA1201-1205)

GOA repeated the same plot sown protocol employed in 2011 on a further four sites in 2012.

Yield and oil % results were analysed by factorial analysis (ANOVA) with the outcome listed in the table 4.

In 2012 there was no response to added S in yield or oil %. In two of the trials there was a significant response to increasing the N from 50kg/ha to 100kg/ha in yield. At the Wellington N site, yield was increased by 24% with the increased N rate and by 7% on the second site.

DPI collaborative trials 2012 (GOA1206 and 1207 or NSW DPI site)

In 2012, in collaboration with the NSW DPI, two trials were undertaken at Trangie and Coonamble. The trials were a factorial design with four N rates (0, 25, 50 & 100kg/ha) and four S rates (0, 10, 20 & 30kg/ha) and two canola varieties in Pioneer®43C80 and Pioneer®44Y84 sown at the Trangie site but only Pioneer®44Y84 sown at the Coonamble site.

Yield and oil % results were analysed by factorial analysis (ANOVA) with the outcome listed in the table 5.

At the Coonamble site there was no response to the addition of N or S in either yield or oil %.

Table 4. Canola yield and oil % performance to increasing applied S or N fertiliser, GOA 2012

Site	Total N 0-70cm kg/ha#	Total S 0-70cm kg/ha#	Trial av. Yield t/ha	Yield response		Oil % response	
				Nitrogen	Sulfur	Nitrogen	Sulfur
Narromine	75	18.3	2.79	n.s.d		n.s.d	
Curban	88	33.8	1.27	n.s.d		n.s.d	
Wellington N	32	37	0.61	+ 0.13t/ha	n.s.d	n.s.d	
Wellington S	71	50	1.4	+ 0.1 t/ha	n.s.d	n.s.d	

*# calculated N/S total = (soil test value * bulk density * depth)*

Table 5. Canola yield and oil % performance to increasing applied S or N fertiliser, DPI/GOA 2012

Site	Total N 0-90cm kg/ha#	Total S 0-90cm kg/ha#	Trial av. Yield t/ha	Yield response		Oil % response	
				Nitrogen	Sulfur	Nitrogen	Sulfur
Coonamble	73	20	2.56	n.s.d		n.s.d	
Trangie	113	141	1.81	+ 0.35 t/ha	n.s.d	-1.60%	n.s.d

*#calculated N/S total = (soil test value * bulk density * depth)*

The Trangie site resulted in no significant response to S in yield or oil % but would not be expected given soil S levels. There were significant responses to N in yield and oil %. Increasing N rates increased yields but decreased oil %. There was a significant response to variety with Pioneer®44Y84 outperforming Pioneer®43C80 in both yield and oil % (data not presented).

DPI northern region trials 2012 (NSW DPI Northern trials booklet)

DPI established two trials in Northern NSW investigating N and S interactions.

The trials were a factorial design with four N rates of 0, 40, 80 and 120kg/ha at Moree and 0, 50, 100 and 200 kg/ha at Blackville both with four S rates of 0, 11, 21 & 41kg/ha and two canola varieties. Nitrogen was applied as urea with sulphur applied as granulated gypsum applied pre sowing.

Yield and oil % results were analysed by factorial analysis (ANOVA) with the outcome listed in the table 6.

There was no response to added S at either site in yield or oil % as would be expected with such high levels of soil S. Both sites responded strongly to the addition of N, in yield the response was positive but both negative in oil %.

NGA trials 2012 (AM1201, RH1207)

NGA established two trials in 2012 investigating nutrition of canola in the northern region. The trials investigated the interaction of N and S as well as phosphorus (P).

The trials were a factorial design with three N rates of 34, 84 and 134kg/ha with three S rates of 1, 16 and 31kg/ha. Nitrogen was applied as urea with sulphur applied as Gran Am (SOA) applied pre sowing.

Yield and oil % results were analysed by factorial analysis (ANOVA) with the outcome listed in the table 7.

There was no response to added S at either site in yield or oil %. At both sites there was a positive response to increasing N rates, 13% at Bellata and 20% at Yallaroi. At Bellata there was a negative response in oil % to increased N rates. The Bellata site responded to added P, at the Yallaroi site there was a trend to increase with added P but was not significant (not in the table).

Table 6. Canola yield and oil % performance to increasing applied S or N fertiliser, DPI 2012

Site	Total N 0-90cm kg/ha#	Total S 0-90cm kg/ha#	Trial av. Yield t/ha	Yield response		Oil % response	
				Nitrogen	Sulfur	Nitrogen	Sulfur
Blackville	28	130	1.54	+ 1 t/ha	n.s.d	-0.79%	n.s.d
Moree	46	94	1.15	+ 0.74 t/ha	n.s.d	-1.60%	n.s.d

*#calculated N/S total = (soil test value * bulk density * depth)*

Table 7. Canola yield and oil % performance to increasing applied S or N fertiliser, NGA 2012

Site	Total N 0-90cm kg/ha#	Total S 0-90cm kg/ha#	Trial av. Yield t/ha	Yield response		Oil % response	
				Nitrogen	Sulfur	Nitrogen	Sulfur
Bellata	69	164	1.37	+ 0.15 t/ha	n.s.d	-2.80%	n.s.d
Yallaroi	30	NA	1.79	+ 0.31 t/ha	n.s.d	n.s.d	

*#calculated N/S total = (soil test value * bulk density * depth)*

Central West Farming Systems (CWFS)

CWFS have undertaken a number of trials at their regional sites investigating canola S nutrition over a number of seasons (www.cwfs.org.au). Unfortunately individual trial data was not available at the time of writing this paper but personal comments regarding their trials over recent seasons by John Small (CWFS) are below.

'There has been no clear or statistically significant response to the addition of S in terms of yield or oil performance in canola over a number of trials by CWFS over recent seasons.'

Readers should seek further clarification and data from CWFS concerning these trials before finalising one's conclusion. The outcomes of these trials will however be valuable in the sense that they would generally be undertaken on red soils of our region, more likely to respond than the heavier soils of the northern regions.

Discussion

As indicated above there has been no response to S in terms of yield or oil % in recent trial work. This work has been undertaken by a number of agencies across a range of soil types and three seasons. It should also be noted that all but one of GOA's trial sites were selected specifically for low soil S levels and were predicted by soil tests to be responsive.

Why have responses not been achieved?

As stated above, CRP is that all canola paddocks should receive S fertiliser. However of the original trial work that formed this recommendation only six of the fourteen sites detailed responded to S in yield and only three in oil % (Sykes, 1990). Many of these sites did not respond despite prediction by soil tests.

The most commonly reported trial was at the Wellington site where yields increased from 1t/ha to 4t/ha with the addition of S. At this site 75% of the site maximum yield was achieved at 10kg of S/ha, and 92% at 20kg/ha of S applied. A similar result was demonstrated at Baradine, but these could be described as the two worst documented cases of S deficiency.

Many of the other responsive sites did not realise such magnitude of improvement. At the Gollan site at the 40kg N/ha rate- increasing S from 0 to 20kg/ha only increased yields by 590kg. At 80 kg N/ha rate- there was a 325 kg/ha improvement by increasing S from 0 to 20 kg/ha. At the Junee Reefs and Tamworth sites a maximum response was achieved of approximately 400 kg/ha. These were then and would still be now, worthy economic responses on today's fertiliser prices but the penalties nowhere close to the extent that is often promoted.

The ACIL report also mentions other previous work in 1990 commenting, 'A major field study of canola in NSW reported significant grain yield increases from the addition of N but no significant responses to S (Sykes and Coulton, 1990)'.

More recent work as detailed above shows no response to the addition of S over three years and a range of soils predicted to respond.

In summary, the frequency of response to added S is quite low, considering just the detailed trials in this paper less than 14% of trial sites were responsive (excluding the field study of 1990 and those of CWFS). In terms of recent trials, 0% responded to added S.

Industry accepted grain removal rates used in nutrient budgets may also lend support to the CRP. Current industry references suggest that removal rates are 10kg S/ t of grain and that crop requirements of canola are much higher than that of wheat (Coulton *et al*, 1992).

Analysis of grain samples from GOA's and NGA's trial work have shown that grain removal is much lower than these levels. Published data by Janzen and Bettany (1994), Pinkerton *et al*. (1993) and Hocking *et al*. (1996) all measured grain S contents in their range of experiments. Grain S levels no greater than that of ~0.5 % or 5kg S/t of grain was measured, even in treatments with adequate S. In many cases the S levels were even lower resulting in them being less than half the industry benchmarks.

When considering this for formulating crop requirements and fertiliser programs there may be little difference between the removal for wheat or canola. For example an average wheat yield for the GOA region may be 3 t/ha, removing approximately 1.8 kg/t of S or 5.4 kg/ha of S. Canola will generally perform at 50% of comparable wheat yields (Parker, 2009) so 1.5t/ha crop, removing 3.6 kg/t. The critical threshold described by Hocking *et al*. (1996) will remove only 5.4 kg/ha of S or similar amounts to the wheat crop.

So a possible explanation of the lack of responsiveness in all of these trials was that the prediction regarding the sites' responsiveness was misleading. These predictions, were supported by a crop demand much higher than what seems apparent now, and therefore, was there adequate S contained in the soil profile and subsequent mineralisation to satisfy crop demands?

For example, using the highest achieved yield in the GOA trials of ~ 2.8t/ha the crop removal rate would be 9.8 kg/ha. If we assumed an arbitrary uptake or transfer efficiency of 50%, the crop would only have a growing requirement of 20 kg/ha. All of the sites detailed in this paper would have satisfied this requirement with starting soil levels and only a minimal amount of mineralisation; no additional fertiliser would be required.

So what is the critical soil level to indicate when S may be required to be added?

To supply this requirement of 20kg/ha of S a soil KCl-40 test would have a critical level of ~2.3 mg/kg averaged in the top 60cm of soil depth (i.e. 2.8t/ha * 3.5kg/t / 50% = crop requirement/1.4 (soil bulk density) / 6 (10 cm soil segments)). If this is indeed the soil critical level, few cropping soils would be lower.

But what of the sites that did respond in 1992?

Interestingly the second most responsive site was at Baradine. Although details of soils tests are scant, the report by Sykes indicates there was some 675kg of S available at this site, certainly enough to satisfy crop requirements. Was the response at this site a function of availability within the effective root zone for that crop? If the subsoil was dry that year and as such the crop was not able to access this nutrient layer, deficiency is possible despite significant soil reserves.

This view could also explain by the trial at Andersons from 1992 where early deficiency symptoms were seen in the crop but despite this the nil S plots recovered to result in no yield response possibly when rain fall and root development accessed adequate S reserves deeper in the soil.

S is mobile in the soil and susceptible to leaching from the topsoil and accumulating at depth. Low or no subsoil starting moisture due to the farming system of the time or seasonal or locality differences could foreseeably see crops sown into circumstances where deficiency may be experienced if the crops cannot access the reserves accumulated deeper in the soil. Later season rainfall, wetting the soil deeper may see the crop being able to access these reserves and rectify without action any earlier deficiencies.

Anecdotally deficiency is often noted more in the southern regions with less summer rain to wet the profile to depth prior to planting.

The new paradigm in canola nutrition

Reducing Sulfur fertiliser rates

When considering fertilising canola, a distinguishing difference from most other field crops is its S requirement. As such, it is often the first nutrient addressed after that of starter P fertiliser applications in fertiliser programs and its requirement of N then follows.

More than 20 trials run over the past three seasons that have been briefed above have failed to demonstrate responses to added S in either yield or oil %. Average crop removal rates do not support the requirement of 20kg S/ha universally.

Given this scenario, reducing the CRP of 20kg/ha of S to rates which more closely match crop yields and subsequent removal rates would certainly be a more economic approach whilst being sustainable in the longer term.

However the complete lack of S response in recent trials raises the possibility of completely removing intended S applications as it is done in wheat. Given there is often no yield or oil % response, profitability in the short term will only decline with any additions of S.

However if growers are to take this this approach, soil tests may still be useful to predict potential responsiveness if using removal rates. If soil level concentrations and subsequent calculations of soil available S outstrip the predicted conservative crop requirements at 4-5 kg of S/t of crop potential, the likelihood of crop responses or a deficient situation developing is unlikely.

In these situations of no S applications, growers do risk that deficiencies may develop despite prediction to the contrary. If this deficiency is identified prior to stem elongation and S applied, trial work by Hocking *et al*. (1996) showed that both final yield and oil % will not be penalised. But remember the frequency of such a deficiency on the basis of recent trial work is low but not zero.

However consider the location of this S, whether deep or shallow in the profile, and the crops likely ability to access it. Low subsoil moisture at planting and low in crop rainfall may see deficiencies experienced and surface applications warranted. However if sufficient rainfall through the growing season wet the soil deeper allowing plants to access this deeper S, deficiencies may be alleviated.

Re-focus investment on nitrogen instead of sulfur

In contrast, the majority of all trials have demonstrated response to N.

Twelve of the fourteen trials undertaken in 1992 resulted in significant and economical responses with an average increase to 80 Kg of N of 600kg/ha (Sykes, 1990). Of the two that did not, one of the trials was following five years of grass free legume based pasture; the other was compromised by frost resulting in a high trial CV.

Three of the four trials of GOA's in 2011 responded significantly to increasing N from 50kg/ha of N to 100kg/ha. The average yield increase over the three sites was 280kg/ha returning around 200% ROI (canola at $500/t and urea at $700/t). Two of GOA's trials in 2012 returned a significant yield response to increasing N as well. Returns were much lower with the dry spring conditions with the yield increases only breaking even after additional costs.

Trials by NGA in 2012 demonstrated a 13% yield increase or about 150kg/ha (break-even) by increasing N from 34 kg/ha to 84 kg/ha in one trial. The second site saw an increase yield of 20% or ~310kg/ha, resulting in approximately a 200% ROI.

It should be noted that GOA's and NGA's trials did not have zero N treatments but they were all clearly N responsive sites.

In the DPI/GOA trials in 2012 treatments of 0 N were included and this allows a response curves to be generated. The Trangie site showed strong responses to N with yield increasing by 0.35t/ha or 21% by increasing N from zero to 100kg/ha. The economics of such applications are demonstrated in Figure 1.

Columns headed by the same letter denotes no significant difference

Although the starting soil N at this site was high at 113kgha, yield and resultant gross income has increased almost in a linear response and the treatments have not demonstrated a clear upper limit. The responsiveness of canola to high rates is reinforced at three other sites detailed in Figure 2; again there was no clear indication of a yield plateau even up to 200 kg N/ha.

So although canola will tend to respond to increasing N, the ROI declined beyond the 25kg/N rate but still remained positive. This is only one trial in a dry spring but it demonstrates that the most economical rate is not necessarily the point of yield

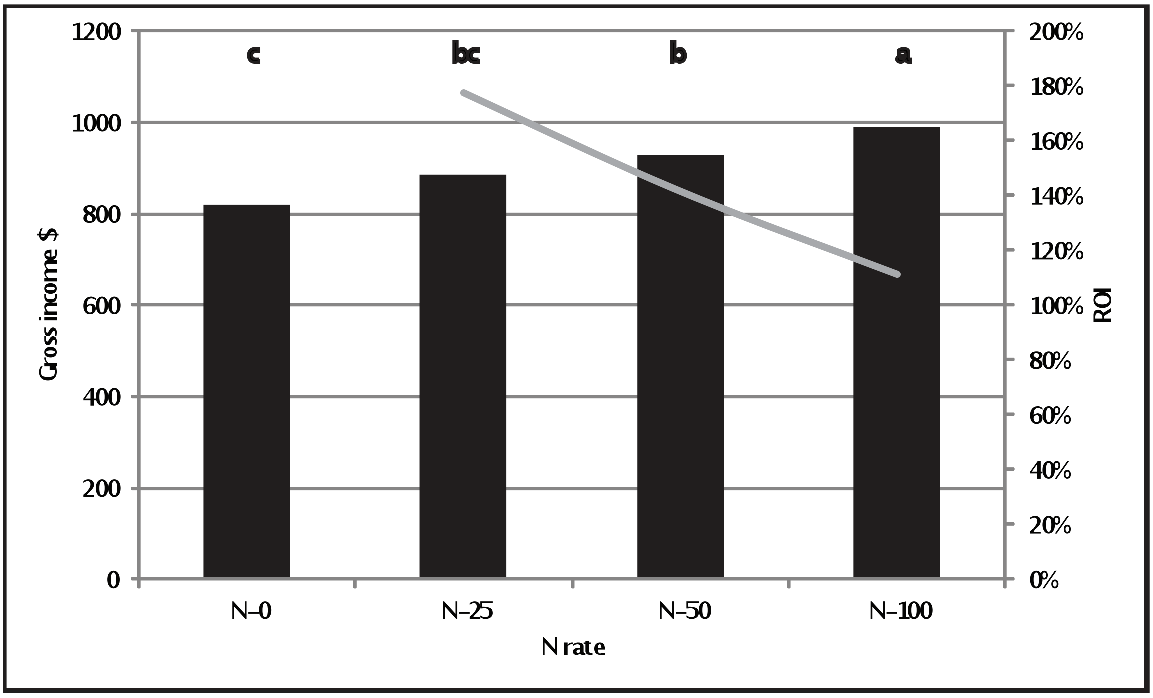


Figure 1. Canola yield performance in relation to applied N rate and the corresponding return on investment (ROI), Trangie (Source: DPI/GOA (2012)).

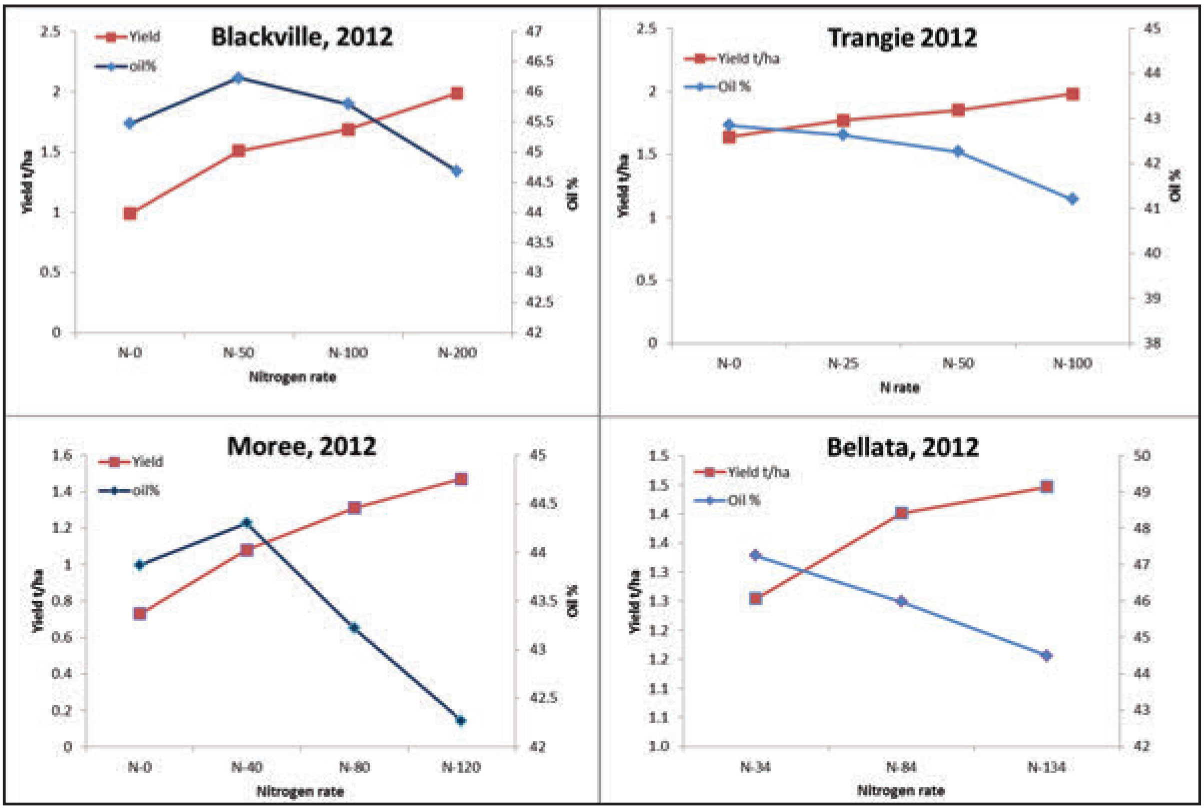


Figure 2. Canola yield and oil % performance demonstrating the inverse relationship to applied N (Source: DPI/NGA/GOA (2012)).

maximisation. The economically optimum level for N rates may be different for each situation.

Determining the optimal N rate for canola through deep soil tests coupled with yield forecasting may be one approach and probably the most reliable.

It is worth noting that increasing N rates may have the effect of reducing oil % as demonstrated in the Trangie, Bellata, Blackville and the Moree trials (Figure 2). Many of the trials from 1992 also showed statistically significant reductions in oil content from increased N rates. Increased N can lead to increased protein. Protein's relationship to oil % is inverse so this can lead to depressed levels of oil. However in all cases the increased yield more than adequately offset this loss.

Summary

In summary, 20 trials have now recently been undertaken across a number of seasons and locations in NSW. None of them have demonstrated S responses in yield or oil %. This does not exclude deficiency and yield penalties from occurring but does highlight that the frequency and the likelihood is not high.

The results and the ensuing extension message regarding the need for S from the trial work in 1992 may have lost its original perspective. Within the original reports, the data suggested that N was paramount to achieve maximum profitability for canola in nearly all cases. The data also suggested that in only some cases canola responded to S as well.

However, the one extension message that resulted and stuck was that all canola crops needed 20 kg/ha of S and sometimes more needed to be applied. The then lower cost of S fertiliser and the significant penalties seen in deficient situations, saw this recommendation adopted rapidly, whether S was needed or not.

Declining terms of trade over the last 20 years, does not allow now for such a luxurious approach to be taken, particularly if not warranted.

Through GOA's efforts a number of shortcomings in the understanding of canola agronomy have been highlighted. Removal rates are over-estimated and the lack of calibrated soil critical levels is a major problem. Improvement in both of these may improve the predictability of S responsiveness.

With the reduced frequency of response and considering the reviewed S demand of canola, the CRP may need revision to closely match S removal rates. This will result in increased profitability and sustainability for growers.

Complete removal of S from fertiliser programs may be risky but will prove to be the most profitable practice in many cases. However, wheat has a similar requirement per hectare, and the predominant fertiliser applied is MAP/DAP which contains only minimal S and wheat is not noted to suffer yield impacts through deficiencies. And it should be remembered deficient situations can be easily rectified by in crop applications.

There is a good case for the savings in expenditure on S to be redirected to N where the response is much more common. But determination of the optimal rate of N may need to be revisited or targeted through soil tests and nutrient budgets to ensure the return on investment is maximised not simply the yield.

'Current recommendations consider S to be non-negotiable and N applications more seasonally dependent. This approach needs to be reversed; S application needs to be more prescriptive in its use and we need to refocus our attention and redirect our expenditure on getting our N rates right.'

Additional information

www.nga.org.au

www.grainorana.com.au

www.dpi.nsw.gov.au/agriculture

www.cwfs.org.au

References

ACIL Consulting (1998). *Sulfur test KCl40 and the growth of the Australian canola industry.* Arawang Communication Group, Canberra.

Anderson, Geoffrey C., Peverill, Ken I. and Brennan, Ross F. (under review - to be published 2013) *Soil sulfur – crop response calibration relationships and criteria for field crops grown in Australia*

Coulton, R and Sykes, J. (1992) Canola Agfact P5.2.1 fourth Ed. NSW Agriculture.

Good, A.J., Pinkerton, A., Hocking, P., Blair, g., Sykes, J (1993). *Nitrogen and sulfur affect canola seed yield and oil percentage.* Retrieved- www.regional.org.au/asa/1993/poster/grain-legumes-oilseed/1993pgs342-pos 7th Feb. 2011.

Good, A.J and Glendinning, J. S. (1998) *Canola Needs Sulfur.* Better Crops International, Vol 12, No 2, November 1998. Retrieved from http://anz.ipni.net/ipniweb/regions/anz/regionalPortalANZ.nsf/4d69fbe2e4abc746852574ce005c0150/d6dd95ec92bd94de852576ff0082d61c/$FILE/BC%20sulfur%20and%20canola.pdf

McCaffery, D., Potter, T. Marcroft, S. and Pritchard, F. (2009). - *Canola Best Practice Management Guide for South-Eastern Australia* - GRDC Coretext

Hocking, P.J. , Pinkerton, A., Good, A. (1996) *Recovery of field grown canola from sulfur deficiency. Australian Journal of Experimental Agriculture*, **36**, p79-85

Janzen, H.H. and Bettany, J.R. (1984). *Sulfur nutrition of rapeseed. Influence of fertiliser nitrogen and sulfur rates. Journal of the soil Science Society of America* **48**, 100-7

Khan, T., Norton, R., Edis, Walker, C. and Chen, D. (2011) *Comparing N and S sources to improve yield and nutrient efficiencies in canola cropping systems is south eastern Australia.* 17th Australian Research Assembly on Brassicas, Wagga Wagga 2011.

Mullens, C and Druce, S J. (no date) *Variable canola performance on heavy grey clay soils of upper central New South Wales.* Retrieved from http:/regional.org.au.au.gcirc/2/504.htm?PO_0&print=1

Pinkerton, A., Hocking, P. J., Good, A., Sykes, J., Lefroy, R. D. B. and Blair, G. J. (1993) *A preliminary assessment of plant analysis for diagnosing sulfur deficiency in canola.* 'Proceedings of the 9th Australian Research Assembly on Brassicas'. Wagga Wagga, NSW. (Eds N. Wratten and R. J. Mailer.) pp. 21-8.

Street, M. (2011) *Sulfur Nutrition in Canola- Gypsum vs. SOA and Application Timings.* GRDC Update proceedings, Dubbo 2011. Retrieved from http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Sulfur-nutrition-in-canola-gypsum-vs-sulphate-of-ammonia-and-application-timing

Sykes, J (1990) *Sulfur removes variability from nitrogen applications.* Retrieved from http://trials.incitecpivotfertilisers.com.au/document/trial/12abdad4c6b3f705b48d5f7e8660a270.pdf

Contact details

Maurie Street
Grain Orana Alliance Inc. (GOA)
0400 066 201
maurie.street@grainorana.com.au

Dual-purpose wheat and canola – finding the best fit with experiments, experience and modelling

John Kirkegaard[1], Hugh Dove[1], Julianne Lilley[1], Lindsay Bell[1], Susie Sprague[1], John Graham[1], Scott McDonald[1], Jeff McCormick[2], Jim Virgona[3], Peter Hamblin[4] and Alex Murray[4],

[1]CSIRO National Sustainable Agriculture Flagship; [2]Lincoln University, Christchurch NZ, formerly Charles Sturt University, Wagga; [3]Graminus Consulting P/L, Wagga, formerly Charles Sturt University, Wagga; [4]Kalyx, Young

GRDC project codes: CSP00132 CSP00160

Keywords

grazing crops, feed gaps, crop simulation, grain and graze, mixed farming

Take home messages

- **Understanding crop development is the key to success; to best match sowing date to variety and to plan lock-up times.**
- **Early-sown, slower maturing varieties of both wheat and canola provide best grazing potential, and similar or higher grain yield potential than later (May)-sown crops.**
- **Phenology-based grazing rules remain sound, but could be improved with advice on the residual biomass needed at lock-up to avoid yield loss.**
- **Modelling can assist experiments and experience to better understand risk, variability and trade-offs at paddock and farm-scale; but the assumptions made and limitations should be understood.**

Background

In southern NSW a long history of experiments and experience in grazing dual-purpose cereals (and more recently, canola) has provided robust 'best-bet' management guidelines for growers and their advisers (see references). Success on mixed farms in these traditional medium rainfall areas has sparked interest in new areas; drier western and northern areas on larger crop-focussed farms, and in the traditional livestock-focussed higher rainfall zones. New varieties and circumstances also require ongoing refinement of management recommendations in traditional areas.

In recent years, we have combined modelling with experiments and experience to refine our guidelines for dual-purpose crops in traditional areas and expand them into new areas. Some approaches used and some key outcomes of the recent work are discussed.

Modelling approaches

Why use models?

Validated wheat and canola crop models can predict forage production, crop development and yield for a range of sites, seasons and management;

and thus expand the insights we can get from specific experiments and experience. Models must be *validated*, and the *assumptions made clear* together with their limits. We used APSIM wheat and canola models to ask questions about specific crops and whole-farm implications; what variety is best to sow?, how much biomass can I produce for grazing?, will increasing N or plant density increase feed supply?, what stocking rate will optimise feed utilisation? and/or will yield be affected by grazing?.

What did we do?

Our aim was to provide advice on matching the different phenology types of wheat and canola with sowing times in different environments to maximise benefits from dual-purpose crops. Briefly, the way we used the validated wheat and canola APSIM models with long-term weather data is as follows:

1. Use long-term weather records to identify the optimum flowering window to minimize frost and heat risk at a specified site (e.g. for canola at Young, Figure 1).
2. Use the model to predict crop development (based on temperature and daylength) and identify sowing dates for different phenology types to hit the optimum flowering time.
3. Use long-term weather records to determine the likelihood of a sowing opportunity in that sowing window.
4. Run the model over historic weather data to predict forage production and grazing value, and seed yield. In this we assumed:
    - Grazing starts at set biomass (e.g. 1 t/ha), ceases at Z30, and sheep eat 1 kg dry-matter/DSE/day; and
    - yield is assumed unaffected by grazing provided grazing ceases at Z30.

As well as sites, varieties and sowing dates, we also used the model to investigate the impacts of agronomic management such as N management and plant density as these can be changed in the model. We carried out the analysis at 13 sites across Australia's HRZ but report here only a summary of NSW sites at Delegate, Young and Quirindi. A separate study by Dr Jeff McCormick used similar approaches to investigate the potential for dual-purpose canola at Wagga. In all cases we 'laugh-tested' the outcomes with local consultants and growers and validated it against our experimental data.

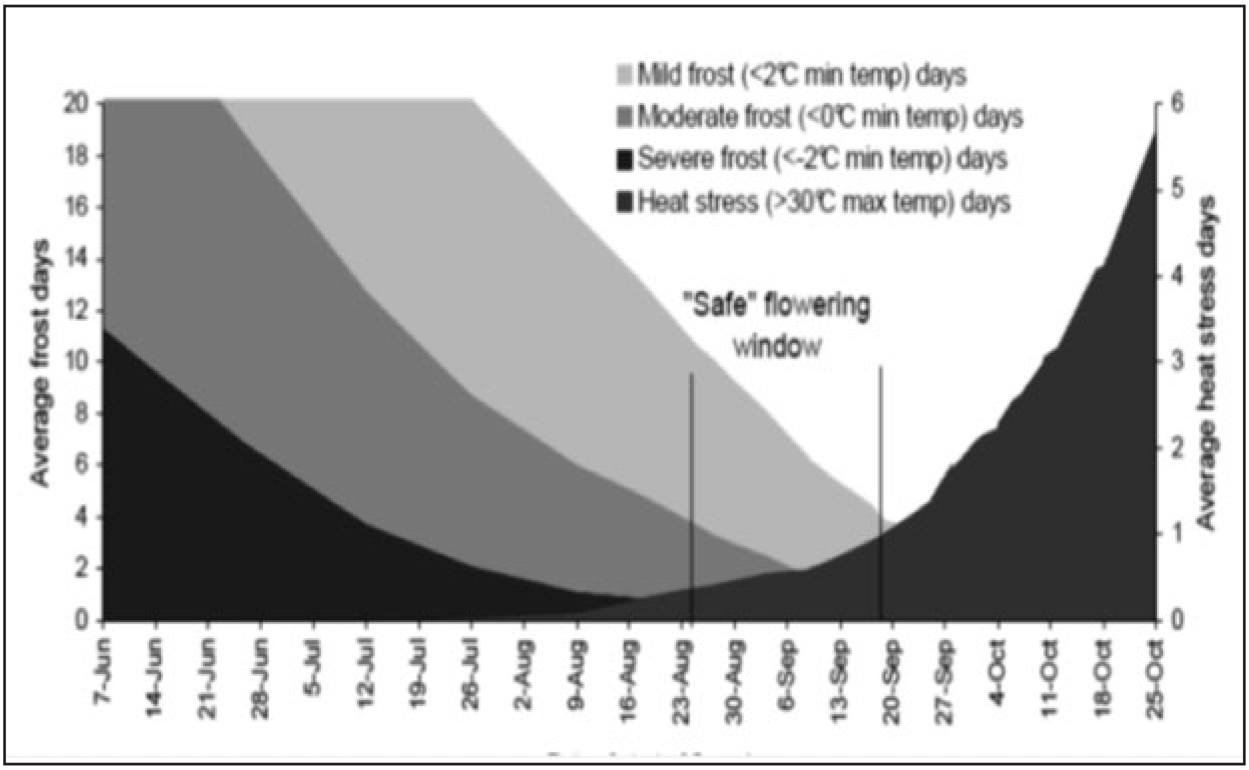


Figure 1. Optimum flowering window (for canola at Young, NSW) is identified as the period that minimises heat and frost risk. Frequency of frost and heat events occurring in the sensitive window after flowering commences for Young. Upper lines of shaded areas show number of mild, moderate and severe frost (left) and heat (right) events

What did we find?

A summary of outcomes for the three NSW sites for both wheat and canola is shown in Table 1. The shaded grey areas of the table show the sowing window for each variety that will result in *flowering in the optimum window.* The number shown within the area shows the % of years when a sowing opportunity is likely in that window. The last two columns show the predicted mean grazing days and potential grain yield for each variety (over 50 years 1959-2009) if sown in the shaded window and grown according to the assumptions specified in the Table (i.e. density, N management). Thus for each site in Table 1, the recommended options would be those shaded options which have a high chance of sowing, high grazing and grain yield potential.

Table 1. Summary of predicted long-term safe sowing window, probability of a sowing opportunity in that window, potential mean grazing and grain yield for four different maturity types of wheat and canola at three NSW locations. [Assumptions: wheat at 150 pl/m2, 150 kg N/ha in soil at sowing and 100 kg N/ha post-grazing; canola at 60 pl/m2, 150 kg N/ha in soil at sowing and 100 kg N/ha post-grazing].

<table>
<tr><th rowspan="2">Location</th><th rowspan="2">Cultivar – phenology type</th><th colspan="9">Sowing window intervals</th><th rowspan="2">Mean predicted grazing days (DSE/ha)</th><th rowspan="2">Mean potential yield (t/ha)</th></tr>
<tr><th>8 Mar</th><th>22 Mar</th><th>5 Apr</th><th>19 Apr</th><th>3 May</th><th>17 May</th><th>31 May</th><th>14 Jun</th><th>28 Jun</th></tr>
<tr><td colspan="13">Wheat</td></tr>
<tr><td>Delegate</td><td>Winter</td><td colspan="3">78%</td><td></td><td></td><td></td><td></td><td></td><td></td><td>1830</td><td>5.3</td></tr>
<tr><td></td><td>Mid-winter</td><td></td><td colspan="7">100%</td><td></td><td>1200</td><td>5.1</td></tr>
<tr><td></td><td>Mid-spring</td><td></td><td></td><td></td><td colspan="3">84%</td><td></td><td></td><td></td><td>750</td><td>5.7</td></tr>
<tr><td></td><td>Fast spring</td><td></td><td></td><td></td><td colspan="3">84%</td><td></td><td></td><td></td><td>650</td><td>5.7</td></tr>
<tr><td>Young</td><td>Winter</td><td colspan="2">44%</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>2050</td><td>4.7</td></tr>
<tr><td></td><td>Mid-winter</td><td colspan="7">98%</td><td></td><td></td><td>1500</td><td>4.5</td></tr>
<tr><td></td><td>Mid-spring</td><td></td><td></td><td></td><td></td><td colspan="3">89%</td><td></td><td></td><td>720</td><td>5.1</td></tr>
<tr><td></td><td>Fast spring</td><td></td><td></td><td></td><td></td><td colspan="3">89%</td><td></td><td></td><td>600</td><td>5.1</td></tr>
<tr><td>Quirindi</td><td>Winter</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>Mid-winter</td><td colspan="7">93%</td><td></td><td></td><td>1830</td><td>4.6</td></tr>
<tr><td></td><td>Mid-spring</td><td></td><td></td><td></td><td></td><td colspan="3">85%</td><td></td><td></td><td>800</td><td>5.4</td></tr>
<tr><td></td><td>Fast spring</td><td></td><td></td><td></td><td></td><td></td><td colspan="2">78%</td><td></td><td></td><td>600</td><td>5.4</td></tr>
<tr><td colspan="13">Canola</td></tr>
<tr><td>Delegate</td><td>Winter</td><td></td><td colspan="3">75%</td><td></td><td></td><td></td><td></td><td></td><td>680</td><td>4.2</td></tr>
<tr><td></td><td>Winter/Spring</td><td></td><td></td><td></td><td colspan="3">84%</td><td></td><td></td><td></td><td>400</td><td>4.2</td></tr>
<tr><td></td><td>Late-Spring</td><td></td><td></td><td></td><td></td><td colspan="3">88%</td><td></td><td></td><td>230</td><td>4.0</td></tr>
<tr><td></td><td>Mid-Spring</td><td></td><td></td><td></td><td></td><td colspan="2">62%</td><td></td><td></td><td></td><td>380</td><td>4.2</td></tr>
<tr><td>Young</td><td>Winter</td><td colspan="2">44%</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>1300</td><td>3.9</td></tr>
<tr><td></td><td>Winter/Spring</td><td></td><td colspan="3">65%</td><td></td><td></td><td></td><td></td><td></td><td>1360</td><td>3.9</td></tr>
<tr><td></td><td>Late-Spring</td><td></td><td></td><td></td><td colspan="3">80%</td><td></td><td></td><td></td><td>580</td><td>3.9</td></tr>
<tr><td></td><td>Mid-Spring</td><td></td><td></td><td></td><td colspan="3">80%</td><td></td><td></td><td></td><td>570</td><td>3.9</td></tr>
<tr><td>Quirindi</td><td>Winter</td><td colspan="2">27%</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>1580</td><td>3.9</td></tr>
<tr><td></td><td>Winter/Spring</td><td colspan="3">56%</td><td></td><td></td><td></td><td></td><td></td><td></td><td>1720</td><td>4.0</td></tr>
<tr><td></td><td>Late-Spring</td><td></td><td></td><td></td><td colspan="2">55%</td><td></td><td></td><td></td><td></td><td>800</td><td>3.9</td></tr>
<tr><td></td><td>Mid-Spring</td><td></td><td></td><td></td><td></td><td colspan="2">48%</td><td></td><td></td><td></td><td>560</td><td>3.9</td></tr>
</table>

Wheat: winter (e.g. Revenue⁽ᵇ⁾); Mid-winter (e.g. Wedgetail⁽ᵇ⁾); mid-spring (e.g. Gregory⁽ᵇ⁾); fast-spring (e.g. Suntop⁽ᵇ⁾)
Canola: winter (e.g. CB™Taurus); winter/spring (CBI406); late spring (46Y83); mid-spring (Hyola®50)

There are some obvious conclusions that can be drawn from these outcomes:

- Later maturing varieties should generally be sown earlier.
- Earlier sowing with later maturing varieties provides the greatest grazing potential across all sites.
- Maturity types sown in the optimum window differ little in potential grain yield, but greatly in grazing.
- In general wheat provides more grazing than canola.
- Sites vary in the frequency of early sowing opportunities for long-season types.
- Some warmer sites (e.g. Quirindi) are too mild to adequately vernalise winter types.
- Some varieties (e.g. Wedgetail⦶) have a wide sowing window to achieve the optimum flowering.

Note: These comparisons are for the standard common agronomy as specified in the Table and could be individually optimised according to specific seasons and circumstances (see later).

What about risk and variability?

Table 1 has useful comparisons for best options and average production at different sites, but do not provide an indication of the variability and risk associated with different options. In Figure 2 the variability in wheat and canola grain yield (left) and grazing (right) for different sowing times is shown for two maturity types of wheat (Wedgetail⦶ and Gregory⦶) and canola (CB™Taurus and Hyola®50)

The modelling outcomes in Figure 2 provide some indication of the variability in grazing and yield outcomes for the different options, rather than simply the mean result, and also show the impact of sowing outside the recommended windows suggested in Table 1. Some of the obvious outcomes are:

- Forage production is much less variable year-to-year than grain yield (i.e. smaller boxes).
- Forage production declines more rapidly with later sowing than grain yield.
- The impact of frost on early-sown (April), short-season crops (Gregory⦶, Hyola®50) is clear
- The impact of heat stress and shorter growth period in late-sown crops (especially canola) is also clear.
- The wide sowing window of maturing types like Wedgetail⦶ is clear, but later sowing is riskier.
- A switch from Wedgetail types to spring types like Gregory⦶ after early May is suggested.
- The yield of winter canola types like CB™Taurus becomes much more risky if sown after mid-April.
- A switch from winter type (Taurus type) to spring (Hyola50 type) canola is suggested early-April.

What about effects of nitrogen and crop density?

Rapid early biomass production is desirable for grazed crops to maximise forage production and aside from timely sowing, both N nutrition and plant density will influence forage production and grazing potential. In grain-only crops, where the canopy growth may need to be controlled to avoid excessive growth and water-use, the optimum density and starting soil N levels may be lower and topdressing a suitable strategy. These variables can be investigated using the model as shown for the wheat at Young (Figure 3).

Grazing from winter wheat types (Wedgetail⦶) sown early (150 pl/m^2) responded up to 150 kg N/ha starting N, and up to 100 kg N/ha for later-sown spring types (Gregory⦶). For canola (60 pl/m^2) the required levels were higher (250 kg N/ha for winter types and 150 kg/ha for spring types).

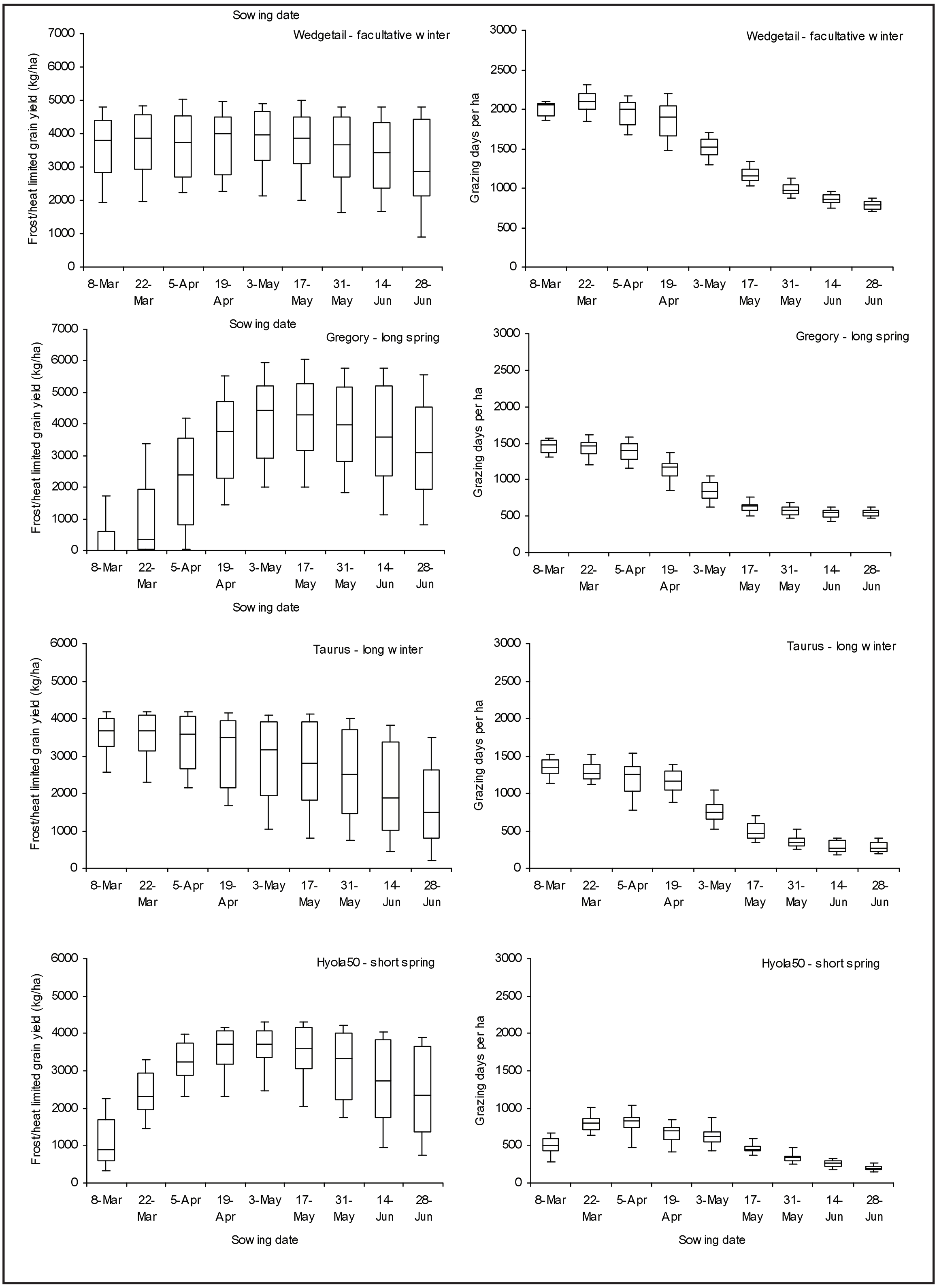


Figure 2. Effect of sowing date on predicted grain yield (left) and grazing (right) for wheat (upper graphs Wedgetail$^{(d)}$ and Gregory$^{(d)}$) and canola (lower graphs CB™Taurus and Hyola®50) at Young, NSW. Boxes show median, 25 and 75% outcome and whiskers 10% and 90%.

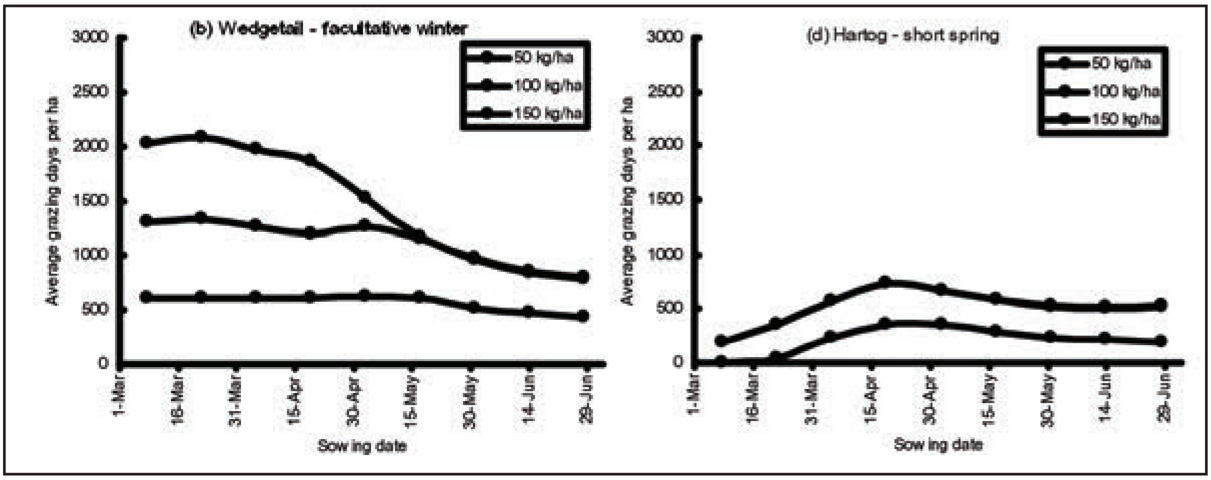


Figure 3. Effect of nitrogen availability at sowing on the average grazing days obtained from Wedgetail⁽ᶲ⁾ and Gregory⁽ᶲ⁾ wheat sown at different times at Young, NSW.

As far as crop density goes, the modelling analyses along with grower experience and experimental work suggests that there is little impact in wheat above 150 pl/m^2 with respect to grazing value and this is also a reasonable target for grain-only in medium and high rainfall zones. In canola, the use of more expensive and vigorous hybrid varieties may warrant a lower optimum than that suggested by modelling, and densities of 40-50 pl/m^2 are usually advised to optimise both grazing and grain outcomes, though grain-only crops perform well from lower populations.

What about in lower rainfall areas like Wagga?

In lower rainfall areas (e.g. Wagga), early sowing opportunities will be fewer, the season shorter and dry spring conditions likely to limit crop recovery; so how feasible are grazing crops? Dr Jeff McCormick used a combination of experiments and modelling to investigate the feasibility of grazing canola at a drier site like Wagga. Jeff realised that canola yield plateaus when the flowering biomass was ~ 5 t/ha and used this as a biomass target to guide crop and grazing management. He assumed 25 mm over three days was required for sowing; that optimum flowering for canola was around September 1; a grazing threshold of 1 t/ha (to commence) and lock-up time to ensure 5 t/ha at flowering.

His work showed; sowing would need to occur before May 15, which was possible in 53% of years, with 50% of those years providing grazing opportunities prior to June 7. Depending on stocking rate, crops could be grazed until early to mid-July providing 400-1000 DSE.days.ha-1 of grazing without compromising a target biomass threshold at flowering of 5000 kg.ha-1 to ensure maximum yield potential (in many years a lower threshold would be sufficient due to dry springs).

Figure 4 shows the predicted grazing options that maintain 5000 kg/ha at flowering (see where line on lower graph intersects with median) while maximising grazing potential (see arrows that show best options). These include 20 DSE/ha removed by 8 July, or 30 DSE/ha removed in 1 July, which both generate a potential range of 400-1000 DSE grazing days. Lower biomass thresholds could be considered if a lower yield target was acceptable, and this would mean that higher stocking rates and later removal times could be feasible. Grower experience and experiments have confirmed these predictions in the area since Jeff's work.

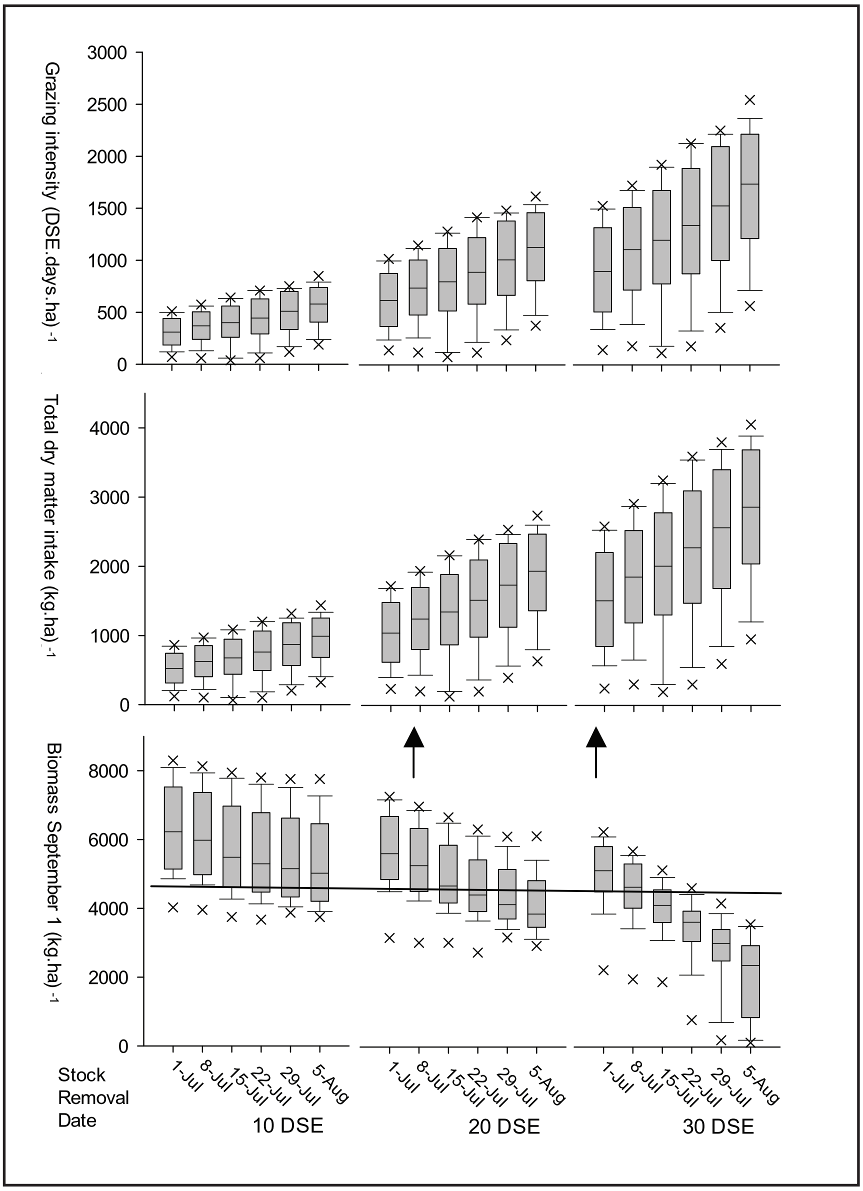


Figure 4. Grazing achieved (DSE. days/ha[1]) and biomass on September 1 for canola at Wagga (cv. 46Y78 at 60 pl/m^2 and 200 kg N/ha) assuming three different stocking rates for multiple stock removal dates. Box plots show range from 25-75th centile of the data with a median line marked, whiskers extend to 10-90th centile of simulations with outliers marking 5th and 95th centiles.

What about the economics at paddock and farm scale?

<u>If dual-purpose crops replace grain-only crops</u>

Until now we have focussed on avoiding yield loss by restricting the grazing to ensure yield is unaffected. In this case any grazing value becomes direct profit above the grain-only crop. However as the grazing has value, this can be traded-off against grain yield penalties and the degree of the trade-off depends upon the relative value of the livestock production vs grain. Bell et al. (2013) compiled all the published data on dual-purpose crops in Australia and by assuming different relative prices for grain and meat and examined the economic outcomes for those studies (Figure 5).

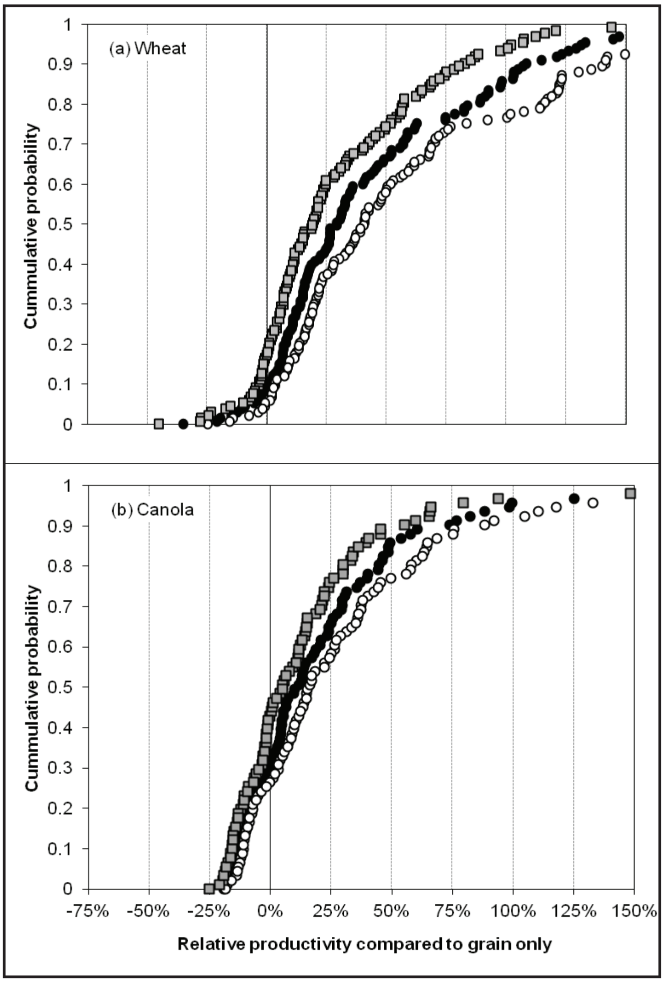


Figure 5. Summary of relative estimated returns from (a) grazed dual-purpose wheat (n = 134 experiments) and (b) canola (n=87 experiments) compared to grain only systems in Australian experiments. The impact of different price ratios of [$/kg liveweight] : [$/kg grain] on total returns are shown as hollow circles when prices for livestock:crop are relatively high (wheat-10:1, canola-5:1), filled circles when average (wheat-8:1, canola-4:1) and grey squares when low (wheat-6:1, canola-3:1). Livestock yield assumes feed conversion 0.17 kg LW/kg forage consumed.

In wheat, combined returns from both grain and grazing were usually higher than from grain production only; with <10% of cases of grazing causing reduced total crop returns, a median increase of 25%, and in a third of cases >75% increase. The relative prices between wheat and livestock had little impact on the frequency that dual-purpose grazing was more profitable; even under low livestock-wheat price ratio, only 17% of years had lower returns than grain only. Grazing canola reduced returns in 25% of cases as canola typically provides less grazing for livestock than cereals, is more sensitive to grazing and has higher grain value. Thus greater attention to grazing management is required to avoid the higher risks of economic loss due to grazing.

<u>If dual-purpose crops replace perennial pasture in high rainfall zones?</u>

We conducted a systems experiment near Canberra (2009-11) to investigate the value of integrating dual-purpose wheat and canola crops onto a livestock farm where it replaced perennial pasture. The experiment used large replicated 0.23ha plots to measure forage and grain yield of the crops, sheep live-weight gains as well as the spelling advantage for pasture production while the crops were grazed (see CSIRO website). The 2010 and 2011 years provided contrasting conditions; early-sowing, warm winter and good spring (2010) and late sown, cold winter and dry spring(2012). We used the data arising from the study to scale up to *whole-farm production and economics* given the crop area displaces pasture that would otherwise provide year-round grazing. We assumed the average of the contrasting 2010 and 2011 seasons provided a reasonable mean outcome. The value of dual-purpose wheat, dual-purpose canola and a combination of both crops to farm returns was estimated, taking into account the different livestock and grain production.

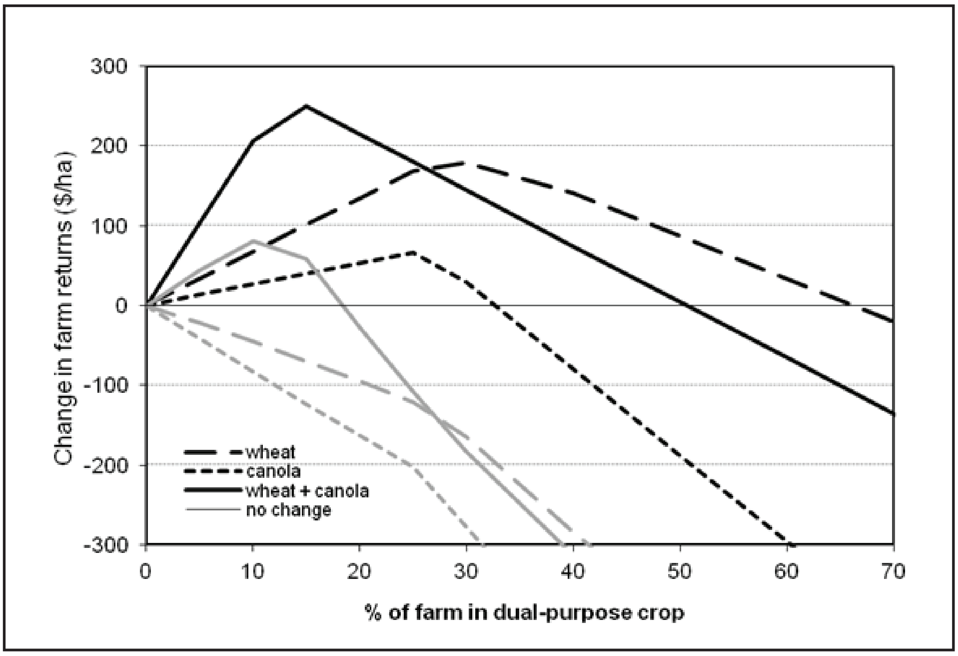


Figure 6. Predicted change in farm economic returns ($/farm ha) with increasing area of the farm removed from permanent pasture and sown to dual-purpose crops (wheat only=dash; canola only= dots; 1:1 wheat-canola grazed in sequence=solid). Black includes pasture spelling benefit, grey excludes pasture spelling benefit. Data sourced Canberra experiment 2010 and 2011, and typical costs and prices were assumed. (Note for the purpose of the exercise the entire farm was considered arable, which is unlikely in reality).

The results suggest that:

- Accounting for the pasture spelling benefit significantly improves predicted returns,
- farm returns were optimised when ~15% of the farm is sown to dual-purpose wheat and canola,
- increase in return is less from individual crops at up to 20-30% of farm area,
- grazed wheat provides greater returns than canola - more grazing from forage and stubble,
- returns decline at higher crop area due to the 'crop penalty' - cropped area cannot be grazed for much of the year and summer pasture supply and summer stocking rate limits production,
- the absolute value of the benefit depends on many assumptions all of which can be debated; and
- two growers in the area who 'laugh-tested' the data report benefits of around $100 per farm ha.

Note: the example deals with the biophysical constraints only; those related to labour, infrastructure and cropping expertise essential for transitions from livestock to cropping need consideration.

Insights from recent experiments and experience

Models help expand our understanding of the best fit for dual-purpose crops but ongoing experiments and experience are essential to improve our advice. Recent results from our main site at Greenethorpe in 2013 are summarised below.

Refining phenology-based grazing rules

Current guidelines for grazing stress the importance of locking-up before Z30 in cereals and before buds elongate>10cm in canola to avoid significant yield loss. Recent experience especially with grazing cereals in shorter-season areas suggests that grazing can cause yield penalties even when locked up by these dates, IF heavy grazing leaves insufficient biomass for recovery. But how much biomass is enough?

At Iandra near Greenethorpe in 2013, we sowed a range of different wheat and canola varieties on different dates to hit their optimum flowering window. We grazed or defoliated at different times and intensities to measure effects of residual biomass on yield recovery. A summary is shown next page.

Table 2. Effect of timing and severity of cutting/grazing on forage and grain yield (+ std err) of wheat and canola varieties at Iandra in 2013. Residual biomass immediately after cutting/grazing is shown

Crop and variety	Treatment	Date/s cut (lock-up)	Biomass Removed (t/ha)	Residual Biomass (t/ha)	Grain yield (SE) (t/ha)
Wheat					
Wedgetail (sow 25/3)	Uncut	Uncut	None		4.7 (0.3)
	Z30 Hard	2 July	2.6	1.1	4.4 (0.2)
	Z30 Graze	4-6 July	2.6	1.7	4.5 (0.4)
	Triple cut	23/4;19/6;15/7	3.0	0.2	3.4 (0.1)
	Z32 Hard	15 July	4.1	0.6	3.5 (0.1)
Bolac (sow 23/4)	Uncut	Uncut	None		5.0 (0.2)
	Z30 Hard	15 July	0.8	0.3	4.3 (0.2)
Gregory (sow 8/5)	Uncut	Uncut	None		4.1 (0.2)
	Z14	2 July	0.3	0.1	4.0 (0.4)
	Z30 Hard	15 July	0.4	0.2	4.0 (0.1)
	Z30 Graze	17-20 July	0.4	0.2	3.8 (0.1)
	Z32 Hard	30 July	1.2	0.4	3.7 (0.1)
Canola					
Hyola971CL (sow 25/3)	Uncut	Uncut (July)	None		2.8 (0.2)
	6-8 lf	7 May	0.9	0.4	2.9 (0.2)
	6-8 lf + Aug	7 May, 6 Aug	3.7	3.6	2.8 (0.1)
	Grazed	4-6 July	5.6	0.4	2.0 (0.1)
Hyola575CL (sow 23/4)	Uncut	Uncut	None		2.8 (0.2)
	6-8 lf Hard	17 July	0.7	0.2	2.6 (0.1)
	BV Hard	24 July	0.7	0.6	2.3 (0.1)
	SE Hard	30 July	1.4	0.7	2.0 (0.1)
	Grazed	25-27 July	0.9	0.2	2.1 (0.1)

Elevated site with little frost; red gradational loam; spray-fallowed lucerne pasture

23 cm row spacing; 270mm GSR (A-O) and 88mm in March; Soil test pre-sowing 200 kg N/ha

'Hard' cut was to 5cm height in wheat and 8cm height in canola

A few observations from these results (and further analysis was underway at time of writing):

- Generally canola has performed very well compared with the wheat despite the relatively dry spring, yielding around 60% of wheat yield.

- In un-grazed (grain-only) treatments the early-sown, slower-maturing varieties of wheat and canola performed as well or better than later-sown, faster-maturing varieties demonstrating the potential for high yields for early sown crops targeting optimum flowering windows (see Hunt article in this booklet).
- The earlier sown crops provided much more biomass for grazing/cutting in the safe windows (for wheat: Wedgetail⁽ᵗʰ⁾ 2.6 t/ha, Bolac⁽ᵗʰ⁾ 0.8 t/ha, Gregory⁽ᵗʰ⁾ 0.4; for canola: Hyola®971CL 3.7 t/ha, Hyola®575CL 0.7 t/ha).
- Grazing late in the unsafe window (i.e. Z32 or SE in canola) resulted in significant yield penalties as expected, but so too did leaving too little biomass *even in the 'safe' windows.* For example the Triple cut in Wedgetail⁽ᵗʰ⁾ was at Z30 but too little biomass remained, and BV Hard and Grazed in Hyola®575CL were also 'safe' but suffered yield penalties.
- The trade-off for late grazing in Wedgetail⁽ᵗʰ⁾ (Z32) compared to grazing safe (Z30) was to gain 1.5 t/ha of forage, but lose 1 t/ha of grain. In Gregory⁽ᵗʰ⁾ the trade-off was 0.8 t/ha forage gain for 0.3 t/ha yield loss. In canola the same effects were obvious; winter canola 1.9 t/ha extra forage for 0.8 t/ha grain loss and spring canola 0.7 extra forage for 0.6 grain loss.

Refining the phenology-based grazing rules with estimates of required residual biomass to avoid yield loss is the goal of ongoing work.

References

http://www.csiro.au/Organisation-Structure/Divisions/Plant-Industry/HRZ-dp-crops.aspx

http://www.grdc.com.au/uploads/documents/GRDC_Dual-PurposeCrops.pdf

www.farmlink.com.au/LiteratureRetrieve.aspx?ID=145498

Bell L et al. (2013) http://dx.doi.org/10.1016/j.eja.2013.04.007

Kirkegaard JA et al. (2012) Refining crop and livestock management for dual-purpose spring canola. *Crop and Pasture Science* **63**, 429-443.

Sprague SJ et al. (2014) Crop and livestock production for dual-purpose winter canola in high rainfall zone of south-eastern Australia. *Field Crops Research* **156**, 30-39.

McCormick JI et al. (2012) Growth, recovery and yield of dual-purpose canola (Brassica napus) in the medium-rainfall zone of south-eastern Australia. *Crop and Pasture Science* **63**, 635-646

Contact details

John Kirkegaard

GPO Box 1600, Canberra ACT 2601

0262465080

John.kirkegaard@csiro.au

Notes

To windrow or not to windrow in 2014? This is the question, but if so, when?

Maurie Street,
Grain Orana Alliance

GRDC project code: GOA00001

Keywords

canola, windrowing, windrow, swathe, timing, direct head, shattering, yield loss, harvesting loss, desiccation, Pod Ceal™

Take home messages

- **Windrowing timing within an acceptable window has no impact on oil% in canola.**
- **Windrowing timing can have a significant positive impact on yield and profitability of canola.**
- **Yield increases up to 0.5t/ha have been seen over relatively short delays in windrowing of only eight days.**
- **Yield loss to shattering with later windrowing has not shown to be as bad as first thought, particularly in contrast to negative yield impacts for going too early.**
- **Windrowing timing has a limited effect on oil potential in canola.**
- **Direct heading is a viable option to harvest canola and in many cases could maximise profitability.**
- **An economic benefit of over $200/ha can be gained from choosing the best method and timing of canola harvesting.**

Background

Local focus group meetings of winter 2009 highlighted an interest in validating current recommendations for ideal windrowing times in canola, particularly in the central west of NSW. One common understanding of the impact of timing was simply that windrowing too early may only reduce oil contents and by windrowing later, yield may be lost through excessive pod shelling and shattering. Fear of the more tangible and costly loss in pod shattering had seen many paddocks being windrowed much earlier than recommended.

Grain Orana Alliance (GOA) ran multiple trials in 2009, 2010 and 2011 to examine the impact of windrowing timing on oil, yields and profitability as well as the alternate option of direct heading. One of the first trials undertaken at Coonamble in 2009 also investigated the impact on yield and oil when the crop was direct headed using pre harvest treatments with Pod Ceal™ and desiccation with Reglone™.

Methods

All trial sites were large scale replicated trials applied to commercial, farmer sown paddocks of canola. All windrowing and harvesting was carried out by commercial windrowers (25-40ft swathe) and headers (25-40ft).

This methodology was chosen as it best explores the impact on yield in a full-scale context. Potential for pod shattering during the windrowing operation is a key influence over final yield and could not be duplicated in small scale trial work.

Pod shattering was quantitatively assessed at a number of the sites through catch trays. The methods used for this need further refinement to accurately represent the situation, and therefore, these details are not included in this report. It should be noted though that any yield loss through shattering is accounted for by a reduction of the final harvested yield. It is harvested yield that drives profitability regardless of shattering at any level.

Windrow timings are described as % colour change (CC), this refers to the percentage of seeds that have started to change colour in the **middle third of the main stem** of the canola plant. To determine this, 30 pods were sampled from the treatment areas, shelled out and visually assessed for colour change. This was completed three times for each replicate/plot. Once the level of CC was established the relevant treatment area was windrowed.

All windrowing timings and direct headed treatments were harvested at the same time when all treatments were considered to be ripe enough to harvest. Yields of the whole treatment area were measured with mobile weigh bins with the exception of Nyngan which was weighed over a weighbridge. Grain qualities were assessed by commercial service providers using standard testing procedures.

Yields and grain qualities were assessed by ANOVA using Statistix 9 software at a 95% confidence level.

Coonamble 2009

Treatments included windrowing at three timings: 10%, 50% and 70% CC, a Reglone™ (Reg) treatment at label recommendations (2.25L/ha) which was then direct headed, Pod Ceal™ (PC) at label recommendations (1L/ha) which was also direct headed and the final treatment which was direct headed with no other treatments. Sprayed treatments were applied by ground but harvested areas did not include wheel track areas.

Dubbo 2009

Three timings were applied in this trial 10%, 50% and 70% colour change.

Warren (Site 1) 2010

Four timings of windrowing were applied at this site, 5%, 40%, 70% and 95% colour change.

Nyngan 2010

Rain prevented the first timing of windrowing to be completed on time so only two timings at 60% and 90% CC were applied at this site.

Warren (Site 2) 2010

Three timings were applied in this trial, 5%, 60% and 95%.

Nyngan 2011

Three timings were applied at 10%, 50% and 90%.

Warren 2011

This trial compared a single windrowing timing at 85% colour change to direct heading with a draper header front fitted with a finger reel and top auger.

Wongarbon 2011

This trial compared single windrow timing at 95% colour change and direct heading with a conventional "tin front" and a Draper front with a finger reel. A different header was used for the harvesting with a Draper front than was used for the other two treatments. The header used for the windrow and conventional treatments maintained the same separator settings for both treatments.

Wellington 2011

This trial compared two windrow timings of 90% CC another timing 6 days later (++100%) and direct heading with a draper front fitted with a finger reel. The same header was used for both harvesting treatments with the same separator settings.

Results

Coonamble 2009

- W1, the earliest timing was the lowest yielding treatment of the three timings.
- Each of the three windrow timings are significantly different and increased as windrowing was delayed.
- The yields between direct headed (no other treatment), Pod Ceal™, desiccation with Reglone™ and W3 were not significantly different and were the highest yielding treatments.
- Desiccation with Reglone™ and W2 were not significantly different.
- There was no significant impact upon oil% for any windrow timing or direct heading treatment.

Dubbo 2009

- W1 was the lowest yielding treatment.
- W3 was the highest yield treatment but was not significantly different to W2.
- There was no significant impact on oil% to any timing.

Warren 2010 (Site 1)

- W1 timing was the lowest yielding treatment.
- The other three timing were not significantly different to each other but there was a trend to higher yields with delays past W1 to W3.
- Windrowing later than W3, decreased yields but only slightly and the difference was not significant.
- There was no significant impact on oil% to any treatment.

Nyngan 2010- no graph shown

- From a delay in windrow timing from 60% to 90% there was no significant difference in yield or oil%.

Warren 2010 (Site 2) - no graph shown

- There was no significant impact on yield or oil at this site.

Nyngan 2011

- W1 was the lowest yielding treatment.
- W2 and W3 were not significantly different but yielded significantly more than W1.
- There was a significant response in oil% with W2 and W3 achieving higher oil than W1.

Warren 2011 (no graph)

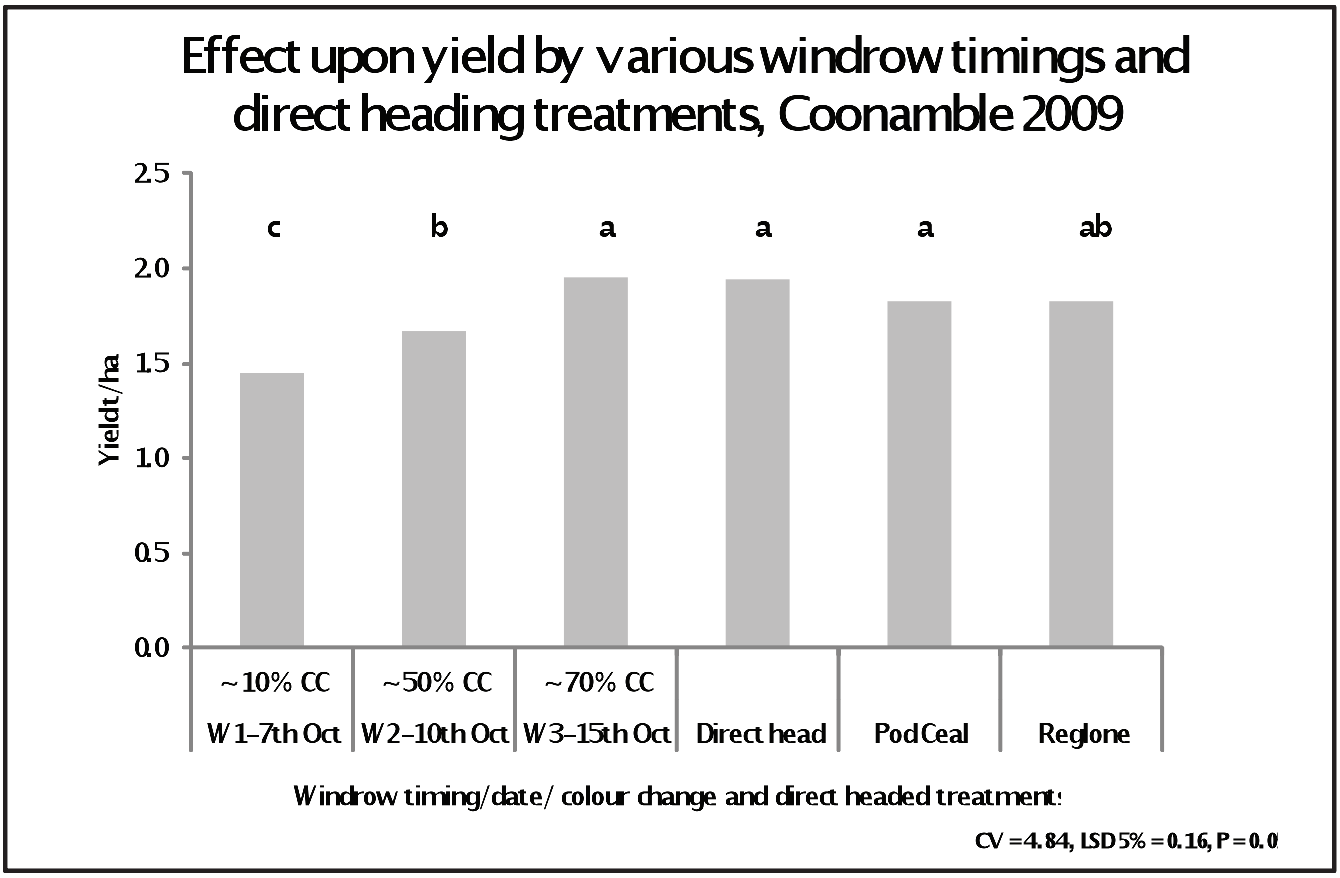
- There was no significant difference in yield between windrowing at 85% colour change and direct heading.
- There was no impact on oil%.

Wongarbon 2011

- It should be noted that the trial area experienced a heavy wind storm (>50km/hr) between windrowing and direct heading. This shattered an amount of the standing treatments. The windrows were relatively unaffected.
- Two separate headers were used for the two direct heading treatments and it could not be guaranteed their separator configurations were the same.
- Neither style of header front was significantly different to the windrow timing of 95% for yield.
- The conventional header performed worse than the draper front however it must be noted that there were issues with the reel of the conventional front going too fast for harvesting speed.

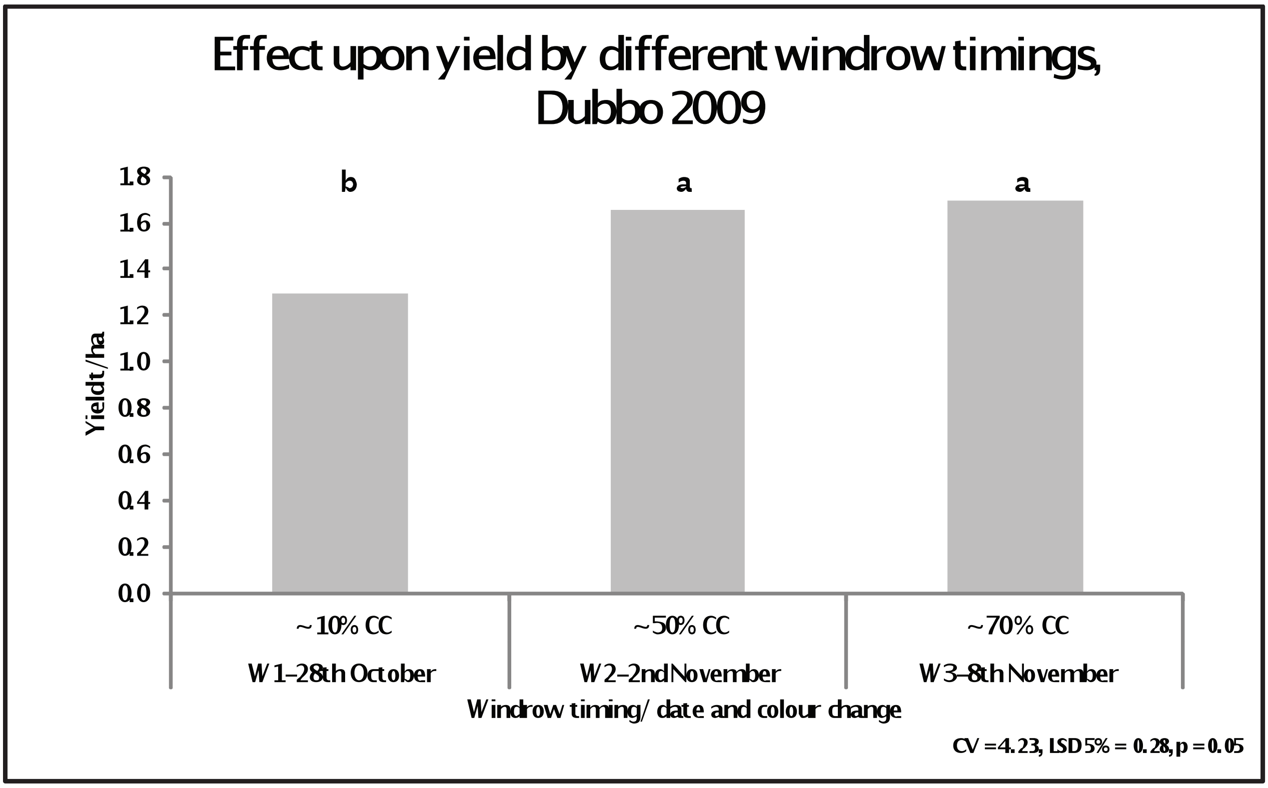
Wellington 2011

- Direct heading with a draper front was no different than windrowing at 90%.
- Windrowing at the later timing (+100%) yielded ~250 kg/ha lower than W1 at 90% CC or direct heading.
- There was no impact on oil% by any treatment.



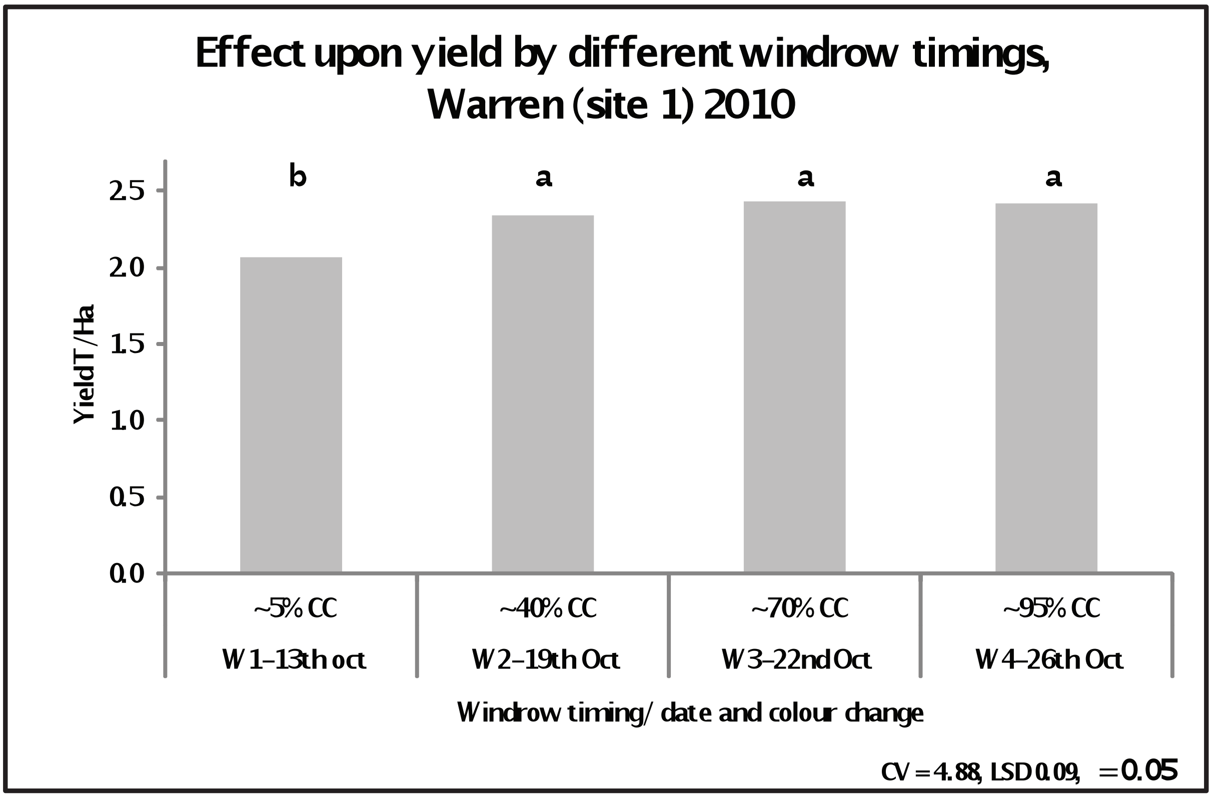
Treatments headed by the same letter denotes no significant difference

Figure 1. Canola yield for direct harvest, PodCealTM, RegloneTM and windrow treatment timings at Coonamble.



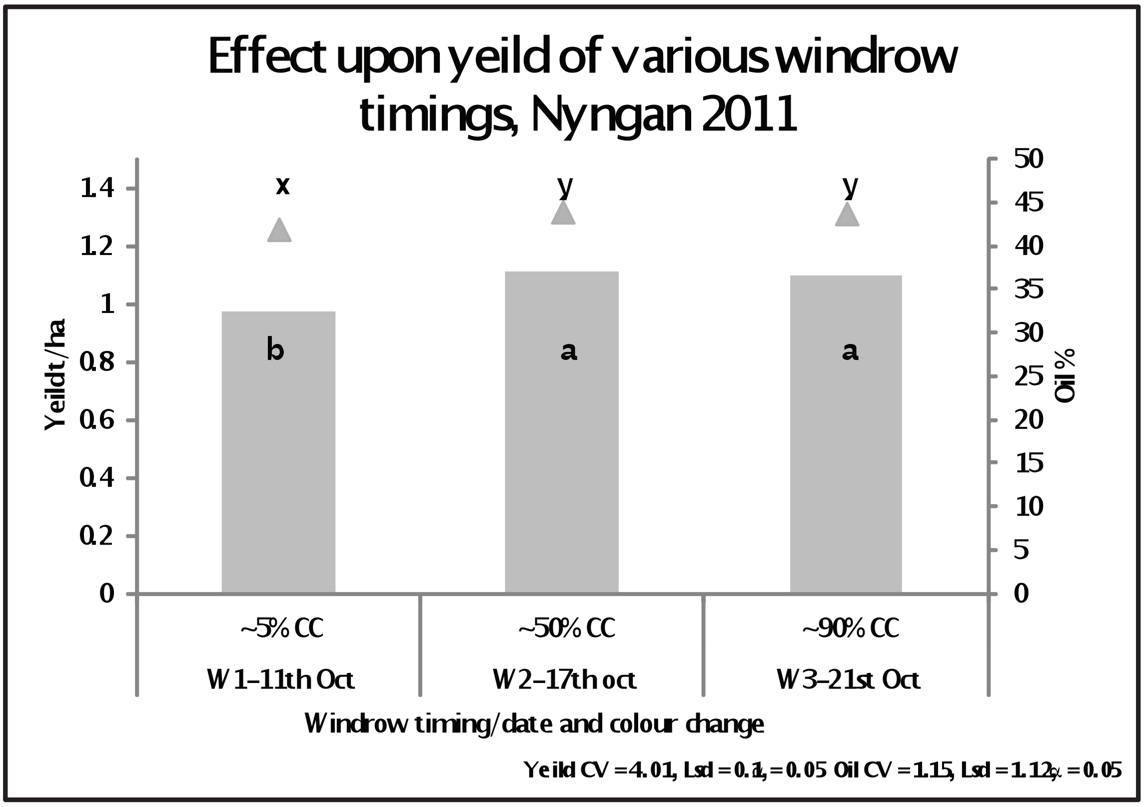
Treatments headed by the same letter denotes no significant difference

Figure 2. Canola yield for the three windrow treatment timings at Dubbo.



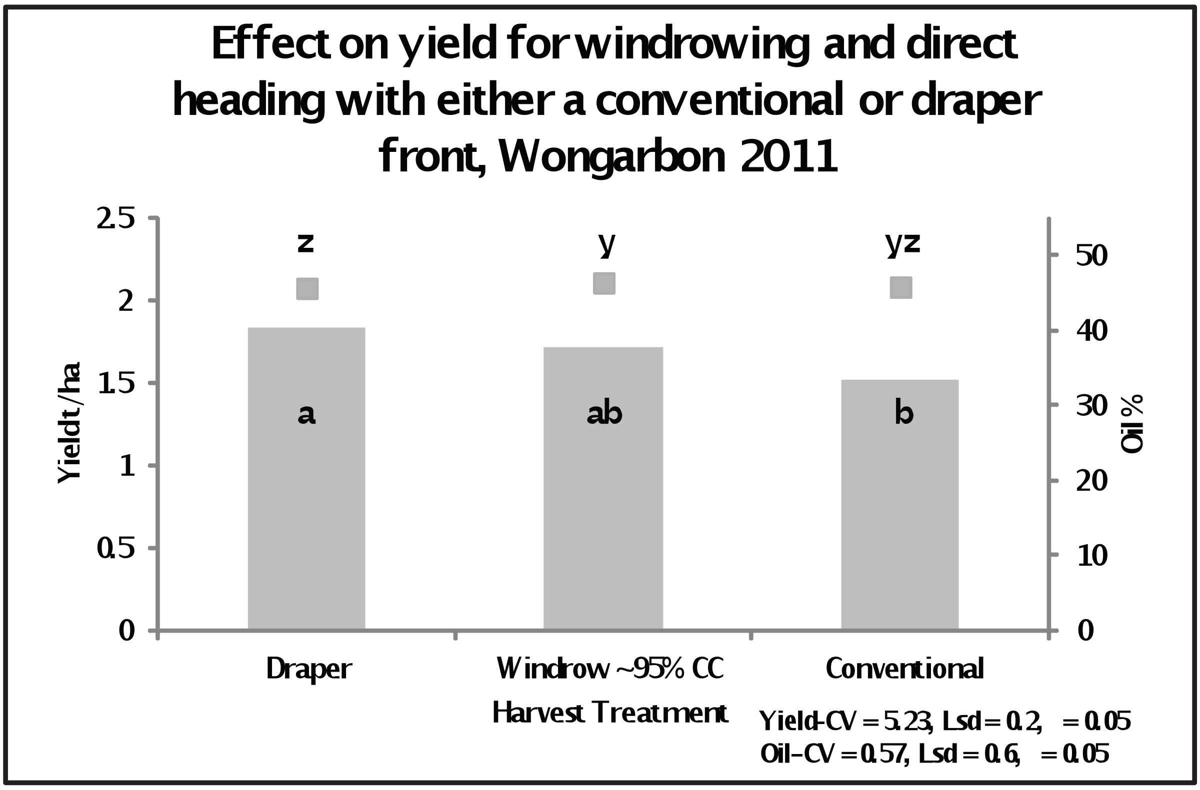
Treatments headed by the same letter denotes no significant difference

Figure 3. Canola yield for the four windrow treatment timings at Warren 2010.



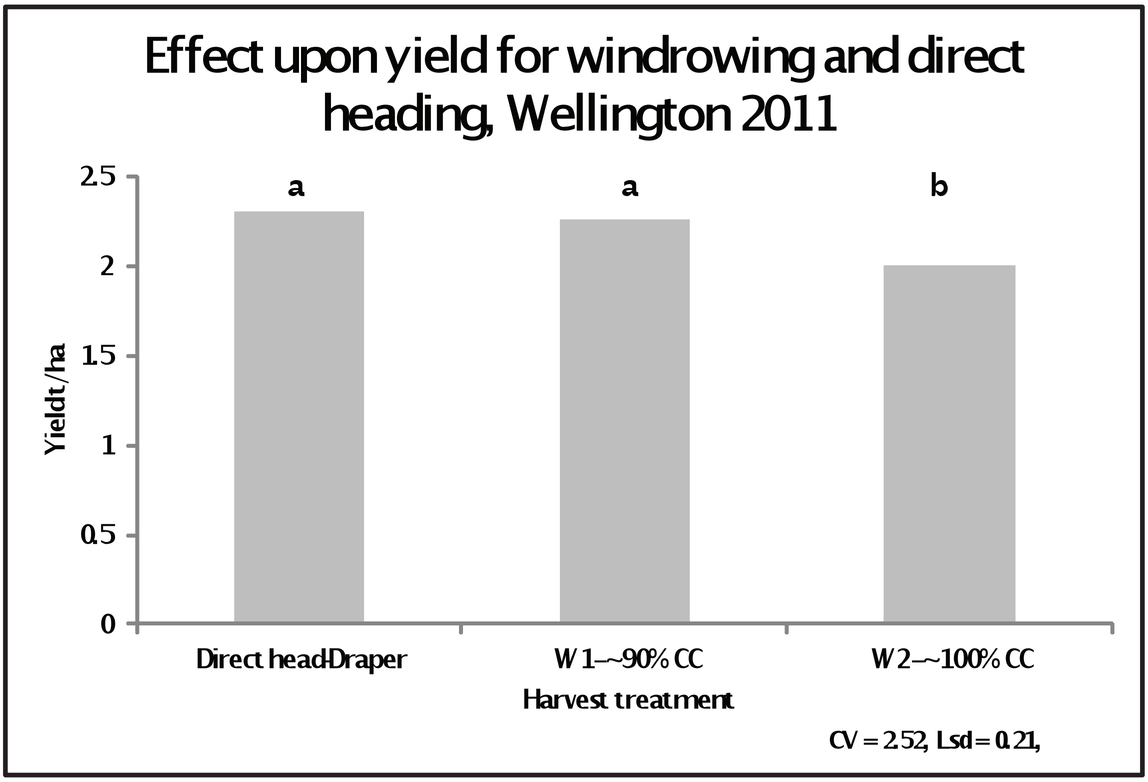
Treatments headed by the same letter denotes no significant difference

Figure 4. Canola yield for the three windrow treatment timings at Nyngan 2011.



Treatments headed by the same letter denotes no significant difference

Figure 5. Canola yield and oil% as a result of various harvest methods, Wongarbon 2011.



Treatments headed by the same letter denotes no significant difference

Figure 6. Canola yield as a result of various harvest methods and two different windrowing timings, Wellington 2011.

Discussion

Yield

Across the three seasons and a number of sites, early windrowing around 5-10% colour change has consistently resulted in lower yields than later windrow timings. However windrowing past the currently recommended 40-60% colour change has not always resulted in further significant yield increases. It could be said that there often is a consistent trend to increase yields past these timings, with trends to decline yields slightly only at 90-95% but not statistically or commercially significant levels. However increases in yield over a similar range have been sometimes quite significant. At Coonamble a ~250 kg/ha yield improvement was realised in only a five day delay in windrowing from a 50% to 70% CC timing.

This is best explained by considering the process of windrowing whereby the plant's growth is ceased at time of cutting when part of the crop, including seeds, are still green and growing. Once cut, key processes within the plant cease and seed will simply start to dry down regardless of their level of maturity and grain weight. This directly prevents any further growth or grain fill of green seeds; those that have not yet reached maturity, and therefore, prevents any further yield accumulation that would have occurred otherwise.

Seed maturity, when seed will no longer increase in size, can be indicated by colour change in the seed and windrowing timing is based on only a percentage of the seed within the crop having changed colour. So at the lower end of current recommended timings of 40% CC there is up to 60% of seed that is green, immature and still filling. Therefore the earlier the windrowing timing the greater the proportion of seed that will not fill to its maximum potential. Therefore delaying any action that has the potential to cease grain fill will see more seeds achieve their maximum size and hence improve yield.

Two recent small plot replicated trials run by Kathi Hertel from NSW DPI supports this theory that seed growth continues up to the point of seed physiological maturity as indicated by colour change. This worked showed that mean 1000 grain weight of the seed on the **main stem** reaches its maximum at 77% CC at the Gilgandra site and 47% CC at the Wellington site (Hertel, 2012). When seed was sampled at earlier timings than this, it had reduced size which would lead to reduced crop yields.

This potential maximisation of yield must be weighed against the risks associated with delaying windrowing or delaying to direct head. As the crop passes through the physiological mature stage and starts to dry down, the brittleness of the crop and pods increase. This exposes pods to potential shattering or splitting which would result in yield loss when the crop is either standing; before or during windrowing. The ideal windrowing stage therefore should be a balance between maximising the grown yield and not losing this increase in yield through excessive pre windrowing or windrowing losses.

The question that should be asked then is how much of an issue is pod shattering, and when does this start occurring? Current recommendations and industry commentary often suggest that yield will decline through pod shattering, and the risk of this increases substantially as maturity progresses past 60% CC towards 100% CC. However this has not been demonstrated in our trial work with delayed windrowing timing as detailed below;

- Warren in 2010 (site 1) demonstrated no decrease in yields between windrowing at 70% or 95% CC.
- Nyngan in 2010, delays from 60% to 90% CC showed no decrease in yields.
- Warren 2010 (site 2) showed no decrease yield by delaying from 60% to 95% CC.

In addition to this yield data, combinations of both quantitative and visual measurements of shattering at windrowing were made following each windrowing timing at most sites. In summary there was no 'concerning' level of seed loss observed at any trial or timing, correlating well with the yield data.

However at Wellington in 2011 due to bad weather, the first of two windrowing timings were already late at 90% CC. The second timing which was well in excess of 100% CC was very late and resulted in a decrease in yield of 0.25t/ha or ~11% which was statistically significant. **It must be remembered that this second timing was potentially 7 days later than an already late timing so is an extreme example.**

In summary, yield loss as a result of delayed windrowing timing, assumedly through shattering, has not been demonstrated except in one extreme case with very late timings and colour change in excess of 100%. The belief that significant losses occur when windrowing is delayed past 60% up to ~90% CC is not supported by this data.

When considering the comparisons above also note that if any shattering was to occur it would have been most likely to occur at the late end of the range mentioned i.e. closer to 95% CC. Yields may have actually increased later than the 60% timing before declining, therefore the point of maximum yield could be in some cases above 60% CC. This has been demonstrated at both Coonamble and Gilgandra where measured yield or grain size was maximised at 70% and 77% CC, respectively.

Given that windrowing has the potential to reduce yields because it is done before all seed has matured, does direct heading have potential to capture higher yields? Four trials have shown that yields from direct headed situations have generally only matched the yields of a **well-timed** windrowing (~70-80% CC). However if compared to currently recommended windrowing timing of 40-60% or earlier as can be seen at Coonamble in 2009, direct heading has outperformed the windrowing.

In the case of two different styles of header fronts being tested (Wongarbon trial site), the results could be best treated as inconclusive. Problems with reel speed on the conventional front and pod shatter due to weather in direct heading treatments pre harvest may have compromised the results. However despite these two negative impacts neither header front style outperformed the windrowing at 95% CC.

In considering whether to windrow or direct head canola, the Coonamble result further demonstrates an interesting point. This work has shown that windrowing timing can a have a significant impact on yield over very short periods. In this situation windrowing five days earlier than optimum, has led to yield being penalised by ~250kg/ha, demonstrating a potentially small window to windrow. The question is, if timing delays for a direct headed crop will realise a similar level of impact?

Trial work was undertaken by GOA in 2013 investigating the yield impacts through delayed direct heading of canola. This trial demonstrated that the impact of delaying direct heading in canola caused a much smaller consequence than that in windrowing timing.

There are a number of new products in the market place promoted to manage potential shattering. If successful they could address one of the key concerns growers have with direct heading of canola. One such product is Pod Ceal™ which was trialled at the Coonamble site. Pod Ceal™ aims to minimise pod shatter through a coating applied over the pod. In this trial, treatment with Pod Ceal™ was not statistically different to either direct headed after desiccation with Reglone™ or direct headed with no other treatment. However this site in all treatments had minimal shattering problems. If the site experienced conditions supporting greater shattering the advantages of such a product could well be justified. But again, how big is the issue of shattering?

Oil levels

The potential for harvest management of canola through such things as windrowing timing or direct heading has shown to have a very limited impact on oil%. Very few trials have shown any significant differences in oil % due to windrowing timing or direct heading within an acceptable window, as discussed above. Of the trials that have resulted in significant differences in oil %, the magnitude has been small, often less than 1%.

Oil accumulation in canola starts early after fertilisation but often slows substantially as the seed starts to approach the later stages of development. By the time the crop reaches maturities for windrowing, accumulation has all but ceased.

Relative performance of an individual crop in terms of oil % should not be taken as an indication of ideal windrow timing.

Assessing crop maturity- is there a better way?

Assessing crop maturity to identify the optimum windrowing timing is not well understood or consistent with either growers or advisers (Hertel, 2012). There are many conflicting perceptions of what colour change is and what part of the plant to assess as well as simply what is the ideal windrowing timing, the latter hopefully clearer after reading this paper.

Currently recommended industry practice assesses crop maturity on the main stem only. However it is worth noting that pods from other parts of the plant contribute to the overall yield potential. Changes in farming practice with reduced sowing rates and established plant populations is resulting in proportionally more grain being carried on podding sites other than the main stem measured in the aforementioned research. One mathematically calculated estimate is that as little as 15% of yield may be carried on the main stem (i.e. Yield 2000kg/ha = 200g/m^2 /15 plants/m^2 = 13 g/pl. Main stem seed weight = ~30pods * ~20 seed/pod = 600 seeds * 0.003g/seed = 2gm. Main stem seed weight to whole plant 2g/13g = 0.15).

Given that seed on the secondary and tertiary branches will be less mature than that on the main stem, the maturity for the whole crop would be later than what is estimated by the main stem. That is, current assessment methods have the potential to overestimate the overall crop maturity, but the magnitude of these inaccuracies will vary with plant populations.

Assuming the relationship between colour change in the main stem seed and seed weight detailed by Hertel (2012) was transferable to the whole plant; assessing canola maturity based on colour change over the whole plant could be a better estimate of crop maturity? This method would also have the benefit of making allowances for changing plant populations.

This method of assessment would however require further testing and calibration in the field before adoption, but the concept is worth considering.

What is it all worth?

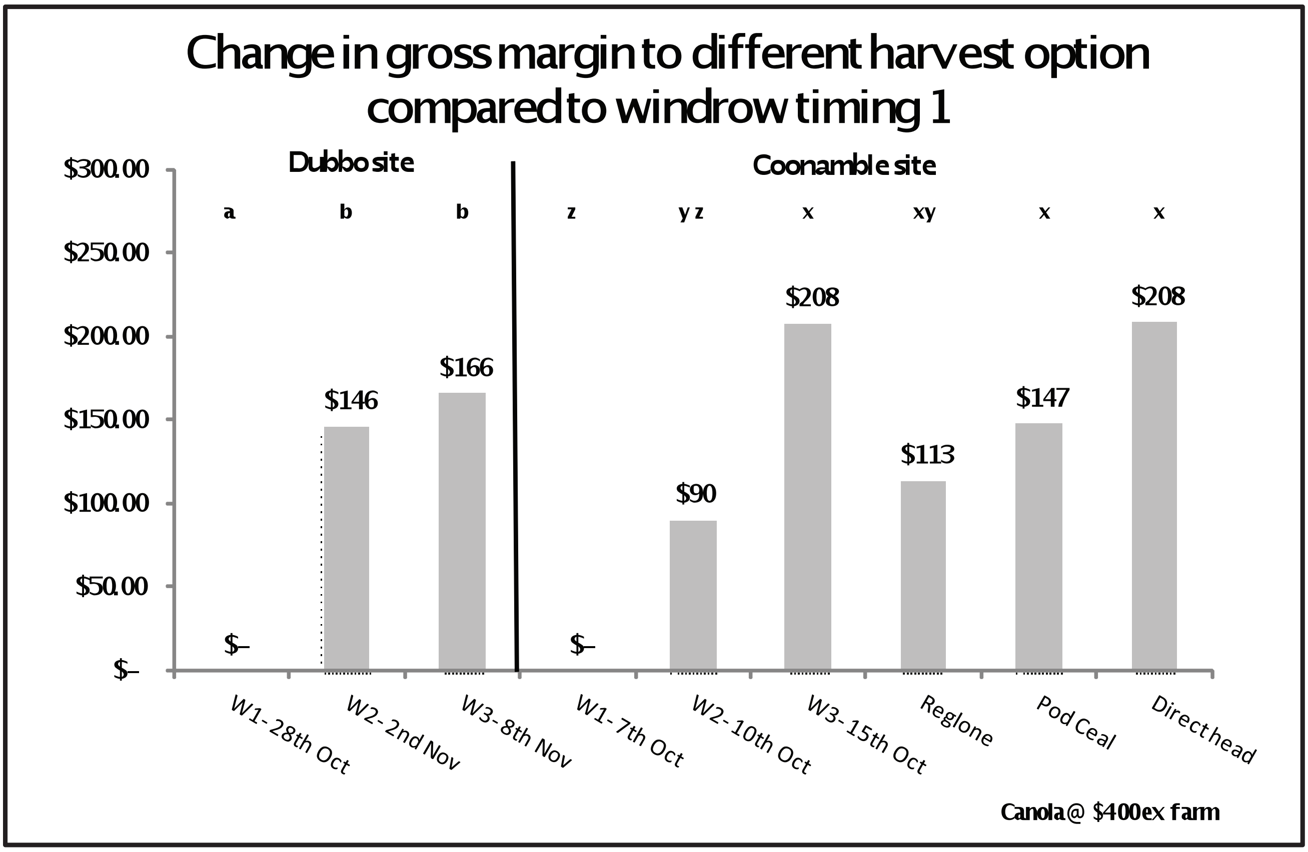
In terms of manipulating windrowing timing to target higher yields it should be remembered that if there is no change in costs but simply a delay in time, any increase in yield is 100% profit. And the improvement in profit can be substantial, as demonstrated in Figure 7; with an extra $208/ha increase by delaying windrowing timing for only eight days at Coonamble.

Work by Hertel (2012) suggested that yield increases through delayed windrowing can be up to $50/ day at their peak.

However, comparing windrowing to direct heading can be more complicated. There are obvious savings in windrowing costs when direct heading, but the rate of harvesting windrows to direct headed crops can vary. Key considerations may include the width of the windrower swathe compared to that of the header front when direct heading but also the potential shortening of daily harvesting hours in extreme conditions when direct heading. Recently published was a Harvest Module in the Canola Technology Update 2012 which provides a lot of data and information to help compare the two harvesting options for your own circumstance.

This resource can be accessed at; http://www.australianoilseeds.com/__data/assets/pdf_file/0016/9142/MODULE_7_-_Harvest_Management_Kathi_Hertel_-_V2_Sep_2012.pdf

However many comparisons often suggest there is little difference in harvesting costs for direct headed crops and those that are windrowed may have a slight cost advantage over direct heading. This is demonstrated in Figure 7 which shows similar impacts on gross margins between a well-timed windrowing and direct heading.



Treatments headed by the same letter denotes no significant yield difference (α=0.05)

Figure 7. Relative cost / profit difference of different harvest options to W1 at the Dubbo and Coonamble canola harvest trials.

Figure 7 depicts the benefits for the average of all the treatments, taking into account average yields and additional costs as well as oil penalties/bonuses from Dubbo and Coonamble in 2009.

Therefore the choice on harvesting methods may depend more on other positive and negative aspects of each method rather than that of the direct economics. These aspects are covered well in the publication mentioned above. But it is clear that windrowing timing can have a substantial impact on profitability of growing canola.

Conclusion

From these trials it could be concluded that windrowing timing has a limited effect on oil percentages in canola.

Windrowing earlier than the current recommended timings has always resulted in a significant reduction in yields which could seriously challenge profitability of crops in some situations.

The findings from these trials suggest that striving to meet the **upper end** of the current recommended windrowing timings is important (40-60% CC) and should be targeted as a **minimum** as significant yield penalties have been demonstrated consistently if cutting earlier than these levels. However there have been trials such as at Coonamble in 2010 and Gilgandra in 2011 that have clearly demonstrated that delaying past these times have shown to further improve yields. In all of GOA's trials the trends in yields have continued to increase up to 90+% CC.

One major concern with such a practice is the risk of shattering before or during windrowing when timings are delayed. These trials have demonstrated no yield penalty from delays in windrowing except in an extreme case. Therefore this fact infers that the magnitude of the shattering is small and statistically insignificant against any potential yield gains over the same period.

In the decision to delay windrowing later than 60% CC, growers and advisers should consider that each season or indeed each paddock could be different. Firstly growers and advisers should consider the crops current growing conditions. If the crop is experiencing terminal moisture stress delays beyond 60% it may not be warranted but if moisture is still available, even if limited, consider the findings of this work;

- Windrowing later than current recommendations may or may not result in increased yields, but in some cases they have; and
- windrowing up to 90% colour change has not demonstrated any significant yield decline.

So if there is a potential for improved yields with delaying till later with little downside risk, why not delay windrowing? Also remember that direct heading is an option if you cannot get the windrowing done when you need to.

Selection of varieties with greater shattering tolerance through breeding programs, changes in plant populations and farming systems, as well as better machinery may mean that pod shatter may not be the issue that it was when the original recommendations of timings were founded. This may have contributed to this drift in an "ideal" timing recommendation which is now over 30 years old.

Direct heading has also shown to be a suitable management option for canola demonstrating that it often matches the performance in terms of yield of a well-timed windrowing, not so compared to ill-timed windrowing.

The choice to direct head canola therefore is better based upon the other pros and cons of such a practice, which are well detailed in the GRDC's recently published Direct Heading Fact Sheet that can be accessed at; http://www.grdc.com.au/~/media/F3089AE19FFC498389DE786683461209.pdf

What these trials do hope to demonstrate is the potential economic benefit gained by getting it right. The availability of windrowers at the correct time or the other advantages offered through windrowing should be considered.

Acknowledgements

Special thanks to:

Clyde Agriculture "Netherway" Coonamble,

Graeme Callaghan- Graeme Callaghan & associates, Dubbo

Garry Evans- "Larry's Plains", Dubbo

Lindsay Northcott, North-Hill harvesting, Young

Syngenta crop protection, Australia

Agspec, Australia (Pod CealTM Distributors)

John DeLyall- Pioneer Hi Bred Australia

"Haddon Rig" Warren

A Walker-"Erlside" Warren

R Ledger "Erlside" Warren

The Waas family at Nyngan

The Street family- Wongarbon trial site

Mason Family, "Spicers Run" Wellington

Michael White and Co. Wellington

Julie Monroe- GOA

All other windrowers, agronomists and growers that have helped out along the way.

References

Hertel, K A, (2012) Canola technology update. Module 7 Harvest Management V2 September 2012. Australia Oilseed Federation.

Contact details

Maurie Street

Grain Orana Alliance,
PO Box 2880, Dubbo NSW 2830

0400 066 201

maurie.street@grainorana.com.au

New and potential malting barley variety update and agronomic developments

Rick Graham[1], Ian Menz[1], Nick Moody[1] and Neroli Graham[1],
[1]NSW DPI Condobolin

GRDC project code: DAN00173

Keywords

malting accreditation, grain protein concentration, grain yield, time of sowing

Take home messages

- **Malting accreditation typically takes two to three years to complete, it does not guarantee varietal uptake, market demand or price premiums. The agronomic adaptability and potential of a variety to achieve malt specifications will influence its adoption.**
- **Time of sowing (TOS) trials help to determine how a new variety compares in maturity and yield against benchmark varieties, enabling growers to better select combinations of sowing time and variety. Of the newer varieties Fathom⦶, La Trobe⦶ and Skipper⦶ exhibited good yield potential, with the malt varieties Commander⦶, and Scope CL⦶ and the food variety Hindmarsh⦶ performing consistently within the TOS trial at Condobolin in 2012.**
- **Variety specific guidelines in terms of nitrogen (N) management may be necessary for some varieties in order to maximise yield potential and increase the probability of achieving grain quality parameters. Preliminary results from trials looking at N and seed rate response, highlighted the yield and quality potential of some of the new and potential malt varieties, with varieties such as Compass⦶ and La Trobe⦶ showing good adaptability particularly in low to medium rainfall zones. Initial findings also indicated that Commander⦶ and potentially Compass⦶ may be less N responsive in terms of grain protein concentration (GPC) whilst Bass⦶ and Flinders⦶ may be more GPC responsive.**

Background

The Australian barley industry is going through a period of transition, as breeding companies bring on line their next generation of malting varieties. Since 2012 six new barley varieties have received malting accreditation from Barley Australia, with a further five potential releases in the next two years, that could be grown in NSW. Due to marketing and logistical restrictions around varietal purity and segregation limitations, it is apparent that not all newly accredited malt or 'potential malt' varieties will be widely adopted. The malting barley industry (maltsters, brewers and marketers) would also prefer some rationalisation of the number of malting varieties. The question facing growers is which of these new malting and or food/feed varieties should I grow?

Growers need to consider both agronomic merit and market potential when making a decision to adopt a new malting variety, as the successful uptake of a variety will ultimately depend on its agronomic performance and market demand. Although market acceptance drives the successful commercialisation of a variety, poor agronomic performance limits its adoption and long-term viability. The agronomic response of a variety to management inputs (e.g. time of sowing, nitrogen fertiliser and seeding rate) particularly in terms of the probability of achieving malting specifications, will for example, affect likely adoption (Paynter *et al.* 2013). Likewise, varietal adaptability in terms of maintaining yield potential and grain quality receival specifications across a range of agro-ecological zones or environments will also impact on variety adoption and uptake. This paper aims to (i) provide an update on new malting, potential malt and feed barley varieties (ii) outline the potential agronomic and market fit of these varieties and (iii) present preliminary research findings and observations related to Genotype (G) x Environment (E) x Management (M) information on varieties, to assist with the development of variety specific management guidelines.

Malting barley variety update

Since 2012 six new malting barley varieties have been accredited by Barley Australia. There are also a number of cultivars currently undergoing Barley Australia malting and brewing accreditation that may become available to growers in the next two years. This commercial accreditation process typically takes two to three years to complete. Details of the process and lines undergoing evaluation can be found on the Barley Australia website; www.barleyaustralia.com.au. A list of recently accredited malting varieties and cultivars currently undergoing Barley Australia evaluation and their targeted accreditation dates are shown in Tables 1 and 2. This does not include niche malting quality, proprietary varieties such as SouthernStar(b and Charger(b, that are grown under closed loop contracts. Although it should be noted that VT Admiral(b; a new malting barley developed by the University of Adelaide and Joe Whites Malting (JWM) and grown under production contracts to supply JWM, is undergoing Barley Australia accreditation.

It is important to note that malting accreditation does not necessarily guarantee varietal adoption or market uptake. Completion of Stage 1 of the accreditation process also does not imply that a variety will meet or comply with the requirements for Stage 2. The 'Food' accredited variety Hindmarsh(b being a recent example.

Following the accreditation of a variety, there is a period of market development during which there may be a lack of clear market signals and uncertainty in market demand. During this market development or transition phase, unless there is an established niche or defined market, the expectation should be to deliver the newly accredited malting variety as feed, until there are clearer segregation, pricing and market demand signals (GIWA Barley Council, 2013). If the expectation is to deliver a malting variety for a premium, growers should refer to the Barley Australia list of 'Preferred Varieties' and

Table 1. Summary of malting varieties recently accreditated by Barley Australia

Variety	Accredited	Tested as	Fermentability profile	Notes
Bass⁽ᵖ⁾	2012	WABAR2315	High	Market Development
Navigator⁽ᵖ⁾	2013	WI4262	Low	Domestic malt
GrangeR⁽ᵖ⁾	2013	SMBA09-3353	Medium	Market Development
Henley⁽ᵖ⁾	***2013***	***NSL97-5547***	***Medium-High***	***Withdrawn due to risk of blue aleurone***
Scope CL⁽ᵖ⁾	2013	VBHT0805	High	Derived from Buloke, Imidazolinone tolerant line
Westminster⁽ᵖ⁾	2013	GS5033	Medium-High	Domestic and Export Malt

Table 2. Summary of varieties undergoing malting accreditation by Barley Australia

Variety	Tested as	Year 1 status	Year 2 status	Target accreditation date	Fermentability profile	Notes
Macquarie	TI677	Complete	2013	2014	Low	Domestic, sugar adjunct
Wimmera	VB0432	Complete	2013	2014	High	Export, starch adjunct
SY Rattler	SYN0937-3	2013			Low	Held over, domestic malt
Admiral⁽ᵖ⁾	WI4259	Complete	2013	2014	High	Under licence to JWM
Flinders⁽ᵖ⁾	WABAR2537	2013			Medium-High	Export, starch adjunct
La Trobe⁽ᵖ⁾	IGB1101	Complete	2014	2015	High	Export, starch adjunct
Skipper⁽ᵖ⁾	WI4446	2013		2015	Medium	Export malt, Shochu
Litmus⁽ᵖ⁾	WABAR2625	2014		2016		Export, acid tolerant line
Compass⁽ᵖ⁾	WI4593	2013		2015	Medium	Domestic, export similar to Commander

or liaise with their preferred grain acquirer regarding market demand. GrainCorp for example, have published a list of preferred malting varieties by zones for the coming 2014/15 season.

Past experience has shown that once markets have been established, varieties with a wide agro-ecological fit or broad adaptation have achieved rapid adoption. The period from 2010 to 2013, for example can be characterised by a significant change in barley varietal sowings in southern Australia, and in particular the rapid adoption of the malting varieties Buloke$^{\phi}$ and Commander$^{\phi}$ and the food variety Hindmarsh$^{\phi}$. Buloke$^{\phi}$, accredited as a malting variety in 2008 now represents approximately 28% of sowings in central and southern NSW and around 10% in Victoria. Likewise in South Australia, Buloke$^{\phi}$ is estimated to be around 10% of the area sown to barley. Commander$^{\phi}$ released in 2009 as an accredited malt variety is now acknowledged as a dominant variety with estimates placing it at 15% of plantings in South Australia, and central and southern NSW and at 10% in Victoria. Hindmarsh$^{\phi}$ which was given a food classification in 2011 has achieved widespread adoption, estimated at 50% of plantings in Victoria, 17% in South Australia and 20% in central and southern NSW.

Apart from market signals there is also a need to consider the agronomic potential and or adaptation of these varieties. NVT trialling has shown that the new and potential malt varieties have yield and or grain quality advantages over current standard varieties and rival dedicated feed barley varieties. It is also important to note that some of these varieties perform very similarly agronomically in terms of G x E x M interactions and grain quality parameters, which will assist in the development of variety specific guidelines. Examples of this include Buloke$^{\phi}$ and Scope CL$^{\phi}$, Hindmarsh$^{\phi}$ and La Trobe$^{\phi}$ and to some extent also Commander$^{\phi}$ and Compass$^{\phi}$ (higher yielding, targeted at low to medium rainfall zones).

Management of Barley and Barley Cultivars for the Southern Region

Management of Barley and Barley Cultivars for the Southern Region project (DAN00173); a GRDC co-funded collaborative tri-state project led by NSWDPI and including the research partners Birchip Cropping Group (BCG) and South Australian Research and Development Institute (SARDI), has been established to develop management advice and improved agronomic practices for new barley varieties. Recent research has included evaluation around agronomic fit of varieties, G x E x M responses related to time of sowing, nitrogen management and seeding rate, and weed competitiveness of varieties. Some preliminary findings from 2012 and 2013 are presented in this paper.

Time of sowing and new varieties

Time of sowing (TOS) is a major determinant of crop yield and grain quality parameters. In combination with variety, it determines timing of developmental stages and the likelihood of environmental stresses at key developmental stages, such as flowering (Fettell 2011).Varietal responses to TOS trials help to determine how a new variety compares in maturity and yield with benchmark varieties, enabling growers to better select combinations of sowing time and variety. TOS yield results for Condobolin in 2012 (Table 4), with excellent pre-sowing soil moisture (210 mm rainfall February-March) and decile 5 growing season rainfall (April to October) of 176.8 mm, showed that delayed time of sowing resulted in reduced yield potential. The decline in yield was more pronounced between TOS 2 and TOS 3. Averaged across all varieties, yield decreased by 1.53t/ha or approximately 0.5t/ha per week. It is however, important to note the response or interaction of varieties to time of sowing and to consider varietal maturity as a risk management option. That is, grain yield results showed a significant interaction ($P<0.01$) between variety and TOS, indicating that varieties ranked differently in response to TOS. Importantly newer varieties showed significant improvements in yield and quality parameters.

Table 3. Grain yield (t/ha) for main season across sites analysis from 2008 to 2012 when compared to Gairdner⁽ᵖ⁾

Variety	North East		North West		South East		South West	
	Percent of Gairdner (%)	Trial number	Percent of Gairdner (%)	Trial number	Percent of Gairdner (%)	Trial number	Percent of Gairdner (%)	Trial number
Bass⁽ᵖ⁾	100	13	100	20	100	7	105	14
Baudin⁽ᵖ⁾	92	7	94	15	96	9	96	18
Buloke⁽ᵖ⁾	101	12	99	20	101	9	109	18
Commander⁽ᵖ⁾	107	16	107	25	107	9	110	18
Compass⁽ᵖ⁾			113	5			120	4
Fairview⁽ᵖ⁾	109	3			102	6	105	4
Fathom⁽ᵖ⁾	109	8	105	15	106	6	118	12
Fitzroy⁽ᵖ⁾	100	16	102	25			106	4
Flagship⁽ᵖ⁾	102	11	99	15	99	7	106	14
Flinders⁽ᵖ⁾	104	8	100	15	102	6	111	12
Gairdner⁽ᵖ⁾	**100**	**16**	**100**	**25**	**100**	**9**	**100**	**18**
GrangeR⁽ᵖ⁾	116	8	105	10	108	6	114	8
Grimmett⁽ᵖ⁾	96	16	93	25				
Grout⁽ᵖ⁾	101	16	100	25	99	5	109	6
Henley⁽ᵖ⁾	107	12	105	15	105	8	111	10
Hindmarsh⁽ᵖ⁾	106	16	102	25	105	9	119	18
La Trobe⁽ᵖ⁾	103	5	101	10	107	4	116	8
Mackay⁽ᵖ⁾	106	12	102	25				
Macquarie⁽ᵖ⁾	102	16	105	10	102	9		
Navigator⁽ᵖ⁾	96	14			99	7		
Oxford⁽ᵖ⁾	110	12	109	20	108	9	108	14
Schooner⁽ᵖ⁾	94	15	90	25	91	9	98	18
Scope CL⁽ᵖ⁾	102	12	99	20	101	8	109	14
Shepherd⁽ᵖ⁾	105	16	102	25	101	9	107	18
Skipper⁽ᵖ⁾	107	10	104	15	104	6	116	10
Tulla⁽ᵖ⁾					101	4	101	10
Urambie⁽ᵖ⁾	104	16	103	20	102	9	107	14
Westminster⁽ᵖ⁾	103	16	106	3	101	8		
Wimmera⁽ᵖ⁾	105	12	102	15	103	9		
Gairdner⁽ᵖ⁾ (t/ha)	**3.86**		**3.71**		**3.77**		**2.74**	

Data is sourced from the National Variety Trials; additional grain yield/quality information on varieties is available from the National Variety website at www.nvtonline.com.au

Table 4. Grain yield (t/ha) for individual varieties when sown on 7th May, 29th May and 20th June 2012 at Condobolin in 2012

Variety	Grain Yield (t/ha)		
	7th May 2012	29th May 2012	20th June 2012
Bass⸸	4.75	3.65	2.13
Buloke⸸	4.13	3.93	2.34
Commander⸸	5.28	3.77	2.46
Fathom⸸	5.22	4.40	2.59
Fleet⸸	5.29	4.15	2.55
Flinders⸸	4.25	3.13	2.27
Gairdner⸸	3.85	3.62	2.09
GrangeR⸸	4.36	3.68	1.70
Henley⸸	3.44	4.19	2.23
Hindmarsh⸸	5.31	4.03	3.23
La Trobe⸸	4.44	4.67	2.61
Navigator⸸	3.50	3.49	2.17
Oxford⸸	3.74	2.94	1.67
Schooner⸸	4.03	3.58	1.79
Scope CL⸸	4.69	3.72	2.84
Shepherd⸸	3.60	3.61	2.36
Skipper⸸	5.04	4.28	2.17
Urambie⸸	4.06	3.81	2.28
Westminster⸸	3.36	3.66	1.68
Wimmera⸸	3.73	3.51	2.11
Mean	4.30	3.79	2.26
LSD TOS (P=0.05)	0.31		
LSD TOS x Variety (P=0.05)	0.75		

Of the newer varieties Fathom⸸, La Trobe⸸ and Skipper⸸ maintained yield potential (Table 5), with the malt varieties Commander⸸, and Scope CL⸸ and the food variety Hindmarsh⸸ also performing consistently. Apart from yield, mean grain quality parameters averaged across the three TOS highlighted the agronomic weakness and potential of varieties. Gairdner⸸, for example showed its agronomic issues around grain size (retentions) and to a lesser extent screenings in this environment, one of the reasons for its decline. During this transition phase where there is no dominant replacement variety, malsters are utilising a range of varieties, as Gairdner⸸ is being superseded, in order to meet their specific customers' needs (Malteurop, *pers. Comm*).

Table 5. Mean predicted varietal values for grain yield (t/ha), retention (%), screenings (%), test weight (kg/hl) and thousand grain weight (g) averaged across sowing times, Condobolin in 2012

Variety	Grain Yield (t/ha)	Retention (%)	Screenings (%)	Test weight (kg/hl)	Thousand grain weight (g)
Bass⁽ᵈ⁾	3.51	92.2	1.3	69.5	41.8
Buloke⁽ᵈ⁾	3.47	73.7	2.1	68.0	43.6
Commander⁽ᵈ⁾	3.84	88.7	1.7	67.7	40.1
Fathom⁽ᵈ⁾	4.07	89.3	1.5	67.2	45.0
Flinders⁽ᵈ⁾	3.21	79.6	2.0	67.0	36.8
Gairdner⁽ᵈ⁾	3.19	59.5	3.5	68.6	39.8
GrangeR⁽ᵈ⁾	3.25	76.8	3.2	68.5	38.5
Hindmarsh⁽ᵈ⁾	4.19	89.0	1.2	67.0	39.5
La Trobe⁽ᵈ⁾	3.90	85.1	2.0	69.5	39.6
Navigator⁽ᵈ⁾	3.05	85.1	1.6	69.4	38.2
Schooner	3.13	72.9	2.6	68.6	38.9
Scope CL⁽ᵈ⁾	3.75	85.6	1.3	69.3	44.7
Skipper⁽ᵈ⁾	3.83	86.3	1.6	68.7	40.2
Westminster⁽ᵈ⁾	2.90	79.9	2.1	69.3	39.8
Wimmera⁽ᵈ⁾	3.12	85.5	2.0	68.8	39.6
Mean	3.45	78.9	2.6	68.3	40.4
LSD (P=0.05)	0.43	6.01	1.14	0.44	1.06

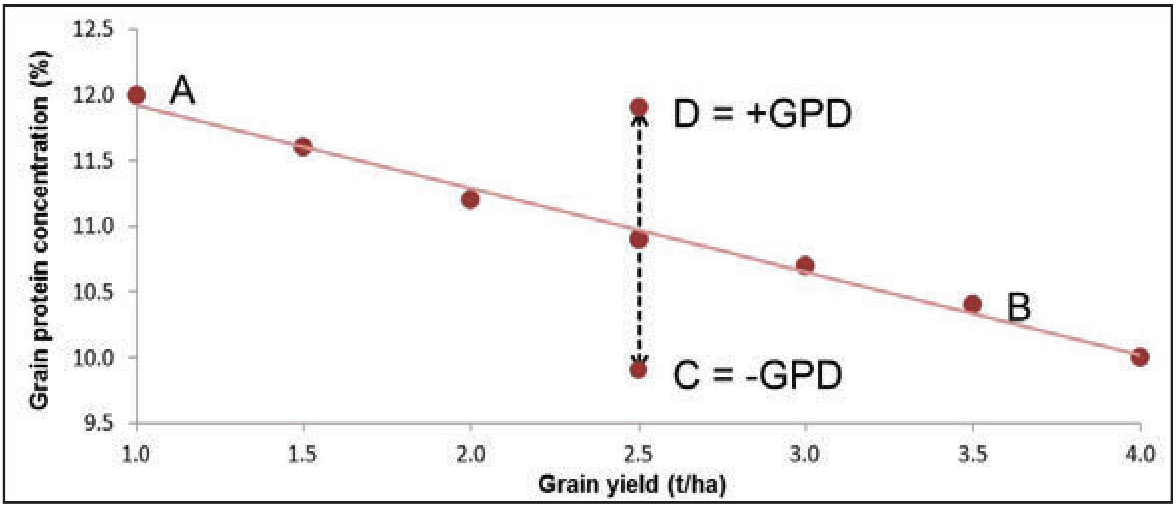


Figure 1. Grain Protein Deviation (GPD) – illustrating varieties expressing either a negative (C) or (D) positive GPD (Paynter and van Burgel 2014).

Table 6. Predicted mean varietal values for yield (t/ha), protein (%), screenings (%), retention (%), test weight (kg/hl) and thousand gain weight (g) from across site analysis

Variety	Yield (t/ha)	Protein (%)	Screenings (%)	Retention (%)	Test Weight (kg/hl)	Thousand Grain Weight (g)
Bass⏀	4.15	11.14	0.56	92.36	70.17	43.08
Buloke⏀	4.12	10.82	1.07	81.34	68.50	46.71
Commander⏀	4.19	10.54	1.72	87.75	67.01	41.63
Flinders⏀	4.11	11.15	1.09	89.98	69.51	42.52
GrangeR⏀	4.20	10.56	1.03	90.22	69.02	41.92
La Trobe⏀	4.64	10.33	0.90	91.16	69.36	41.84
Skipper⏀	4.11	11.01	0.68	93.81	68.94	43.78
Wimmera⏀	4.00	11.16	1.18	89.82	68.71	40.73
LSD (P=0.05)	0.16	0.31	0.72	4.71	0.50	0.84

Nitrogen management in barley

To achieve malt specifications, growers in southern Australia need to meet strict industry grain protein concentrations of between 9.0 to 12.0% (dry basis). A question often asked by growers is, how do barley varieties differ in their GPC and response to nitrogen (N) management? Recent studies by Porker and Wheeler (2013) and Paynter and van Burgel (2014) incorporating South Australian and Western Australia NVT data sets respectively, were able to show that varieties do differ in GPC. Looking at grain protein deviation, defined as the deviation from the regression line for grain yield and GPC (Figure 1) both groups were able to show that Buloke⏀, and Commander⏀, achieved a lower GPC for a given yield level. Whilst, varieties such as Flinders⏀, and Bass⏀, may be high grain protein accumulators (Figure 2).

Graham *et al.* (2013) in a collaborative trial series, involving the GRDC funded Management of Barley and Barley Cultivars in Western Australia (DAW00224) and the Management of Barley and Barley Cultivars for the Southern Region (DAN00173) projects, initiated to compare yield and quality responses of potential malt varieties likely to be grown nationally, under a range of management practices, also observed that varieties did appear to differ in their GPC response to applied N. In the study, eight varieties, selected with a national rather than a regional focus, were sown across five locations (Walebing, Katanning and Gibson from WA, and Condobolin and Parkes from NSW). The varieties selected were Bass⏀, Flinders⏀, GrangeR⏀, La Trobe⏀, Skipper⏀ and Wimmera⏀, with Buloke⏀ and Commander⏀ included as controls. At each site, varieties were sown with factorial combinations of three seed rates (targeting 75, 150 and 300 plants/m^2) and three N fertiliser rates (0, 30 and 90 kg N/ha). Grain yield and quality parameters were measured using commercial receival methods, with differences between varieties observed. Results from this trial summarised in Table 6 showed that on limited data, varieties appeared to differ in their GPC response to applied N, Commander⏀ being less responsive and Bass⏀ more responsive. La Trobe⏀ on the other hand appeared to follow the classic yield dilution response or negative correlation between grain yield and GPC; following the regression line it also exhibited a significant yield advantage over the other cultivars. Overall, Bass⏀ exhibited a significantly higher test weight than Commander⏀, while both Bass⏀ and Skipper⏀ achieved better grain size, lower screenings and higher retentions.

Table 7. Predicted varietal values for grain yield (t/ha), grain protein (%), retention (%), screenings (%), test weight (kg/hl) and thousand grain weight (g) for the Barley National Trial conducted at Parkes in 2013, across all treatments

Variety	Grain Yield (t/ha)	Grain Protein (%)	Retention (%)	Screenings (%)	Hectolitre weight (kg/hl)	Thousand grain weight (g)
Bass⁽ᴅ	3.72	13.9	97.9	0.3	71.9	49.0
Buloke⁽ᴅ	4.09	12.7	94.6	0.6	71.9	52.8
Commander⁽ᴅ	4.62	11.4	96.7	0.7	71.1	49.4
Compass⁽ᴅ	4.77	11.1	98.3	0.3	70.5	51.6
GrangeR⁽ᴅ	4.35	12.2	96.0	0.5	71.7	47.8
La Trobe⁽ᴅ	4.59	12.1	96.3	0.6	72.8	46.4
Skipper⁽ᴅ	4.36	13.1	98.0	0.3	72.1	49.2
Wimmera⁽ᴅ	3.90	12.0	93.9	0.7	66.1	44.8
Mean	4.30	12.3	96.5	0.5	71.0	48.9
LSD (P=0.05)	0.26	0.37	1.32	0.19	0.45	0.79

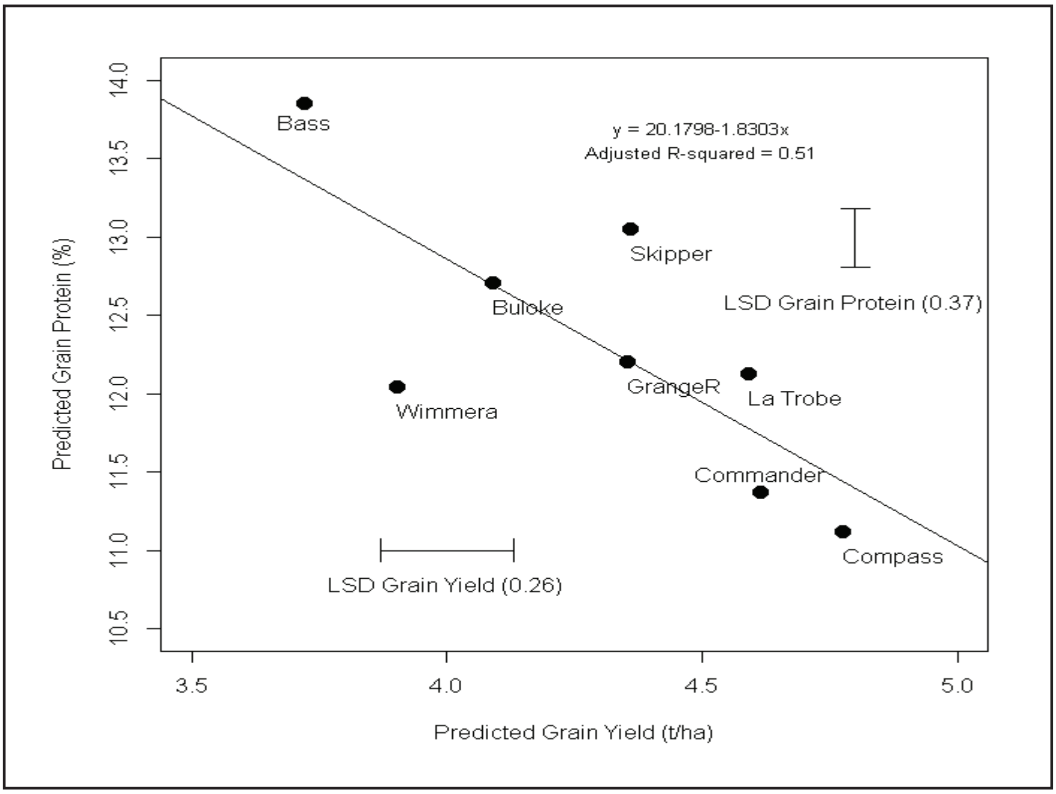


Figure 2. Linear relationship between predicted grain yield (t/ha) and grain protein (%) for eight varieties grown at Parkes 2013.

In 2013 the collaborative trial series (also referred to as the Barley National Trial) was repeated at both Parkes and Condobolin. The Parkes trial was sown on 31st May, and had a relatively high starting mineral N value of 112kg/ha (0-60cm). Despite this, both Compass⍉ and Commander⍉ were both within GPC specifications, and appeared to perform similarly in terms of yield and grain quality parameters, both showing that they may be less protein responsive than varieties such as Bass⍉. It was interesting to note that at Condobolin (data not shown) with a late sowing (21st June) Compass⍉ (76.5%) was able to achieve the Grain Testing Australia quality retention standards whereas Commander⍉ (67.5%) was outside malt specifications.

Preliminary results from these trials have highlighted the yield and quality potential of some of the new and potential malt varieties, with varieties such as Compass⍉ and La Trobe⍉, showing good adaptability particularly in low to medium rainfall zones. These trials have provided valuable environment by management information (G x E x M) for all varieties tested, helping to develop management guidelines so as to enhance adoption and agronomic potential. It is already apparent that variety specific guidelines in terms of N management may be necessary for some varieties in order to maximise yield potential and increase the probability of achieving grain quality specifications. Initial findings have indicated that Commander⍉ and potentially Compass⍉ may be less N responsive in terms of GPC whilst Bass⍉ and potentially Flinders⍉ may be more GP responsive.

References

Fettell N. (2011) 'Sowing times critical to maximise barley yields'. Farming Ahead April 2011 No. 231 pp 64-66 www.farmingahead.com.au

GIWA Barley Council (2013) 'Western Australian Malting Barley Varietal Recommendations for the 2014/15 Harvest, 26 August, 2013

Graham R, Paynter B, Fettell N, Gardner M, Porker K, Hills A, Malik R, Craig S, Moody N, Graham N (2013) Yield and quality responses of potential malting barley varieties of national significance. Proceedings of 16th Australian Barley Technical Symposium, 8-11 September 2013, Melbourne, Victoria.

Paynter B, van Burgel A (2014) Barley cultivars differ in their protein concentration. GRDC Crop Updates, Perth February, 2014 pp. 4 *in press*

Paynter B, Hills A, Malik R, McLarty A (2013) Sensitivity of Barley Varieties to Crop Management. GRDC Crop Updates, Perth 25-26 February, 2013. pp. 4

Porker K, Wheeler R (2013) Managing grain protein; variety specific responses to nitrogen. Proceedings of 16th Australian Barley Technical Symposium, 8-11 September 2013, Melbourne, Victoria.

Acknowledgements

The contributions of Daryl Reardon, Katrina Thomas and Linda Brangwin are gratefully acknowledged for their technical support in conducting these trials. Dr Neil Fettell is also acknowledged for his contribution to this project.

Contact details

Rick Graham

NSW Department of Primary Industries

Condobolin Agricultural Research Station, PO Box 300, Condobolin NSW 2877

02 6895 1009

ricky.graham@dpi.nsw.gov.au

Quantifying herbicide resistance in modern farming systems – Griffith region 2012/2013

Barry Haskins,
Ag Grow Agronomy and Research Pty Ltd

GRDC Fast track project

Keywords

ryegrass, sow thistle, herbicide resistance, cross resistance

Take home messages

- **Herbicide resistance is becoming a major issue in cropping systems. Ryegrass and sow thistle were evaluated in this project; however other weeds such as wild oats, wild radish, mustards, poppy, etc. are also developing resistance in this region.**
- **This project evaluated samples taken from both known resistant populations and non-resistant populations. 100% of ryegrass samples and 22% of sow thistle samples were resistant or developing resistance to at least one herbicide. Multiple resistance in ryegrass was common.**
- **Growers and advisers were accurate 74% of the time when predicting ryegrass resistance. This reduced to 65% for post emergent herbicides.**
- **Cross resistance between Logran® and Hussar® in ryegrass was lower than expected. This has raised some questions.**
- **No-till continuous cropping rotations hosted higher resistance levels and often to more herbicides than less intensive rotations that included pasture. However in many cases, samples from paddocks that have had minimal herbicide applications often showed resistance to multiple herbicides.**
- **This project was initiated by NSW DPI, and taken over by Ag Grow Agronomy as a result of restructuring. This project highlights the importance of pre-emergent herbicides in conjunction with non-herbicide weed control for a sustainable farming future.**

Background

Herbicide resistance in annual ryegrass (*Lolium rigidum*) and common sowthistle (*Sonchus oleraceus*) in the western riverina region of NSW has elevated significantly in recent years.

The nature of the cropping and pasture rotations in the region have made managing herbicide resistance extremely difficult, and recent random herbicide resistance surveys funded by GRDC have included only limited samples from this region.

The majority of the region is marginal dryland winter cropping (2t/ha average) where no-till farming adoption has elevated to over 75% (Ag Grow crop benchmarking, 2013). Spending money on expensive alternative herbicides is difficult as farm sizes are large (>3500ha) and returns are often low and variable.

In comparison, the highly intensive irrigation cropping systems within the region, where tight rotations (including horticulture), high herbicide inputs and large areas of channels and roads exist, have resulted in extremely high perceived levels of herbicide resistance.

Widespread flooding in the region in March 2012 caused significant seed dispersal across large areas, and growers and advisers felt unarmed with the appropriate knowledge to choose the right herbicides for effective weed control, particularly for ryegrass and sow thistle.

This was raised as an issue with GRDC, and therefore, a fast track project was established to provide growers and advisers with the necessary information to manage the problem.

It is important to note that this project was originally established between NSW DPI and GRDC, however as a result of structural changes in NSW DPI, Ag Grow Agronomy and Research was contracted to complete the project.

Aim

The aim of this project was to capture the current resistance status of a large sample of ryegrass and sow thistle; to key pre-emergent and post emergent herbicides in the western riverina region of SW NSW.

In addition, the project aimed to measure the risks of herbicide resistance according to the rotational history and farming practices, and also the ability of growers and advisers to predict the resistance status of each sample.

Methodology

Sampling

101 annual ryegrass and 31 sow thistle samples were collected by growers and advisers during harvest in 2012.

Samples were taken from both known resistant populations and non-resistant populations.

An A4 envelope of seed was required following weed maturity, and samples were taken at every five to ten paces aiming to avoid bias towards single populations.

Samples were appropriately identified, GPS referenced, and submitted with the appropriate questionnaire sheet.

The questionnaire sheet requested information about the history of the paddock, the current farming system and the expected resistance status of the sample.

Testing

The resistance screening took place at the Graham Centre resistance testing facility in Wagga Wagga, and was performed under the same protocols as commercial tests.

Results

The results of the herbicide resistance testing were quite remarkable and somewhat unexpected.

The results can be analysed broadly whereby trends are linked to each herbicide, and also individually where specific background information are linked to each sample which allows a detailed interpretation of the reasoning why a sample may be resistant to a particular herbicide.

Table 1. Herbicides and rates used for resistance screening

Herbicide	Example trade name	Pre- or post-treatment	Rate (Lt or g/ha)	Rate (g ha^{-1} a.e.)	Adjuvant (rate % v/v)
Ryegrass					
diclofop-methyl	Hoegrass®	Post	0.75Lt	375	Chemwet 1000 (0.25)
haloxyfop-R	Verdict™	Post	0.075Lt	39	Uptake (0.5)
clethodim	Status®	Post	0.5Lt	120	Hasten (1.0)
pinoxaden + cloquintocet-mexyl	Axial®	Post	0.3Lt	30	Agidor (0.5)
imazamox + imazapyr	Intervix®	Post	0.75Lt	48	Hasten (0.5)
iodosulfuron-methyl-sodium	Hussar®	Post	0.1Lt	10	Chemwet 1000 (0.25)
triasulfuron	Logran®	Pre	35g	26.25	-
trifluralin	Triflur X®	Pre	1.7Lt	816	-
prosulocarb + S-metolachlor	Boxer Gold®	Pre	2.5Lt	2300	-
pyroxasulfone	Sakura®	Pre	118g	100.3	-
glyphosate	Roundup	Post	1.2Lt	648	-
Sow thistle					
metsulfuron-methyl	Ally®	Post	5g	3	Chemwet 1000 (0.1)
iodosulfuron-methyl-sodium	Hussar®	Post	0.1Lt	10	Chemwet 1000 (0.25)
MCPA + imazapyr + imazapic	Midas®	Post	0.9Lt	286	Supercharge (0.5)
clopyralid	LontrelTM	Post	0.125Lt	75	-
MCPA	MCPA	Post	1.4Lt	700	-
glyphosate	Roundup	Post	1.2Lt	648	-

Table 2. Rotation and farming system details of samples

Rotation	Ryegrass			Sowthistle		
	Dryland	Irrigated	Total	Dryland	Irrigated	Total
Continuous cropping no till	30	4	34	9	1	10
Continuous cropping with cultivation	13	21	34	4	8	12
Cropping and fallow with cultivation	13	4	17	2	2	4
Mixed farming including cropping and pasture	4	2	6	0	0	0
No till with chemical fallow	6	1	7	4	0	4
Pasture > 5yrs	3	1	4	0	1	1
Grand Total	**69**	**33**	**102**	**19**	**12**	**31**

Table 3. Expected versus actual resistance levels in ryegrass and sow thistle

	Expected resistance in ryegrass		Actual resistance in ryegrass		
	Yes	No	Yes	Developing	No
Glyphosate	32	70	8	13	78
Treflan™	0	102	0	3	96
Sakura®	0	102	0	0	0
Boxer Gold®	0	102	0	0	0
Logran®	57	45	82	14	5
Hoegrass®	53	49	62	18	21
Axial®	39	63	43	18	37
VerdictTM	30	72	49	20	29
Status®	31	71	2	8	89
Intervix®	14	88	19	21	57
Hussar®	19	83	17	8	72
	Expected resistance in sowthistle		**Actual resistance in sowthistle**		
	Yes	**No**	**Yes**	**Developing**	**No**
Glyphosate	7	24	0	0	0
Ally®	7	24	3	3	25
MCPA	1	30	0	0	31
Lontrel™	0	31	0	0	31
Hussar®	0	31	0	0	31
Midas®	0	31	0	1	30

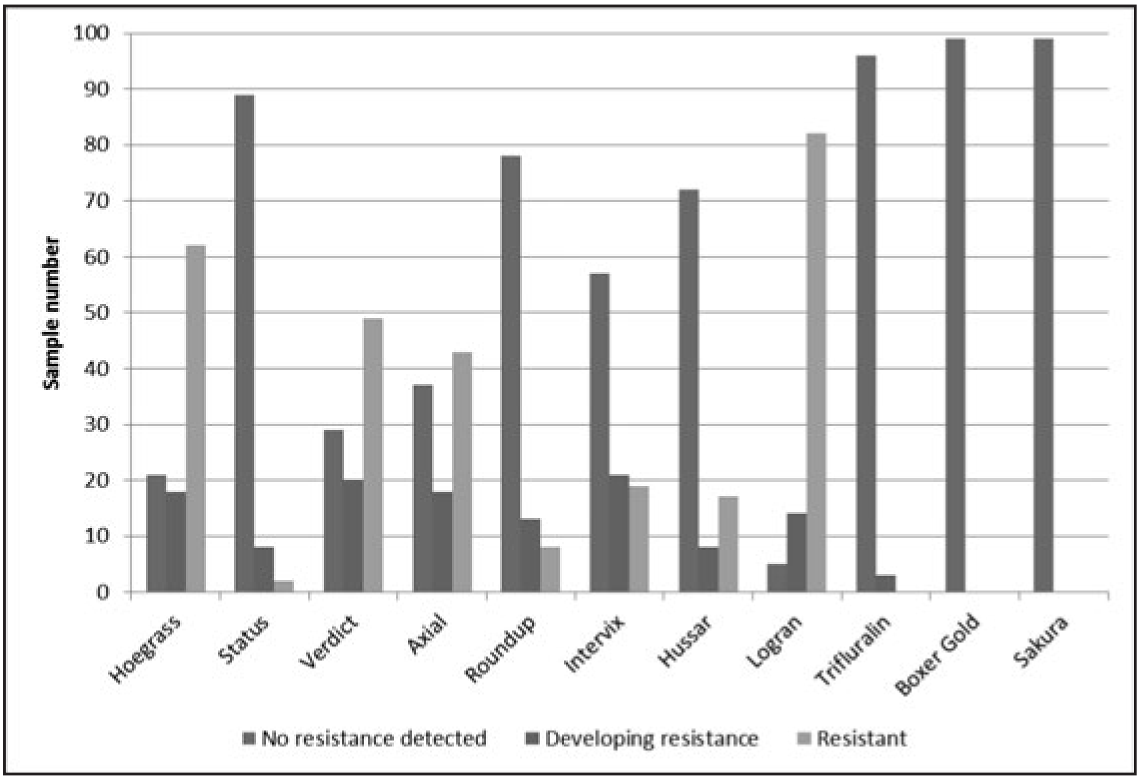


Figure 1. Herbicide resistance test results in ryegrass averaged across each herbicide.

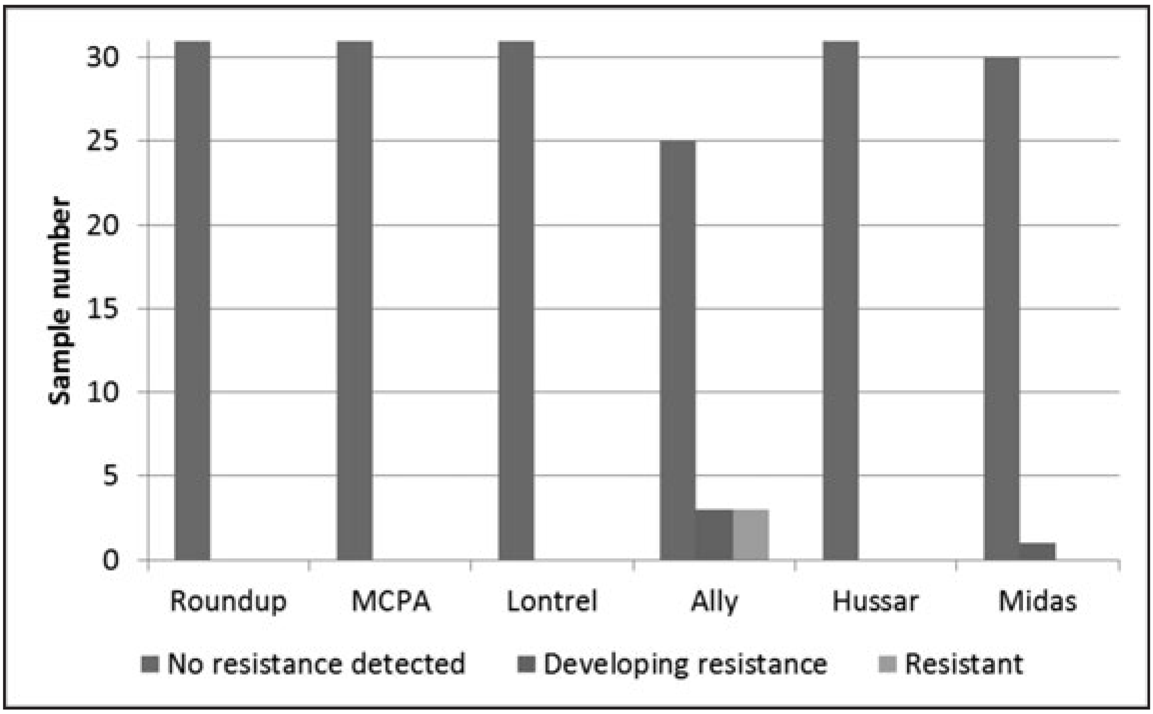


Figure 2. Herbicide resistance test results in sow thistle averaged across each herbicide.

Resistance test results

There were a number of samples that were resistant to one or more herbicides. Importantly, the number of samples that were resistant to all key post emergent herbicides that control ryegrass was disturbing. This highlights the necessity of utilising pre- emergent herbicides such as Treflan®, Boxer Gold® and Sakura®, but also the necessity for non-herbicide weed control tactics.

Resistance levels to more conventional type herbicides such as Logran® and Hoegrass® were higher than expected, however the result was not that surprising.

Resistance to Roundup however, is much higher than what would have been suggested by industry trends; however levels were as expected by growers and advisers. This highlights the need to utilise other knockdown herbicides such as Gramoxone® in conjunction with other non-herbicide knockdown tactics to extend the life of Roundup.

The same could be said for Axial® and Verdict™, however the elevated levels caught many growers and advisers by surprise.

What was extremely interesting was the lack of association between Logran® and Hussar® resistance. Both herbicides belong to the sulfonyl urea group B herbicide group, and therefore, some cross resistance would be expected. This was not the case in this project, and levels of cross resistance are much lower than industry experience (industry expectations would be around 10-15%). The level of cross resistance experienced in this project was 67% (i.e. in 67% of the time a sample that showed resistance to Logran® was non-resistant to Hussar®). The reasons these trends have occurred are beyond the scope of this project, and may form an interesting topic for research by industry specialists. It is worth noting that many paddock scenarios in 2013 reinforced the test results from the laboratory.

Grower/adviser ability to predict resistance

Another point of discussion was the ability of the grower/adviser to predict if resistance was going to be present in the sample submitted.

The prediction accuracy averaged across all herbicides was 74%, however for post emergent herbicides; the prediction accuracy was only 65%. This is concerning, as most growers/advisers that presented samples were highly experienced and familiar with the issues they were facing with resistance on their farms. The fact that 26% of the time the grower/adviser thought that a sample was non-resistant but in actual fact the sample was resistant may paint a picture as to the level of failed herbicide applications that occurs commonly in the farming system. And this survey was conducted with the top level farmers and advisers!

Effect of rotation on resistance levels

Results showed that higher cropping intensity correlated with higher the resistance to a wider number of herbicides.

What was very interesting however, was the level of resistance measured in samples with no expected resistance. In many cases, these paddocks had never had an application of the herbicide that it was resistant to. In some cases, the paddocks had never had any herbicides applied to them at all. However, they still hosted resistance to at least one herbicide. Experience in the field has also shown this to be true.

This would suggest that either the populations were naturally resistant to that herbicide type, or resistance has crept into the population either by seed movement in wind, water, stock, wild animals, etc., or other means such as pollen movement (as ryegrass is a cross pollinating weed). The latter explanation is unlikely however, in some cases the only reasonable answer. Industry experts would suggest that pollen movement would only be likely within short distances (e.g. 10-20m), and the details behind such movement of herbicide resistance is beyond the scope of this project.

Acknowledgements

This project would not have initiated without the involvement of NSW DPI district agronomists and management staff.

The technical expertise in establishing collection and testing protocols, and resistance testing was performed by John Broster, Graham Centre.

AgGrow Agronomy and Research would like to formally acknowledge all farmers involved in the project, and agronomists John Ronan and Heath McWhiter (Elders), Peter Hill and Thane Pringle (Yenda Producers Coop), Chris Lvitzke (Landmark), Allan Jones (Agronomic Business Solutions) and Pat Connell (PC Agronomy) for submitting samples and being involved in the extension of the project.

Contact details

Barry Haskins

barry@aggrowagronomy.com.au

Notes

Robotics and intelligent systems for large scale agriculture

Robert Fitch and Salah Sukkarieh,
Australian Centre for Field Robotics, School of Aerospace, Mechanical and Mechatronic Engineering, University of Sydney, NSW

Keywords

agricultural robotics, autonomous systems, unmanned ground vehicles, unmanned aerial vehicles, whole-farm optimisation

Take home messages

- **Significant advances in future farm productivity will be enabled by robotics and autonomous systems.**
- **Production advances will be by a step-change in productivity through the use of many small autonomous robots that operate within a whole-farm optimisation context.**
- **The key challenge to be addressed in realising the benefits of these new technologies is to 'think beyond the robot' and develop a new logistics and information systems view of farm operations.**

Introduction

Australian food production in the 21st century is being asked to respond to significant new demands and pressures (DAFF, 2013). Although current production allows for roughly half of all food produced to be available for export, projections of massively increasing demand from Asia have prompted government to set aggressive targets for production increases. One such target is to increase exports by 45% by year 2025. Because natural resources are limited, achieving such goals must involve increasing the efficiency of production while at the same time engaging in environmental stewardship, and contending with rising human labour costs and diminishing availability of human labour.

Established trends in mechanisation for farming seek increased productivity through ever-larger tractors and implements, and in the last decade, through the use of GPS guidance technology to restrict vehicle impact to precisely defined tracks. The downside of increased vehicle size is that the associated increased weight leads to long-lasting damage to soil structure. The soil under the precisely guided tracks becomes hyper-compacted, leading to substantial and long lasting loss of land productivity.

Concurrently, the number of people involved in agriculture has been in steady decline for the last four decades (Australian Bureau of Statistics, 2012). The number of farmers in Australia has dropped by 40% since 1981. This decrease is due in part to the reluctance of young people to remain in family farms. Worse, nearly one quarter of farmers are at or above retirement age.

In order to increase its competitive position, Australian agriculture and horticulture are beginning to invest heavily in mechanisation and automation through robotics. One of the leaders of Australian agricultural robotics research is the Australian Centre for Field Robotics (ACFR) at The University of Sydney. The Centre is recognised as one of the largest field robotics groups in the world and one of the largest robotics research organisations. We conduct basic and applied research using both ground robots and aerial robots that is helping to shape the future of farm mechanisation. In this short paper, we briefly describe our current work that addresses weed maintenance and crop intelligence. We also discuss the broader role of robotics in an operational context.

Ground robots for weed maintenance and crop intelligence

The drawbacks of increasingly large tractors are evident in zero-tillage agriculture. We are involved in a collaborative project with Queensland University of Technology (QUT) and Bendee farm in Emerald, Qld to address these drawbacks through robotics (SwarmFarm, 2013). In this project, we are creating a new robotic vehicle technology that replaces a single large soil-compacting vehicle with many small vehicles that move lightly across the surface without compacting the soil or disturbing its protective top layer. The core challenge is to develop the intelligent robotic technology that will enable a single operator to manage a team of small vehicles, rather than a single large vehicle. We are demonstrating the capability and benefits of this new robotic technology in its application to weed eradication in broadacre agriculture on 4000 hectares at Bendee farm (Queensland Country Life, 2013). Our prototype robot platform is shown in Fig. 1 (left).

Another important application of agricultural robotics is crop intelligence, where robots are used to perform autonomous farm surveillance (mapping,

Figure 1. Small autonomous robot for zero-tillage agriculture (left), two ground robots and one aerial robot for crop surveillance in tree-crop applications (right).

classification, detection) and autonomously gather valuable information about crop growth and health. We are working in collaboration with Horticulture Australia Ltd (HAL) to demonstrate the capability of robots in tree crop applications such as almonds and apples, and also in the vegetable industry. Figure 1 (right) shows two ground robots and one aerial robot used in this work. These ideas could also be applied to broadacre agriculture, possibly in combination with weed maintenance. The value of crop intelligence lies in its ability to provide timely and accurate information, such as real-time yield estimates, to support management decisions.

Aerial robots for weed detection and maintenance

Another approach to counter the drawbacks of large tractors is to employ small aerial robots equipped with sensors. Although large manned aircraft may be cost prohibitive for routine information gathering, small autonomous platforms have strong potential. We have completed several projects where we developed and demonstrated aerial robotic systems for weed maintenance in an environmental monitoring context, including aquatic weeds such as alligator weed (with Land and Water Australia), and larger woody weeds such as prickly acacia (with Meat and Livestock Australia). In these projects, the idea is to locate sparse concentrations of weeds that exist in large areas, and then to deploy the herbicide locally and in a targeted manner. Weeds are automatically identified using classification algorithms that operate on visual imagery collected by the aerial robots. Herbicide can then be delivered manually or via a specially equipped robot. In the broadacre context, this type of approach can complement ground robot systems by rapidly finding concentrations of problem weeds that can then be efficiently targeted by the ground robots on an as-needed basis.

Whole-farm optimisation

Although the projects we have described, as well as others worldwide, are focussed on addressing the fundamental capabilities of isolated farm robots, the role of robots in a whole-farm context remains an open question. How will such robots be used operationally, and to what benefit? Answering this question requires a whole-farm optimisation approach. Crop intelligence and weed maintenance must be considered along with other farm operations, such as autonomous harvesting. The farm of the future will not simply replace manual operation with autonomous operation, as is the case with GPS-guided tractors, but instead will adopt a systems view that coordinates all activities. Whole-farm optimisation can be seen as 'thinking beyond the robot' to restructure farm operations in terms of the timing and logistics of all activities, and in terms of information systems where individual crop elements have a 'personality' that is accurately tracked over the crop lifecycle. The ACFR has a long history of working in large-scale operations and optimisation within defence (BAE Systems, US Air Force, Ministry of Defence UK, DSTO), mining (Rio Tinto, BHP), and commercial aviation (Qantas, Airways NZ), and we are now beginning to apply the successful methodologies developed as part of this work in the agriculture domain for more efficient operations and production systems. This whole-farm optimisation approach is where we see the greatest benefit to broadacre farming.

Summary

Significant advances in future farm productivity will be enabled by robotics and autonomous systems. The incremental gains provided by monolithic tractors and implements with add-on automation such as GPS guidance will be replaced by a step-change in productivity through the use of many small autonomous robots that operate within a whole-farm optimisation context. We have described several current projects that demonstrate ground and aerial robots performing two initial applications of agricultural robots: weed maintenance and crop intelligence. The key challenge to be addressed in realising the benefits of these new technologies is to 'think beyond the robot' and develop a new logistics and information systems view of farm operations.

References

Australian Bureau of Statistics. (2012). *Australian Social Trends.* Catalogue number 4102.0.

DAFF. (2013). *National Food Plan, Our food future.* Department of Agriculture, Fisheries and Forestry, Canberra.

Queensland Country Life. (2013). *Robocrop: farm robots a reality.* From http://www.queenslandcountrylife.com.au/news/agriculture/agribusiness/general-news/robocrop-onfarm-robots/2663726.aspx

SwarmFarm. (2013). From http://swarmfarm.com

Contact details

Salah Sukkarieh

Australian Centre for Field Robotics,
The Rose St Building, J04,
The University of Sydney, NSW 2016

02 9351 8154

salah@acfr.usyd.edu.au

Robert Fitch

Australian Centre for Field Robotics,
The Rose St Building, J04,
The University of Sydney, NSW 2016

02 9036 9194

rfitch@acfr.usyd.edu.au

Maintaining market access – keeping it clean

Ian Reichstein,
Department of Agriculture

National Residue Survey 2012–13 Domestic grains

The program

The grains program has been part of NRS random residue testing programs since the early 1960s, and since 1993 has been funded by a 0.015 per cent ad valorem NRS levy on 21 tradeable grains.

The program covers both export and domestic grain. The key objective of the domestic program is to cover all known grain streams within Australia. This comprises a number of sub-programs such as maltsters, stockfeed manufacturers, feedlots, flour millers, oilseed crushers, oat processors and chickpea canners.

The domestic grain program is a collaborative effort between NRS and organisations including Pulse Australia, Australian Oilseed Federation, Stock Feed Manufacturers Council of Australia, Australian Lot Feeders' Association, Grain Producers of Australia and Australian flour mills.

Sampling

The majority of domestic grain samples are collected at receival at grain processing sites. The rate of sampling is approximately one sample per 4 000 tonnes received/processed.

The largest domestic program is milled grains. From the 24 flour mills involved in the program, NRS tests samples of wheat, other milled grains, flour, bran and other fractions. Samples of whole wheat and other milled grains are taken randomly prior to milling and corresponding 'matched' flour, bran and other fractions are collected during the milling process.

The number of matched samples depends on the volume of wheat milled in each mill. All domestic grain samples are collected according to NRS protocols and are then forwarded to a NRS-contracted laboratory for analysis.

Chemical screen

The chemical screens for analysing pesticide residues in grain are developed in consultation with industry, taking into account registered chemicals and chemical residue profiles. The chemical groups covered in the analytical screens include insecticides (including post-harvest grain protectants), fungicides (including dithiocarbamates), herbicides, insect growth regulators, environmental contaminants (including heavy metals) and fumigants such as phosphine.

Results

During 2012–13, 806 grain samples were collected from domestic grain establishments. Results from the analysis of the samples showed 97.2 percent compliance with Australian standards.

Residue testing results over the past decade indicate a high degree of compliance with Australian Standards. These results demonstrate that the Australian grain industry uses in-crop and post-harvest agricultural chemicals according to good agricultural practice, and assures customers of the excellent residue and contaminant status of Australian grains.

Milled grain program results

Commodity	Samples	Compliance (%)
Wheat	100	100
Other milled grains	12	100
Wheat flour/other flour	95	100
Wheat bran/other bran	96	99

Traceback

If a sample is found to contain a residue above the relevant Australian Standard, a traceback investigation is undertaken to establish the cause. The responsible state or territory agency then provides advice to the producer to prevent recurrence. In more serious circumstances regulatory action may also be taken.

All traceback activities and findings are reported to NRS. This feedback is important in highlighting potential problems (such as inappropriate chemical use) and improving farm practices. Where appropriate, traceback information is also forwarded to industry and government authorities for consideration. Traceback information may also be forwarded to the Australian Pesticides and Veterinary Medicines Authority for consideration during its chemical review processes.

Laboratory performance

NRS has been accredited by the National Association of Testing Authorities (NATA) as a proficiency test provider since July 2005. The NRS proficiency testing system is recognised within the laboratory community as meeting internationally accepted standards (ISO/IEC 17043:2010) to establish the technical competence of participating laboratories.

Residue testing is conducted by several laboratories under contract with NRS. Laboratories are selected through the Australian Government tendering process on the basis of their proficiency, accreditation against international standards (ISO/IEC 17025:2005) and value for money. Laboratories are proficiency tested by NRS to ensure the validity of analytical results. Current laboratory contracts began on 1 July 2011 and will run to 30 June 2014.

National Residue Survey 2012–13 Export grains

The program

The grains program has been part of NRS random residue testing programs since the early 1960s, and since 1993 has been funded by a 0.015 per cent ad valorem NRS levy on 21 tradeable grains.

The export grains program covering bulk shipments and container/bag consignment involves collaboration between NRS and grain exporters, marketers and bulk handlers/packers.

Australian export markets acknowledge the veracity of the NRS grains residue monitoring program given all bulk shipments and all known container exports are sampled at out-turn and analysed for over 100 in-crop and post harvest chemicals, and environmental contaminants.

Sampling

Approximately 3000–5000 export grain samples are collected and analysed each year. NRS arranges for bulk export grain samples to be collected from the loaded holds of each ship to which bulk export grain is being out-turned at the 17 grain export terminals located throughout Australia.

Bulk grain samples are collected using automatic sampling equipment in accordance with NRS procedures and protocols. For containerised or bagged export grain, samples are collected from the grain packing sites during packing.

All samples are sent to the NRS-contracted laboratory for analytical testing.

Chemical screen

The chemical screens are developed in consultation with industry, taking into account registered chemicals, market sensitivities and chemical

Commodity	Bulk export samples	Container export samples
Wheat	2496	736
Barley	572	143
Sorghum	124	92
Other cereals	34	39
Oilseeds	425	29
Pulses	151	190
Total	3802	1229

Year	Samples	Compliance (%)	Samples	Compliance (%)
2000–01	4559	99.9		
2001–02	4436	100		
2002–03	3233	100		
2003–04	3822	100		
2004–05	3659	99.9	77	100
2005–06	2953	100	89	100
2006–07	2085	100	168	100
2007–08	2055	100	565	99.6
2008–09	2621	100	391	98.2
2009–10	2673	99.8	827	98.3
2010–11	3302	99.8	821	98.9
2011–12	4005	99.9	886	99.0
2012–13	3802	99.8	1229	98.9

residue profiles. The chemical groups covered in the analytical screens include insecticides (including post-harvest grain protectants), fungicides (including dithiocarbamates), herbicides, insect growth regulators, environmental contaminants (including heavy metals) and fumigants such as phosphine.

Results

Residue testing results over the past decade indicate a very high degree of compliance with Australian Standards. These results demonstrate that the Australian grain industry uses in-crop and post-harvest agricultural chemicals according to good agricultural practice, and assures customers of the excellent residue and contaminant status of Australian grains.

Traceback

If a sample is found to contain a residue above the relevant Australian Standard, a traceback investigation is undertaken to establish the cause. The responsible state or territory agency then provides advice to the producer to prevent recurrence. In more serious circumstances regulatory action may also be taken.

All traceback activities and findings are reported to NRS. This feedback is important in highlighting potential problems (such as inappropriate chemical use) and improving farm practices. Where appropriate, traceback information is also forwarded to industry and government authorities for consideration. Traceback information may also be forwarded to the Australian Pesticides and Veterinary Medicines Authority for consideration during its chemical review processes.

Laboratory performance

NRS has been accredited by the National Association of Testing Authorities (NATA) as a proficiency test provider since July 2005. The NRS proficiency testing system is recognised within the laboratory community as meeting internationally accepted standards (ISO/IEC 17043:2010) to establish the technical competence of participating laboratories.

Residue testing is conducted by several laboratories under contract with NRS. Laboratories are selected through the Australian Government tendering process on the basis of their proficiency, accreditation against international standards (ISO/IEC 17025:2005) and value for money. Laboratories are proficiency tested by NRS to ensure the validity of analytical results. Current laboratory contracts began on 1 July 2011 and will run to 30 June 2014.

International maximum residue limits

NRS maintains international maximum residue limit tables for countries that are major export markets for Australian primary produce. These tables can be found on the NRS website.

The National Residue Survey

The National Residue Survey (NRS) is part of an Australian Government and industry strategy to minimise chemical residues and environmental contaminants in Australian food products and promote market access. NRS residue monitoring programs support Australia's food industry and primary producers by confirming Australia's status as a producer of clean food and facilitating access to key export markets. NRS programs provide confirmation of good agricultural practices, help to identify potential residue problems, and indicate where follow-up action is needed.

Residues can be present in food either through natural circumstances or as a consequence of agricultural or industrial activities. NRS contracts laboratories to analyse samples for residues of pesticides, veterinary medicines and environmental contaminants. Samples are collected from 21 animal products including meat, honey, eggs, wild-caught fish and aquaculture products; 21 grains, pulses and oilseeds; and six horticultural products including pome fruit, macadamia, onion, almond and citrus.

Originally established in 1961 following concerns about pesticide residues in exported meat, NRS is largely industry-funded through levies on participating animal and plant commodity producers. NRS testing includes random and targeted programs. All NRS programs are underpinned by an ISO 9001:2008 quality management system.

General enquiries daff.gov.au/nrs
Phone 1800 420 919
Fax (02) 6272 4023
Email nrs@daff.gov.au

Postal address
National Residue Survey
GPO Box 858, Canberra ACT 2601 Australia

Contact details

Ian Reichstein
ian.reichstein@daff.gov.au

New South Wales

Grains Research UPDATE

Further Information

the RUST BUST

www.rustbust.com.au

Have a rust management plan this season

1. Grow varieties with adequate resistance to stem, stripe and leaf rust.
2. Phase out very susceptible (VS) or susceptible (S) varieties from your rotation.
3. Remove the green bridge (volunteer plants) four weeks prior to sowing.
4. Know the seedling and adult rust resistance characteristics of your varieties, and identify whether they require fungicide support.
5. Monitor your crop – early detection and management is best.
6. Use appropriate fungicide support to maximise crop performance and minimise disease build-up in your crop.
7. Report and/or submit suspected rust infections to the Australian Cereal Rust Survey, Private Bag 4011, Narellan NSW 2567

LEAF RUST

STEM RUST

STRIPE RUST

"If you spot rust in your crop - be proactive and tell your neighbour"

The Rust Bust is an initiative of the Australian Cereal Rust Control Program Consultative Committee, with support from the Grains Research and Development Corporation.

GRDC Grains Research & Development Corporation

Australian Cereal Rust Control Program

Establishing pastures – the trade-off between crop and livestock

Geoff Casburn[1,2], Richard Hayes[1,2], Jeff McCormick[3], Guangdi Li[1,2], Tom Nordblom[1,2], Tim Hutchings[1]

[1]Graham Centre for Agricultural Innovation (NSW Department of Primary Industries and Charles Sturt University), Wagga Wagga Agricultural Institute, PMB, Wagga Wagga, NSW 2650;[2]CRC for Future Farm Industries, 35 Stirling Highway, Crawley, WA 6009, Australia; [3] Lincoln University Ellesmere Junction Road/Springs Road, Lincoln 7647, Canterbury, New Zealand

Introduction

A recent survey by the EverCrop™ project indicates that 83% of farmers within the mixed farming zone of southern NSW, regularly under-sow their pastures. In other words they use a cover crop.

This practice goes against traditional research and extension advice which recommends pastures to be sown without a cover crop (straight sown), because under-sown pasture is at greater risk of poor establishment and less productive over the pasture phase. However, most previous research focused primarily on pasture density and biomass production. It did not quantify the financial implications of the cover crop or the potential effect on livestock productivity.

Farmers usually under-sow pastures because the potential income from the cover crop covers the cost of sowing the pasture. The success of this practice is difficult to assess and varies from year to year. A new decision support tool (DST) is under development to help producers predict when pasture establishment under a cover crop is likely to be the best option compared to the straight sown option.

The DST operates under the premise that a pasture is to be sown in a particular paddock the next year. The user is able to consider the costs and income from grain and livestock production during the pasture phase.

Methods

The underlying calculation for the DST is the net income from under-sowing (US) pasture minus the net income from straight-sowing (SS) pasture for the length of the pasture phase:

Net income = (Crop income + US livestock income - US variable cost) - (SS livestock income – SS variable cost)

Model inputs

An important component of the model is the capacity for the user to change a range of inputs to match their enterprise. The inputs in the DST include expected grain price, grain yield, stocking rate and livestock gross margin ($/DSE), establishment costs, the length of the pasture phase and relative effect that under-sowing has on pasture production (Figure 1).

Table 1. Inputs for Decision Support Tool

DST Inputs	An example of input variables
Grain Price ($/t)	180
Grain Yield (t/ha)	2.5
Stocking Rate (DSE/ha)	10
Livestock Gross Margin ($/DSE)	25
US* variable cost (crop and pasture; $/ha)	200
SS** establishment cost (pasture only; $/ha)	120
Length of pasture phase (Pasture Years)	4
US relative effect (proportion; 0-1)	0.5

* US – under-sown pasture; ** SS – self-sown pasture

Livestock Gross Margin has been derived from NSW DPI budgets[1] and is the net income from livestock and includes costs for stock and pasture management. The length of the pasture phase is the length of the intended pasture phase minus the establishment year when grazing is limited. The DST does not calculate pasture production *per se* but instead calculates the differences in stocking rates for the different establishment options, which we assume is related to pasture production. The user is asked to estimate on the basis of their experience the under-sowing relative effect, which is the proportion of production from an under-sown pasture relative to a straight sown pasture. For example, 0.5 being half the production of the straight-sown method.

[1] http://www.dpi.nsw.gov.au/agriculture/farm-business/budgets/livestock

Model outputs
The DST provides a single number in the Outputs to estimate which method of pasture establishment is more profitable. If the value is positive then greater profitability is obtained from under-sowing. By contrast, if the value is negative, straight sowing the pasture would be more profitable. The model produces sensitivity graphs to demonstrate how factors change the result, such as crop yield and grain price.

Results
Using the values in Table 1, the DST produces a value of -$5.00/ha which indicates that straight sowing the pasture is marginally more profitable for the nominated length of the pasture phase (Figure 1). The DST comments that this value is “too close to call” and that under these set of conditions the decision to under-sow or not might need to be made by the user on the basis on other ‘non-financial’ considerations.

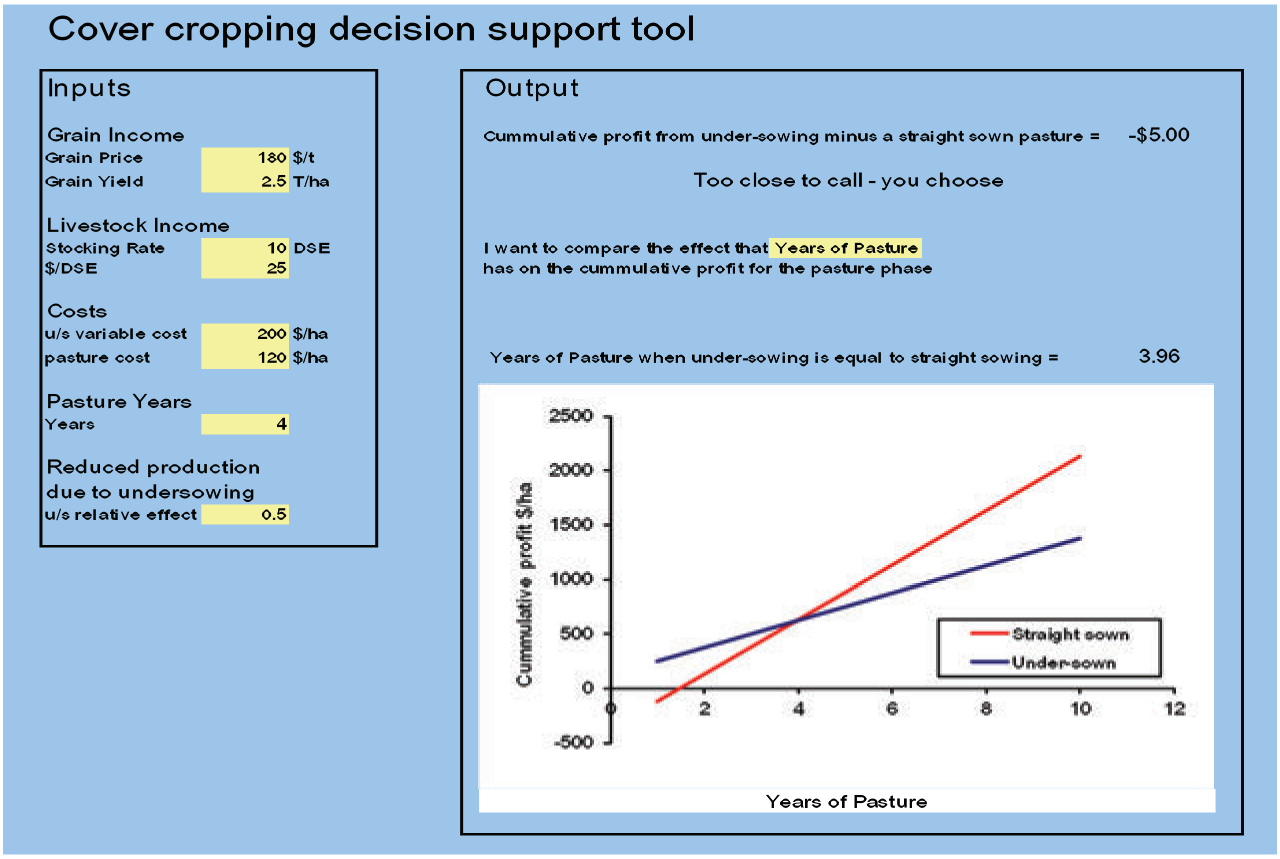


Figure 1. Interface of the prototype decision support tool, using the input data (Table 1).

The DST can produce a number of sensitivity graphs, with length of the pasture phase (Figure 1) indicating that straight sown pasture is the best option (a greater cumulative profit) with phases greater than 4 years. However a minimum 6 year pasture phase is required when the under-sowing relative effect is 0.7 (Figure 2a), increases to 8 years with a grain value of $240 (2b) and 9 years with a 3.0 t/ha grain yield (2c).

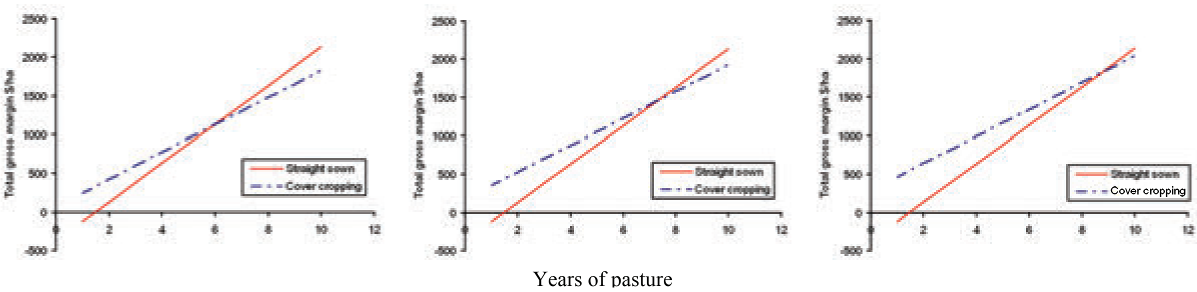


Figure 2. Sensitivity graphs produced by varying pasture inputs from Table 1:

a = Pasture relative effect of 0.7 using inputs from table 1.

b = Pasture relative effect of 0.7, combined with a grain price of $240.

c = Pasture relative effect of 0.7, combined with a grain price of $240 and 3.0 t/ha grain yield.

Increases in livestock enterprise gross margin or stocking rate will favour establishment of pastures by straight sowing (Figure 3a, b). In this case an increase from $25 to $30/DSE reduces the minimum length of the pasture phase to 5 years, and when combined with a stocking rate increase to 15 DSE/ha the minimum length is 4 years. Conversely a decrease in gross margin and stocking rate to $20/DSE at 6DSE/ha increases the minimum pasture rotation using straight sowing to 11 years (figure 3c).

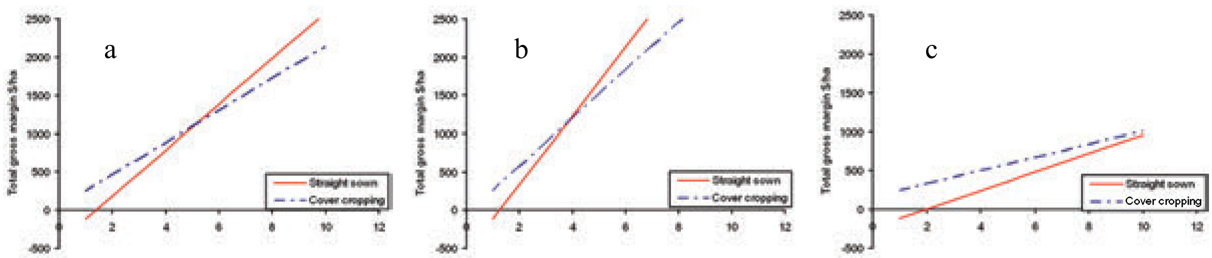


Figure 3. Sensitivity graphs produced by varying livestock inputs from Table 1:

a = Pasture relative effect of 0.7, combined with a $30/DSE (GM)

b = Pasture relative effect of 0.7, combined with a $30/DSE (GM) and 15DSE/ha.

c = Pasture relative effect of 0.7, combined with $20/DSE (GM) and 8DSE/ha.

Discussion

The primary purpose of the DST is to enable users to include important inputs into the decision making process. There is limited data on the relative effect that under-sowing has on pasture production , however it is likely to fall between 0.5-0.8 in normal years. It is likely there will be different perceptions of the 'relative effect' due to differences in climate and soil. The DST relies on the users experience in establishing pastures to set their 'under-sown relative effect' and their potential crop yield.

The user should also remember that the DST does not substitute for good agronomy. A major reason for poor establishment of pastures is likely to be because many pastures that are under-sown in southern NSW are sown towards the end of the crop sowing window. Pastures should be sown earlier in the sowing window to maximize establishment to counter their poorer seedling vigour relative to most crop species. If the DST suggests it is more profitable in a given set of circumstances to establish a pasture under a cover-crop, sowing should occur earlier in the sowing window.

Conclusion

The DST enables the user to identify whether under-sowing is more profitable under a given set of circumstances compared with straight-sowing. The range of sensitivity graphs helps determine how responsive the calculations are to a particular factor. Grain yields greater than 2.5 t/ha or grain prices greater than $180/t tend to improve the profitability of under-sowing. Alternatively, increases in stocking rate and livestock gross margins will result in straight sowing pasture being more profitable, especially with a relative pasture effect of 0.6 or lower. The length of the pasture phase also has a significant impact with longer phases favouring the straight-sown pasture option.

The EverCrop™ project team continues to test and refine this decision support tool with both advisors and farmers. The tool is compatible with most common computer systems and anyone wishing to trial it is encouraged to contact Geoff Casburn on (02) 6938 1630 or via email at geoff.casburn@dpi.nsw.gov.au

Sustainable management of insect pests in grain crops

Is the insect a pest or beneficial? Is control action economic / warranted? When is action needed? What should be considered when determining control options? Could management have avoided the problem?

Advisers and growers are invited to participate in a GRDC supported workshop on insect management in grain crops

Topics include:

- Implementing an integrated approach to insect management and associated decision making process
- Monitoring, record keeping and economic thresholds
- Integrated pest management tools including cultural control, conserving beneficial insects & 'softer' or more 'selective' insecticide options
- Key pest ecology and management strategies for regionally important crops

The morning session at all workshops will be indoors. The after lunch sessions at some workshops (Pittsworth, Goondiwindi, Casino, Grafton & Horsham) will be in the field (weather permitting) to discuss practical aspects of pest identification, scouting and management.

Workshops discussions will be led by extension and research staff from Queensland DAFF, NSWDPI, cesar and SARDI and facilitated by John Cameron (ICAN). Please come dressed suitably for in-field activities (weather permitting). Catering is provided.

Workshop dates and details.

- **31st March - Kadina, SA** (Farm Shed) 8:30am – 1:30pm
- **1st April - Kapunda, SA** (Golf Club) 8:30am – 1:30pm
- **8th April - Albury, NSW** (Commercial Club) 8:30am – 1:30pm
- **9th April - Bendigo, Vic** (Barclay on View) 8:30am – 1:30pm
- **10th April - Horsham, Vic** (Grains Innovation Park) 8:30am – 3:00pm

To enable in-depth discussion on key issues, workshop numbers are limited. Book early to avoid disappointment!

Workshops are targeted at advisers and leading growers who seek an improved understanding of insects and their management to implement more sustainable insect management practices. In practice, this means:

- use of scouting techniques, appropriate to the insect population and crop being assessed,
- use of economic thresholds based on insect number, damage, crop value, crop growth stage, seasonal conditions and the cost of control,
- consideration of paddock history and farm planning in relation to pest management,
- understanding of pest ecology,
- consideration of the role and impact of beneficial insects on pest populations and
- use of softer insecticide options to maintain beneficial populations when appropriate.

Workshops will focus on pests of local significance. Participants receive access to a first class resource kit including Fact Sheets, Ute Guides course notes and presentations. Technical input for workshops run in this 'DAFF Queensland Managed project', come from: DAFF Qld, SARDI, cesar, NSWDPI and ICAN.

Cost: These GRDC supported workshops are locally sponsored by Dow AgroSciences and Syngenta.
This support has enabled the cost for participation to be kept to $50 (inclusive of GST)

Note: Numbers are limited. Registrations will be closed when workshops are full.

To register, contact John Cameron or Erica McKay on 02 9482 4930 or erica@icanrural.com.au or on-line registration at http://www.icanrural.com.au

Non-herbicide weed control - not as sexy as a new herbicide but really important

Peter Newman,
AHRI

GRDC project codes: DAW00196, UWA00146

Keywords

non-herbicide weed control, crop competition, harvest weed seed control, mouldboard plough

Take home messages

- **Herbicides are not the answer to herbicide resistance. We need to do something else. There is a very short list of effective non-herbicide weed control practises on offer to Australian grain growers. Harvest weed seed control and mouldboard ploughing have been successfully adopted by many Western Australian grain growers. There is a lot of room for improvement in crop competition with weeds.**

Crop competition

Weeds are a problem in crops because they compete for resources. The crop needs to compete back or the weeds will win.

Most grain growers are reluctant to reduce their row spacing for a number of good reasons. However, many growers are now using ribbon sowing or paired row sowing techniques that effectively reduces the row spacing without affecting the tine spacing. These seeding techniques in combination with higher seed rates (where environmental conditions allow) have the potential to further increase crop competition with weeds. In 2012 we embarked on some crop competition research in the Geraldton area in the northern wheatbelt of WA. For this research we modified our seeding machinery to seed with a Stiletto seeding boot to sow paired crop rows 75mm apart in combination with seeding rate and herbicide treatments.

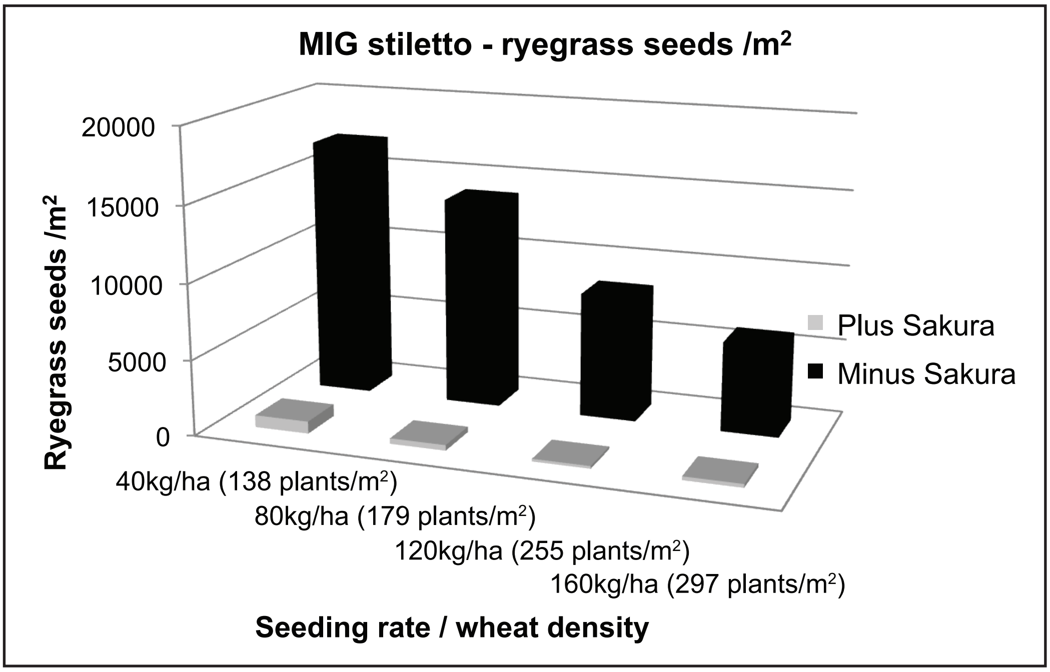


Figure 1. Ryegrass seed production per m^2 at Mingenew for four seeding rates, plus and minus Sakura herbicide 118 g/ha pre-sowing (average of single and paired row sowing). Wheat plant density is shown in brackets.

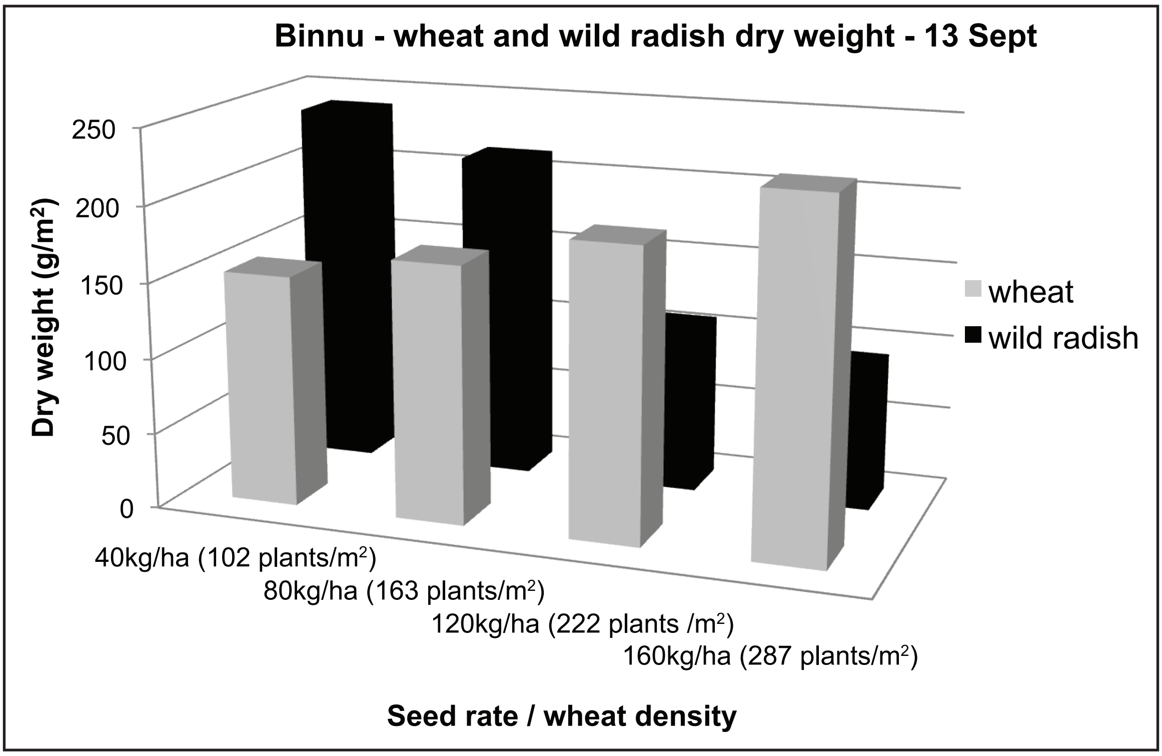


Figure 2. Wheat and wild radish (un-sprayed) dry weight (g/m^2) at Binnu as measured on 13 September from area of trial where no post-emergent herbicide was applied.

Mingenew trial – annual ryegrass

Ryegrass seed set was significantly reduced by increasing seeding rate ($p<0.05$; lsd 2768 seeds / m^2) (Figure 1).

Binnu trial – wild radish

This research demonstrates what many other crop competition trials have demonstrated in the past. As crop density increases, crop biomass increases, and weed growth and seed set decreases (Figures 1 and 2). The concept is not new. The challenge is to do this in a practical and cost effective way.

Paired row sowing achieved using the Stiletto boot in this trial, has the potential to improve grain yield and competition with weeds.

Harvest weed seed control (HWSC)

Removing weed seeds at harvest is currently our greatest non-herbicide weed control tool in Australian grain cropping. This practice is now widely adopted in the form of narrow windrow burning, chaff cart, bale direct, diverting weed seeds onto permanent tramlines, and now the Harrington Seed Destructor. All of these tools are equally effective at removing weed seeds, averaging 55% removal of annual ryegrass seeds (Walsh, 2012). They all differ in their cost and the amount of residue that they remove from the paddock.

The following data relates to a selection of 24 focus paddocks where the growers are cropping dominant with no livestock in the farming system. These focus paddocks have been monitored for twelve years as a part of a GRDC funded project to promote practical weed management.

Eight of the growers regularly practice harvest weed seed control (HWSC) either in the form of windrow burning or towing a chaff cart. On average, these growers practiced HWSC in 58% of years while achieving an average cropping intensity of 88.5% (Table 1). The frequency of HWSC is a little lower than expected, however the droughts of '02, '06 and '07 reduced the amount of harvest weed seed management due to a lot of paddocks either not harvest or not cropped. Also, some growers used HWSC for 5 years in a row by which time weed numbers were down so they cut back to burning lupin and canola windrows only.

Sixteen of the growers practiced HWSC in the form of narrow windrow burning in only 12% of years (i.e. Herbicides only group). This includes some whole paddock "cool burns". If we remove these cool burns the amount of windrow burning drops to 8% of years. These growers maintained a cropping intensity of 88% (Table 1), almost identical to that of the plus HWSC group.

Table 1. Cropping intensity (%) and the percentage of years in which harvest weed seed control (HWSC) was practiced for 16 cropping dominant growers who rarely practice HWSC (Herbicides only) compared with eight cropping dominant growers who regularly practice HWSC

	Herbicides Only	Herbicides + Harvest Weed Seed Control
% Crop	88	88.5
% of years using Harvest Weed Seed Control	12	58

The plus HWSC group have been on or are very close to the "zero line" for ryegrass since 2008, demonstrating the benefits of removing weed seeds at harvest. This group started with 183 ryegrass / m^2 in 2001 compared to 125 ryegrass /m2 in 2001 for the herbicides only group.

It is quite remarkable that growers have been so successful at eroding annual ryegrass seed banks of paddocks, while maintaining a cropping intensity of 88%. Many of the original messages about managing herbicide resistance in the 1990's were built around the concept of phase farming, and rightfully so. However, these growers are now demonstrating that it is possible to crop at high intensity while eroding the weed seed bank despite some of the highest levels of herbicide resistance on the planet.

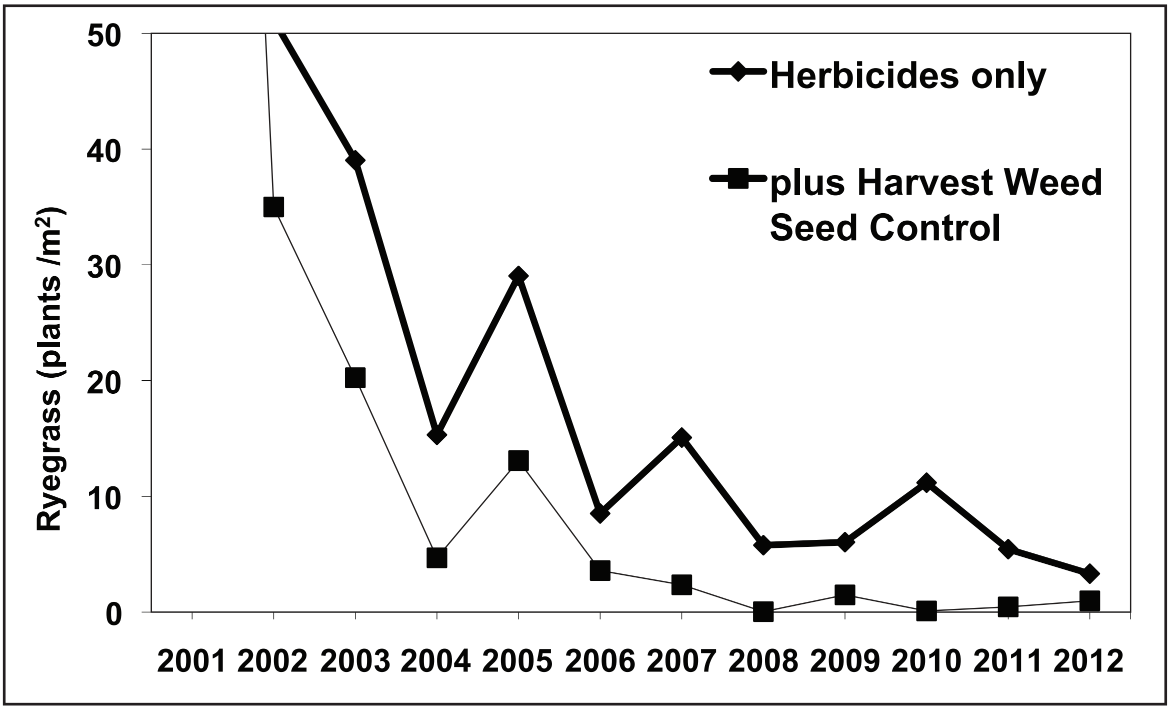


Figure 3. Average surviving ryegrass (in August) for 16 focus paddocks of cropping dominant growers who rarely practice harvest weed seed control (HWSC) (Herbicides only) compared with eight cropping dominant growers who regularly practice HWSC.

The growers who have had the most success at managing ryegrass populations are those who have practiced harvest weed seed control in the form of narrow windrow burning or by towing a chaff cart (Figure 3). These growers started with a higher seed bank which was eroded to very low levels in just four years. In the eighth year of using this practice these growers had zero ryegrass in their focus paddocks and have averaged less than 1.5 ryegrass plants /m2 ever since. Harvest weed seed control does not fix a system that is broken but can be the key lynch pin to making a system work. The herbicides only group have also been very successful at eroding the ryegrass seed bank while maintaining the same cropping intensity as the plus HWSC group at 88%. However, the heavy reliance on herbicides of this group is likely to result in higher levels of resistance in these paddocks.

Mouldboard ploughing – back to the future!

There are currently about fifteen large mouldboard ploughs owned and operated by growers and contractors in the northern wheatbelt of WA and several more are on their way in sea containers from Europe. This all started with some Department of Agriculture and Food research conducted by myself, Sally Peltzer and Alex Douglas. This research showed that we could correct four of our biggest constraints to sandplain farming in one fell swoop, namely:

- Non-wetting soil – burying of non-wetting top soil,
- herbicide resistant weeds – burying of the seed bank regularly achieving 99% control,

- sub-soil acidity – deep burial of lime sand to correct acidity at depth; and
- compaction – deep ripping effect to a depth of 35cm (14”).

The ploughs that have been imported by growers are typically 8 to 14 furrow. Eight to ten furrow ploughs are typically pulled with a 300hp front wheel assist tractor with three point linkage. These machines can plough 2.5 to 3.5 ha / hour. The bigger ploughs are pulled with large wheeled or track tractors in the 400 to 500hp range. The 14 furrow plough is pretty much the biggest in the world, towed by the biggest tractors on the planet and can plough 5 to 5.5 ha / hour. The cost of ploughing for owner operator machines is approximately $70 to $100 /ha.

Research has shown average yield response to ploughing of 400 kg/ha across a range of crops. In many cases these yield responses are enduring for five years or more. Often the cost of ploughing is paid for in the first year and profit is made in the following years. Two large sandplain growers in the northern wheatbelt of WA are aiming to plough their entire farms. One has 12,500 ha and the other a 20,000 ha farm. These are successful growers who can see the income potential from adopting this technology.

Contact details

Peter Newman

AHRI

0427 984 010

petern@planfarm.com.au

Notes

THE GRDC IN YOUR SOUTHERN REGION

KEITH PENGILLEY (CHAIR)
0448 015 539
kgpengilley@bigpond.com

As a panel, we want to hear more about what is happening in our region and the needs of our stakeholders. The new GRDC structure and operating processes will help us achieve this.

The regional location of a GRDC manager grower services and our panel support team will help the panel spend more time at events and activities in the region, while remaining in close contact with the GRDC staff in Canberra.

In addition to the 10 members of the Southern Panel and the GRDC Executive Manager, we now have 42 grower and agronomist members of the four Regional Cropping Solutions Networks. These people are spread across the region in four networks, based on rainfall zone or the use of irrigation. Two or three panel members are associated with each network.

The networks play a key role in capturing research ideas and prioritising short-term issues. This leaves more time for the panel to work on strategic investment requirements that often require longer-term strategies."

REGIONAL CROPPING SOLUTIONS NETWORKS

Bringing together a consistent approach to evaluating research priorities with a large network of growers, advisers and researchers across the region has the potential to provide a focused regional portfolio of research, development and extension investments.

The objectives of the Regional Cropping Solutions Networks are to:

1. Create and manage knowledge on grains industry issues.
2. Build regional D&E capacity among growers and advisers.
3. Proactively respond to regional industry issues in a timely manner.
4. Provide enduring links between growers, advisers and the GRDC.

Four networks have been established in the southern region, each supported by a facilitator. The networks will meet face-to-face up to three times each year.

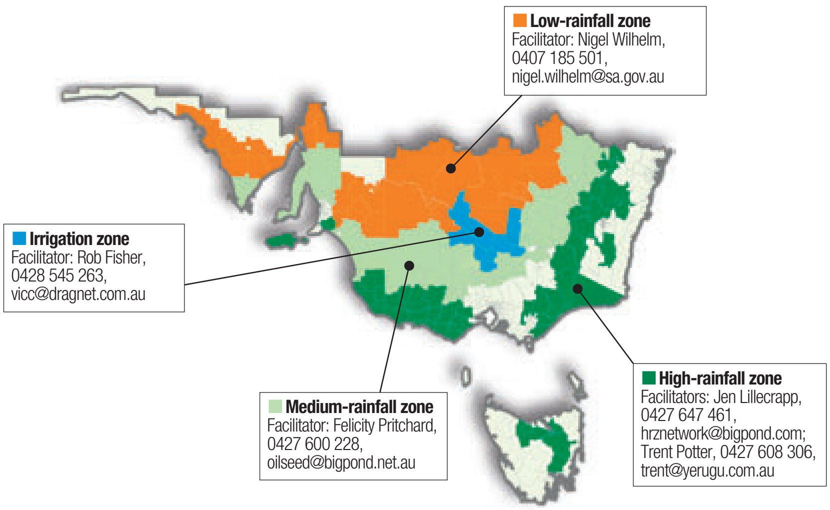
Each network will liaise with the wider grower community in their production zone, including convening regional meetings with relevant groups.

The facilitator provides each network with an effective interface with regional farming systems groups, agribusiness and research and development organisations across the regions.

While the primary focus of these facilitators will be working with farming systems groups and advisers, their work will also extend into maintaining a regional industry RD&E database of GRDC project activities and results.

Names of the members of the networks are listed on the GRDC website (www.grdc.com.au/RCSN).

GRDC Regional Cropping Solutions Networks – locations and key contacts in the southern region.



GRDC MANAGER REGIONAL GROWER SERVICES – SOUTH

As one of the three regionally based managers, Andrew Rice brings the face of the GRDC into the Southern Region. Having GRDC staff in the region offers visibility, accessibility and understanding. The skills set of the grower services manager provides another dimension to the operation of the GRDC. Andrew believes that pairing the new position of manager grower services – south, with the establishment of the facilitated Regional Cropping Solutions Networks provides the capacity and links to really make a difference.

M 0427 965 469 E andrew.rice@grdc.com.au

THE 2013-2015 GRDC SOUTHERN REGIONAL PANEL

GRDC
Grains Research & Development Corporation
Your GRDC working with you

Chair
Keith Pengilley

Keith is the general manager of a dryland and irrigated family farming operation at Conara in the northern Midlands of Tasmania, operating an 8300 hectare mixed farming operation over four properties. He is a Director of Tasmanian Agricultural Producers P/L, a grain accumulation, storage, marketing and export business.

M 0448 015 539
E kgpengilley@bigpond.com

Deputy Chair
Dr Chris Blanchard

Chris is an Associate Professor in Food Science at Charles Sturt University's School of Biomedical Sciences in Wagga Wagga and has an Honours Degree in applied science, a PhD in molecular biology and qualifications in teaching and management. His research has included projects in genetically engineering plants, human genetic diseases, grain quality and the development of functional food ingredients.

T 02 6933 2364 M 0438 662 992
E cblanchard@csu.edu.au

Neil Fettell

Based at Condobolin in the central-west of NSW, Neil is an authority on cropping and tillage systems, stubble and soil management and crop physiology. A University of New England part-time Lecturer in Crop Production, he also assists the Central West Farming Systems group and previously led grain research projects across the southern region.

M 0427 201 939
E fettells@esat.net.au

Susan Findlay Tickner

Susan is a partner in Yellow Grain Pty Ltd, an innovative and expanding dryland cropping enterprise producing cereals, pulses and oilseeds near Warracknabeal in north-west Victoria. She has a background in science communication, specialising in grains and climate research, development and extension. Susan has a Masters in Communication, a Diploma in corporate governance and is a graduate of the Australian Rural Leadership Program.

M 0428 622 352
E susanfindlaytickner@gmail.com

Richard Konzag

Richard has been a grain grower at Mallala, in SA's Lower North, since 1981. He is currently cropping about 1800 hectares to wheat, durum, barley, beans, lentils, canola and oaten hay. He has served on the SA Advisory Board of Agriculture, representing the board on various forums and committees and chairing its 'Achieving an Informed and Supportive Government' working group. Richard has also served on the Plant Biosecurity CRC Grains Advisory panel since 2008.

M 0417 830 406
E richard.konzag@gmail.com

Bill Long

Bill is an agricultural consultant and farmer on South Australia's Yorke Peninsula. He has led and been involved in many research, development and extension programs and was one of the founding members of the Yorke Peninsula Alkaline Soils Group and chairman of the Ag Excellence Alliance. He has a strong interest and involvement in farm business management and communication programs within GRDC. He is a Churchill fellow.

M 0417 803 034
E bill@agconsulting.com.au

Geoff McLeod

Geoff runs an irrigated cropping farm near Finley in southern NSW. The farm produces a range of winter cereal, oilseed and grain legume crops and soybeans using both overhead and surface irrigation systems. Geoff has a degree in Agricultural Science and 30 years experience with irrigated and dryland farming systems in southern Australia. Geoff is a board member of SoyAustralia and chairman of Southern Growers, a local grower group in the southern Riverina. Geoff also provides consultancy services to government, industry and catchment management authorities related to land and water management.

M 0427 833 261
E geoffrey.mcleod@bigpond.com

John Minogue

John runs a mixed broadacre farming business and an agricultural consultancy, Agriculture and General Consulting, at Barmedman in south-west NSW. John is the chairman of the district council of the NSW Farmers Association, Deputy Chair of the Lachlan Catchment Management Authority and a winner of the Central West Conservation Farmer of the Year award.

M 0428 763 023
E jlminogue@bigpond.com

Rob Sonogan

From Swan Hill in north-west Victoria, Rob is an extension agronomist who has specialised within government agencies in the areas of soil conservation, resource conservation and dryland farming systems. Over some three decades he has been privileged to have had access to many farmers, businesses, consultants, rural industry and agribusiness advisers. Rob also has been closely involved in rural recovery and emergency response into issues as diverse as locusts, fire, mice, flood and drought. Rob is currently employed part-time within the Mallee consultancy group AGRIvision.

M 0407 359 982
E sonoganrob@gmail.com

Mark Stanley

Mark has had extensive experience in field crops development and extension and more recently in natural resources management with the State and Commonwealth Governments and with industry. He has led a number of extension programs including the introduction of canola in SA and the national TOPCROP program. He currently operates his own project management business, Regional Connections, on the Eyre Peninsula of South Australia. Mark is the executive officer with the Ag Excellence Alliance, supporting farming systems groups across SA, and is also on the board of the Eyre Peninsula Agricultural Research Foundation. He is a committee member of the Lower Eyre Agricultural Development Association.

M 0427 831 151
E mark@regionalconnections.com.au

Stuart Kearns

Stuart joined the GRDC in 1998 as the Northern Panel Officer and has worked in a number of roles throughout the organisation since then. He is currently the Executive Manager Regional Grower Services. The aim of the Regional Grower Services Business Group is to deliver new, innovative, high-value and improved regionally relevant products and services that meet the needs of growers and their advisers.

T 02 6166 4500
E stuart.kearns@grdc.com.au

Southern Panel Support
Belinda Cay (nee Barr)

Belinda and the Raising the Barr (RTB) team are a communication company that design creative science education programs and corporate exhibits, plus offer media, marketing, facilitation and communication services. She has a Bachelor of Science (Honours) and a Graduate Diploma in Scientific Communication. RTB provides panel support services to the Southern Regional Panel.

M 0423 295 576
E belindacay@baonline.com.au

Level 1, Tourism House | 40 Blackall Street, Barton ACT 2600 | PO Box 5367, Kingston ACT 2604 | **T** +61 2 6166 4500 | **F** +61 2 6166 4599 | **E** grdc@grdc.com.au | **W** www.grdc.com.au

WE LOVE TO GET YOUR FEEDBACK

For your convenience, an electronic copy of the evaluation form has been created and can be accessed via the QR code provided or by typing the URL address into your internet browser.

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

- It must be completed on the one device (i.e. don't swap between your iPad and Smartphone devices, information will be lost).
- Once you start the survey, others should not use your device to complete their survey (i.e. one person per device).
- This survey allows respondents to start and stop the survey whenever they choose. For example, after the morning session you could complete that session's relevant questions and then re-access the survey following the afternoon session.

Thank you for your feedback.

ORM COMMUNICATIONS

URL https://www.surveymonkey.com/s/Temora

GRDC Adviser Update - NSW 2014

❶ Which of these best describes your main role? *(circle)*

1 Government Adviser

2 Government Researcher

3 Agribusiness Agronomist

4 Agribusiness Sales/Administration

5 Agribusiness R & D

6 Private Consultant

7 Grain Marketing

8 Environment/ Catchment Management

9 Farmer

10 Other (specify)………………………........................

❷ How many years experience have you had in this role?

…………………… Years

❸ Which other Grains Research Updates have you attended? *(circle)*

2013 2012 2011 2010 2009 2008

❹ From the list below of the highly rated topics from the 2013 NSW GRDC Adviser Update, please tick those that have influenced your advice in the last 12 months?

☐ Enhancing mental and emotional resilience *(Dennis Hoiberg)*

☐ Sowing dates – getting the best from our varieties *(James Hunt)*

☐ Managing blackleg and sclerotinia *(Kurt Lindbeck)*

☐ The strategic use of tillage within conservation farming *(Mark Conyers)*

☐ Game changer – the role of broadband *(David Lamb)*

☐ Meeting the cropping system's demand for nitrogen *(John Angus)*

❺ Organisers wonder whether you are happy with the content of the 2014 program? *(Tick box and/or write, suggestions and comments)*

- **sensible topic selections?**

  Yes ☐ **Partly** ☐ **No** ☐

  ………………………………………………………………………

  ………………………………………………………………………

- **the chance to explore selected topics in-depth?**

  Yes ☐ **Partly** ☐ **No** ☐

  ………………………………………………………………………

  ………………………………………………………………………

- **enough access to specific agronomy recommendations (including proceedings)?**

  Yes ☐ **Partly** ☐ **No** ☐

  ………………………………………………………………………

  ………………………………………………………………………

- **opportunity to attend issues of greatest interest?**

  Yes ☐ **Partly** ☐ **No** ☐

  ………………………………………………………………………

  ………………………………………………………………………

- **intellectual stimulation?**

  Yes ☐ **Partly** ☐ **No** ☐

  ………………………………………………………………………

  ………………………………………………………………………

Please indicate any other issues you noted

………………………………………………………………………

………………………………………………………………………

❻ What is the likelihood that you will use three pieces of information from this conference in your business?

Rate on 0 – 100% likelihood scale where 0% = completely unlikely and 100% = totally likely __________%

❼ **What is the likelihood that you will attend an Update like this next year?**

Rate on a 0 –100% likelihood scale where 0 = totally unlikely, and 100% = totally likely ________%

❽ **Would you agree with the Updates providing only electronic proceedings in 2015 (i.e. no hard copy)?** **Yes** ☐ **No** ☐ **Not yet** ☐

❾ **Please rate your degree of satisfaction with the following** *(tick)*

	1 very poor	2 poor	3 average	4 good	5 excellent
Overall program	☐	☐	☐	☐	☐
Proceedings	☐	☐	☐	☐	☐
New Release Booklet	☐	☐	☐	☐	☐
Venue	☐	☐	☐	☐	☐
Visual aids	☐	☐	☐	☐	☐
Audio	☐	☐	☐	☐	☐
Meals	☐	☐	☐	☐	☐
Organisation	☐	☐	☐	☐	☐
Registration	☐	☐	☐	☐	☐

❿ **Please make any extra comments on anything organizers can do to deliver a better conference for you.**

....

....

....

....

....

....

⓫ **Perhaps you have been to a conference where you experienced something you really liked that could be adapted for these Updates. What was that?**

....

....

....

....

....

....

⓬ Program content

For each presentation you attended, please rate on a scale of 0 to 10 (where 0 = totally dull and 10 = outstanding) the content of the presentation and how it was presented by placing a number in each box. If you didn't see that presentation, leave the boxes blank. Your comments are encouraged

DAY 1 – Tuesday

	Content	Presentation	/10 Comments
Feeding the dragon – modernisation of China's food industry and what it means to the Australian grains industry? - *Ian Perry*	☐	☐	....
Strategies and tactics to extend whole farm water use efficiency – sow on time or early - *James Hunt*	☐	☐	....

CONCURRENT SESSIONS

	Content	Presentation	/10 Comments
Pulses – new varieties and new management bring new options - *Eric Koetz*	☐	☐	....
The fundamentals of increasing nitrogen use efficiency - *Chris Dowling*	☐	☐	....
Improved slug management - *Michael Nash*	☐	☐	....
What's new with zinc – maybe just some critical reminders? - *Rob Norton*	☐	☐	....
Canola establishment – does size matter? - *Rohan Brill*	☐	☐	....
Biopesticides – fresh hope for the future - *Gavin Ash*	☐	☐	....

LUNCH

	Content	Presentation	/10 Comments
Is social media working for you? - *Prudence Cook*	☐	☐	....

Canola and pulse disease management – maintaining the vigilance in 2014 - *Kurt Lindbeck* ☐ ☐ ....

....

Soil organic matter – what does it mean for you? - *Harm van Rees* ☐ ☐ ....

....

FINAL SESSION

Can canola meal be used to treat cancer? - *Saira Hussain* ☐ ☐ ....

....

Unlocking the potential of Australian chickpea - *Christina Chin* ☐ ☐ ....

....

Accelerating adoption of innovative agronomy – experiences from Alberta, Canada - *Steve Larocque* ☐ ☐ ....

....

BACKCHAT SESSIONS

For each backchat presentation, please rate out of 10 the value of the discussion and whether there was sufficient time for you to ask questions (Yes/No) (please circle)

	Value	Sufficient time	
Ian Perry	☐	**Yes**	**No**
James Hunt	☐	**Yes**	**No**
Chris Dowling	☐	**Yes**	**No**
Michael Nash	☐	**Yes**	**No**
Rob Norton	☐	**Yes**	**No**
Rohan Brill	☐	**Yes**	**No**

DAY 2 – Wednesday

	Content	Presentation	/10	Comments

CONCURRENT SESSIONS

Crown rot – an update from the north - *Steven Simpfendorfer* ☐ ☐ ……………………………

……………………………………………………………………………………………

Maintaining flexibility and options with pre-emergents - *Chris Preston* ☐ ☐ ……………………………

……………………………………………………………………………………………

Review of sulfur strategy to improve profitability in canola in the central west of NSW - *Maurie Street* ☐ ☐ ……………………………

……………………………………………………………………………………………

MORNING TEA

Dual–purpose wheat and canola – finding the best fit with experiments, experiences and modelling - *John Kirkegaard* ☐ ☐ ……………………………

……………………………………………………………………………………………

To windrow or not to windrow in 2014? This is the question, but if so, when? - *Maurie Street* ☐ ☐ ……………………………

……………………………………………………………………………………………

New and potential malting barley variety update and agronomic developments - *Rick Graham* ☐ ☐ ……………………………

……………………………………………………………………………………………

Quantifying herbicide resistance in modern farming systems – Griffith region 2012/13 - *Barry Haskins* ☐ ☐ ……………………………

……………………………………………………………………………………………

FINAL SESSION

Robotics and intelligent systems for large scale agriculture - *Robert Fitch* ☐ ☐ ……………………………

……………………………………………………………………………………………

Maintaining market access – keeping it clean - *Ian Reichstein* ☐ ☐ ……………………………

……………………………………………………………………………………………

Herbicide resistance – fresh approaches ☐ ☐ ……………………………

……………………………………………………………………………………………

BACKCHAT SESSIONS

For each backchat presentation, please rate out of 10 the value of the discussion and whether there was sufficient time for you to ask questions (Yes/No) (please circle)

	Value	Sufficient time	
Steve Larocque	☐	**Yes**	**No**
Chris Preston	☐	**Yes**	**No**
Steven Simpfendorfer	☐	**Yes**	**No**
John Kirkegaard	☐	**Yes**	**No**

Please place this evaluation form in the return boxes located at the registration desk or mail back to ORM, PO Box 189, Bendigo 3552

Thank you for your feedback which will be evaluated and utilised to help improve future programs.