

Research for the
Riverine Plains 2014

Farmers promoting excellence in farming systems by providing quality information, leading research and sharing ideas for the economic, environmental and social benefit of the Riverine Plains.

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Acknowledgements

Welcome to *Research for the Riverine Plains 2014*. This year we have an array of articles around topics of relevance, which we hope you find interesting and informative.

As the research portfolio of Riverine Plains Inc continues to evolve, we are proud to share the results of our research with you. These results provide local information on options to improve water use efficiency, management of growth and disease in retained stubble systems and field-scale validation of strategies to build soil carbon.

In addition to research carried out by Riverine Plains Inc, we have also included results from other research organisations and industry bodies, who provide information relevant to our region and the agronomic issues we face. On behalf of Riverine Plains Inc, I would like to formally thank all authors for their willingness to share their results with our members.

We particularly recognise the ongoing support provided by the Grains Research and Development Corporation (GRDC) and the Australian Government Department of Agriculture — *Action on the Ground Program*, which enables us to deliver research outcomes that address local issues.

A very special thanks to the Riverine Plains Inc staff and committee for their efforts in planning this publication and sourcing articles of interest, and a special thanks to Fiona Hart and Allison Glover for their hard work in coordinating the process. Thanks also to sub-editor Catriona Nicholls and graphic designer Josephine Eynaud for producing a professional publication, which presents technical information in a manner which is easy to interpret and understand.

We hope you enjoy reading *Research for the Riverine Plains 2014*, and we wish you all the best for the 2014 cropping season.

Dr Cassandra Schefe
Extension Officer, Riverine Plains Inc



Contents

Area covered by Riverine Plains Inc

Membership area

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Units of measurement

Row spacings

Some trials carried out during 2013 have investigated the effect row spacings play in crop production.

Riverine Plains Inc recognises that while the research sector has moved toward metric representation of row spacings, most growers remain comfortable with imperial measurements.

Following is a quick conversion table for handy reference when reading the following trial result articles.

TABLE 1 Row spacing conversions

Inches	Centimetres
7.2	18.0
9.0	22.5
9.5	24.0
12.0	30.0
14.4	36.0
15.0	37.5

Standard units of measurement

Through this publication, commonly-used units of measurement have been abbreviated for ease of reading they include:

centimetres — cm

gigahertz — GHz

hectares — ha

kilograms — kg

kilojoules — kJ

litres — L

metres — m

millimetres — mm

tonnes — t

Cereal growth stages

Why are they important to cereal growers?

A growth stage key provides a common reference for describing crop development, so we can implement agronomic decisions based on a common understanding of which stage the crop has reached.

Zadoks cereal growth stage

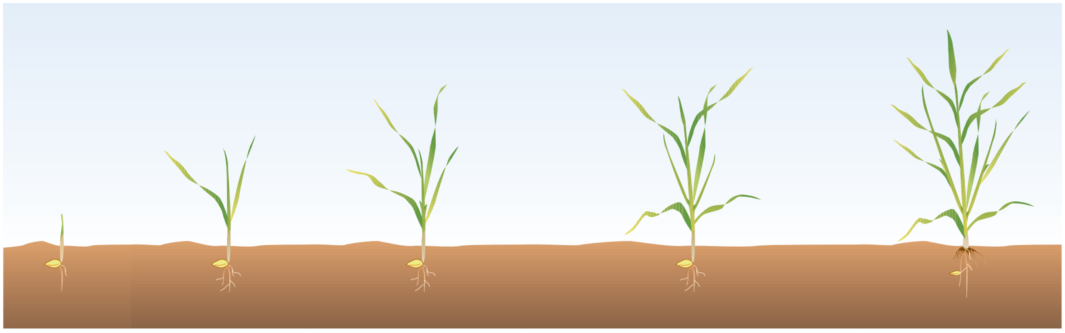
The most commonly used growth stage key for cereals is the:

- Zadoks decimal code, which splits the development of a cereal plant into 10 distinct phases of development and 100 individual growth stages.
- It allows the plant to be accurately described at every stage in its life cycle by a precise numbered growth stage (denoted with the prefix GS or Z e.g. GS39 or Z39)

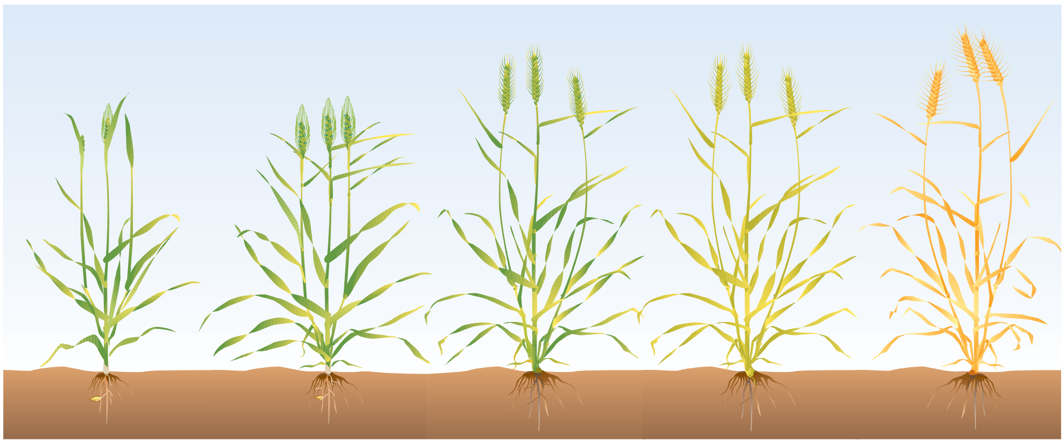
Within each of the 10 development phases there are 10 individual growth stages, for example, in the seedling stage:

- GS11 describes the first fully unfolded leaf
- GS12 describes two fully unfolded leaves
- GS13 describes three fully unfolded leaves
- GS19 describes 9 or more fully unfolded leaves on the main stem

This information has been reproduced with the permission of the Grains Research and Development Corporation (GRDC) and is taken from *Cereal Growth Stages: The link to crop management*, by Nick Poole.



Zadoks growth stage	GS00–09	GS10–19	GS20–29	GS30–39	GS40–49
Development phase	Germination	Seedling growth	Tillering	Stem elongation	Booting



Zadoks growth stage	GS 50–59	GS60–69	GS70–79	GS80–89	GS90–99
Development phase	Ear emergence	Flowering	Milk development (grain fill period)	Dough development (grain fill period)	Ripening

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Management is by a local Board. The Chair is Mrs. Alex Anthony (Moulamein), with Board members: Richard Bull (Holbrook); David Wolfenden (Rand); Jennie Hehir (Finley); Ken Crossley (Deniliquin); Graham Allitt (Deniliquin) and Terry Gorman (Balranald).

Our funding to work with landholders and local communities comes from investment by the NSW and Australian Governments and our ratepayer base.

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BIOSECURITY

ANIMAL HEALTH

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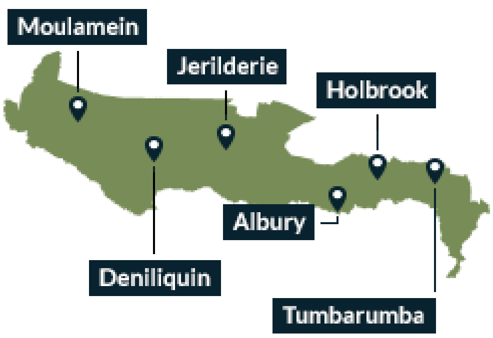
TRAVELLING STOCK RESERVES

The Travelling Stock Reserves in the Murray region, previously managed by Hume and Riverina LHPAs will continue to be managed with many of the same staff involved. Contact our offices for information and permits.





Preface

Trials versus demonstrations — what the results mean

Research on the Riverine Plains takes different shapes and forms, each of which has the potential to make an important contribution to increasing the understanding about agricultural systems in the area. However, it is important to keep in mind results from the different forms of research need to be analysed and interpreted in different ways.

It is important to understand the difference between trials and demonstrations in the use of results for benefit on farms. A replicated trial means that each treatment is repeated a number of times and an averaged result is presented. The replication reduces outside influences producing a more accurate result. For example, trying two new wheat varieties in a paddock with varying soil types and getting an accurate comparison can be obtained by trying a plot of each variety, say four times. Calculation of the average yield (sum of 4 plots then divided by 4) of each variety accounts for variations in soil type.

Statistical tests for example, Analysis of Variance — ANOVA, Least Significant Difference — LSD) are used to measure the difference between the averages. If there is no significant difference between treatments the results will be accompanied by the mark NS (meaning not significantly different). A statistically significant difference is one in which we can be confident that the differences observed are real and not a result of chance. The statistical difference is measured at the 5% level of probability, represented as 'P<0.05'.

Table 1 shows an LSD of 0.5t/ha. Only Variety 3 shows a difference of greater than 0.5t/ha, compared with the other varieties. Therefore Variety 3 is the only treatment that is significantly different.

TABLE 1 Example of a replicated trial with four treatments

	Treatment	Avg yield (t/ha)
1	Variety 1	4.2
2	Variety 2	4.4
3	Variety 3	3.1
4	Control	4.3
	LSD (P<0.05)	0.5

A demonstration is a comparison of a number of treatments, which are not replicated. For example, splitting a paddock in half and trying two new wheat varieties or comparing a number of different fertilisers across a paddock. Because a demonstration is not replicated results cannot then be statistically validated. For example, it may be that one variety was favoured by being sown on the better half of the paddock. We can talk about trends within a demonstration but cannot say that results are significant. Demonstrations play an important role as an extension of a replicated trial that can be tried in a simple format across a large range of areas and climates.

Demonstrations are accurate for the paddock chosen under the seasonal conditions incurred. However, care must be taken before applying the results elsewhere.

Trials and demonstrations play a different role in the application of new technology. Information from replicated trials is not always directly applicable but may lead to further understanding and targeted research. Demonstrations are usually the last step before the application of technology on farm.

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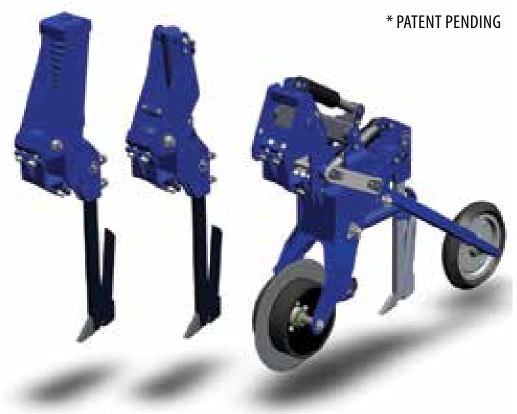

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A word from the Chairman

Evan Ryan
Chairman 2012–13

Riverine Plains Inc has had another successful year with a number of key extension, research and committee achievements.

On the extension front, the year started off extremely well, with about 150 farmers and advisors turning out for the *2013 GRDC Grains Research Update* hosted by Riverine Plains Inc at Corowa during late February. An impressive list of speakers shared the latest in grain industry research and extension and this event gave everyone plenty to consider in terms of preparing for the 2013 cropping season.

In May, the Baxter family, from Berrigan, kindly opened their farm gates to anyone interested in seeing a cotton harvest. Approximately 20 members made the most of the opportunity to see the harvest process in what is understood to be the southern-most cotton crop grown to date.

During early June, Riverine Plains Inc joined with RSM Bird Cameron and NAB Agribusiness to present the *Sustainable Farming Business Workshop*. The interactive workshop was designed to assist farmers in driving their agricultural business into the future. An audience of more than 100 heard about innovative business models for family farms, the *Personal Property Securities Act (2009)*, commodity prices, the interest rate outlook and were given a glimpse into world economics.

Technology is playing an ever-increasing role in our farming businesses and during July, 60 attendees came along to the *Tech Toolkit* workshop. The day was held at Corowa and provided farmers with the opportunity to interact with major agri-software providers and learn some of the many ways in which technology can help improve the triple bottom line of their modern farming businesses.

Riverine Plains Inc is passionate about providing high-quality and timely information to members and the importance of seasonal information was evident as 80 growers and agribusiness representatives attended the *In-Season Update*, held at Mulwala during early August. The day provided some useful information on slug management, the impact of time of sowing on yield, the remaining seasonal outlook, global agriculture, crop sensors and biosecurity issues in the grains industry.

The *Spring Bus Tour* is another annual highlight and during 2013, the tour focus was on the many great things to see and learn in our own Riverine Plains backyard. In early September, a group of 20 visited Godde's Grain and Fertiliser at Culcairn to learn how old silos had been converted into sealed storage. Riverine Plains Inc soil carbon project officer, Dr Bill Slattery, outlined the trial at Culcairn and discussed why this trial may be beneficial in reducing greenhouse gases (results can be found on page 32 of this publication). A factory tour of Kotzur Silos generated much interest, as did a tour of the Trevethan Family Farms where the group learned about diversification and enjoyed a close look at the machinery.

Following the bus trip, Nick Poole led a successful *Spring Paddock Walk* at Yarrawonga. The audience of 55 heard about the Riverine Plains Inc canopy management and row spacing trials. A lively and interactive discussion followed, which focused on management, particularly late season nitrogen and fungicide options for the 2013 crop. The group also visited two new trials, the plant growth regulator (PGR) and yellow leaf spot (YLS) trials (see results on pages 22 and 28).

In response to the problematic issue of slug management, an *Integrated Pest Management (IPM)* workshop was held during late September with a focus on options in stubble-retained systems. A total of 18 people attended the workshop, which covered decision-making principles and the design and implementation of a successful IPM program.

The 2014 extension program also started off well as Riverine Plains Inc held its first international farm study tour. With the assistance of an Industry Development Award from the Grains Research and Development Corporation (GRDC) a group of 20 visited the south island of New Zealand, where they examined high-input farming techniques from some of the region's leading grain and mixed farmers. The trip was an amazing success, both in terms of the ideas participants came home with and also on the social front. It also paved the way for some other international forays in the future.

Print and other media

In addition to the many opportunities for Riverine Plains Inc members to gain information and experience through tours, workshops, technical updates, farm walks and field days, we also provide information through our regular print and electronic publications.

Farmers inspiring farmers

The 2013 edition of *Research for the Riverine Plains* was distributed during August and this comprehensive publication continues to be an important means of providing quality research information to members.

The Riverine Plains Inc Grower Bulletin (via email) was produced as required throughout the growing season in response to seasonal conditions and challenges and the group's website also continues to keep members and the agricultural industry up to date with group events, news and information.

Another opportunity presented when Michelle Pardy and Fiona Hart participated in the ABC Online Open 'Day in the Life Of' series. The end result was a three-minute short film story about Barooga farmer (and current chair) John Bruce, which also starred his wife Sarah and daughter Lexie. The piece was available online and broadcast on TV and generated a lot of positive comment for Riverine Plains Inc.

Sponsorship

During 2013, Riverine Plains Inc again received fantastic support from agribusiness through the form of sponsorship. Our group continues to be successful and that is due, in no small part, to the contribution of our sponsors. We especially recognise the input we receive from our sponsors in terms of trial contributions, project advice and input at field days, workshops and other presentations. These contributions combine to allow Riverine Plains Inc to deliver information in ways that successfully meet the needs of our members.

Research

The Research Subcommittee worked tirelessly to manage a significant suite of projects during 2013.

During June, it was announced that Riverine Plains Inc was set to receive $1.4 million over five years from the GRDC to deliver an important project looking at improving and maintaining profit and sustainability in the region's stubble-retained cropping systems.

The 'stubble initiative' follows on from the highly successful 'water use efficiency (WUE) initiative', which Riverine Plains Inc has been part of for the past five years. The project uses a combination of large, commercial-scale trial plots and smaller trial plots to investigate a range of agronomic measures that can improve the profitability and sustainability of crops grown in stubble-retained systems.

The project specifically investigates the different measures available to treat and handle stubble and also looks at the interactions between crop nitrogen and plant growth regulators and also the interactions between applied nitrogen and fungicide on YLS and yield.

Staff

Another highlight of 2013 was the appointment of our new Finance Officer, Kate Coffey. Kate's employment marks a significant step in the growth of the organisation and will enable the group to better manage its human and financial resources into the future.

During early 2014, we also welcomed our new Extension Officer, Dr Cassandra Schefe, to the Riverine Plains Inc team. Cassie will be responsible for rolling out a comprehensive and exciting new extension package for the group, centred around our research work. Cassie will also have input into a range of issues and her involvement should see some valuable flow-on benefits for members.

Committee

As this is my last Chairman's report, I wish to make special thanks to retiring committee members, Jenny Owen, David Wolfenden, Andrew Godde and Jan Davis. I wish to thank each of you for the tremendous work, time and effort you have put into the committee over the years.

I would also like to make special mention of the work David Wolfenden did in getting the 'soil carbon' project up and running. There is an immense amount of time required in writing funding applications and David put in a huge effort to secure the funds for this project. David also chaired the Victorian Grower Group Alliance and we have seen the synergies between grower groups in Victoria develop as a result of David's enthusiasm and drive.

I would also like to thank Jan Davis for the contribution she has made to the group over the past 11 years. In the beginning Jan was our paid administrator but as the group developed, she relinquished that position and moved onto the Committee where she became an active, diligent and enthusiastic member. Jan has made an enormous contribution to the group and been a key driver behind some of the group's most significant changes through her roles as Treasurer, Public Officer and Administration Subcommittee Chair. Jan has been a tremendous ambassador for the group, always going above and beyond to make members and sponsors feel welcome and known to each other. Jan's contribution has been fundamental to the growth of Riverine Plains and I wish her all the best for the future.

I also wish the 2014 office bearers and committee members all the very best for the future. The Committee works extremely hard to generate new ideas and to make sure the group is run professionally and with a level of dedication and integrity that reflects the needs of members. Without their hard work and persistence, Riverine Plains Inc would not be the dynamic and influential group that it is today.

As I step down from the role as Chairman, I am particularly pleased to be able to hand over the chairmanship to someone as capable and well regarded as John Bruce. John has been an active committee member for the past four years and has chaired the Extensions Subcommittee before taking on the role of Deputy Chair. John is passionate about farming and his drive for continual improvement will provide the group with the leadership it needs to see it grow and prosper over the next few years.

On a more sombre note we have recently bid farewell to a dear friend of Riverine Plains — John Sykes. Many of those associated with the group in the past and present will no doubt fondly remember John who was associated with the group since its inception more than a decade ago. John worked tirelessly with the committee and staff to realise the goals and aspirations of all involved. Many of us linked closely to Riverine Plains Inc had a strong personal and professional relationship with John and he is remembered by all those he assisted and touched with his generous nature and fighting spirit through his short but heroic battle with illness. We have lost an outstanding professional co-operator and an irreplaceable personality who has contributed enormously to the community fabric in which we all work and live.

Similarly, esteemed member John Hanrahan also will be deeply missed. John passed away suddenly in February. During the past five years the Hanrahan family hosted our GRDC-funded *Water Use Efficiency* trials on their property at Coreen. Without the willingness and commitment of farmers, such as the Hanrahan family, to host and actively participate in trials, the group's research simply wouldn't be possible.

On behalf of Riverine Plains Inc I would like to express our deepest condolences to the Sykes and Hanrahan families.

Finally, I would like to thank our staff members and the committee for their support during the past couple of years.

I look forward to the future growth and expansion of Riverine Plains, under fresh chairmanship, with the capable leadership and guidance of Fiona, all staff and the committee over the coming term.

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A word from the incoming Chair

John Bruce
Chairman 2014

Riverine Plains Inc is a dynamic group run by a capable and passionate committee of volunteers and staff who are committed to bringing you the best information to help you manage your farming business.

I'm humbled, excited, and a little daunted to be your new Chair, but I'm also looking forward to growing the group in ways that ensure we continue to meet the information needs of our farmer members and research partners.

We currently have a diverse and exciting range of research projects underway and a full extension program planned for 2014, which aims to deliver research outcomes in a number of different ways.

As Evan mentioned, the Riverine Plains Inc study tour to New Zealand was a resounding success and we also have hosted another well-attended and successful *GRDC Grower Update* at Corowa.

We have co-hosted a stubble forum in Corowa, with the EH Graham Centre, which covered a range of issues specific to stubble retention systems and have rolled out the first of our focus/discussion group meetings on the issue of maintaining profitability in stubble-retained systems. These are the first of many events planned for this year.

But a successful extension program is only part of the story for Riverine Plains Inc. The other part of what we do is research — because this is what drives the change and improvement within our systems.

Riverine Plains Inc has a sizeable research program and we are pleased to be able to bring you the results of our latest work in this latest *Research for the Riverine Plains* compendium. The 'trial book' is our flagship publication and as well as our own research, it also brings to you other relevant research undertaken in the region by other organisations.

A particular highlight of this year's publication is the inclusion of the final results from the six-year *Water Use Efficiency* research project. This project has demonstrated the importance of row spacing, sowing density and nitrogen application on crop yield and water use efficiency in the first wheat crop after canola. Such information provides strong evidence of the links between productivity gains and efficiency of water use, which is of high value when making agronomic decisions.

On a sadder note, the end of this project also marks the loss of farmer collaborator John Hanrahan. During the past five years the Hanrahan family hosted our GRDC-funded *Water Use Efficiency* trials on their property at Coreen. Sadly, John passed away in February 2014.

On behalf of the group I would like to join Evan Ryan in expressing our sincere thanks and deepest condolences to the Hanrahan family and also to the family of the late John Sykes, who also contributed tirelessly to our group over the years.

I would also like to take the opportunity to publicly thank Evan for his dedication to the organisation since taking on the Chair's role in 2012. During his time as Chair, Evan oversaw some significant changes within the group. He was the driving force behind the move to the Yarrawonga office and the subsequent move to the Mulwala office. Evan also oversaw the continued implementation of the group's Strategic Plan, which saw, among other things, the employment of our Finance Officer, Kate Coffey. These were significant changes for the group and I'd like to congratulate Evan for his efforts.

I would like to thank Cassie Schefe, Allison Glover and Fiona Hart for their work in collating this year's *Research for the Riverine Plains 2014* publication and ensuring it meets the high standards expected by our members. I would also like to recognise the ongoing support provided by funding bodies such as the Grains Research and Development Corporation (GRDC), Australian Government Department of Agriculture — *Action on the Ground Program* which enables locally-based research to continue.

The trial book is an annual milestone for the group and a major achievement. I hope you enjoy the many gems of information in these pages and we look forward to your feedback and comments throughout the 2014 season.

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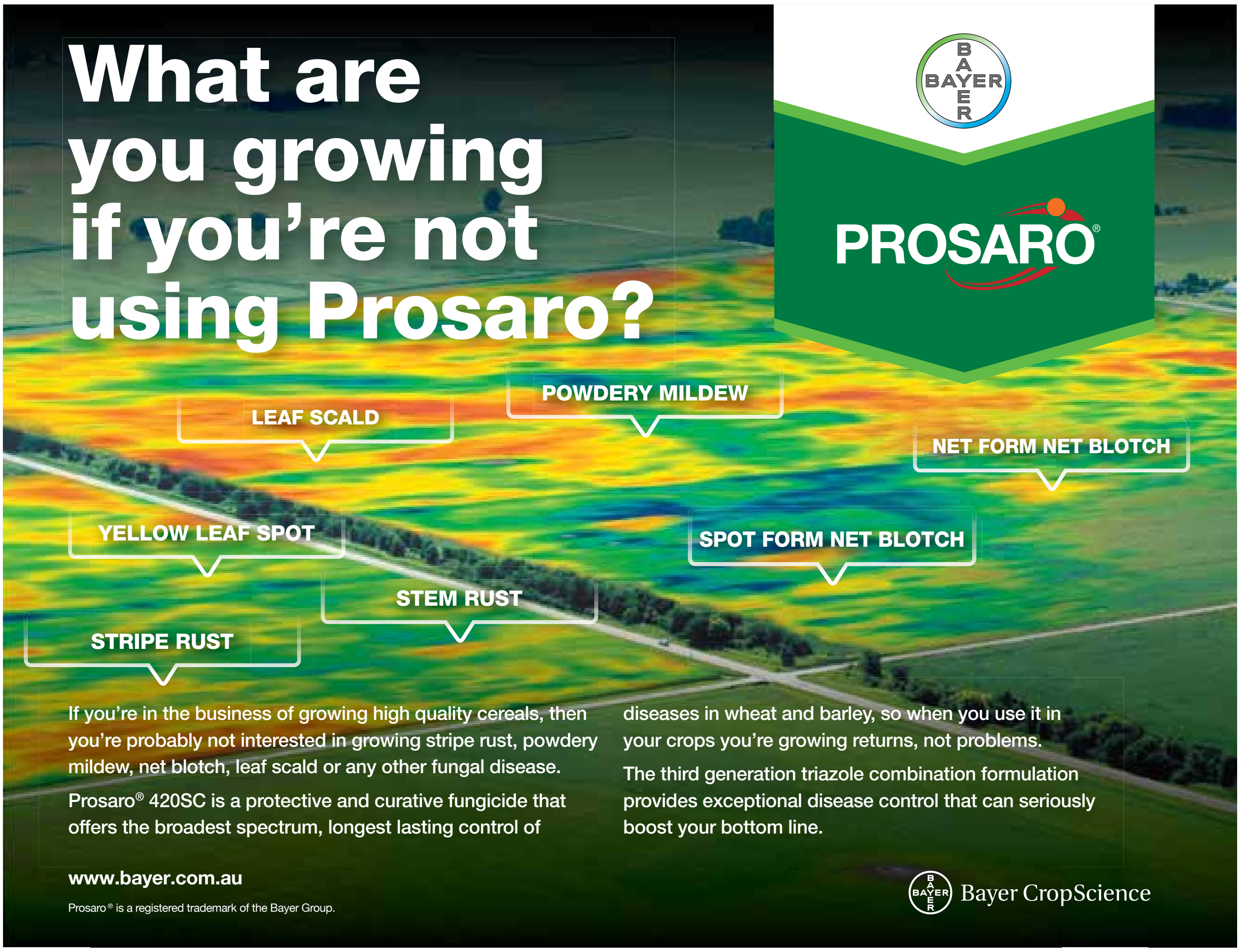

Performance of first wheat under no-till full stubble retention (NTSR) using in-crop nitrogen, plant population and row spacing at Yarrawonga

Nick Poole and Tracey Wylie
Foundation for Arable Research, Australia in conjunction with Riverine Plains Inc

Key points

- First wheat following canola yielded between 3.65–5.35t/ha depending on row spacing, plant population and nitrogen (N) application.
- A narrow row spacing of 22.5cm produced higher dry matter (DM), grain yields and water use efficiency (WUE) than a wider row spacing of 37.5cm.
- Higher grain yields were associated with plant populations of 150–165 plants/m^2.
- Wide row spacing reduced grain yields by an average of 6.5% and DM by 15% compared with narrow row spacing.

Location: Yarrawonga, Victoria

Rainfall:
Annual: 378mm
GSR: 222mm (April–October)
Stored moisture: 32mm (estimated at 35% fallow efficiency)

Soil:
Type: Loamy clay

Sowing information:
Variety: Gregory
Sowing date: 15 May 2013
Sowing equipment: Janke tine with Janke presswheel
Treatments: Row spacing x nitrogen application x plant population

Row spacing: 22.5cm and 37.5cm

Paddock history:
2012 — canola
2011 — wheat
2010 — pasture

Plot size: 16m x 2m

Replicates: 4

Overall goal

Improved water use efficiency (WUE) in no-till cropping and stubble retention systems in spatially and temporally variable conditions in the Riverine Plains.

Aim

The aim of this trial was to evaluate the performance of in-crop nitrogen (N), plant population and row spacing interaction in a first wheat no-till full-stubble-retention (NTSR) scenario.

Method

A replicated experiment was established to test the effect of four nitrogen timing strategies across four combinations of: two row spacings (22.5cm and 37.5cm) and two target plant populations (100 and 200 plants/m^2).

The four nitrogen timing treatments were based on 50kg N/ha timed at: sowing in the seedbed, early stem elongation (pseudo stem erect to first node — GS30–31), a 50% split of 25kg N/ha between both timings and nil nitrogen fertiliser.

Nitrogen application in these treatments was based on prilled urea fertiliser (46% nitrogen by weight).

A further four nitrogen strategies (25kg N/ha in the seedbed, 25kg N/ha at GS30–31, 100kg N/ha in the seedbed and 100kg N/ha at GS31) were applied to additional plots established on a 22.5cm row spacing and the higher crop density target of 200 plants/m^2.

The trial was sown in fully-retained canola stubbles that were approximately 45cm in length.

Statistical analysis was carried out using Statistix (version 9.0).

The trial was analysed as two trials: row spacing, plant population and nitrogen timing was analysed as a factorial design and nitrogen rate by timing (22.5cm row spacing and 200 plants/m^2 population target) was analysed separately as a factorial and a randomised complete block.

Reference to significant differences in the text denotes a p value equal to or <0.05.

Results

Crop establishment

Plant establishment differed significantly as a result of target plant population and row spacing. The 22.5cm row spacing established significantly more plants/m^2 than the 37.5cm spacing for the same sowing rate. The plant populations were greater than the target of 100 plants/m^2 and 200 plants/m^2 for the narrow row spacing but not for the wide row spacing.

Applying nitrogen to the seedbed did not significantly affect plant establishment, regardless of the nitrogen rate applied (25 and 50kg N/ha), when averaged across the two target plant populations and two nitrogen timings (see Table 1).

Nitrogen (0, 25, 50, 100kg N/ha) applied at sowing (established at 22.5cm row spacing with the higher target population) had no significant effects on plant establishment (see Figure 1).

Dry matter production

i) Plant population

Higher plant populations produced significantly more DM (larger canopies) than the lower plant populations until harvest, at which time there was no difference between the two target populations (see Figure 2).

TABLE 1 Plant establishment at three-leaves-unfolded stage (GS13), 37 days after sowing

Nitrogen treatment	Plant establishment (plants/m^2)					
	Target 100 plants/m^2			Target 200 plants/m^2		
Row spacing (cm)	**22.5**	**37.5**	**Mean**	**22.5**	**37.5**	**Mean**
Nil nitrogen	167	96	**132**	272	152	**212**
50kg N/ha seedbed (SB)	163	88	**126**	273	157	**215**
50kg N/ha GS30–31*	159	87	**123**	270	151	**211**
50:50 seedbed:GS30–31 split*	164	86	**125**	269	146	**208**
Mean	**163**	**89**		**271**	**151**	
LSD [plant population]	10					
LSD [row spacing]	10					
LSD [nitrogen treatment]	14					
LSD [pop^n x row spacing]	14					
LSD [pop^n x nitrogen treatment]	19					
LSD [pop^n x row x nitrogen treatment]	27					
Interaction — plant population x row spacing p value <0.001						

*At the time of assessment the GS31 nitrogen application had not been applied
Pop^n — plant population

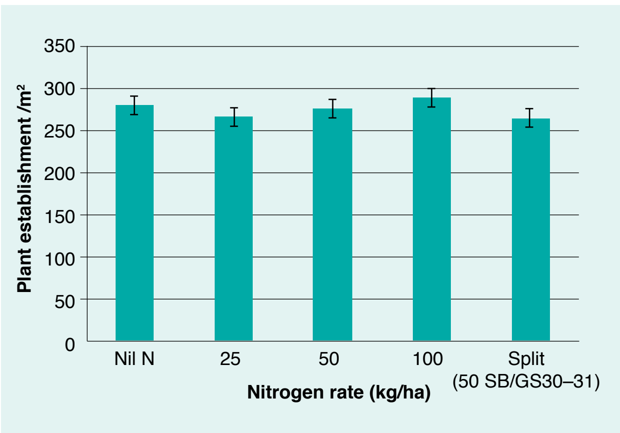

FIGURE 1 Influence of different nitrogen rates at sowing on plant establishment at a targeted plant population of 200 plants/m^2 sown on 22.5cm row spacings*

* Error bars presented as LSD value

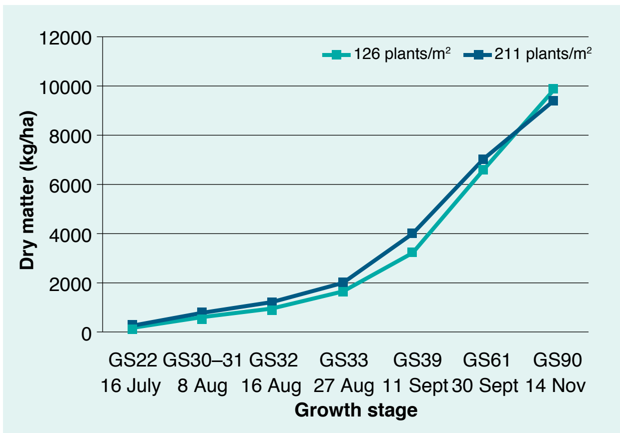

FIGURE 2 Influence of plant population on dry matter production*

LSD (5%): GS22; 55 , GS30–31; 85, GS32; 124, GS33; 196, GS39; 270, GS61; 373, GS90; 479kg DM/ha

* Mean of two row spacings and two nitrogen strategies (16 July – 27 August), mean of two row spacings and four nitrogen strategies (11 September – 14 November 2013)

The growth rate between flag leaf emergence (GS39) and harvest was significantly greater where the lower plant population was established (103kg DM/day) versus the higher population (84kg DM/day).

ii) Row spacing

Sowing the crop at the narrow row spacing (22.5cm) produced significantly more DM/ha than establishing the crop at the wider row spacing (37.5cm) at each of the seven assessment timings (see Figure 3).

The narrow row spacing averaged a growth rate of 98kg DM/day, which was significantly greater than growth at the wider spacing of 84kg DM/day between GS39 and harvest.

iii) Plant population and row spacing

With a wider row spacing, increasing plant population (density) from less than 100 plants/m^2 to 150 plants/m^2 increased DM production until GS39, after which the difference was not statistically significant.

At higher plant populations (163 increased to 271) with the narrow row spacing, the same effect was observed; the higher plant population produced more DM until GS39, after which there was increased growth by the lower plant population, which significantly increased DM by harvest (see Figure 4).

Overall, increasing plant population with a wide row spacing did not allow the crop to achieve the levels of DM production measured with a narrow row spacing.

iv) Nitrogen application: timing and rate

Applying nitrogen at sowing did not significantly influence DM production at the first assessment at

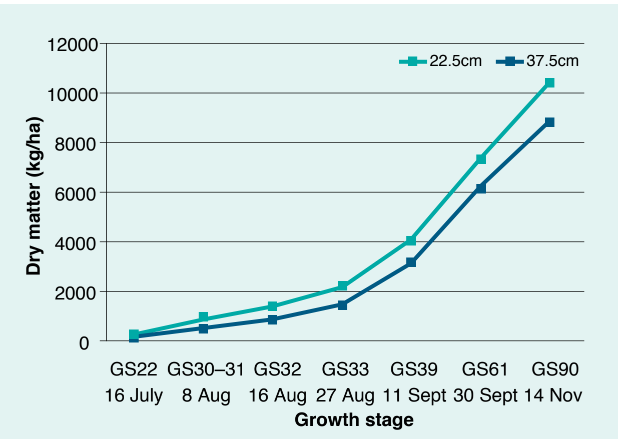

FIGURE 3 Influence of row spacing on dry matter production*

LSD (5%): GS22; 55, GS30–31; 85, GS32; 124, GS33; 196, GS39; 270, GS61; 373, GS90; 479kg DM/ha

* Mean of two plant populations and two nitrogen strategies (16 July — 27 August), mean of two plant populations and four nitrogen strategies (11 September — 14 November 2013)

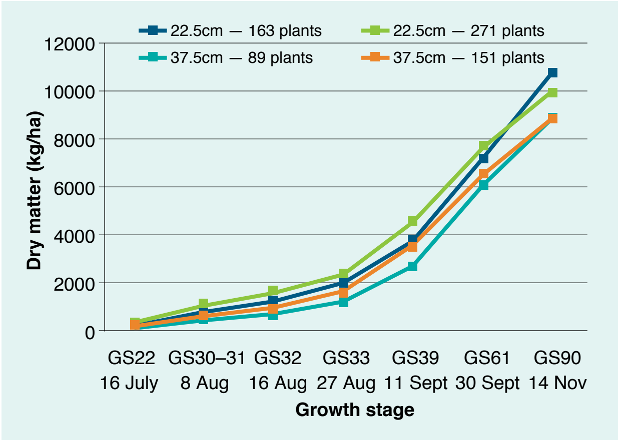

FIGURE 4 Influence of plant population and row spacing on dry matter production*

LSD (5%): GS22; 77, GS30–31; 125, GS32; 175, GS33; 277, GS39; 382, GS61; 527, GS90; 677kg DM/ha

* Mean of two nitrogen strategies (16 July — 27 August), mean of four nitrogen strategies (11 September — 14 November 2013)

tillering (GS22 main stem and two tillers). However, from the pseudo-stem erect stage (GS30) assessment through to third node (GS33) the addition of 50kg N/ha in the seedbed significantly increased the amount of DM compared with the untreated and GS30–31 nitrogen-fertilised plots.

When assessed at GS39 the 50kg N/ha applied at sowing also produced significantly more DM than the split nitrogen application (where 25kg N/ha was applied in the seedbed with a further 25kg N/ha at GS30–31). At the same assessment (GS39) there was no difference in DM production between the split application (25kg N/ha seedbed and 25kg N/ha GS30–31), the stem elongation application (GS30–31) or the untreated treatments.

Between the nitrogen application on 6 August at GS30–31 and sampling at GS39 on the 11 September there was 31mm of rain.

Assessments at the start of flowering (GS61) showed that applying nitrogen at sowing resulted in significantly more DM compared with where nitrogen application was delayed until GS30–31. However, both nitrogen application strategies produced significantly more DM than the nil-nitrogen treatment.

At harvest there was no statistical difference in DM between the three nitrogen strategies (100% seedbed, 100% GS30–31 and split 50%:50% between the two timings) with a range of DM from 9600–10,100kg/ha DM (see Figure 5). However, all three nitrogen treatments significantly increased DM production over the nil-nitrogen treatment (8800kg/ha DM).

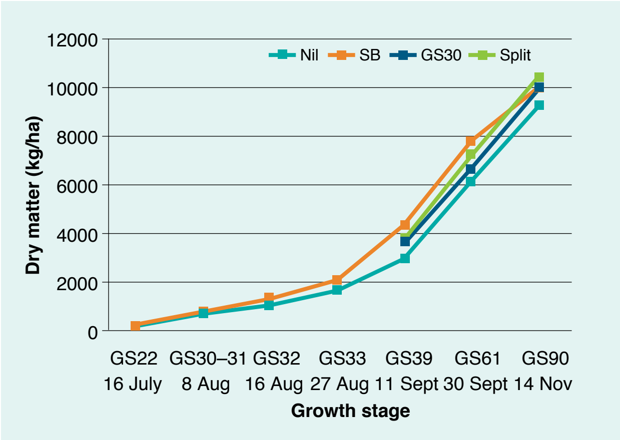

FIGURE 5 Influence of 50kg N/ha applied to the seedbed at sowing, at GS30–31 and 50:50 split between seedbed and GS30–31 on dry matter production (16 July – 14 November)*

LSD (5%): GS22; 55, GS30–31; 85, GS32; 124, GS33; 196, GS39; 382, GS61; 528, GS90; 677kg Dm/ha

* Mean of two row spacing and two plant populations

The rate of nitrogen applied, when averaged across two application timings (seedbed and start of stem elongation: GS30–31), generated significant differences in DM production at harvest. All levels of nitrogen application increased DM production significantly over the unfertilised treatment.

There was no difference in DM between the 100 and 50kg N/ha rates of application, and no difference between 50 and 25kg N/ha treatments. However, the trend was that more nitrogen produced more DM (see Figure 6).

v) Nitrogen uptake

As was measured with DM production, there were no differences in nitrogen uptake in the crop between treatments when assessed at the early growth stages.

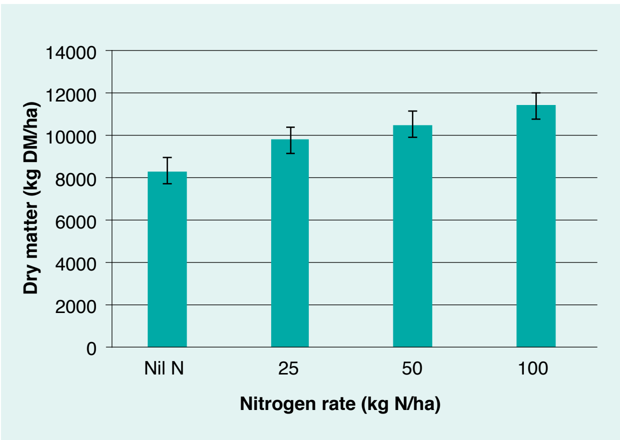

FIGURE 6 Influence of nitrogen rates applied on dry matter production at harvest (14 November) when sown at 22.5cm row spacings at a target plant population of 200 plants/m²*

* Mean of two application timings: seedbed and GS30–31

(Error bars presented as LSD value)

However, at second node (GS32) there was significantly more nitrogen in the plant shoot biomass (canopy) where nitrogen was applied to the seedbed at sowing.

From the GS39 assessment through to harvest, the nil-nitrogen treatment had significantly less biomass nitrogen than when nitrogen was applied (see Figure 7).

Note that at crop maturity (GS90) the unfertilised crop had taken up 145kg N/ha compared with those crops that had been fertilised (with 50kg N/ha), which had taken up 168–186kg N/ha, indicating the crop had access to a relatively large soil nitrogen reserve.

Crop structure

Tiller production was greatest where 50kg N/ha was applied at sowing, though there was no statistical advantage over 25kg N/ha applied at the same time when assessed at GS30–31. Both nitrogen application rates promoted significantly more tillers than the nil-nitrogen control treatment.

The 50kg N/ha at sowing treatment also produced the most heads at harvest, however the advantage was not significant over the other two nitrogen application timings.

Tiller mortality was relatively low in the trial at 6–11% (see Figure 8).

Overall, relatively high nitrogen uptake in the unfertilised crop treatment and dry conditions during spring have restricted the overall nitrogen response.

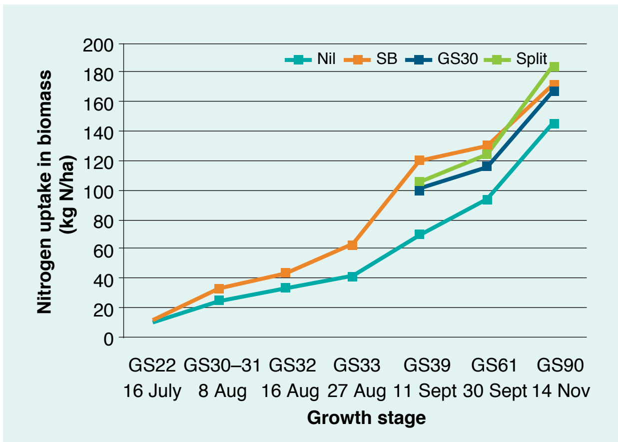

FIGURE 7 Addition of 50kg N/ha applied in the seedbed at: GS30–31 and 50:50 split between seedbed and GS30–31 on nitrogen uptake, compared with the nil-N control (16 July – 14 November)*

LSD (5%): GS22; 3, GS30–31; 4, GS32; 4, GS33; 6, GS39; 11, GS61; 13, GS90; 13kg N/ha

* Mean of two row spacings and two plant populations

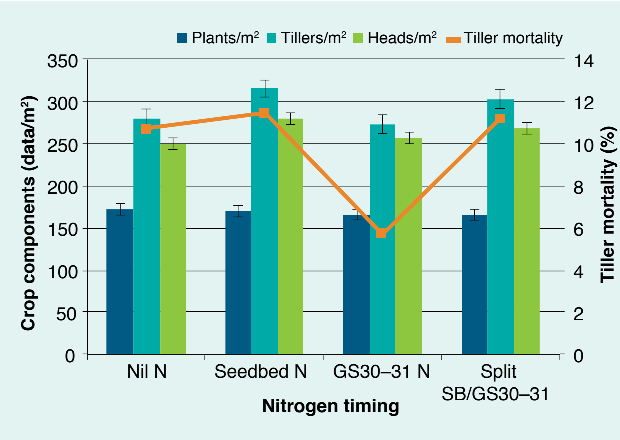

FIGURE 8 Influence of nitrogen application (50kg N/ha) on crop structure (plants 24 June, tillers 14 August, heads 14 November)*

* Mean of two row spacings and two plant populations

Error bars presented as LSD value

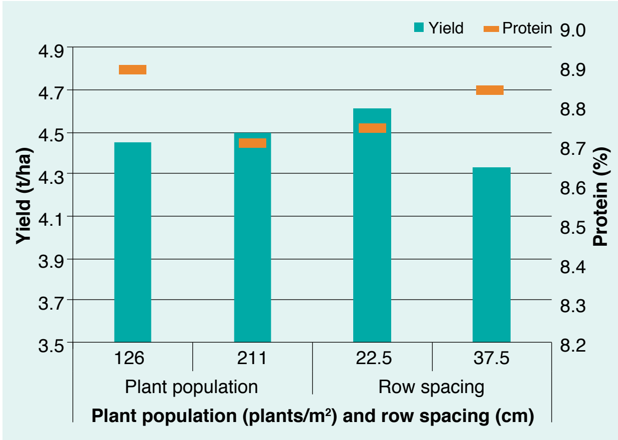

FIGURE 9 Influence of target plant population* and row spacing^ on yield and protein.

* Plant population is the mean of two row spacings and four nitrogen timings. ^ Row spacing data is the mean of two plant populations and four nitrogen timings.

LSD (5%); plant population and row spacing yield 0.11t/ha, protein 0.12%, compare plant population and row spacing separately

Yield and quality

i) Influence of row spacing and plant population

The narrow row spacing significantly out-yielded the wider row spacing by 0.3t/ha when averaged across all treatments, with no difference recorded in protein content due to row spacing (see Figure 9). There was also no effect of plant population on yield (see Table 2).

The influence of row spacing and plant population on yield is consistent with the differences recorded in DM production.

There was significantly higher protein content in the lower plant population (8.9% in the 100 plants/m² treatment versus 8.7% in the 200 plants/m² treatment) (see Figure 9). This result is the same as that recorded during the 2012 trial year.

There was a significant interaction between plant population and row spacing, which is probably the result of the actual plant population ranges established. There was no significant difference in yield between the two plant populations established (271 versus 163 plant/m²) with the narrow row spacing (22.5cm), while at the wider row spacing (37.5cm) increasing plant population from 89 plants/m² to 151 plants/m² significantly increased yield (see Figure 10).

Note that the comparison of plant population at the narrow row spacing was assessed at higher populations than the wider row spacing; a factor that is likely to have influenced this interaction.

TABLE 2 Yield at harvest (10 December 2013)

	Yield (t/ha)					
Nitrogen treatment	**Target 100 plants/m²**			**Target 200 plants/m²**		
Actual plant population (m²)	**163**	**89**		**271**	**151**	
Row spacing (cm)	**22.5**	**37.5**	**Mean**	**22.5**	**37.5**	**Mean**
Nil N	3.93	3.65	**3.79**	3.90	3.70	**3.80**
50kg N/ha seedbed	4.85	4.55	**4.70**	4.68	4.68	**4.68**
50kg N/ha GS30–31	4.93	4.30	**4.61**	4.80	4.58	**4.69**
50:50 seedbed GS30–31 split	5.00	4.38	**4.69**	4.83	4.83	**4.83**
Mean	**4.68**	**4.22**		**4.44**	**4.55**	
LSD [plant population]	0.11					
LSD [row spacing]	0.11					
LSD [nitrogen treatment]	0.16					
LSD [pop^n x row spacing]	0.16					
LSD [pop^n x nitrogen treatment]	0.23					
LSD [pop^n x row x nitrogen treatment]	0.32					

Significant interaction — plant population x row spacing p = 0.003
Pop^n — plant population

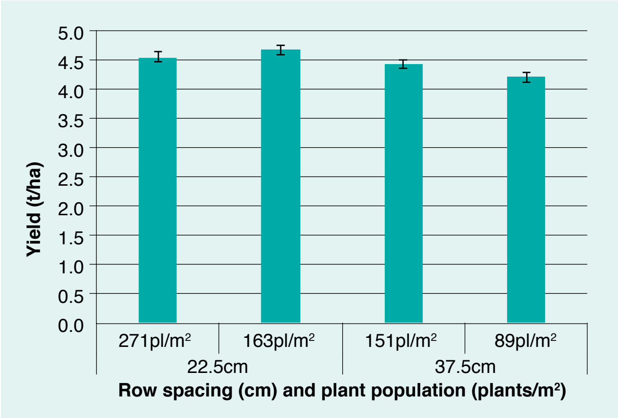

FIGURE 10 Interaction of plant population and row spacing on yield*

* Mean of four nitrogen timings

Error bars presented as LSD value

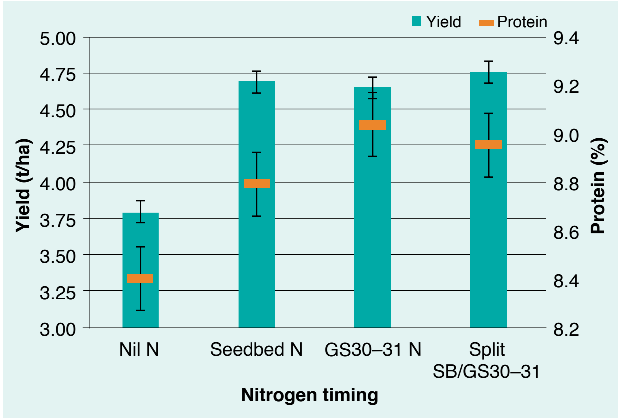

FIGURE 11 Influence of nitrogen application timing (50kg N/ha) on yield and protein content *

* Mean of two row spacings and two plant populations

Error bars presented as LSD value

The optimum combination of row spacing and plant population (22.5cm at 163 plants/m²) yielded 0.25t/ha more than the nearest equivalent population (151 plants/m²) at the wider 37.5cm row spacing and 0.47t/ha more than the wide spacing at the lower population of 89 plants/m².

ii) Influence of nitrogen timing and rate

Irrespective of timing, the application of 50kg N/ha significantly increased yield and protein content over the unfertilised plots (mean of two row spacings and two plant populations) (see Figure 11).

There was no yield difference due to the timing of nitrogen applications when 50kg N/ha was applied; a result that concurs with DM assessments at maturity.

Grain protein was highest with GS30–31 applied nitrogen, indicating greater nitrogen use efficiency in grain nitrogen uptake, since overall nitrogen uptake in the crop canopy as a whole was the same with all nitrogen timing strategies at maturity (see Figure 7). The nitrogen uptake in the grain of the split application was intermediate, as might be expected.

When comparing the influence of nitrogen rate at the higher plant population and 22.5cm row spacing, all nitrogen rates gave a significant yield advantage over the nil-nitrogen control. The application of 100kg N/ha yielded significantly more grain than all other treatments, with no difference in the two 50kg N/ha treatments (applied as a single or split application) (see Figure 12).

Grain protein content followed similar trends to yield, with higher nitrogen application rates delivering higher grain protein levels (see Figure 13).

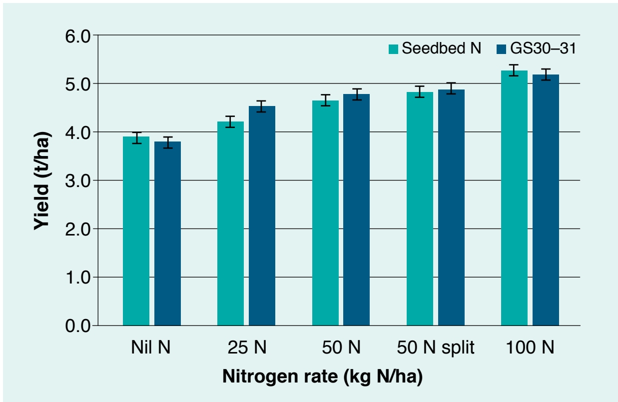

FIGURE 12 Influence of nitrogen rate and timing on yield when sown at a 22.5cm row spacing and 270 plants/m²*

* Error bars presented as LSD value

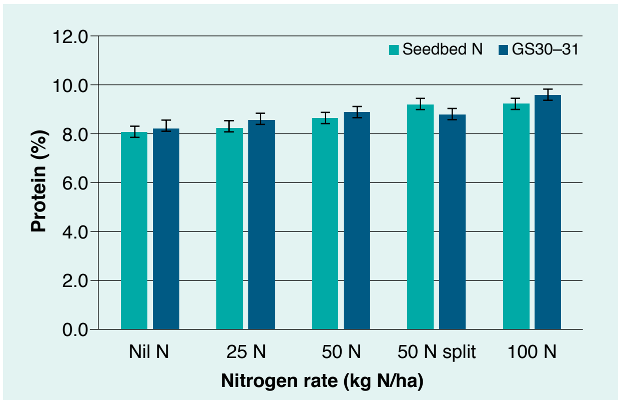

FIGURE 13 Influence of nitrogen rate and timing on protein when sown at a 22.5cm row spacing and 270 plants/m²*

* Error bars presented as LSD value

TABLE 3 Biomass at harvest, yield, harvest index (HI), water use efficiency (WUE), transpiration, evaporation/drainage and transpiration efficiency (TE)

	Biomass (kg/ha)	Yield[5] (kg/ha)	HI (%)	WUE[1] (kg/mm)	Transpiration[2] (mm)	Evaporation[3] (mm)	TE[4] (kg/mm)
Plant population (plants/m^2)							
100 (target)	9807	3891	**40**	15.3	178	76	**21.8**
200 (target)	9394	3935	**42**	15.5	171	83	**23.0**
LSD	479	100	**2.5**	0.39	8.7	8.7	**1.37**
P value	0.089	0.345	**0.153**	0.345	0.089	0.089	**0.153**
Row spacing (cm)							
22.5	10,369	4036	**39**	15.9	189	66	**21.4**
37.5	8833	3790	**43**	14.9	161	94	**23.6**
LSD	479	100	**2.5**	0.39	8.7	8.7	**1.37**
P value	<0.001	<0.001	**0.003**	<0.001	<0.001	<0.001	**0.003**
Nitrogen treatments (50kg N/ha)							
Nil nitrogen	9202	3320	**36**	13.1	167	87	**19.8**
Seedbed	9947	4102	**41**	16.1	181	73	**22.7**
GS30–31	9873	4069	**41**	16.0	180	73	**22.7**
50:50 split	10407	4162	**40**	16.4	189	65	**22.0**
LSD	677	142	**3.5**	0.56	12.3	12.3	**1.94**
P value	0.003	<0.001	**0.040**	<0.001	0.003	0.003	**0.040**

[1] Based on 222mm of GSR (April – October) + 35% fallow efficiency (32mm) for January – March rainfall (total GSR + stored = 254mm) with no soil evaporation term included and assuming no drainage in periods of excessive rainfall.
[2] Transpiration through the plant based on a maximum 55kg harvest biomass/ha/mm transpired.
[3] Unproductive water (evaporation, drainage and water left unused at harvest) is the difference between transpiration through the plant and GSR (mm) + stored water at sowing.
[4] Transpiration efficiency based on kg/ha grain produced per mm of water transpired through the plant.
[5] Note that yields have been presented at 0% moisture content rather than 12.5% moisture as is the case in Table 2.

The highest yields were achieved with 100kg N/ha (at sowing and at GS31) (5.25–5.35t/ha), however at this nitrogen level only the narrow row spacing at the 270 plants/m^2 was examined. When the treatments that covered all of the combinations of nitrogen application, row spacing and plant population were considered, the highest grain yield (5.00t/ha) was produced with a combination of narrow row spacing, 164 plants/m^2 and a split nitrogen approach with 50% nitrogen applied at sowing and 50% at GS30–31 where 50kg N/ha had been applied. This combination also produced the highest WUE, as a result of higher DM production and a relatively high harvest index (HI) — proportion of biomass partitioned (harvested) as grain.

Observations and comments

The widest row spacing (37.5cm) produced the highest HI and the greatest transpiration efficiency (see Table 3). However this result was principally a feature of the lower overall levels of biomass produced (8800kg/ha DM) and as a result less water loss (transpiration) from that biomass. Although the HI was lower with the narrow row spacing, the higher biomass produced offset this disadvantage resulting in higher grain yields and overall significantly higher WUE (which takes into account the losses from the soil and the plant).

The calculations suggest that wider rows led to greater water loss either through evaporation from the soil or as water left unused. Water use efficiency rates were higher during the 2013 season compared with 2012.

The WUE peaked with the split nitrogen application at 16.4kg grain/mm (presented as an average of row spacing and plant population).

Sponsors

This trial was carried out as part of the Riverine Plains Inc GRDC-funded project *Improved WUE in no-till cropping and stubble retention systems in spatially and temporally variable conditions in the Riverine Plains* (RP100007).

Thanks go to farmer co-operators, the Inchbold family and Agrisearch as the principle trial contractor.

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Performance of second wheat under no-till full stubble retention (NTSR) using in-crop nitrogen, plant population and row spacing at Yarrawonga

Nick Poole and Tracey Wylie
Foundation for Arable Research, Australia in conjunction with Riverine Plains Inc

Key points

- Wheat on wheat (cv Gregory) sown 15 May 2013 yielded between 3.35–4.70t/ha depending on row spacing, plant population and nitrogen (N) application.
- The narrow row spacing (22.5cm) produced the same yield and water use efficiency (WUE) as the wider row spacing (37.5cm).
- There was no difference in dry matter (DM) at harvest and grain yield due to plant population, though the lower plant population produced grain with significantly higher protein levels.
- Wider-row-spaced crops produced significantly higher protein than narrow-row crops, though there was no difference in grain yield.
- Wide row spacing significantly reduced DM compared with narrow row spacing at all assessments from tillering onwards until harvest when the difference was not statistically significant.
- This result is in contrast to first wheat after canola, where the wider row spacing (37.5cm) yielded less and had a lower WUE compared with the narrower rows.

Location: Yarrawonga, Victoria

Rainfall:
Annual: 378mm
GSR: 222mm (April – October)
Stored moisture: 32mm (estimated at 35% fallow efficiency)

Soil:
Type: Loamy clay

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2005–09 — pasture

Plot size: 16m x 2m

Replicates: 4

Overall goal

Improved water use efficiency (WUE) in no-till cropping and stubble retention systems in spatially and temporally variable conditions in the Riverine Plains.

Aim

The aim of this trial was to evaluate the performance of in-crop nitrogen (N), plant population and row spacing interaction in a no-till full-stubble-retention (NTSR) scenario.

Method

A replicated experiment was established to test the effect of four nitrogen timing strategies across four combinations of: two row spacings (22.5cm and 37.5cm) and target plant population (100 and 200 plants/m^2).

The four nitrogen timing treatments were based on: 50kg N/ha applied at sowing in the seedbed, at early stem elongation (pseudo stem erect to first node — GS30–31), a 50% split of 25kg N/ha between both timings and nil nitrogen fertiliser. Nitrogen application in these treatments was based on prilled urea fertiliser (46% nitrogen by weight).

A further four nitrogen strategies (25kg N/ha in the seedbed, 25kg N/ha at GS30–31, 100kg N/ha in the seedbed and 100kg N/ha at GS31) were applied to additional plots established on a 22.5cm row spacing with a plant density target of 200 plants/m^2. The trial was sown in fully-retained wheat stubbles approximately 30cm in length.

Statistical analysis was carried out using Statistix (version 9.0). The trial was analysed as two trials: row spacing, plant population and nitrogen timing was analysed as a factorial design and nitrogen rate by timing (22.5cm row spacing and 200 plants/m^2 population target) was analysed separately as a factorial and a randomised complete block.

Reference to significant differences in the text denotes a p value equal to or <0.05.

Results

Crop establishment

The plant density (plants/m^2) was greater than expected for both target plant populations with the narrow row spacing. Row spacing generated significant differences in establishment: the 22.5cm spacing produced more plants per square metre than the 37.5cm spacing at both high and low target populations.

There was a significant interaction between row spacing and target plant population, indicating that as the sowing rate increased the plant establishment decreased in the wide row spacing relative to the narrow spacing (see Table 1).

There was some evidence (at higher target plant populations) that nitrogen at sowing increased plant establishment relative to crops that did not receive nitrogen fertiliser, however differences were not significant (see Figure 1).

Dry matter production

i) Plant population

This second wheat trial followed the same trend as the first wheat trial in that the higher target plant populations produced significantly larger canopies throughout the season until harvest, by which time the lower target population had compensated, resulting in equivalent dry matter (DM) production (see Figure 2).

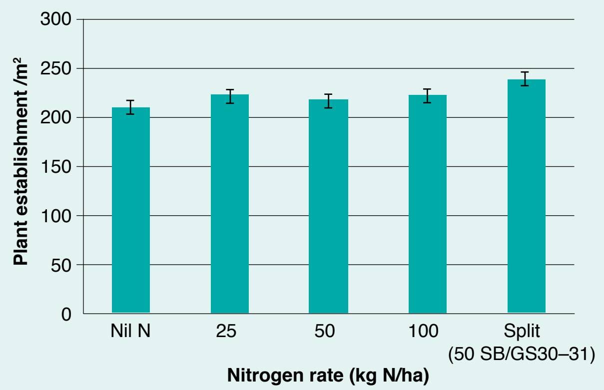

FIGURE 1 Influence of nitrogen application at sowing on plant establishment at a targeted plant population of 200 plants/m^2 sown on 22.5cm row spacings*

* Error bars presented as LSD value

TABLE 1 Plant establishment at three-leaves-unfolded stage (GS13), 37 days after sowing*

Nitrogen treatment	Plant establishment (plants/m^2)					
	Target 100 plants/m^2			Target 200 plants/m^2		
Row spacing (cm)	**22.5**	**37.5**	**Mean**	**22.5**	**37.5**	**Mean**
Nil nitrogen	129	103	**116**	216	167	**191**
50kg N/ha seedbed	136	106	**121**	255	166	**211**
50kg N/ha GS30–31	128	104	**116**	209	166	**188**
50:50 seedbed:GS30–31 split	129	95	**112**	229	180	**205**
Mean	**131**	**102**		**227**	**170**	
LSD [plant population]	10					
LSD [row spacing]	10					
LSD [nitrogen treatment]	13					
LSD [pop^n x row spacing]	13					
LSD [pop^n x nitrogen treatment]	19					
LSD [pop^n x row x nitrogen treatment]	27					
Interaction — plant population x row spacing p value <0.001						

* At the time of the GS13 assessment the GS31 nitrogen application had not been applied.
Pop^n — plant population

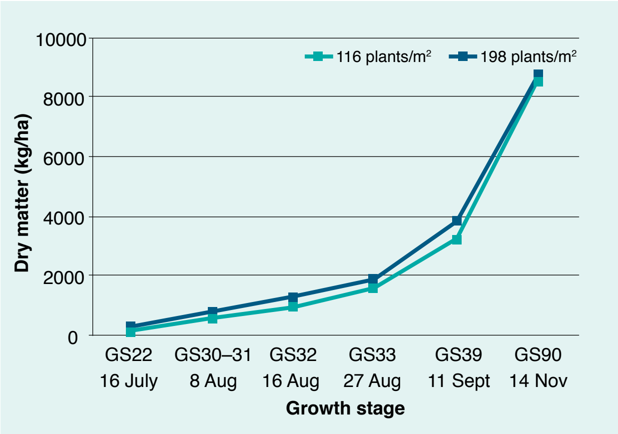

FIGURE 2 Influence of plant population on dry matter production*

LSD (5%): GS22; 29, GS30–31; 64, GS32; 120, GS33; 153, GS39; 250, GS90; 705kg DM/ha

* Mean of two row spacings and two nitrogen strategies (16 July – 27 August 2013), mean of two row spacings and four nitrogen strategies (11 September – 14 November 2013)

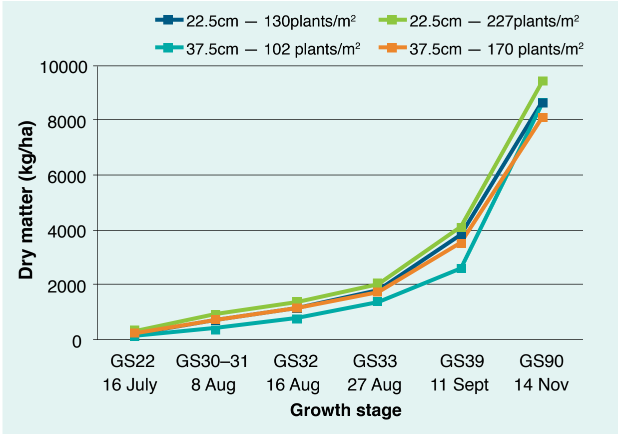

FIGURE 4 Influence of plant population and row spacing on dry matter production*

LSD (5%): GS22; 41, GS30–31; 91, GS32; 169, GS33; 217, GS39; 354, GS90; 998kg DM/ha

* Mean of two nitrogen strategies (16 July – 27 August 2013), mean of four nitrogen strategies (11 September – 14 November 2013)

ii) Row spacing

The narrower row spacing produced significantly more DM/ha throughout the growing season. However, by harvest the difference was no longer significant (see Figure 3).

iii) Plant population and row spacing

Significant differences in DM production were only evident at the flag-leaf-fully-emerged stage (GS39) when DM in the wider row spacing combined with the lower target plant population was less than the other three treatments (see Figure 4). This is partly due to fewer plants/m², since the higher target plant population on wider rows did not show a significant DM disadvantage.

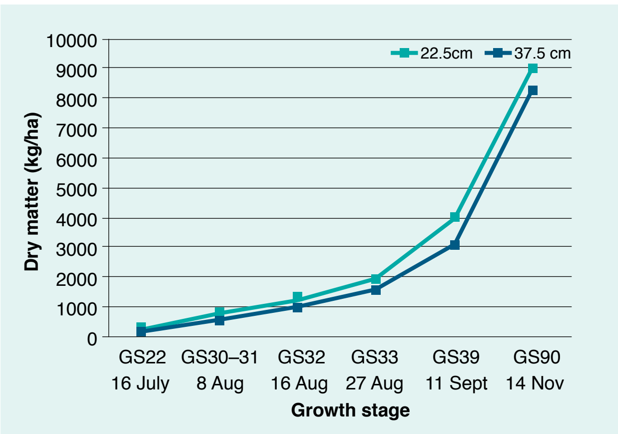

FIGURE 3 Influence of row spacing on dry matter production*

LSD (5%): GS22; 29, GS30–31; 64, GS32; 120, GS33; 153, GS39; 250, GS90; 705kg DM/ha

* Mean of two plant populations and two nitrogen strategies (16 July – 27 August), mean of two plant populations and four nitrogen strategies (11 September – 14 November 2013)

However, the trend in data would still indicate that a wider row spacing does not fully compensate in terms of DM per unit area compared with a narrower row spacing.

At harvest, although the narrow row spacing and higher target plant population produced the highest DM, the differences were less pronounced than in the first wheat trial (see page 6).

iv) Nitrogen application: timing and rate

From GS30–31 through to harvest there was significantly more DM produced when 50kg N/ha was applied at sowing. At GS39 there was no significant difference in DM production between applying all the nitrogen at sowing or splitting the application 50:50 between sowing and GS30–31.

At harvest the seedbed application of 50kg N/ha had produced the largest amount of DM (see Figure 5), with all three nitrogen treatments significantly increasing DM production compared with the untreated crop.

The nitrogen rate applied had a significant impact on DM production at harvest. When averaged across two nitrogen application timings — seedbed and GS30–31 — assessments showed no significant advantage of applying 25kg N/ha over the untreated crop, however there was an advantage in applying 50–100kg N/ha compared with the untreated crop (see Figure 6).

v) Nitrogen uptake

From the second assessment (8 August 2013) at GS30–31, there was greater nitrogen uptake in the larger crop canopies where nitrogen was applied at sowing. From GS39 through to harvest, the untreated crop had

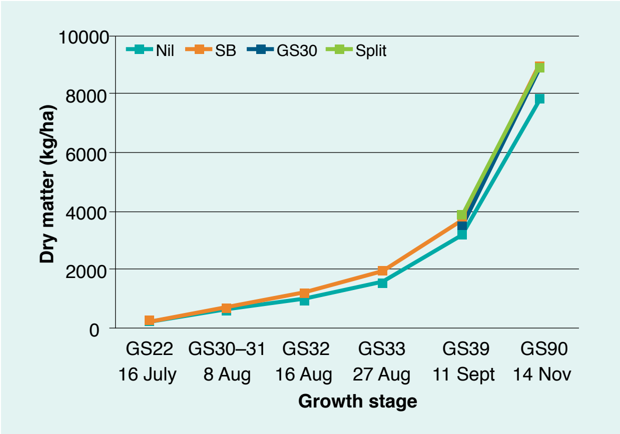

FIGURE 5 Influence of 50kg N/ha applied in the seedbed at GS30–31 and 50:50 split between seedbed and GS30–31 on dry matter production*.

LSD (5%): GS22; 29, GS30–31; 64, GS32; 120, GS33; 153, GS39; 354, GS90; 998kg DM/ha

* Mean of two row spacings and two plant populations (16 July – 14 November)

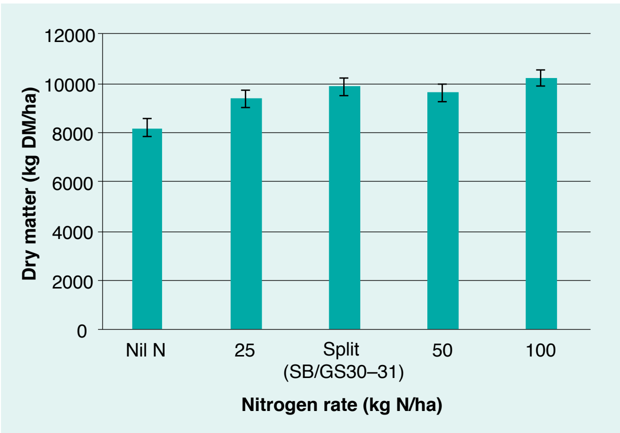

FIGURE 6 Influence of nitrogen rates applied on dry matter production at harvest (14 November 2013) when sown at 22.5cm row spacings at a target plant population of 200 plants/m²*

* Mean of two application timings — seedbed and GS30–31

Error bars presented as LSD value

significantly less nitrogen in the above-ground biomass than where 50kg N/ha had been applied. There were no differences in nitrogen uptake as a result of nitrogen timing from GS39 onwards (see Figure 7).

Crop structure

The 50kg N/ha applied to the seedbed at sowing produced the greatest number of tillers per unit area, which was significantly higher than when 25kg N/ha was applied (as part of a split application of 50kg N/ha), which in turn was significantly higher than the untreated crop.

At harvest, when head counts were made, all nitrogen treatments resulted in more heads per metre square than the untreated crop, but there were no differences between the various nitrogen strategies (see Figure 8).

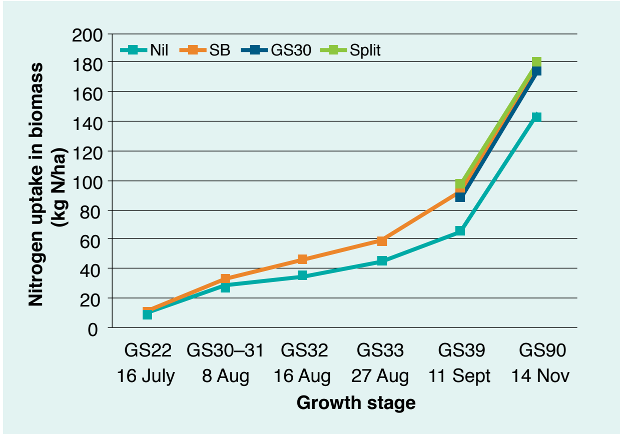

FIGURE 7 Influence of 50kg N/ha applied in the seedbed at: GS30–31 and 50:50 split between seedbed and GS30–31 on nitrogen uptake*

LSD (5%): GS22; 1.5, GS30–31; 2.9, GS32; 4.2, GS33; 5.3, GS39; 9.9, GS90; 19.8kg DM/ha

* Mean of two row spacings and two target plant populations (16 July – 14 November)

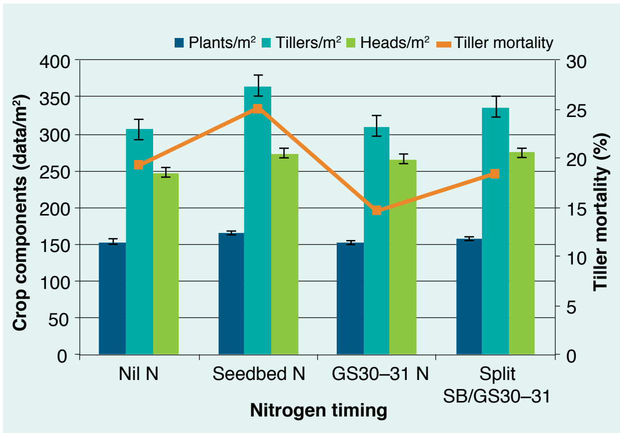

FIGURE 8 Influence of timing of nitrogen application (50kg N/ha) on crop structure *

* Mean of two row spacings and two plant populations (plants 24 June, tillers 14 August, heads 14 November)

Error bars presented as LSD value

This second wheat trial had a mean yield of 4.02t/ha. Grain yield was unaffected by target plant population or row spacing (see Table 2).

Both row spacing and plant population affected the protein content of the harvested grain: the narrow spacing and higher target plant population had significantly lower protein contents than crops established in wide rows or at low target plant populations (see Figure 9). Nitrogen application increased yield over the untreated crop although there was no difference in yield due to nitrogen timing (see Figure 10). In terms of timing, where nitrogen was applied at GS30, grain protein was higher than the other two nitrogen treatments (at sowing and the split application approach), which in turn were higher than the untreated crop (see Figure 10). Grain protein levels were

TABLE 2 Yield at harvest (9 December 2013)

Nitrogen treatment	Yield (t/ha)					
	Target 100 plants/m^2			Target 200 plants/m^2		
Actual plant population (m^2)	131	102		227	170	
Row spacing (cm)	22.5	37.5	Mean	22.5	37.5	Mean
Nil nitrogen	3.57	3.29	**3.43**	3.45	3.41	**3.43**
50kg N/ha seedbed	4.14	4.02	**4.08**	4.18	4.16	**4.17**
50kg N/ha GS30–31	4.31	4.12	**4.21**	4.23	4.28	**4.25**
50:50 seedbed:GS30–31 split	4.25	4.27	**4.26**	4.39	4.28	**4.33**
Mean	**4.07**	**3.92**		**4.06**	**4.03**	
LSD [plant population]	0.10					
LSD [row spacing]	0.10					
LSD [nitrogen treatment]	0.14					
LSD [pop^n x row spacing]	0.14					
LSD [pop^n x nitrogen treatment]	0.20					
LSD [pop^n x row x nitrogen treatment]	0.29					
Interaction – plant population x row spacing			ns			

Pop^n —plant population

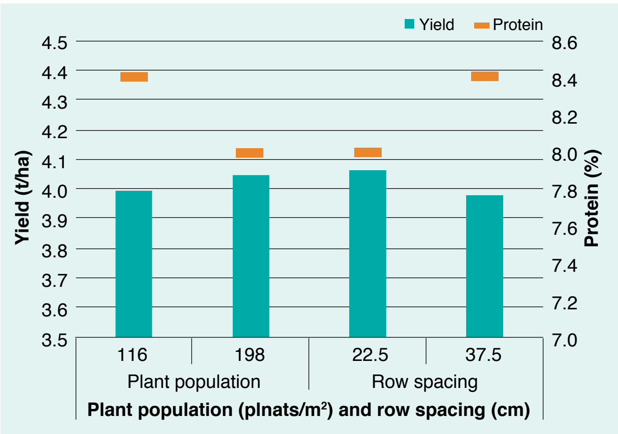

FIGURE 9 Influence of target plant population* and row spacing^ on yield and protein

* Plant population is the mean of two row spacing and four nitrogen timings

^ Row spacing data is the mean of two plant populations and four nitrogen timings

LSD (5%): compare yield 0.10t/ha, protein 0.18%, plant population and row spacing separately

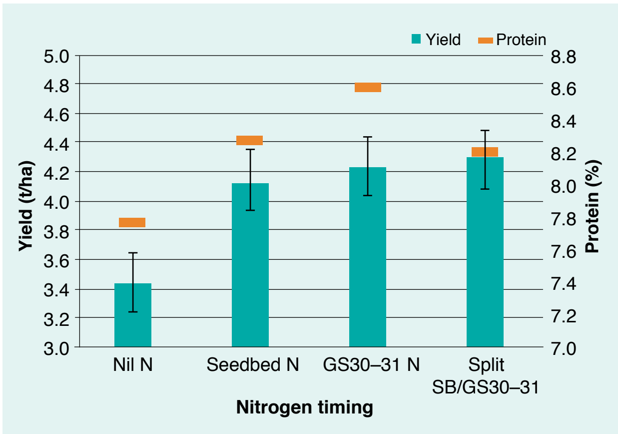

FIGURE 10 Influence of timing of nitrogen application (50kg N/ha) on yield and protein content*

* Mean of two row spacings and two plant populations

Error bars presented are LSD

low indicating that yield would not have been optimised, even with an application of 50kg N/ha (see Figure 11).

Nitrogen rate had a significant influence on grain yield (tested at high plant population and the 22.5cm row spacing). The higher the rate of nitrogen applied, the greater the yield response and grain protein obtained (see Figure 11).

Increasing the nitrogen rate also increased grain yield irrespective of whether the nitrogen was applied at sowing or GS30–31 (see Figure 12). The application of 100kg N/ha resulted in significantly higher grain protein, regardless of the timing of application (see Figure 13).

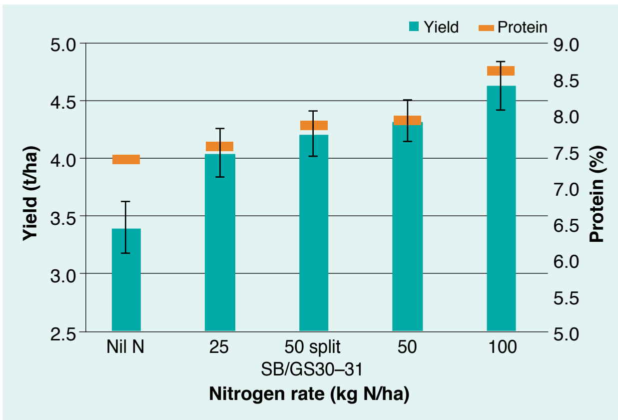

FIGURE 11 Influence of nitrogen rates applied on yield and protein content when sown at 22.5cm row spacings at a target plant population of 200 plants/m^2*

* Mean of two application timings

Error bars presented as LSD value

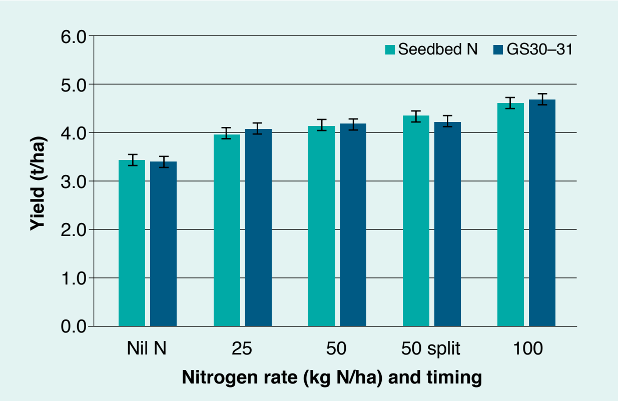

FIGURE 12 Influence of nitrogen rate and timing on yield when sown at 22.5cm row spacing and 200 plants/m²*
* Error bars presented as LSD value

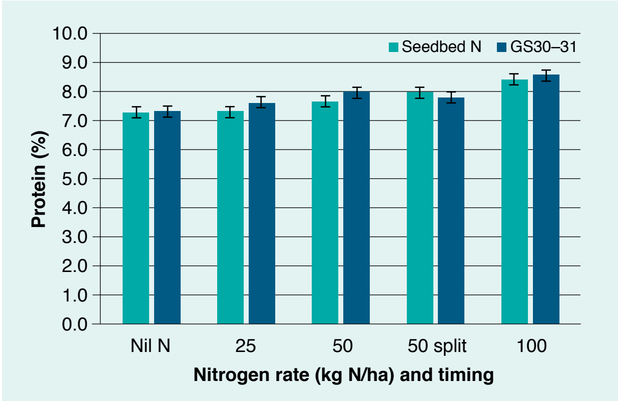

FIGURE 13 Influence of nitrogen rate and timing on protein when sown at 22.5cm row spacing and 200 plants/m²*
* Error bars presented as LSD value

Harvest index and water use efficiency

The narrow row spacing produced more biomass than the wider row spacing but partitioned proportionally (non-significantly) less into grain yield giving a lower harvest index (HI) — % of final crop biomass that was grain. The overall result was no difference in grain yield between the 22.5cm and 37.5cm row spacings.

The split application of nitrogen along with wide row spacing produced the highest HI. The split nitrogen application also generated the greatest WUE at 14.8kg/mm, although it was only significantly different to the nil-nitrogen crop treatment (see Table 3). The untreated crop had the lowest WUE at 11.8kg/mm, with the greatest estimated soil evaporation.

TABLE 3 Biomass at harvest, yield, harvest index (HI), water use efficiency (WUE), transpiration, evaporation/drainage and transpiration efficiency (TE)

	Biomass (kg/ha)	Yield[5] (kg/ha)	HI (%)	WUE[1] (kg/mm)	Transpiration[2] (mm)	Evaporation[3] (mm)	TE[4] (kg/mm)
Plant population (plants/m²)							
100 (target)	8631	3494	**40**	13.7	157	97	**22.3**
200 (target)	8721	3540	**41**	13.9	159	96	**22.3**
LSD	706	89	**3.8**	0.4	12.8	12.8	**2.1**
P value	0.798	0.312	**0.984**	0.314	0.798	0.798	**0.99**
Row spacing (cm)							
22.5	9010	3555	**39**	14.0	164	90	**21.7**
37.5	8342	3480	**42**	13.7	152	102	**22.9**
LSD	706	89	**3.8**	0.4	12.8	12.8	**2.1**
P value	0.063	0.098	**0.258**	0.090	0.063	0.063	**0.26**
Nitrogen treatments (50kg N/ha)							
Nil nitrogen	7789	3000	**39**	11.8	142	113	**21.2**
Seedbed	9019	3609	**40**	14.2	164	90	**22.0**
GS30–31	8918	3704	**42**	14.6	162	92	**22.8**
50:50 split	8978	3757	**42**	14.8	163	91	**23.0**
LSD	998	126	**5.4**	0.5	18.1	18.1	**3.0**
P value	0.047	0.000	**0.692**	<0.001	0.047	0.047	**0.68**

[1] Based on 222mm of GSR (April – October) + 35% fallow efficiency (32mm) for January – March rainfall (total GSR + stored = 254mm) with no soil evaporation term included and assuming no drainage in periods of excessive rainfall.
[2] Transpiration through the plant based on a maximum 55kg harvest biomass/ha.mm transpired.
[3] Unproductive water (evaporation, drainage and water left unused at harvest) is the difference between transpiration through the plant and GSR (mm) + stored water at sowing.
[4] Transpiration efficiency based on kg/ha grain produced per mm of water transpired through the plant.
[5] Note that yields have been presented expressed 0% moisture content rather than 12.5 moisture as is the case in Table 2.

Observations and comments

The following section examines observations made in the two row spacing trials reported in this year's trial book (first and second wheat). Please note these are observations only, as trials were in separate paddocks and therefore cannot be statistically compared.

The average growth rate between GS39 and harvest (80kg DM/ha per day) was not significantly different as a result of row spacing or plant population in the second wheat trial. In the first wheat trial (94kg DM/day average) the narrow row spacing produced 12kg DM/day more than the wider spacing and the lower plant population had a growth rate of 19kg DM/day more than the higher plant population.

The 50kg N/ha applied to the seedbed at sowing in the first wheat crop generated a greater DM response over the untreated crop than in the second wheat trial (see Figure 14). Although both rotation positions tracked a similar path earlier in the season, when the crop was stem elongating the first wheat generated larger canopies (more DM).

Tiller mortality rates in the second wheat rotation position were almost double the levels (15–25%) observed in the first wheat trial.

This second wheat trial had a mean yield of 4.02t/ha, while the mean yield for the first wheat trial following canola was 4.47t/ha.

The first wheat rotation position showed the 22.5cm row spacing to have a significantly greater WUE. Row spacing did not have a significant effect on WUE in the second wheat position.

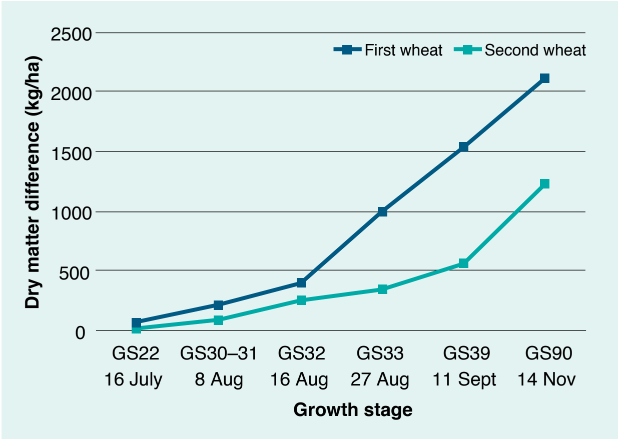

FIGURE 14 Difference in dry matter production between crops treated with 50kg N/ha at sowing and nil-nitrogen crops in a first wheat and second wheat rotation position, established at Yarrawonga (15 May 2013)*

* Mean of two row spacings and two plant populations

Sponsors

This trial was carried out as part of the Riverine Plains Inc GRDC-funded project *Improved WUE in no-till cropping and stubble retention systems in spatially and temporally variable conditions in the Riverine Plains (RP100007*).

Thanks go to farmer co-operators, the Inchbold family and Agrisearch as the principal trial contractors.

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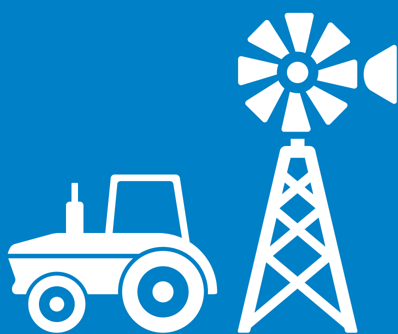

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Interaction between plant growth regulator (PGR) and nitrogen application in early-sown first wheat

Nick Poole and Tracey Wylie
Foundation for Arable Research, Australia in conjunction with Riverine Plains Inc

Key points

- In a low-yielding situation at Coreen, Victoria (less than 2.5t/ha) following a dry spring, plant growth regulator (PGR) application lead to a significant yield reduction (0.14t/ha) in early-sown first wheat.
- PGR application significantly reduced crop height in both trials (by up to 10% in the Coreen trial), but did not reduce crop canopy biomass (dry matter), suggesting that crop biomass was redistributed, not reduced.
- The addition of extra nitrogen (N), over and above the farm standard (75kgN/ha Coreen), significantly increased grain protein but not yield.
- PGR application significantly reduced Normalised Difference Vegetative Index (NDVI) readings taken with a Greenseeker®, particularly where application was superimposed on lower amounts of applied nitrogen.

Location: Yarrawonga, Victoria
Rainfall:
Annual: 377.8mm
GSR: 222mm (April — October)
Soil:
Type: Red loam over clay
Sowing information:
Variety: EGA Wedgetail
Sowing date: 4 April 2013
Sowing equipment: 12m DBS with narrow tines, 15mm individual press wheels
Row spacing: 37.5cm
Paddock history:
2012 — canola
2011 — wheat
2010 — wheat
Plot size: 18m x 3m
Replicates: 4

Location: Coreen, NSW
Rainfall:
Annual: 349mm (Balldale PO 74004)
GSR: 282.5mm (April – October)
Soil:
Type: Clay loam
Sowing information:
Variety: Whistler
Sowing date: 29 April 2013
Sowing equipment: Auseeder DBS (15.3m)
Row spacing: 30cm
Paddock history:
2012 — canola
2011 — wheat
2010 — wheat
Plot size: 15m x 3m
Replicates: 4

Aim

The aim of the trial was to evaluate the effect of plant growth regulator (PGR) application (lodging control, yield effect and net margin) in early-sown first wheat grown under different levels of nitrogen application.

Background

Plant growth regulators are routine inputs for high-yielding cereal crops grown elsewhere in the world and are used primarily to shorten the crop in order to prevent lodging. Recent research carried out by a major agrochemical manufacturer has increased the interest in the role of these products in broadacre cereal production in Australia; however the influence of PGR application can vary depending on the lodging risk (cultivar's resistance to lodging, fertility etc) and moisture status of the crop. Where crop lodging occurs, PGR application is frequently associated with improved crop standing power and significant yield increases as a result of better light interception.

This trial aimed to establish whether the larger crop canopies associated with earlier sowing, higher rates of nitrogen or both are reliable candidates for PGR application in the Riverine Plains region. In addition, the study looked to quantify the crop canopy parameters and environmental conditions that accompany positive and or negative yield effects produced by these agrochemicals.



Method

Two early-sown first wheat trials were established to study the influence of PGR application in first wheat.

The first trial was established at Coreen, New South Wales with the cultivar Whistler, sown 29 April 2013 on a 30cm row spacing following canola. The trial site was subject to 282mm growing season rainfall (GSR: April – October).

The second trial was established at Yarrawonga, Victoria, with the cultivar EGA Wedgetail, sown 4 April 2013 on a 37.5cm row spacing after canola and was subject to 222mm GSR (April – October).

A replicated split plot experiment was established at each site to test the effect of three different nitrogen levels (main plot) and the application of the PGR (sub plot).

i) Nitrogen treatment

Nitrogen rate was based on the paddock standard nitrogen (applied by the host farmer), paddock standard plus 40kg N/ha and paddock standard plus 80kg N/ha with the additional nitrogen applied at the start of stem elongation–first node (GS30–31). Paddock nitrogen application rates for both sites are set out in Tables 1 and 2.

ii) PGR treatment

The PGR, which was a mixture of two active ingredients: trinexapac ethyl and chlormequat (Moddus 200ml/ha + Chlormequat 1L/ha), was applied at second node (GS32) on 1 August 2013 at Yarrawonga and 26 August 2013 at Coreen in 101L/ha water with no adjuvant.

Results

Coreen, NSW

i) Influence of nitrogen rate and PGR on dry matter production

Dry matter (DM) assessments (0.5m row x two per plot) were made at the PGR application timing (26 August) to determine the effect of the additional nitrogen on crop growth and again at early grain fill (GS71) (7 October), 39 days after PGR application to determine the influence of PGR and its interaction with nitrogen. There was no significant effect of the additional 40 and 80kg N/ha on DM at GS32, but there was a significant difference when assessed at GS71 — 80kg N/ha produced significantly more DM than the standard nitrogen input (see Figure 1).

At GS71 there was no recorded difference in DM as a result of PGR application and no interaction with the level of applied nitrogen (see Figure 2).

ii) Influence of nitrogen rate and PGR on crop height and NDVI

There was a significant reduction in crop height of 7–8cm as a result of PGR application recorded at the start and end of grain fill (see Figure 3). Crop reflectance measurements taken with a Greenseeker® at GS71 showed significantly higher NDVI (canopy greenness readings) scores where more nitrogen was applied and significantly lower NDVI scores where PGR was applied (untreated 0.61, PGR 0.58). These scores indicate the greenness of the crop canopy (see Figure 4).

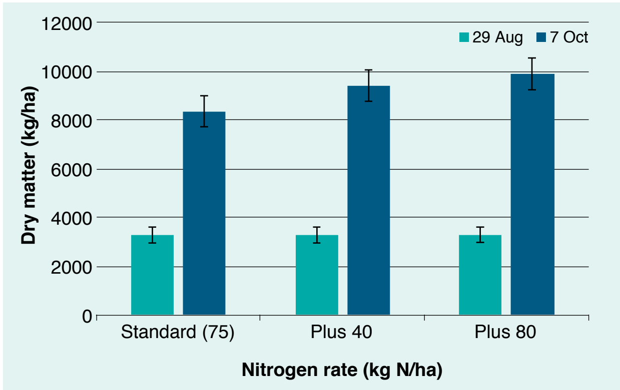

FIGURE 1 Influence of nitrogen rate on dry matter production at second node (GS32), 29 August (38 days after nitrogen application) and early grain fill (GS71), 7 October*

* 7 October assessment is the mean of the nitrogen rates with and without PGR
Error bars presented as LSD value

TABLE 1 Nitrogen application rates and timings — Coreen, NSW

	29 April (sowing) (kg N/ha)	11 June (kg N/ha)	12 July (kg N/ha)	22 July (GS30–31) (kg N/ha)	Total N applied (kg N/ha)
Standard N applied	6	36.8	32.2	Nil	**75**
Standard + 40kg N/ha	6	36.8	32.2	40	**115**
Standard + 80kg N/ha	6	36.8	32.2	80	**155**

TABLE 2 Nitrogen application rates and timings — Yarrawonga, Victoria

	4 April (sowing) (kg N/ha)	10 July (kg N/ha)	28 July (kg N/ha)	23 July (GS31) (kg N/ha)	Total N applied (kg N/ha)
Standard N applied	8	46	46	Nil	**100**
Standard N + 40kg N/ha	8	46	46	40	**140**
Standard N + 80kg N/ha	8	46	46	80	**180**

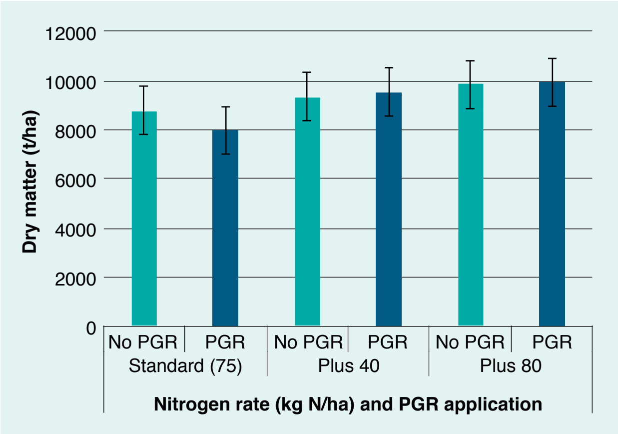

FIGURE 2 Influence of nitrogen rate and PGR application on dry matter production at early grain fill (GS71)*

* Error bars presented as LSD value

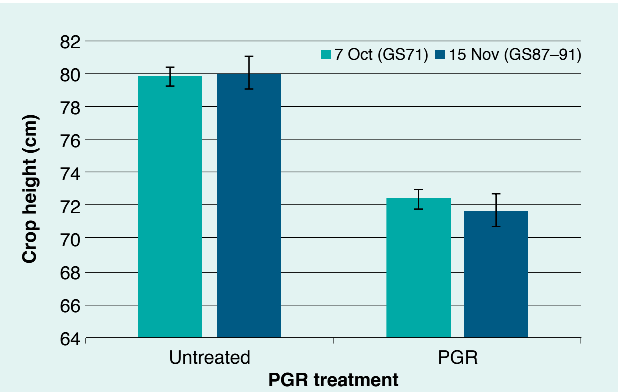

FIGURE 3 Influence of PGR on crop height when assessed at early grain fill (GS71) 7 October and hard dough-ripening (GS87–91) 15 November*

* Mean of three nitrogen rates

Error bars presented as LSD value

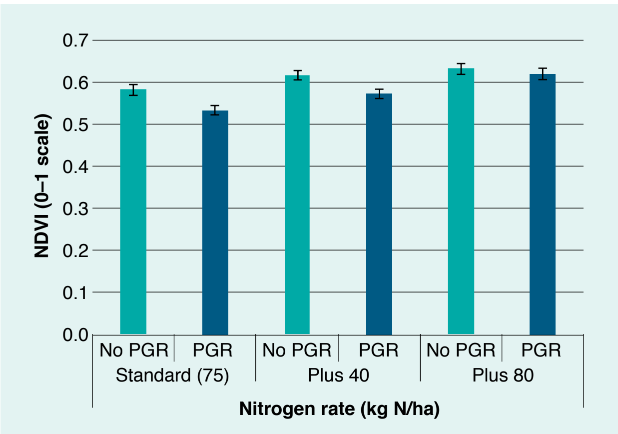

FIGURE 4 Influence of nitrogen rate and PGR application on NDVI, (GS71) 7 October*

* Error bars presented as LSD value

Yield and quality

i) Influence of PGR on grain yield and quality

Yields were less than 2.5t/ha due to the dry spring, which developed after PGR application. Under these conditions there was a significant yield penalty of 0.14t/ha where the crop was treated with PGR at second node (GS32). In terms of grain quality, PGR application significantly increased test weight, however screenings and protein content were unaffected when averaged across the three nitrogen rates (see Table 3).

ii) Influence of nitrogen rate on grain yield and quality

Additional nitrogen application (above the farm standard of 75kg N/ha) significantly increased grain protein, however no significant differences in yield were recorded. The addition of 40kg N/ha increased the protein content by 1% above the standard nitrogen rate and an additional 2.3% when an extra 80kg N/ha was applied giving a protein content of 16.2% (see Table 4).

There was no significant interaction between nitrogen rate and PGR application on yield and quality. PGR application reduced yield irrespective of nitrogen rate applied (see Figure 5).

The highest crop yield was produced by the 75kg N/ha (standard) with no PGR applied, which was significantly higher yielding than 155kg N/ha (standard plus 80kg N/ha) plus PGR. The PGR application and extra nitrogen above the farm standard nitrogen rate was uneconomical.

TABLE 3 Grain yield and quality, comparing untreated and PGR-treated crops*

	Yield (t/ha)	Protein (%)	Test weight (kg/hl)	Screenings (%)
Untreated	2.35[a]	15.0[a]	64.3[b]	8.7[a]
PGR GS32	2.21[b]	15.0[a]	66.6[a]	8.2[a]
P value	0.04	0.64	0.04	0.21
LSD (5%)	0.14	0.31	2.2	0.83

* Mean of three nitrogen rates

[a, b] Values followed by the same letter are not statistically different

TABLE 4 Grain yield and quality, comparing three nitrogen rates*

	Yield (t/ha)	Protein (%)	Test weight (kg/hl)	Screenings (%)
Standard N applied (75kg N/ha)	2.33[a]	13.9[c]	66.4[a]	7.8[a]
Standard + 40kg N/ha	2.33[a]	14.9[b]	66.2[a]	8.1[a]
Standard + 80kg N/ha	2.19[a]	16.2[a]	63.7[a]	9.4[a]
P value	0.32	0.001	0.16	0.27
LSD (5%)	0.23	0.7	3.3	2.3

* Mean of two PGR treatments

[a, b, c] Values followed by the same letter are not statistically different

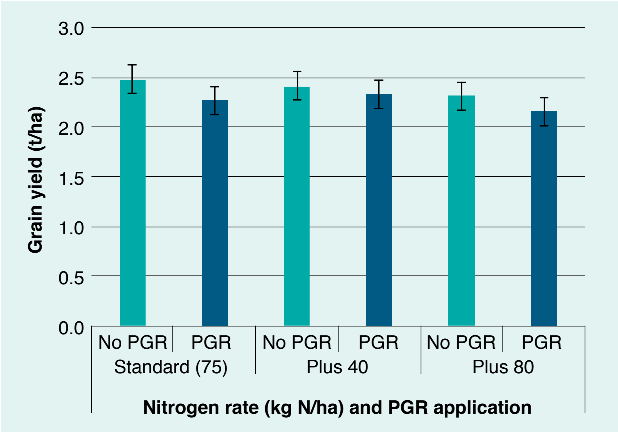

FIGURE 5 Influence of nitrogen rate and PGR application on grain yield (t/ha)*

* Error bars presented as LSD value

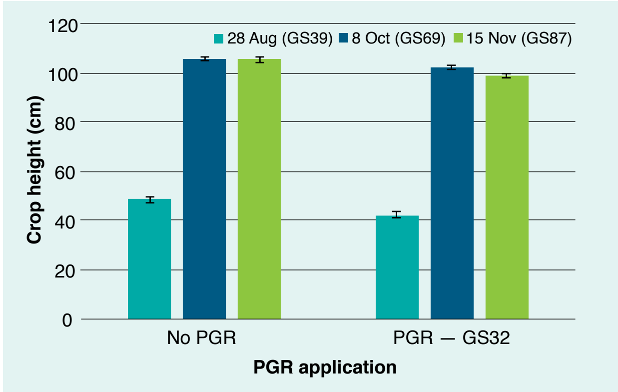

FIGURE 7 Influence of PGR on crop height when assessed on 28 August, 8 October and 15 November (27, 65 and 103 days after PGR application)*

* Mean of two nitrogen rates for 28 August assessment, mean of three nitrogen rates for 8 October and 15 November assessments

Error bars presented as LSD value

Yarrawonga, Victoria

i) Influence of nitrogen rate and PGR on dry matter production

Dry matter production was unaffected by an additional 80kg N/ha (above the farm standard of 100kg N/ha) or the application of PGR at GS32 when assessed at GS37–39, 27 days after PGR application (see Figure 6).

ii) Influence of nitrogen rate and PGR on crop height and NDVI

PGR application significantly reduced crop height at all three assessment timings: flag leaf emergence (GS39), end of flowering (GS69) and hard dough (GS87).

At the GS69 assessment it was also noted that additional nitrogen applied at GS30–31 increased crop height by 2cm (see Figure 7).

NDVI readings showed few significant differences as a result of either additional nitrogen or PGR application (see Figure 8). The only difference generated in NDVI was the lowest NDVI reading was recorded where PGR was applied to the standard nitrogen treatment, a result also recorded at the Coreen site. There was no difference between the other treatments.

iii) Influence of nitrogen rate and PGR on internode length and length of newest emerged leaf

A total of 160 single stem samples (40 samples per treatment) were analysed at GS37–39 to examine the influence of PGR application and extra nitrogen on internal internode length and the length of the newest emerged leaf. The measurements revealed small reductions (0.5–2.0cm) in the internode lengths between first and second nodes and between second

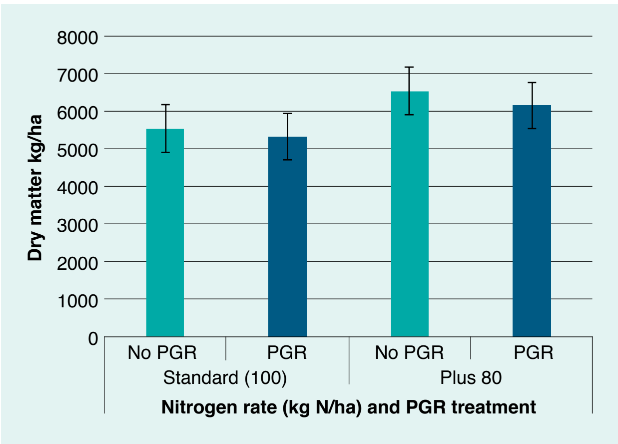

FIGURE 6 Influence of nitrogen rate and PGR on dry matter production at flag leaf emergence (GS37–39), 27 days after PGR application on 28 August*

* Error bars presented as LSD value

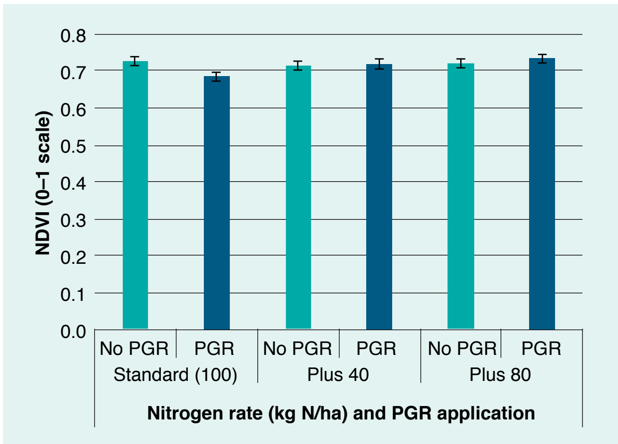

FIGURE 8 Influence of nitrogen rate and PGR application on crop reflectance measurements (NDVI) assessed GS69, 8 October*

* Error bars presented as LSD value

TABLE 5 Influence of PGR and nitrogen rate on internode length and newest emerged leaf length

Treatment	Internode length (cm)			Flag leaf
	Basal to first node	First to second node	Second to third node	Length (cm)
100kg N/ha	3.90^{a}	9.60^{a}	11.68^{a}	33.2
100kg N/ha + PGR	3.98^{a}	9.28^{ab}	10.05^{b}	29.4
180kg N/ha	4.06^{a}	10.25^{a}	11.61^{a}	34.3
180kg N/ha + PGR	3.35^{a}	8.41^{b}	10.05^{b}	30.0
LSD — same level of N	0.99	0.93	1.23	
LSD — different level of N	1.41	1.01	1.19	

$^{a, b}$ Values followed by the same letter are not statistically different

and third nodes and 4cm reductions in the length of the newest emerged leaf (principally the flag leaf) when PGR was added (see Table 5). Differences in internode between the first and second node and the second and third node were significant as a result of PGR application, but nitrogen had no statistical effect.

Yield

Unfortunately this trial was not taken through to yield due to being harvested accidently by the farm header.

Acknowledgments

The trial was carried out as part of the Riverine Plains Inc GRDC-funded project *Maintaining profitable farming systems with retained stubble in the Riverine Plains region.*

Thanks go to the farmer co-operators Telewonga Pty Ltd (Yarrawonga) and Tomlinson Ag (Coreen).

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Yellow leaf spot (*Pyrenophora tritici-repentis*) control with foliar fungicides in second wheat under full stubble retention

Nick Poole and Tracey Wylie
Foundation for Arable Research, Australia in conjunction with Riverine Plains Inc

Key points

- Fungicide applied at third node (GS33) gave significantly better yellow leaf spot (YLS) control and green leaf retention (GLR) than a tillering (GS23) application.
- The improvements in disease control with a single spray timing did not lead to a significant yield increase.
- There was a significant yield advantage (0.27t/ha) when both spray timings were sequenced in a two-spray programme despite the low yield of the trial (2t/ha).
- The value of the extra grain produced from two sprays was $69/ha, which covered the costs of the fungicides and their application.
- The net margin was greater with Tilt® (propiconazole) than Prosaro® (prothioconazole and tebuconazole) largely as result of Prosaro being a more expensive product.
- The best YLS control achieved with a foliar fungicide on the top three leaves was 65% control (recorded on flag-1).

Location: Yarrawonga, Victoria
Rainfall:
Annual: 377.8mm
GSR: 222mm (April – October)
Soil:
Type: Red loam over clay
Sowing information:
Variety: Young
Sowing date: 15 April 2013
Fertiliser: 75kg/ha MAP, 210kg urea throughout the season
Sowing equipment: 12m DBS with narrow tines, 15mm individual press wheels
Row spacing: 37.5cm
Paddock history:
2012 — wheat
2011 — canola
2010 — wheat
Plot size: 18m x 3m
Replicates: 4

Aim

The aim of the trial was to evaluate the value (disease control, yield effect and net margin) of foliar fungicide sprays for the control of yellow leaf spot (*Pyrenophora tritici-repentis*) in wheat established in the stubble of the previous wheat crop under no till. Net margin ($/ha) was calculated as the value of the grain yield increase over the untreated crop, minus fungicide and application cost.

Background

Considerable quantities of foliar fungicide are applied to control YLS in second wheat crops during tillering (GS23–26). There is little positive evidence to support the use of foliar fungicides for the control of the disease at this growth stage. This trial aimed to evaluate the best products available for disease control at both tillering (GS23–26) and third node (GS33) growth stages in terms of disease control, yield and margin.

Method

A replicated split plot experiment was established in a second wheat crop (cultivar Young) at Yarrawonga during 2013 to test the effect of two fungicide products (fungicide plots blocked as main plot) applied at a range of application timings (sub plots of each fungicide main plot).



Young, which is rated moderately resistant to moderately susceptible (MR-MS) to YLS followed a first wheat crop of EGA Wedgetail, which is rated moderately susceptible to susceptible (MS–S) for YLS.

The two fungicide products evaluated were Tilt at 500ml/ha (propiconazole 125g/ha ai) and Prosaro at 300ml/ha (prothioconazole 63g/ha ai and tebuconazole 63g/ha ai) applied at a single spray at GS23–26, GS33 and a two-spray programme applied at both timings.

Results

i) Disease assessments

At the first fungicide application made on 23 July (mid tillering), YLS was present in the crop on all plants assessed. There was a 90% incidence of infection on the second-newest emerging leaf, with 6% severity, while the third-newest emerging leaf had 100% incidence of infection with 24% of the leaf area affected.

Disease progressed up the crop canopy during early stem elongation infecting the top four leaves of the canopy. On 28 August, two days after the second fungicide application at GS33, the untreated crop had 14% disease infection on flag-3, 3% on flag-2 and 1% on flag-1.

Where the fungicide had been applied at mid tillering (GS23) there was 31% more green leaf retention (GLR) on flag-4 and a significant reduction in disease severity on flag-3 (see Table 1). There was no difference between the products with both fungicides giving approximately 42–47% control of the disease on flag-3.

When assessed at early grain fill (GS71–73) on 7 October, differences in disease control and GLR were evident on the top three leaves of the canopy, which correlated to final grain yield. Application timing produced significant differences in disease control when the performance of both fungicides was averaged.

Where a GS33 fungicide spray was made on 26 August (either alone or following an earlier tillering GS23 application) there was significantly better disease control on the flag-1 and significantly better GLR on the flag-2, than where a single application was made at tillering or the crop was left untreated (see Table 2).

The GS23 tillering fungicide spray still gave significantly better disease control results than the untreated on flag and flag-1.

When disease assessments were statistically analysed, excluding the untreated controls, there was no statistical difference evident between the two fungicide products applied. However, there was a trend on all top three leaves for Prosaro to be more effective than Tilt, which was almost significant on flag-1 (see Table 3).

ii) Grain yield

The two-spray fungicide programme (mean of both fungicide products) produced significantly higher yields than the GS23 or GS33 timings alone, which were not significantly different from the untreated crop (see Figure 1).

TABLE 2 Effect of fungicide timing on YLS severity on the flag and flag-1 and GLR on flag-2, measured at GS71–73 on 7 October*

Fungicide timing	% YLS severity		GLR
	Flag	Flag-1	Flag-2
Nil	3.4^{a}	11.8^{a}	33.9^{c}
GS23	2.4^{b}	8.6^{b}	45.1^{c}
GS33	$1.8^{b,c}$	4.1^{c}	60.3^{b}
GS23 + 33	1.2^{c}	3.1^{c}	73.8^{a}
LSD	0.7		11.3
P Value	<0.0001		<0.0001

* Mean of two fungicide products
^{a,b,c} Values followed by the same letter are not statistically different.

TABLE 1 Influence of fungicide application on YLS severity and GLR, assessed at GS33, 28 August, 36 days after the GS23 application

Fungicide treatment		% YLS severity			GLR
Product	Timing	Flag-1	Flag-2	Flag-3	Flag-4
	Nil	0.8^{a}	5.5^{a}	15.1^{a}	40.6^{b}
Prosaro	GS23	0.6^{a}	3.1^{b}	8.0^{b}	67.4^{a}
	Nil	0.7^{a}	$4.1^{a,b}$	13.3^{a}	38.5^{b}
Tilt	GS23	0.6^{a}	3.3^{b}	7.7^{b}	74.5^{a}
LSD		0.4	1.5	2.6	20.0
P value		$0.64^{(n.s.)}$	0.02	<0.01	<0.01

^{a,b} Values followed by the same letter are not statistically different.
N.B. There were two untreated treatments (one blocked with Prosaro treatments and one blocked with Tilt treatments) note that results have been presented separately from both untreated treatments

TABLE 3 Effect of fungicide product on YLS on the flag and flag-1 and the GLR on flag-2, at GS71–73 on 7 October*

Fungicide product	% YLS severity		GLR
	Flag	Flag-1	Flag-2
Tilt	2.1[a]	6.4[a]	53.3[a]
Prosaro	1.5[a]	4.2[a]	66.1[a]
LSD	1.2	2.3	22.5
P Value	0.21	0.054	0.17

* Mean of three application timings — excluding the untreated controls

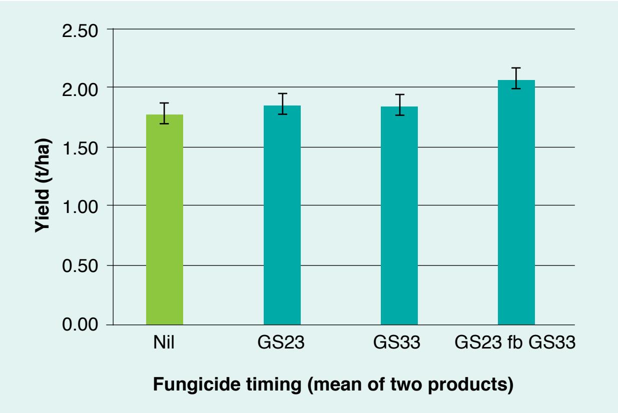

FIGURE 1 Influence of fungicide timing on yield*
* Mean of two fungicide products (Tilt and Prosaro)
fb — followed by
Error bars presented as LSD value

There was no significant difference in yield between the two fungicide products applied at either GS23 or GS33 when the untreated plots were excluded from the analysis, (Prosaro 1.97t/ha and Tilt 1.92t/ha) (see Figure 2). The two-spray approach using either fungicide maximised yield (2.05–2.07t/ha).

Grain quality components (protein, screenings and test weight) were not significantly different as a result of fungicide application compared with the untreated crop.

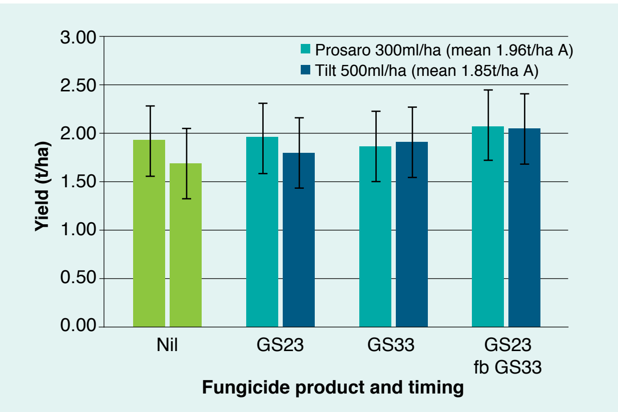

FIGURE 2 Influence of fungicide product and timing on grain yield*
* Error bars presented as LSD value

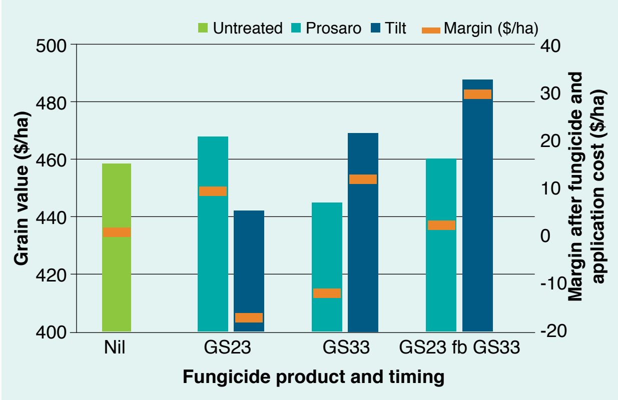

FIGURE 3 Influence of fungicide product and timing on net margin after fungicide cost and application
Please note margin details taken from the average of all eight untreated plots. Prosaro costed at $77/L ($23.10/ha for a single spray and $46.20/ha for two sprays), Tilt costed at $12/L ($6/ha for a single spray and $12/ha for two sprays). Application cost $12/ha for a single spray and $24/ha for two sprays. Yield increases over untreated valued at $256/t.

Frost damage in the trial is likely to have increased the percentage of screenings (trial mean 8.8% screenings). The mean protein content was 13.7% with no significant differences due to treatment.

In terms of economic return from applying fungicide for the control of YLS, the 0.27t/ha obtained with the two-spray programme added $69/ha in terms of gross return (based on $256/t for AGP1 downgraded due to the high screenings). The net margin ($/ha) after application and fungicide costs was greatest at $29/ha with the two-spray Tilt programme. As Prosaro was more expensive, the two-spray programme net margin was lower at just $2/ha.

Note: A second trial was established at Coreen, NSW, in wheat cv. Gregory following canola. Although YLS was present at trial establishment (tillering), the disease did not progress.

Acknowledgments

The trial was carried out as part of the Riverine Plains Inc GRDC-funded project *Maintaining profitable farming systems with retained stubble in the Riverine Plains region.*

Thanks go to the farmer co-operator Telewonga Pty Ltd for spraying the treatments in trial.

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Dr Bill Slattery
Riverine Plains Inc

Key points

- Grain yield at the Rutherglen site increased significantly with both the standing stubble and stubble burnt treatments compared with the disced and mulched stubble treatments. No yield differences were measured at the Culcairn and Tocumwal sites.
- The effect of the fertiliser treatments (post-harvest and at sowing) on yield and soil carbon were inconclusive; interpreting these results requires further investigation.
- The excellent start to the 2014 season has provided optimal conditions to evaluate the field-scale feasibility of increasing soil carbon through post-harvest fertiliser application.

Aim

A CSIRO proof of concept study carried out by Dr Clive Kirkby showed that soil humus (a stable form of soil carbon) could be increased over several years with additions of nitrogen (N), sulphur (S), and phosphorus (P) fertiliser onto stubble residues soon after harvest.

The aim of this project is to trial and demonstrate innovative on-farm practices that increase the sequestration of carbon (C) in the soil under cereal crops through accelerated residue decomposition and nutrient management to increase humus production.

This project supports other similar studies in Victoria and New South Wales, funded by the Australian Government Department of Agriculture — *Action on the Ground Program*, which are applying Dr Kirkby's laboratory and plot studies to larger farm-scale operations.

Method

Three sites were established post-harvest during 2012 to represent both dryland cropping and irrigated cropping conditions. Sites were located at Culcairn and Tocumwal (irrigated), New South Wales and Rutherglen, Victoria.

The three sites included replicated treatments of post-harvest applied fertiliser, sowing fertiliser and stubble residue management as outlined in Table 1, with fertiliser treatments randomly distributed across the stubble treatments at each site.

The rates of post-harvest fertiliser were determined according to the amount of carbon in the residues and the nitrogen, phosphorus and sulphur present in the soil. The rate of post-harvest fertiliser required to optimise soil conditions for stubble breakdown (based on existing carbon and nutrient levels) is referred to as the 100% harvest fertiliser rate (see Table 1). Sowing fertiliser rates were based on the rates commonly used by the farmer co-operators.

Rates of post-harvest fertiliser applied before the start of the 2013 cropping season differed greatly between sites due mainly to the nutrient content of the stubble residue, but were similar (and higher) before the 2014 season (see Table 2). The higher rates for 2014 can be attributed to the low nutrient value of stubble residues, possibly as a consequence of the frost damage in the 2013 crop.

The fertiliser applied in both years was Granuloc 15, which contains 14.3%N, 12%P, and 10.5%S.

Post-harvest fertiliser was applied during February each year. The 2013 crops were sown on 20 March at Rutherglen, 21 May at Tocumwal and 23 May at Culcairn.

The average long-term annual rainfall at each of the sites was 531mm at Rutherglen, 390mm at Culcairn and 398mm at Tocumwal. The annual rainfall for 2013 at Rutherglen was 544mm, at Culcairn it was 572mm and at Tocumwal it was 386mm.

TABLE 1 Treatments applied at each site

Site	Stubble residue treatment				Harvest fertiliser (%)			Sowing fertiliser (%)		
Rutherglen	Disced	Mulched	Standing	Burnt	0	50	100	0	50	100
Culcairn	Disced	Mulched	Standing	-	0	50	100	0	50	100
Tocumwal	Disced	Mulched	Standing	-	0	50	100	0	50	100



TABLE 2 Total post-harvest fertiliser and nutrient quantities applied to stubble residue prior to the 2013 and 2014 cropping seasons

Site	Post-harvest fertiliser (2013)				Post-harvest fertiliser (2014)			
	Crop residue		50% (kg/ha)	100% (kg/ha)	Crop residue		50% (kg/ha)	100% (kg/ha)
Rutherglen	Oats	**Total**	**23**	**45**	Wheat	**Total**	**361**	**723**
		N	*3.3*	*6.5*		*N*	*52*	*103*
		P	*2.8*	*5.4*		*P*	*43*	*87*
		S	*2.4*	*4.7*		*S*	*38*	*76*
Culcairn	Wheat	**Total**	**216**	**432**	Wheat	**Total**	**208**	**416**
		N	*31*	*62*		*N*	*30*	*60*
		P	*26*	*52*		*P*	*25*	*50*
		S	*23*	*45*		*S*	*22*	*44*
Tocumwal	Canola	**Total**	**159**	**319**	Wheat	**Total**	**290**	**580**
		N	*23*	*46*		*N*	*41*	*83*
		P	*19*	*38*		*P*	*35*	*70*
		S	*17*	*33*		*S*	*30*	*61*

Soil characteristics at each site are described in Table 3. In general the soil results from 2012 indicated high fertility at each site with moderate sodicity at Tocumwal in the surface soil and moderate sodicity below 30cm at Rutherglen. Soil texture below the surface 10cm soil layer varied across the sites. Subsoil textures varied from light to heavy clays with a range of granular material (buckshot at the Rutherglen site) and composition (dispersive at the Tocumwal site).

Results for individual soil parameters showed a large variation across all sites. In particular the soil pH varied from as low as 4.5 to more than 6.0 at both Rutherglen and Culcairn (see Figure 1).

It was also important to determine the range in soil organic carbon (SOC) values at each site as small changes need to be detected in samples collected during 2014 and 2015 compared with the 2012 pre-treatment site data. Analysis of these samples will identify if there has been a change in SOC over the 2.5 years of the study.

The 2012 results show the variation in SOC was high at all sites, suggesting a difference of at least 0.6% SOC would need to be measured during 2014 or 2015 in order to demonstrate an increase had occurred due to the application of post-harvest fertiliser onto stubble residues.

2013 crop results

Rutherglen

Grain yield at the Rutherglen site showed a significant difference between the standing stubble and burnt stubble treatments compared with the disced and mulched stubble treatments, but no difference between the stubble standing or burnt treatments (see Figure 2).

As the effect of fertiliser was inconclusive, the results from each fertiliser treatment were combined within each stubble treatment. This was done at all three sites.

The yield map partially reflected the results shown in Figure 2, with higher-yielding areas observed as darker

TABLE 3 Main soil characteristics at each site 2012

Soil parameter	Rutherglen			Culcairn			Tocumwal		
	Soil layer (cm)								
	0–10	10–20	20–30	0–10	10–20	20–30	0-10	10–20	20–30
Soil pH ($CaCl_2$)	5.3	5.3	5.4	5.1	5.0	5.1	5.9	6.0	6.1
Soil pH (water)	6.0	6.1	6.4	5.7	5.9	6.1	6.7	7.0	7.1
Bulk density (gm/cm^3)	1.4	1.6	1.8	1.3	1.6	1.7	1.3	1.4	1.3
Colwell-P (mg/kg)	43	28	20	55	26	16	36	22	11
EC (dS/m)	0.15	0.09	0.06	0.16	0.08	0.05	0.19	0.15	0.15
Soil organic carbon (%)[a]	1.9	0.9	0.5	2.0	0.9	0.5	1.2	0.7	0.6
ESP (% of CEC)	1.7	2.2	3.2	1.0	1.6	1.8	5.8	8.8	9.9

[a] Method for measuring soil organic carbon was Walkley-Black

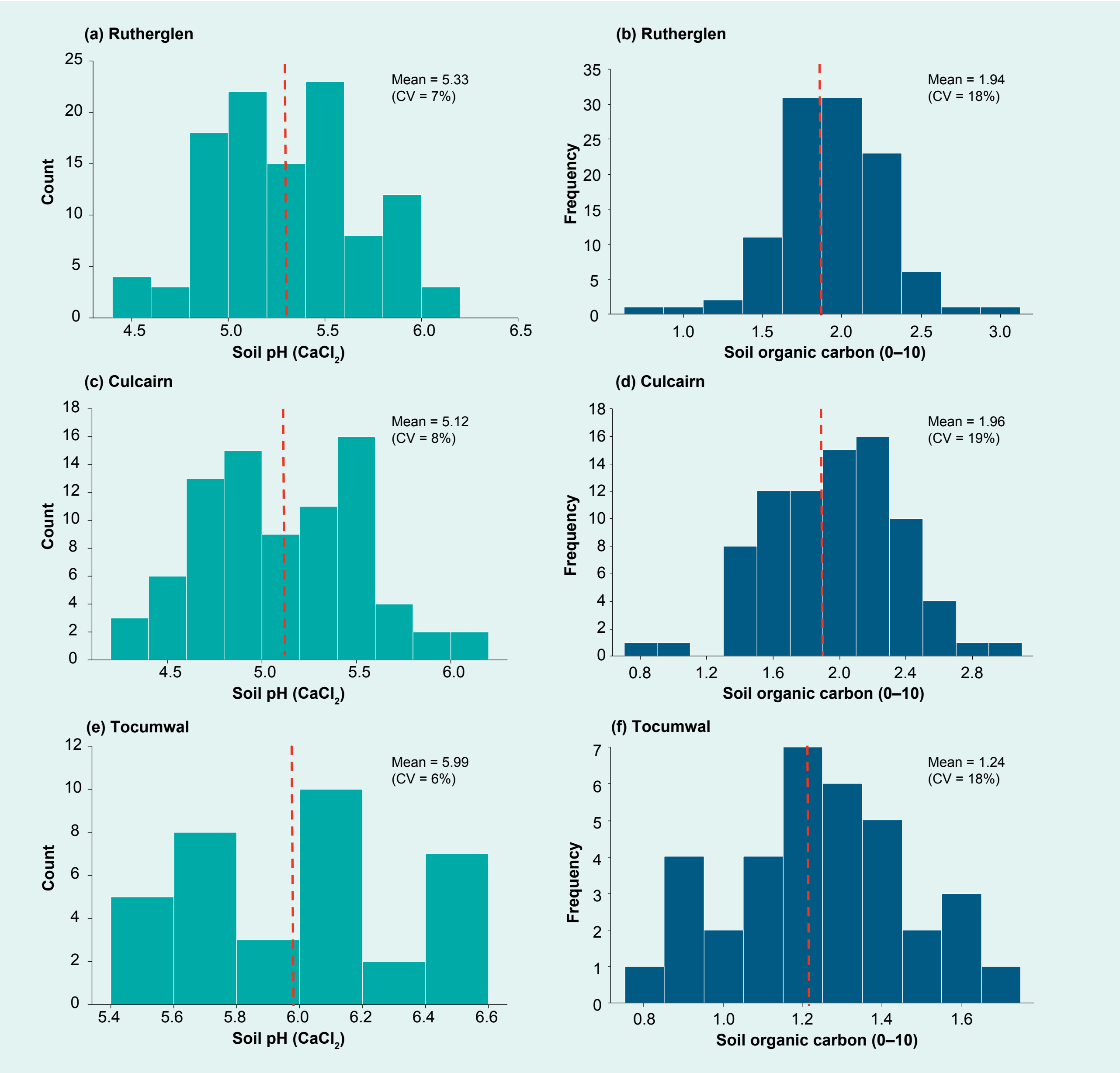

FIGURE 1 Soil pH and soil organic carbon at 0–10cm depth across the three sites 2012*

* Means and co-efficient of variance are shown for each graph

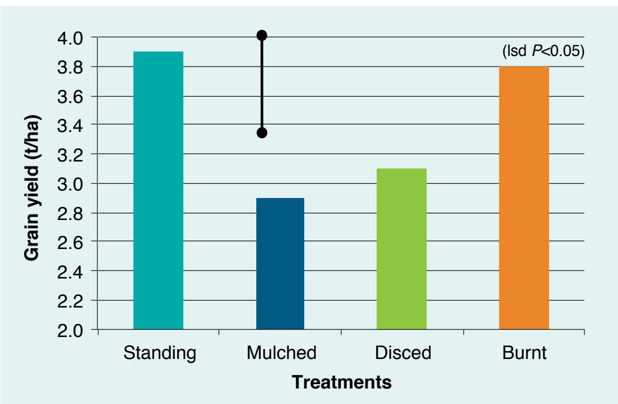

FIGURE 2 Grain yield at Rutherglen 2013*

* Fertiliser treatments within each stubble treatment have been combined

green in the upper half of the yield map where the stubble standing treatments were established. Stubble burnt treatments were located in the bottom section of the yield map and are less reflective of overall yield results (see Figure 3).

Germination counts and tiller counts showed a similar trend to that of grain yield, but none were significant. There were, however, significantly higher head counts for the stubble burnt treatment compared with the standing stubble and mulched stubble treatments (see Figure 4). The dry matter (DM) at harvest also was significantly higher for burnt stubble compared with stubble standing. Both these latter findings are in contrast to the grain yield

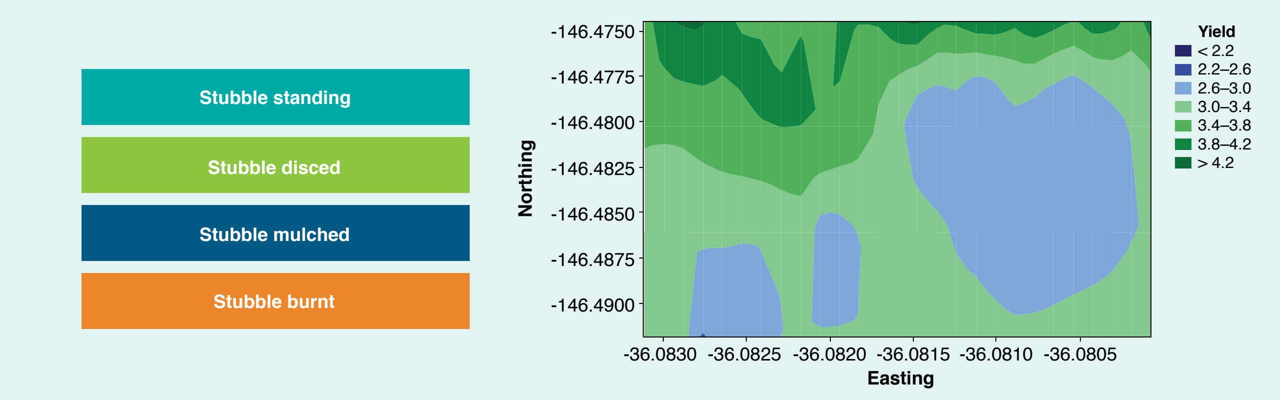

FIGURE 3 Grain yield map for Rutherglen together with the site layout*

* Fertiliser treatments (not identified) are randomly distributed within each stubble treatment

data, where both stubble standing and burnt treatments were highest. It is possible that the late frost during 2013 had a greater impact on those crops with a denser canopy cover, such as the stubble burnt treatment. As such, had there not been a frost it is likely the burnt treatment may have significantly out-yielded the stubble standing treatment given the higher-than-average annual rainfall for 2013. At any rate, the biomass returned as stubble residue is high (average of 10t/ha), which provides an opportunity to increase soil carbon during 2014.

Culcairn

There were no significant yield differences between the stubble management treatments at Culcairn during 2013 (see Figure 5). It is worth noting that grain yields were low due to severe frost damage and no real conclusions can be drawn from the yield data. The yield map (see Figure 6) shows areas of zero yield, despite recording more than 11t/ha of biomass across the site at harvest.

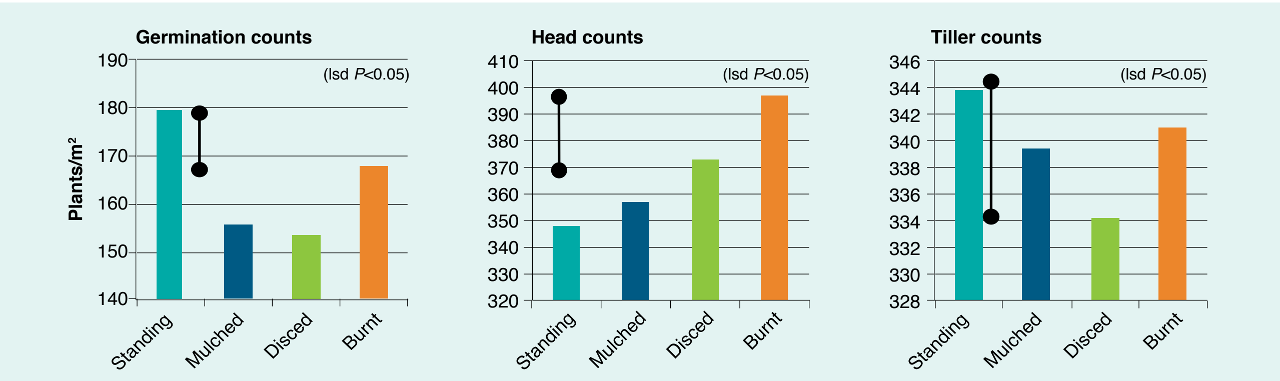

FIGURE 4 Germination counts, head counts and tiller counts for Rutherglen 2013

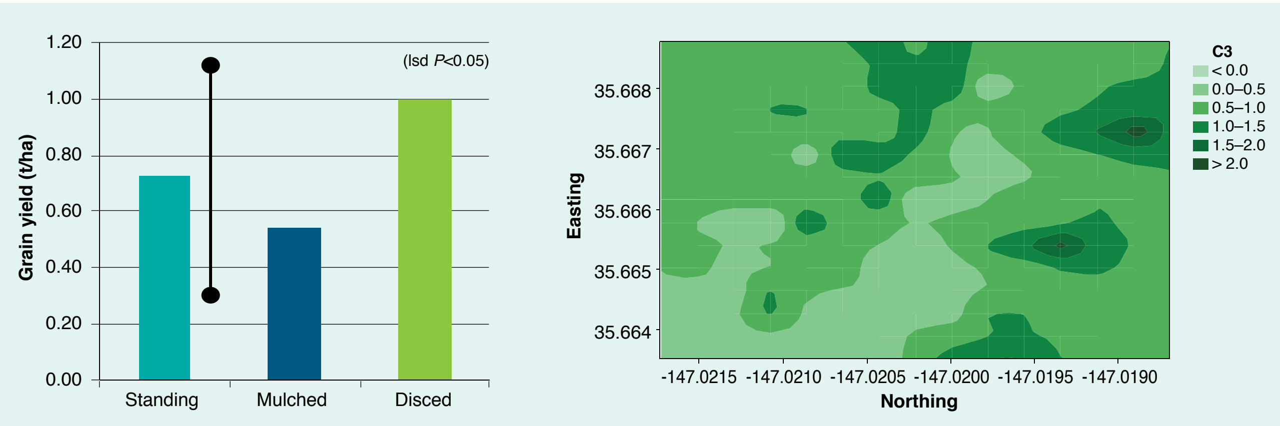

FIGURE 5 Grain yield and grain yield map at harvest at Culcairn 2013*

* Fertiliser treatments within each stubble treatment have been combined

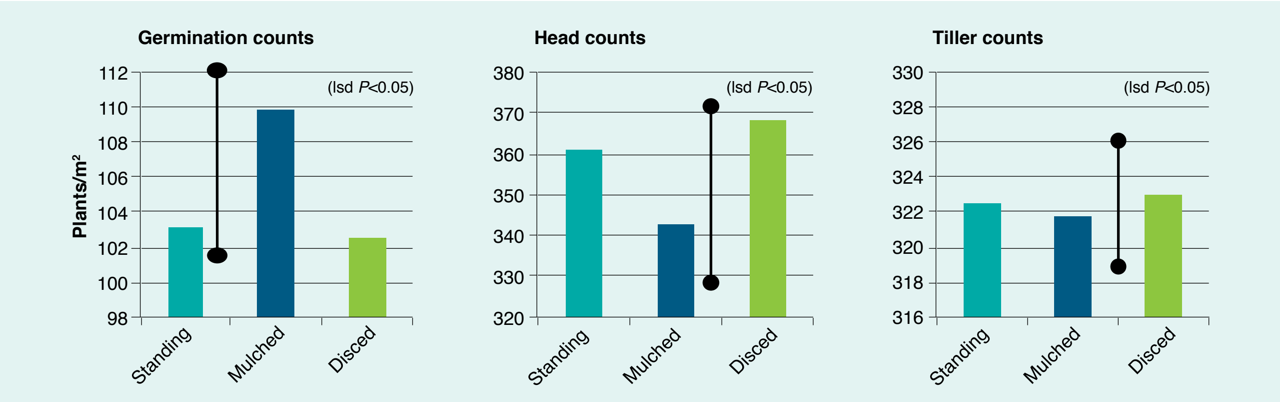

FIGURE 6 Germination counts, head counts and tiller counts at Culcairn 2013

Despite the potential for a high-yielding harvest at Culcairn, there was no difference between stubble treatments for germination counts, head counts or tiller counts (see Figure 6). Although the crop did not yield any substantial grain the biomass returned as retained residues is high (11t/ha) and provides a similar opportunity to the Rutherglen site to increase soil carbon during 2014.

Tocumwal

Grain harvest at the irrigated Tocumwal site showed little yield difference between tillage treatments, with less frost impact than at the other two sites. The yield map reflects the relatively flat response to treatment (see Figure 7) although it appears that the 100% sowing fertiliser rate (which was located in the upper third of the yield map) has positively impacted grain yield. It is worth noting this trend was not significant.

Other agronomic measurements at Tocumwal did not reveal any significant differences between stubble management or fertiliser treatments. The germination counts, head counts and tiller counts are shown in Figure 8.

Nitrous oxide emissions

Nitrous oxide emissions have been recorded at the Rutherglen and Culcairn sites since January 2014. Preliminary data has shown emissions of nitrous oxide on plots that had received fertiliser post harvest, but not on plots that did not receive fertiliser.

This work will continue for these two sites during 2014 and start at the irrigated Tocumwal site during early 2015.

Observations and future work

Although the applications of post-harvest fertiliser provided relatively high rates of nitrogen to certain plots (up to 62kg N/ha) during early 2013, there was little or no yield response for the 2013 cropping season to either the fertiliser applied post-harvest or the fertiliser applied at sowing.

Given the generally high rates of fertiliser applied across all sites and the ideal start to the 2013 season, much stronger plant growth responses were expected. However, soil nitrate–nitrogen levels were quite high at each site, which provided a solid nutritional base for the

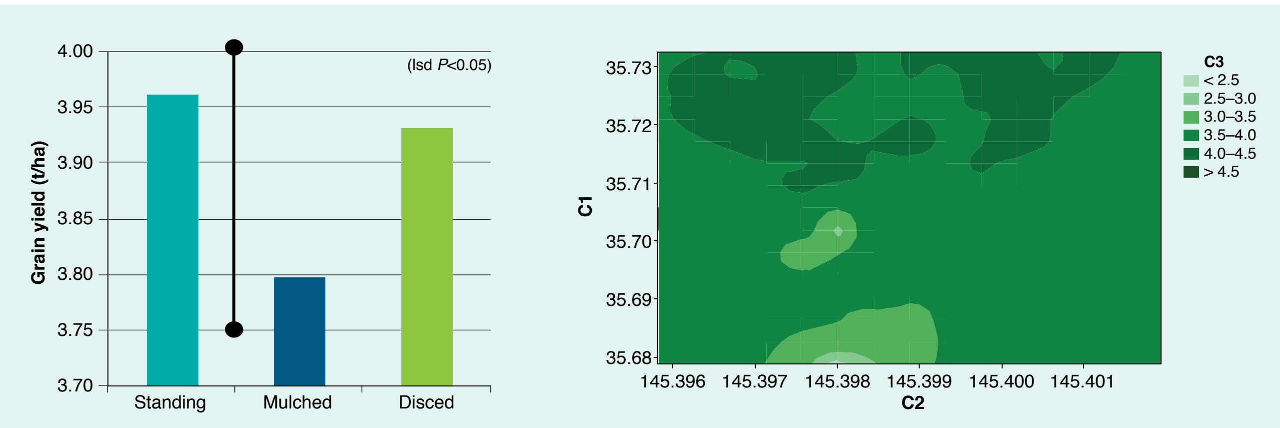

FIGURE 7 Grain yield and grain yield map at harvest Tocumwal 2013*

*Fertiliser treatments within each stubble treatment have been combined

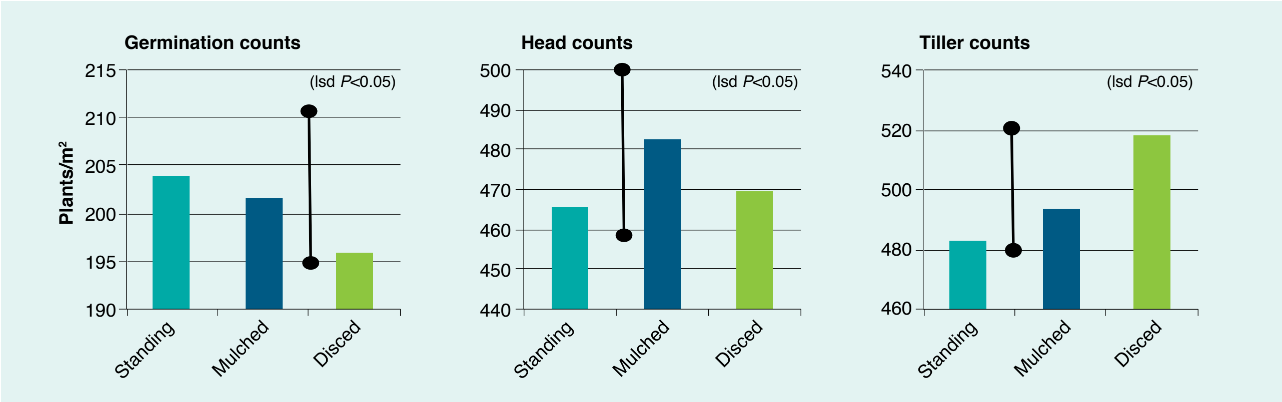

FIGURE 8 Germination counts, head counts and tiller counts at Tocumwal 2013

2013 cropping season. It is therefore not surprising that the high rates of fertiliser applied had little or no impact on plant growth during 2013.

For the start to the 2014 season there have been several rainfall events of 10mm or more while the soil temperature in the surface profile has remained high. These conditions are potentially ideal for microbial activity and the production of humus-carbon. Soil analysis will continue for 2014 and, if an increase in soil carbon is to be realised through the application of post-harvest fertiliser, then it will be measured. In addition, the nitrous oxide emissions work will continue until there are no measured differences between plots receiving the post-harvest fertiliser and those receiving no fertiliser.

Sponsors

This trial was carried out as part of the Riverine Plains Inc *Increased soil carbon by accelerated humus formation from crop residues* project and is supported by funding from the Australian Government Department of Agriculture — *Action on the Ground Program*. Project partners include Murray Local Land Services, North East Catchment Management Authority, the Irrigated Cropping Council and property owners: Godde Farms Pty Ltd (Culcairn), EG Baker and Co (Rutherglen) and Glendaloch Pastoral Company (Tocumwal).

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Maximising the nitrogen benefits from legumes through better inoculation with rhizobia

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Key points

- Inoculating legumes with rhizobia can deliver substantial nitrogen (N) inputs to southern farming systems, even when the impact on legume yield is small.
- Targeted, strategic use of rhizobial inoculants is the best and most cost effective way to maximise nitrogen inputs from legumes.
- Take care in situations where the rhizobia survival is compromised, such as dry sowing, acid soils, and mixing with fertilisers and pesticides.

Background

Inoculating grain and pasture legumes with rhizobia is standard practice for many growers, but a recent national survey has highlighted the need for common-sense, practical guidelines to allow growers to maximise the potential benefits with a more strategic approach to legume inoculation.

Legumes (crops and pasture combined) are estimated to fix almost three million tonnes of nitrogen each year in Australia, which is worth around $4 billion. This amount of fixed nitrogen makes a substantial (around 50%) contribution to the estimated 6Mt of nitrogen required annually for grain and animal production.

The fixed-nitrogen contributions made by legumes vary considerably with species (see Table 1) and situation (e.g. soil type, seasonal rainfall and crop management). As highlighted in Table 1, crop legumes fix about 110kg N/ha annually, on average. However the range is large, varying among individual paddocks from close to zero to more than 400kg N/ha, due to variations in paddock condition, farm management and seasonal conditions.

Nitrogen fixation generally increases with the amount of crop biomass. It follows that effective agronomic management leading to vigorous plant growth will favour higher fixed-nitrogen inputs. In southern Australia, legume growth is strongly influenced by the amount of water the crop or pasture can access from a combination of stored soil moisture and growing season rainfall (GSR). Management practices that optimise water use efficiency (WUE) and keep soil nitrate concentrations low, will favour legume growth and nitrogen fixation. While the legume uses the nitrogen it fixes for growth, any root and shoot residues remaining after harvest (for grain legumes) or grazing (for pasture legumes) contribute to total soil nitrogen for use by subsequent crops (see Table 1).

In addition to the relation with plant biomass, nitrogen fixation is greater when existing soil nitrate levels are below 50kg/ha. Conversely, fixation virtually ceases at soil nitrate levels above 200kg/ha (see Figure 1), although fixation levels again vary with species and situation.

Additional legume benefits

While not the main topic of this article, it is important to remember that legumes often provide a 'disease break' benefit, which can increase the productivity of following cereal and oilseed crops by reducing the carryover levels of key soil-borne pests, such as nematodes and also fungal diseases. Cereals grown after legumes

TABLE 1 Estimated annual nitrogen fixation levels by crop legumes in Australia

Legume	% of crop N requirement fixed	Shoot dry matter (t/ha)	Shoot N (kg/ha)	Root N (kg/ha)	Total crop N (kg/ha)	Total N fixed[1] (kg/ha)
Lupins	75	5.0	125	51	176	130
Peas	66	4.8	115	47	162	105
Faba beans	65	4.3	122	50	172	110
Lentils	60	2.6	68	28	96	58
Soybeans	48	10.8	250	123	373	180
Chickpeas	41	5.0	85	85	170	70

[1] Total N fixed = % N fixed x total crop N. Data sourced primarily from Unkovich *et al.* (2010)



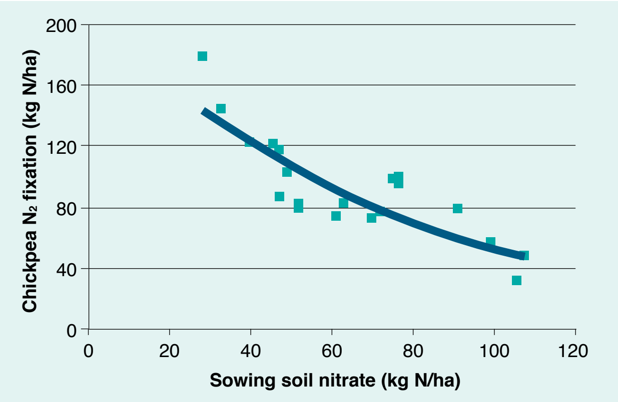

FIGURE 1 Impact of soil nitrate at sowing on chickpea nitrogen fixation in northern NSW

Source: unpublished data of WL Felton, H Marcellos, DF Herridge, GD Schwenke and MB Peoples

generally out-yield cereals grown after non-leguminous crops, partly due to the nitrogen benefit and partly due to pest and disease control by the legume 'break'.

When, where and how to inoculate?

While the benefits to subsequent crop yields from fixed nitrogen and reduced disease risk are significant, legume inoculation is not necessary for every crop in every season.

Most growers have probably heard the phrases "if in doubt, inoculate", "inoculation is cheap insurance" and "inoculate every year".

While often appropriate, these messages can lead to unnecessary inoculation in some instances, or alternatively cause growers to become cynical about the need for inoculation when minimal benefits are realised.

It is possible to adopt a more targeted and strategic approach to legume inoculation by using some basic rules of thumb. Growers can use a risk–benefit framework with respect to the likelihood of obtaining a positive response to inoculation to assist in decision-making, by first considering soil type, legume species and paddock inoculation history. After making the decision to inoculate, it is worth maximising the chances of success with appropriate product choice and application method — inoculation failure is generally difficult and expensive to remedy.

Factors affecting inoculation success

Several factors contribute to the success or failure of legume inoculation.

There is a low likelihood of response to inoculating grain legume crops or pastures in paddocks where: there has been a recent history of inoculation with the appropriate rhizobia (i.e. the correct inoculant group), the soil pH is above 6 (in $CaCl_2$), and recent nodulation, grain yields and pasture production have been in line with expectations based on growing season rainfall.

In any of the above situations, inoculating legumes every four years or so is sufficient, because soil rhizobial populations will generally be maintained at levels considered adequate for effective nodulation. After four years there is increased likelihood of a response to inoculation as the rhizobia that persist in the soil start to lose their capacity to fix nitrogen. At this time a top-up with the appropriate commercial inoculant strain can be beneficial.

If a crop or pasture legume, which uses the same rhizobia, has not been grown during the previous four years, or soil conditions are hostile (acid, very dry or following a very hot summer), then the probability of a response to inoculation is greater.

Where acid-sensitive legumes (e.g. peas, beans and lucerne) are sown into acid soils (pH 5.5 or less in $CaCl_2$) it is prudent to inoculate every time a crop or pasture is sown as rhizobial populations tend to diminish quickly under these soil conditions (see Table 2). Note that lupins are the exception as lupins and their rhizobial strain are well adapted to acid soils.

Where a crop with a specific rhizobia requirement (such as chickpeas) is grown for the first time, it is essential to inoculate as there will be no suitable rhizobia present in the soil. A double rate of inoculant is often used in these situations, to enhance the likelihood of effective nodulation.

TABLE 2 Sensitivity of key rhizobia to pH*

Host legume species	Rhizobia	pH 4	pH 5	pH 6	pH 7	pH 8
Lupins, serradella cowpeas, mungbeans	*Bradyrhizobium* spp.	light green	dark green	dark green	red	dark red
Soybeans	*Bradyrhizobium japonicum*	red	light green	dark green	dark green	red
Clovers	*Rhizobium leguminosarum* bv. *trifolii*	red	light green	dark green	dark green	dark green
Peas, faba beans, lentils, vetch	*Rhizobium leguminosarum* bv. *viciae*	dark red	red	dark green	dark green	dark green
Chickpeas	*Mesorhizobium ciceri*	dark red	red	light green	dark green	dark green
Medics	*Sinorhizobium* spp.	dark red	dark red	red	dark green	dark green

* Red is sensitive, dark green is tolerant

Common inoculation issues faced by growers

Can I sow inoculated seed into dry soil?

Growers in some regions want to sow legumes early; into dry soil. Sowing inoculated seed into dry soil is not recommended where a legume crop is sown for the first time. However, where a legume has been used frequently and the soil is not particularly hostile to rhizobia, the risk of nodulation failure resulting from dry sowing is reduced.

Rhizobial formulations applied 'in furrow', such as granules or peat suspended in liquid, are placed deeper in the soil and have a better chance of surviving dry sowing as the soil conditions will be less extreme at greater depth. There is also some evidence from field trials that placing the inoculum deeper in the soil in a dry sowing is beneficial, but there has not been a great deal of definitive research on this topic to date.

Can I mix inoculated seed with fertiliser, including trace elements?

Some growers claim success in mixing rhizobial inoculant with fertiliser and/or trace elements. Rhizobium biologists recommend against mixing inoculant with fertilisers (particularly superphosphate and other very acidic fertilisers) or other, novel plant nutrition treatments. However farming operations need to be pragmatic for practical and economic reasons. Small-scale testing is recommended when contemplating mixing inoculum with fertilisers and micro-nutrients.

Clean tanks well before using them for rhizobial inoculum. Place the fertiliser or trace elements away from the rhizobial inoculum (e.g. in furrow below the seed) where possible.

It is worth noting the detrimental effects of mixing inoculants and fertilisers are often overlooked because legumes are often sown in paddocks not responsive to inoculation. It is only when a nodulation problem appears in a paddock responsive to inoculation, that the harmful effect of mixing rhizobia with other products becomes clear.

If molybdenum (Mo) is required as a seed treatment (e.g. it is sometimes needed for optimum nodulation, especially in acid soils), then use molybdenum trioxide or ammonium molybdate, NOT sodium molybdate which is toxic to rhizobia.

Can I mix rhizobial inoculant with seed pickles and pesticides?

Some combinations of rhizobia and some pickles and pesticides appear to perform satisfactorily, whereas others are effective at destroying rhizobia. The booklet *Inoculating Legumes: a practical guide* (see Further reading at the end of this article) contains a table that lists the compatibility of different rhizobia groups with seed-applied fungicides, and also discusses specific compatibility issues between rhizobia and certain insecticides.

Pickled seed can be coated with rhizobia (except soybean), but ensure the time interval between inoculation and sowing is kept to a minimum — usually less than six hours. The use of granular inoculants or liquid inoculation in furrow can reduce this impact by separating the pickled seed from the inoculant.

The following mixtures are NOT compatible with peat, liquid and freeze-dried inoculants:

- chemicals containing high levels of zinc, copper or mercury
- fertilisers and seed dressings containing sodium molybdate and manganese (Mn)
- fungicides such as Sumisclex® or Rovral®
- insecticides containing endosulfan, dimethoate, omethoate, or carbofuran.

Measuring success

To determine whether inoculation has been successful, it is important to look below the soil surface and inspect plant roots for healthy nodules. A visual check of root systems is worthwhile to establish if a reasonable number of nodules is present and well distributed across the root system or whether there has been a nodulation delay or failure.

Carefully breaking open nodules to determine if there is a pink or reddish colour in the nodules will show that the nodules are active.

Neither of these visual assessments will indicate the actual level of nitrogen fixation being achieved: sophisticated scientific techniques are required to measure this. However, understanding the level of nodulation in the existing crop can help guide decisions around the need for inoculation in future years.



Dig up several plants about 2–3 months after sowing, wash out the root systems gently and count the number of nodules on the roots.

Recently-produced GRDC publications about rhizobial inoculation provide useful guidelines about adequate numbers of nodules per plant. A guide to assessing nodulation in pulse crops can be found at www.agwine.adelaide.edu.au/research/farming/legumes-nitrogen/legume-inoculation/.

Further reading

Inoculating Legumes: a practical guide (GRDC 2012) Available as free download from www.grdc.com.au/GRDC-Booklet-InoculatingLegumes

Inoculating Legumes: The Back Pocket Guide (GRDC 2013) Available as free download from www.grdc.com.au/Resources/Publications/2013/09/Inoculating-legumes-back-pocket-guide

GRDC Fact Sheet: ***Rhizobial inoculants*** (GRDC 2013) Available as free download from www.grdc.com.au/~/media/B943F697AF9A406ABBA20E136FDB7DC4.pdf

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National survey of legume growers

A national survey of legume growers carried out during 2013 explored grower knowledge and practice in relation to rhizobial inoculation. A total of 405 growers completed the survey, representing a farmed area of more than 1Mha, across all GRDC regions.

Results are still being analysed in detail, but initial indications suggest:

- Growers generally have a good level of knowledge about rhizobia and their use, though 10% did not know that rhizobia fall into different groups specific to certain crop and pasture legumes.
- Virtually all growers know rhizobia are living organisms, but 22% stated it was fine to mix rhizobia with fertiliser and 8% thought it was acceptable to mix rhizobia with pesticides. As discussed, combinations and mixtures can work in some circumstances, but care must be taken to avoid incompatibility and the risk of inoculation failure.
- Ninety per cent of survey respondents reported that they used inoculants. Of the 10% that did not inoculate, more than half specified that inconvenience was a reason and also that the benefit of inoculation was not clear.
- Peat formulation was by far the most common method of application (used by 82% of respondents). Other formulations were also important, however, including granules (19%) and freeze-dried formulations (14%). A substantial proportion of growers used more than one type of formulation.

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Canola and pulse disease management — maintaining the vigilance during 2014

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Key points

- Elevated levels of internal blackleg infection were detected across southern NSW at blackleg monitoring sites in all canola varieties evaluated during 2013.
- Early-flowering canola crops, in combination with wet weather, were conducive to sclerotinia stem rot development during 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 GRDC's *Sclerotinia stem rot in canola* fact sheet 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 — 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 canola (*Brassica napus*) cultivars. The fungal population evolves 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 Hyola50, which went from a rating of resistant to susceptible on the Eyre Peninsula during 2012.

There is a strong relationship between the intensity of canola production within a region and the level of blackleg infection within commercial crops. The blackleg pathogen survives and reproduces on the previous season's canola stubble. It follows that the 500,000ha canola crop grown across New South Wales during 2013 may result in up to 500,000ha of blackleg-infested canola stubble during 2014, releasing wind-blown spores each time it rains.

The warning signs for southern NSW

Cultivars representing each of the blackleg resistance groups were sown at 32 national variety trial (NVT) sites across Australia (10 sites were located in NSW) and monitored for levels of blackleg development during 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 monitoring sites. These data indicate which resistance groups have higher levels of disease compared with the national average at each of the regionally-based NVT canola yield sites and serve as a monitoring tool for local blackleg pathogen populations.

Overall, blackleg severity increased across all cultivars at blackleg monitoring sites during 2013 in southern NSW (see Table 1). Blackleg severity increased from 26% average internal infection level during 2012 to 38% during 2013. The blackleg severity in NSW during 2013 was twice as high as infection levels across Victoria and South Australia. This increase in disease severity is



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

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, 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 group 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

L Low blackleg severity compared with national average — continue with current management techniques.

M Moderate blackleg severity compared with national average — monitor crops for disease, see *Blackleg management guide*.

H High blackleg severity compared with national average — high risk of yield loss, see *Blackleg management guide*.

Note: 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 with the national average at each site.

For more detail consult the individual site summaries and recommendations on the NVT online website.

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 during 2011, the Group D cultivars showed increased susceptibility to blackleg during the following season (2012). This situation could potentially occur in some regions of NSW for 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 500m distance from this season's crop and the previous year's canola stubble. However, as more canola is grown this control measure is becoming more difficult 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 the previous year's stubble and applying the appropriate fungicides (see *2014 Blackleg management guide* for details — www.grdc.com.au).

Another method for minimising disease is to rotate cultivars with different resistance genes. All canola cultivars are now classified into different resistance groups (refer to the *2014 Blackleg management guide* 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 *Sclerotinia sclerotiorum*. This fungus can infect more than 300 plant species, mostly broadleaf plants, including many crop, pasture and weed species. This includes plants such as canola, lupins, chickpeas, sunflowers, 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 structure, 5–10mm in diameter), which germinate from sclerotia (compact mass of hardened fungal mycelium) 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 can germinate in the soil, produce mycelium and directly infect canola plants in close proximity, causing a basal infection.
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. Even if flower petals are infected, dry conditions during petal fall will prevent stem infection development.

Research findings from 2013

A number of commercial canola crops were monitored for the development of sclerotinia stem rot during 2013. These crops were around Cootamundra and south of Henty, NSW in traditionally high-disease-risk districts. Results from observations within these crops found a 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 that extended periods of continual leaf wetness (at least 48 hours or longer) were critical 'trigger' points for stem rot development in both regions.

There were 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 after 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 during 2014 to collect and collate data, which will be used to develop a disease prediction model for NSW.

Where did the disease occur during 2013?

During 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 were higher levels of sclerotinia stem rot observed during 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 plentiful 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 during 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 indicate potential risk, as well as adjacent paddocks.
- The start 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 that flower earlier during winter, when conditions are cooler and wetter, are more prone to disease development.

If I had sclerotinia in my canola 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 clear due to the strong reliance on moisture for infection and disease development.

Important management options include:

1. **Sowing canola seed 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 the previous 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 ideal 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 peas or faba beans.
4. **Follow recommended sowing dates and rates for your district:** Canola crops that 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 spacings 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 about 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 the 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.

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

Consult the *Sclerotinia stem rot in canola* factsheet for further information. This publication is available from the GRDC website — www.grdc.com.au.

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Changing soil organic carbon — strategies for cropped soils at Boorhaman, north east Victoria

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Key points

- Understanding soil bulk density is essential for calculating how much carbon is in the soil.
- Stubble retention is most beneficial where soil organic carbon (OC) stocks are low.
- Stubble loads need to be consistently at least 5t/ha and retained to increase organic carbon in the soils of the Boorhaman area.

Importance of soil organic carbon

Increasing the amount of organic matter (OM) in soil by retaining stubble is one means of improving long-term soil fertility and crop productivity. The organic carbon (OC) in OM helps bind soil together, reduces erosion and improves water retention. Most OC sits in the topsoil of cropped paddocks.

In the short term, retaining stubble can lead to challenges in the following crop including reducing crop emergence and causing nitrogen in the soil to be immobilised, increasing the need for nitrogen fertiliser.

Stubble management

Following harvest, cereal stubble is commonly mulched, grazed, baled or burnt. Each of these stubble management practices has its own advantages and disadvantages for whole-farm management and affects how much carbon is retained in the soil.

The impact of these practices is explored in the following article using the 'Roth C' model, soil data from a farm at Boorhaman and climate data from Boorhaman as sourced from Bureau of Meteorology (BoM).

How much organic carbon is in soil?

When soil tests come back from the laboratory, OC is presented as a percentage. While soil tests are usually conducted on the top 10cm layer of soil and reported as a percentage, total amounts of carbon stock are reported as t/ha in the top 30cm.

To convert %OC into t/ha we need to know the bulk density of the soil — how much soil is present in a soil layer. Bulk density in cropped topsoils tends to range from $1g/cm^3$ to $1.6g/cm^3$.

A formula can be applied to convert the amount of OC in the top 10cm layer to that in the top 30cm (see Table 1).

Increasing soil organic carbon

Stocks of soil OC increase as more stubble is retained. More stubble is retained with stubble management practices such as mulching compared with burning. More stubble also is retained by choosing cropping practices that produce more stubble, such as high-yielding cereals, instead of fallowing.

The highest increase in soil OC occurs when all the stubble from high-yielding cereals is retained in the paddock (see Table 2).

TABLE 1 Conversion of OC as a percentage to tonnes per hectare*

OC in top 10cm of soil (%)	OC stock in top 30cm of soil (t/ha)
0.5	14
1.0	28
1.5	42
2.0	56
2.5	70
3.0	84
3.5	98
4.0	112

* Soil bulk density measured on a farm at Boorhaman at $1.4g/cm^3$). Conversion factor sourced from Valzano *et al* 2005

TABLE 2 Change in soil OC at Boorhaman after using the same stubble management practice for 25 years*

Stubble management practice	Annual stubble load		
	3t/ha	5t/ha	7t/ha
	Soil OC levels (t/ha)		
Burn stubble	-11	-6	-1
Bale stubble	-9	-4	2
Graze stubble	-4	5	14
Mulch stubble	-2	9	19

* $BD=1.4g/cm^3$ in the top 10cm, initial OC = 62t/ha in the top 30cm.

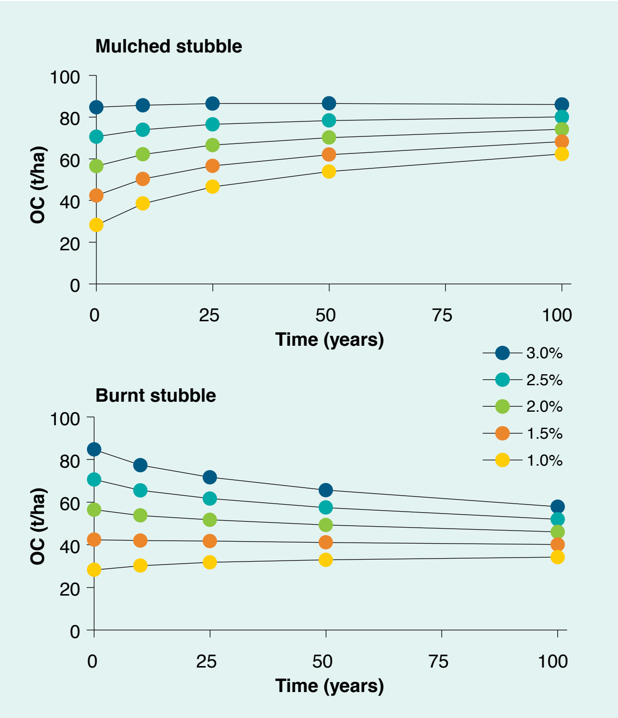

FIGURE 1 The long-term effect of two stubble management practices (burning or mulching 5t/ha of stubble every year) on soil organic carbon stocks (t SOC/ha) at Boorhaman. Modelling starts with five different levels of soil OC%.

Retaining all the crop stubble may not always be possible due to issues such as using stubble for feed, lower-yielding seasons, or occasional stubble burning to control weeds. Less OC accumulates under these conditions and modelling suggests that at Boorhaman, soil OC stocks will decrease even when stubble loads are consistently high (7t/ha).

When stubble load is low (less than 3t/ha) OC will decline regardless of management practice in the Boorhaman area (see Table 2 previous page).

Long-term stubble management

Increasing soil OC is a long-term goal. How long the goal takes to achieve depends on the starting level of soil OC, how much stubble is available and how stubble is managed. Consideration needs to be given to how the amount of stubble varies over the years with crop type and crop growth.

Figure 1 shows that consistently retaining stubble by mulching builds soil OC in soils when there is 3% or less soil OC. Consistently removing stubble by burning depletes soil OC where there is more than 2% soil OC.

Further reading

GRDC (2011) *Stubble management* fact sheet.

Valzano F *et al* (2005). *The impact of tillage on changes in carbon density with special emphasis on Australian conditions*, Tech. Report No. 43. Department of Environment and Heritage. pp164.

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The influence of canola stubble management on wheat production at Boorhaman

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Key points

- Retaining high stubble loads reduces the amount of nitrogen (N) available to the following crop.
- Reduced available soil nitrogen can be overcome by applying nitrogen fertiliser.
- Up to 25kg N/ha is needed to overcome immobilisation as a result of standing stubble.
- More nitrogen fertiliser is needed to overcome immobilisation when stubble loads of 5t/ha or more are retained by incorporation.
- More than 50kg N/ha is needed to overcome the detrimental effects on grain yield of mulching stubble loads greater than 5t/ha.

Stubble management

Stubble is commonly mulched, grazed or burnt in windrows following harvest. Each management practice has its own advantages and disadvantages for whole-farm management.

The way stubble is managed determines how much stubble is left in the paddock at the next sowing and whether the stubble is in contact with the soil.

Influence of stubble on soil nitrogen

The impact of stubble management on nitrogen (N) and subsequent grain yield has been explored through crop modelling using soil data from a farm near Boorhaman, north east Victoria and 124 years of climate data from Peechelba East as sourced from the Bureau of Meteorology (BoM).

The short-term impact of retaining stubble on soil nitrogen levels is for less nitrogen to be available to the following crop due to nitrogen immobilisation (see Figure 1). Immobilisation occurs as the amount of plant available nitrogen is reduced while micro-organisms break down the stubble.

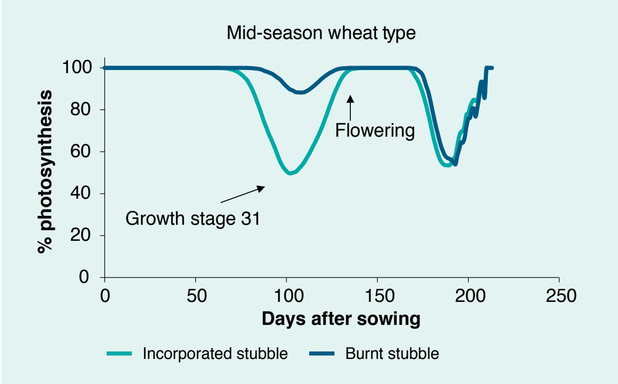

FIGURE 1 Nitrogen stress in unfertilised wheat (cv Gregory) after a canola crop, which has been either burnt or incorporated (10 t/ha)*

* 100% photosynthesis is maximum efficiency and indicates no nitrogen stress. Curves are the average photosynthesis efficiency simulated using APSIM Version 7.3 over 124 years (1889–2012) with climate data from Peechelba East and soil data near Boorhaman.

Nitrogen immobilisation is more likely to occur when:

- stubble loads are high
- stubble has a high carbon:nitrogen (C:N) ratio (i.e. wheat and barley)
- stubble is in contact with the soil
- soil is at a temperature and water content suitable for soil micro-organisms.

The least amount of immobilisation occurs when stubble is burnt, thus burnt stubble is the benchmark for considering the effects of stubble management practices (see Figure 1).

Benefits of stubble

In the long term, retaining stubble enhances soil structure, soil water holding capacity and reduces the risk of soil erosion. In the short term, retaining stubble can increase the risk of crop disease and may interfere with emergence of the next crop.

Effects of canola stubble on nitrogen management in the next wheat crop

The detrimental effect of additional nitrogen stress on grain yield from immobilisation under retained stubbles can be overcome by applying nitrogen fertiliser.

The amount of fertiliser needed to bring the grain yield up to the benchmark attained after a burnt stubble varies with each stubble management practice.



For Boorhaman, the benchmark grain yield without nitrogen fertiliser averaged 4.2t/ha over 124 years of simulations.

Applying 25kg N/ha to wheat near Boorhaman would mitigate the detrimental effects of stubble retention in the less intensive systems (see Table 1).

Up to 50kg N/ha needs to be applied to mitigate the detrimental effects of stubble retention when higher stubble loads are incorporated Even higher rates of nitrogen fertiliser are needed to mitigate immobilisation when higher stubble loads are mulched (see Table 2).

Although applying nitrogen fertiliser compensates for reductions in available nitrogen due to immobilisation, fertilised wheat grown immediately after a burnt stubble still attains higher average grain yields than wheat grown after the other stubble management practices. This is due to less nitrogen fertiliser being needed after stubble burning to compensate for nitrogen immobilisation and therefore more nitrogen fertiliser being available for additional plant growth and yield.

TABLE 1 Median grain yields of mid-season wheat grown with 25kg N/ha after canola with varying stubble loads and management

Stubble load (t/ha)	Wheat yield with 25/kg/ha following canola (t/ha)			
	Burnt stubble	Standing stubble	Incorporated stubble	Mulched stubble
Nil	4.7			
1		4.7	4.3	4.6
3		4.6	4.3	4.3
5		4.7	4.1	3.9
7		4.6	4.0	3.5
10		4.5	3.7	3.4

Tabled grain yields are compared with the median grain yield attained without nitrogen on a burnt canola stubble (4.2t/ha). Grain yields less than 4.2t/ha are shown in red. All grain yields are simulated using APSIM Version 7.3 over 124 years (1889–2012) with climate data from Peechelba East and soil data near Boorhaman.

TABLE 2 Median grain yields of mid-season wheat grown with 50kg N/ha after canola with varying stubble loads and management

Stubble load (t/ha)	Wheat yield with 50/kg/ha following canola (t/ha)			
	Burnt stubble	Standing stubble	Incorporated stubble	Mulched stubble
Nil	4.8			
1		4.9	4.7	4.8
3		5.0	4.7	4.7
5		5.0	4.6	4.5
7		5.0	4.5	4.0
10		5.0	4.3	3.9

Tabled grain yields are compared with the median grain yield attained without nitrogen on a burnt canola stubble (4.2t/ha). Grain yields less than 4.2 t/ha are shown in red. All grain yields are simulated using APSIM Version 7.3 over 124 years (1889–2012) with climate data from Peechelba East and soil data near Boorhaman.

Seasonal variation

It must be noted that grain yields simulated at Boorhaman varied markedly between seasons for the same stubble management strategies (i.e. range was 1.2–5.3t/ha for burnt stubble without nitrogen). This seasonal variation meant grain yield was often not effected by stubble management practice even with heavy stubble loads.

Further reading

GRDC (2011) *Stubble management* fact sheet.

This project was funded by the Grains Research and Development Corporation (GRDC) and the Department of Environment and Primary Industries, Victoria (DEPI).

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Nitrogen management for wheat in north east Victoria

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Key points

- The highest nitrogen (N) use efficiency is achieved with lower rates of nitrogen applied to soil with low starting nitrogen.
- The timing of early nitrogen applications (sowing to mid-tillering) has little impact on grain yield.
- Applying nitrogen fertiliser produces low gains in grain yield on soils with high nitrogen contents, especially for short-season wheat types.
- Long-season wheats benefit more than short-season wheats from the use of nitrogen fertiliser.

The importance of nitrogen

Nitrogen (N) is a major constituent of protein, the main building block of plants. It is essential for cell growth and chlorophyll formation.

Chlorophyll is responsible for photosynthesis — the conversion of sunlight to carbohydrates, biomass and grain.

Nitrogen supply to wheat must match nitrogen demand to maximise grain yield. The amount (rate) of nitrogen needed by wheat and the best timing of fertiliser application depends on starting soil nitrogen, the cultivar type and the season.

Rate and timing of nitrogen application

The effect of various nitrogen fertiliser rate and timing strategies on grain production in wheat has been assessed for the three types of bread and feed wheats (short, mid and long-season types) grown in south-eastern Australia.

These strategies for wheat production were assessed at Boorhaman, north east Victoria and used soil data from a farm near Boorhaman with 124 years of local climate data (1889–2012) at Peechelba East sourced from the Bureau of Meteorology (BoM).

Demand for nitrogen

Wheat needs nitrogen throughout the season, however demand is highest during early stem elongation (GS31) and before flowering (GS65). Figure 1 shows how photosynthesis is reduced around these critical times when nitrogen is only supplied from existing soil nitrogen.

Insufficient nitrogen around GS31 leads to reduced plant growth, while insufficient nitrogen around GS65 can translate into low grain protein. Nitrogen fertiliser tends to be considered early in the season when the aim is to maximise grain yield.

Nitrogen fertiliser strategies

Table 1 (following page) indicates how much extra grain yield was attained for three wheat types grown with low, medium and high starting soil nitrogen.

The grain yields are calculated using 124 years of climate data and soil data from the Boorhaman area. The numbers in the table are the *increase* in grain yield (kg/ha) above the grain yields obtained with only 10kg N/ha. The colours in the table indicate the efficiency of nitrogen fertiliser use.

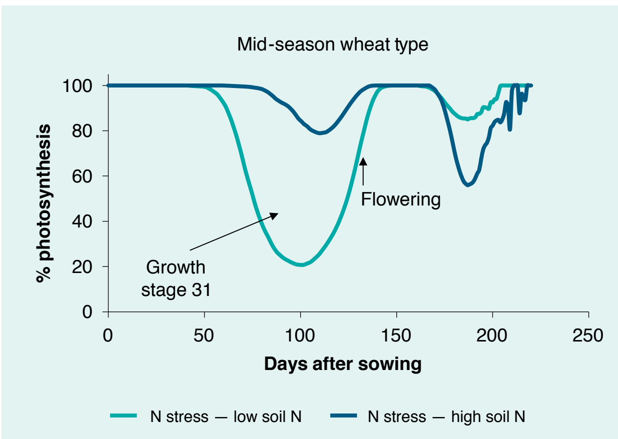

FIGURE 1 Nitrogen stress in a mid-season wheat type (cv Gregory) without nitrogen fertiliser*

* 100% photosynthesis is maximum efficiency and indicates no nitrogen stress. Curves are the average photosynthesis simulated using APSIM Version 7.3 over 124 years (1889–2012) with soil from Boorhaman and climate data from Peechelba East.



TABLE 1 Additional grain yield attained for three wheat types grown with low, medium and high starting soil nitrogen*

Single applications		Short-season wheat	Mid-season wheat	Long-season wheat
N application timing (growth stage)	Total N applied (kg N/ha)	Low starting soil N (kg/ha)		
GS31	50	1385	1246	1247
GS31	100	1578	1425	1361
GS39	50	798	577	735
GS39	100	868	611	738
		Medium starting soil N (kg/ha)		
GS31	50	520	1369	1098
GS31	100	684	1549	1200
GS39	50	282	1037	881
GS39	100	387	1164	885
		High starting soil N (kg/ha)		
GS31	50	31	483	809
GS31	100	52	754	903
GS39	50	17	392	604
GS39	100	26	646	669
Split applications		**Short-season wheat**	**Mid-season wheat**	**Long-season wheat**
N application timing (growth stages)	Total N applied (kg N/ha)	Low starting soil N (kg/ha)		
GS00–GS25 + GS31	90	2081	2323	2097
GS00–GS25 + GS31	190	2188	3151	3120
GS00 + GS31 + GS39	120	2129	2624	2105
		Medium starting soil N (kg/ha)		
GS00–GS25 + GS31	90	683	1930	1854
GS00–GS25 + GS31	190	693	2233	2602
GS00 + GS31 + GS39	120	693	1996	1859
		High starting soil N (kg/ha)		
GS00–GS25 + GS31	90	51	706	1180
GS00–GS25 + GS31	190	52	921	1798
GS00 + GS31 + GS39	120	52	885	1273

Green — moderate efficiency (20–30kg grain kg N); yellow — poor efficiency (10–20kg grain/kg N); grey — very poor efficiency (<10kg grain/kg N).
* Three wheat types simulated using APSIM Version 7.3 are represented by Mace (short-season), Gregory (mid-season), Wedgetail (long-season). The starting soil nitrogen contents are 50kg N/ha (low), 100kg N/ha (medium), 150kg N/ha (high) to 100cm depth.

Nitrogen use efficiency

For Boorhaman, applying nitrogen fertiliser always increased the average grain yield, but often the increase in grain yield was low given the amount of nitrogen applied. In these situations, nitrogen use efficiency is said to be low and the gains in grain yield made by applying nitrogen fertiliser need to be considered alongside the cost of using nitrogen fertiliser.

This project was funded by the Grains Research and Development Corporation (GRDC) and the Department of Environment and Primary Industries, Victoria (DEPI).

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Optimal time of sowing for wheat at Boorhaman, north east Victoria

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Key points

- The optimal time for sowing is a balance between getting the most from the natural resources while minimising the risk of crop damage at flowering due to frost or heat stress.
- The risk of damage at flowering can be minimised by choosing a sowing date that causes flowering to occur when the risk of frost and heat stress are low.
- All wheat types can be sown at Boorhaman at a time that maximises grain yield potential and has a low risk of climatic stress.
- The best time of sowing varies with wheat type.

Different wheat types need different sowing times

Every wheat type (short-season, mid-season and long-season) has a maximum potential grain yield that it is capable of achieving.

Achieving maximum potential grain yield requires adequate light, water and nutrients to be available to plants at the right time, without any adverse factors, such as crop disease (e.g. wheat streak mosaic virus).

Some wheats are sensitive to day length (i.e. photoperiod) and some long-season types need a cold period (vernalisation) to stimulate flowering.

Figure 1 shows the grain yield potentials for three cultivar types sown at Boorhaman every two weeks from 15 February to 1 September. The yields given for each sowing time are the median achieved when the growth of wheat is modelled for 124 years (1889–2012) using soil data from a farm at Boorhaman and long-term climate data from Peechelba East as sourced from Bureau of Meteorology (BoM).

The highest chance of achieving maximum potential grain yield (green squares for >90% maximum potential grain yield) in this area are:

- 15 May — 15 June for short-season type
- 1 April — 1 May for mid-season type
- 15 February — 15 April for long-season type

Sowing times with lower chances of achieving maximum grain yields are shown with teal squares (80–90%) and blue squares (<80%).

Avoiding climatic risks

Frost (temperatures less than 0°C) and heat stress (temperatures above 30°C) can damage wheat during flowering and reduce grain yield. Wheat has the greatest

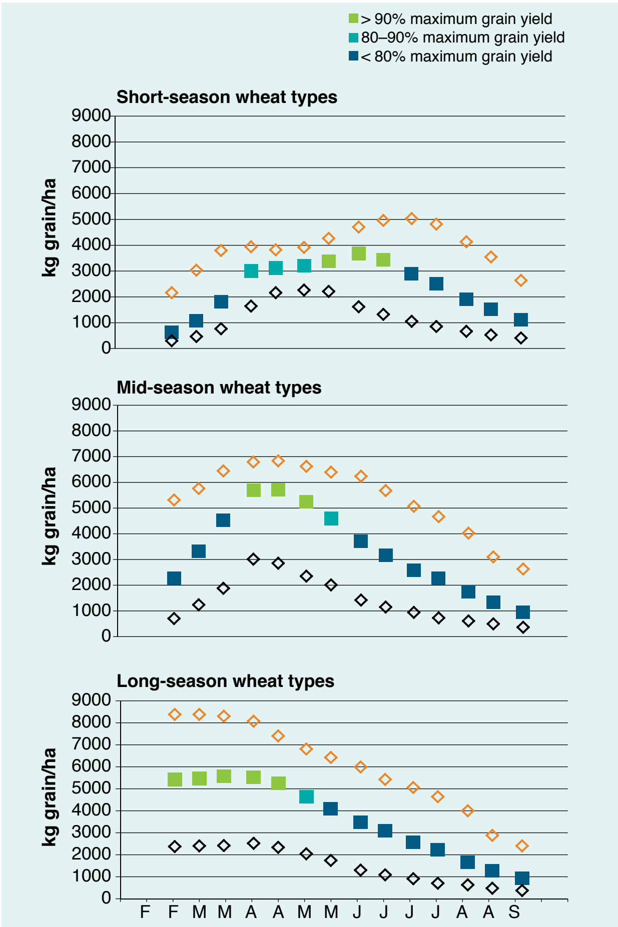

FIGURE 1 Impact of sowing time on yield for different wheat cultivar types

The median grain yield as simulated over 124 years (squares) using APSIM Version 7.3 for three wheat types using soil data from Boorhaman and climate data from Peechelba East. The top 10% of grain yields are above the orange diamonds. The bottom 10% of grain yields are below the black diamonds.



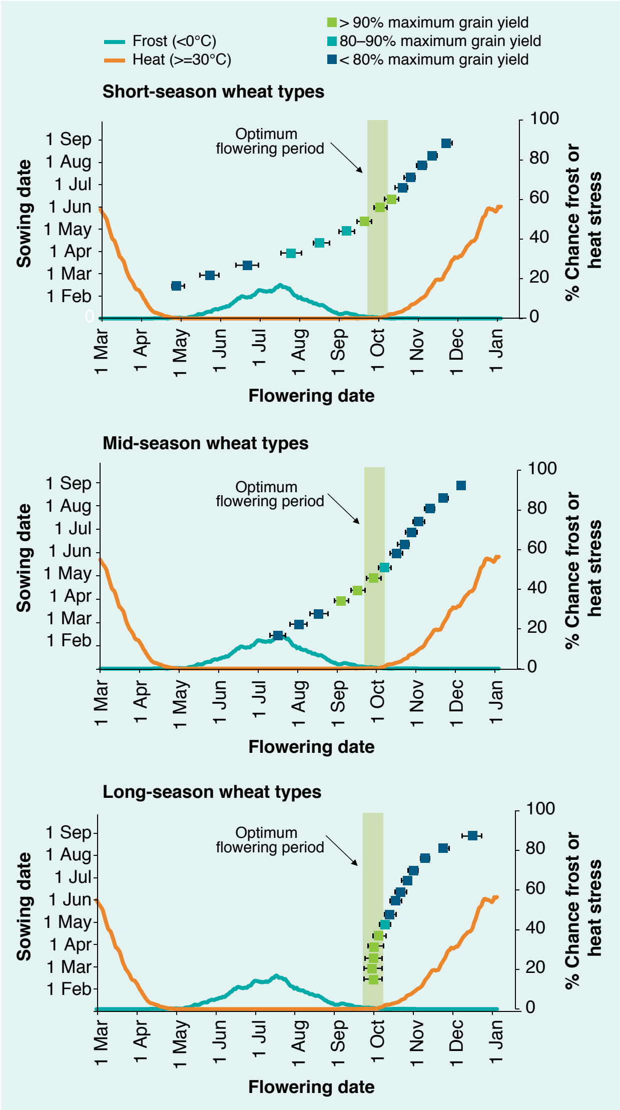

FIGURE 2 Flowering date vs climatic risk for different wheat types*

* Timing of flowering (squares) for various sowing times for three wheat types represented by Mace (short-season), Gregory (mid-season) and Wedgetail (long-season). Chance of frost (blue line) or heat (orange line) risk for the different sowing dates. The green bar indicates the optimum flowering period to minimise climatic risk. Green, teal and blue squares indicate >90%, 80–90% and <80% of grain yield potential in the absence of climatic risk (see Figure 1).

chance of avoiding these risks if it flowers when the there are few incidences of both frost and heat stress. In the Boorhaman area, the optimal time for flowering is 25 September through to 10 October.

This period is when the combined risk of frost and heat stress is less than 1%.

Fortunately, the flowering time for wheat is quite predictable, as growth is controlled by temperature and day length. The amount of temperature (known as day degrees) and the day length requirements are known for each wheat type presented.

Figure 2 shows how the optimal flowering period can be targeted by carefully choosing a wheat type and a sowing date.

Achieving the optimal balance

Ideally, the sowing time that gives the highest chance of attaining maximum potential grain yield (green squares, Figure 2) will be the same as the sowing time needed to ensure flowering occurs when the risk of frost and heat stress are at their lowest.

This ideal combination of maximum potential grain yield and low climatic risk occurs:

- 1 June for short-season types
- 1 May for mid-season types
- 15 February – 15 April for long-season types

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North east Victoria National Variety Testing Trials 2013

Trials conducted by Agrisearch and NSW DPI.
Data collated by Katherine Hollaway (DEPI, Horsham) and Dale Grey (DEPI, Bendigo) from data provided by the NVT website.

TABLE 1 Long-term predicted wheat yield (main-season) in north east Victoria for 2009–13

Variety	Predicted yield (t/ha)	% of EGA Gregory	Site years
Beaufort	4.23	112	6
Scout	4.21	111	14
Impala	4.10	108	17
Phantom	4.06	107	14
Gazelle	4.05	107	16
Correll	3.97	105	17
Harper	3.97	105	14
Merlin	3.97	105	17
Suntop	3.94	104	14
Corack	3.93	104	14
Espada	3.93	104	17
Spitfire	3.91	103	17
Dart	3.91	103	14
Bullet	3.90	103	5
Emu Rock	3.88	102	14
Orion	3.87	102	17
Merinda	3.86	102	3
Estoc	3.85	102	17
Lincoln	3.84	101	17
Wallup	3.84	101	14
Waagan	3.83	101	3
Preston	3.83	101	3
Justica CL Plus	3.82	101	14
Gladius	3.81	101	17
Bolac	3.81	101	14
Trojan	3.81	101	6
GBA Ruby	3.80	100	12
Wyalkatchem	3.80	100	4
Yitpi	3.79	100	14
Cobra	3.79	100	6
EGA Gregory	3.79	100	17
Elmore CL Plus	3.79	100	9
Dakota	3.77	99	3
Barham	3.76	99	17
QAL2000	3.76	99	7
Grenade CL Plus	3.76	99	9
Magenta	3.75	99	17
Gascoigne	3.75	99	12
SQP Revenue	3.73	99	10
Catalina	3.73	98	8
Mace	3.72	98	3
Clearfield STL	3.72	98	11
Sentinel	3.71	98	13
Young	3.71	98	12
Livingston	3.69	97	14
Sabel CL Plus	3.68	97	8
Diamondbird	3.67	97	3
Ventura	3.67	97	12
Sunguard	3.65	96	8
Peake	3.65	96	12
Axe	3.65	96	17
Shield	3.64	96	3
Kord CL Plus	3.62	96	11
Janz	3.61	95	7
Derrimut	3.61	95	17
Gauntlet	3.60	95	9
Forrest	3.58	94	6
Pugsley	3.58	94	3
EGA Bounty	3.55	94	3
Chara	3.52	93	17
Kennedy	3.50	92	9
Frame	3.49	92	12
Clearfield JNZ	3.49	92	14
Yenda	3.48	92	8
Bowie	3.46	91	5
Rosella	3.41	90	3
EGA Wills	3.38	89	3
Crusader	3.32	88	3
Impose CL Plus	3.27	86	3

TABLE 2 Long-term predicted wheat yield (long-season) in north east Victoria for 2009–13

Variety	Predicted yield (t/ha)	% of Bolac	Site years
Beaufort	5.58	110	6
Preston	5.57	110	6
SQP Revenue	5.34	105	6
LRPB Gazelle	5.27	104	5
LRPB Phantom	5.18	102	3
Bolac	5.08	100	6
Bolac	5.08	100	6
Sentinel 3R	5.05	99	6
Forrest	5.04	99	5
Espada	5.04	99	4
LRPB Orion	5.01	99	5
Estoc	4.96	98	6
EGA Gregory	4.96	98	6
Chara	4.86	96	6
Sunguard	4.83	95	3
QAL2000	4.83	95	3
Derrimut	4.82	95	4
Gascoigne	4.82	95	3
Yenda	4.81	95	3
Endure	4.80	95	3
EGA Bounty	4.69	92	4
EGA Wedgetail	4.66	92	6
Barham	4.66	92	4
Kellalac	4.66	92	6
Mansfield	4.59	90	5

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TABLE 3 Yield and quality of wheat varieties (main-season) at Dookie during 2013

Variety	Yield (t/ha)	Test weight (kg/hL)	Protein (%)	Screenings <2.2mm (%)	Seed size (g/1000 seeds)	Height (cm)	Heading year day*
Cobra	5.38	77.9	8.1	2.0	43.9	90	254
Lincoln	5.24	76.5	7.9	3.7	44.5	108	258
Magenta	5.24	77.0	8.1	2.9	45.1	100	261
Phantom	5.23	79.1	8.1	1.7	46.1	100	260
Espada	5.20	78.1	8.4	1.8	45.8	98	260
Mace	5.16	76.5	8.3	1.9	42.2	100	257
Corack	5.12	79.6	8.5	1.7	46.6	95	256
Trojan	5.07	80.9	8.3	1.6	42.7	97	260
Gauntlet	5.06	80.9	8.4	1.5	46.7	95	258
Axe	5.03	-	-	2.0	45.5	97	250
Emu Rock	4.98	79.2	8.5	2.1	51.6	92	252
Scout	4.93	80.2	8.3	1.8	47.3	98	257
EGA Gregory	4.91	80.5	8.0	1.7	44.2	107	264
Estoc	4.86	81.6	8.2	1.9	43.6	93	266
Wallup	4.85	80.1	8.7	2.0	39.7	98	254
Elmore CL PLus	4.84	81.4	8.2	2.2	40.6	92	258
Kord CL Plus	4.84	79.4	8.3	2.0	50.4	97	260
Gladius	4.83	79.0	8.7	2.0	47.8	97	258
Spitfire	4.81	79.1	8.3	2.9	46.7	102	255
QAL2000	4.72	-	7.9	2.2	43.7	103	261
Yitpi	4.71	79.8	8.0	2.1	45.9	107	266
Harper	4.70	80.2	8.0	2.3	42.5	100	263
Justica CL Plus	4.69	79.3	8.5	1.5	41.3	90	261
Orion	4.64	71.7	7.9	2.9	41.8	112	270
Grenade CL Plus	4.61	78.0	8.7	2.1	43.7	102	255
Suntop	4.61	78.8	8.4	2.5	44.2	105	259
Correll	4.58	78.7	8.0	1.9	45.8	103	259
Impala	4.58	81.1	7.9	1.8	39.3	110	257
Chara	4.52	-	8.5	1.9	40.7	98	261
Gazelle	4.51	77.4	7.7	1.5	38.6	103	259
Dart	4.48	78.0	8.9	2.6	41.9	98	249
Derrimut	4.47	75.9	8.3	2.5	38.6	90	259
Gascoigne	4.46	79.8	8.3	2.8	45.1	107	258
Merlin	4.42	81.6	8.8	1.8	45.9	103	253
Barham	4.07	-	7.9	2.5	40.5	105	260
Sown	14 May 2013						
Harvested	29 November 2013						
Site mean (t/ha)	4.83						
CV (%)	7.14						
F prob	<0.001						
LSD (t/ha)	0.57						
pH($CaCl_2$)	4.6						
GSR (Apr–Oct)	298mm						

* Heading year day is the calendar day of the year on which the crop heads emerged.
This trial was sprayed with fungicide during August, September and October.



TABLE 4 Yield and quality of wheat varieties (main-season) at Wunghnu during 2013

Variety	Yield (t/ha)	Test weight (kg/hL)	Protein (%)	Screenings <2.0mm (%)	Seed size (g/1000 seeds)	Height (cm)	Heading year day*
Trojan	3.56	80.9	7.8	2.4	41.2	98	259
Cobra	3.29	79.5	8.1	2.4	36.5	105	257
Mace	3.29	81.4	7.9	2.0	39.4	98	258
Axe	3.25	82.0	8.3	1.6	43.1	102	250
Wallup	3.25	81.9	8.6	1.7	38.1	102	261
Suntop	3.24	81.6	8.4	4.2	41.9	103	259
Corack	3.20	81.8	7.8	1.6	44.1	98	262
EGA Gregory	3.16	84.1	8.2	1.9	40.3	97	257
Espada	3.14	77.8	8.2	2.2	40.8	97	260
Emu Rock	3.05	82.2	8.7	2.5	47.0	98	256
Harper	3.04	82.4	8.4	3.8	38.8	98	258
Estoc	3.02	83.3	8.6	1.8	40.5	93	261
Gascoigne	3.02	83.0	8.3	2.4	40.1	97	256
Kord CL Plus	3.00	81.4	8.1	2.1	44.7	98	257
Magenta	2.97	81.0	8.1	3.5	39.8	93	258
Chara	2.94	82.3	9.0	2.0	37.3	100	260
Elmore CL PLus	2.94	83.0	8.2	2.3	36.0	98	258
Dart	2.93	79.6	8.8	2.1	39.2	87	255
Gauntlet	2.93	82.6	8.5	2.1	39.7	98	256
Justica CL Plus	2.93	80.1	8.6	1.6	37.4	102	257
Correll	2.92	79.0	7.9	2.8	41.4	95	261
Phantom	2.88	82.1	7.8	2.7	40.9	92	256
Gladius	2.86	81.1	8.4	2.1	42.6	97	254
Lincoln	2.85	81.1	8.3	3.0	38.0	100	257
Merlin	2.85	81.6	8.8	3.4	41.0	92	254
Scout	2.84	84.0	7.8	4.5	39.3	100	257
Yitpi	2.81	81.1	8.2	2.28	45.0	105	260
Grenade CL Plus	2.76	78.0	8.5	2.3	40.1	100	259
Gazelle	2.71	76.2	7.7	2.8	34.0	105	255
Spitfire	2.71	82.4	9.2	2.4	40.5	97	256
Orion	2.67	74.3	8.3	2.6	37.8	95	265
Janz	2.61	82.1	8.7	2.0	36.4	106	257
Derrimut	2.60	81.5	8.3	2.3	36.7	98	260
Impala	2.57	81.6	7.7	2.6	33.6	100	256
Barham	2.55	77.9	7.9	3.9	35.5	107	254
Sown	3 May 2013						
Harvest	28 November 2013						
Site mean (t/ha)	3.01						
CV (%)	5.78						
F prob	<0.001						
LSD (t/ha)	0.3						
pH($CaCl_2$)	4.7						
GSR (Apr–Oct)	223mm						

* Heading year day is the calendar day of the year on which the crop heads emerged.
This trial was sprayed with fungicide during August, September and October.

TABLE 5 Yield and quality of wheat varieties (main-season) at Yarrawonga during 2013

Variety	Yield (t/ha)	Test weight (kg/hL)	Protein (%)	Screenings <2.0mm (%)	Seed size (g/1000 seeds)	Height (cm)	Heading year day*
Kord CL Plus	5.23	81.1	10.8	2.14	50.0	93	263
Magenta	5.18	80.2	10.7	2.72	45.5	97	264
Justica CL Plus	5.16	82.4	10.4	2.07	42.2	93	266
Correll	5.13	79.9	10.1	2.02	45.6	98	264
Cobra	5.07	80.9	9.6	2.00	43.2	85	258
Gauntlet	5.03	83.7	10.6	1.69	46.7	90	264
Suntop	4.98	79.8	10.7	3.07	45.1	107	260
Wallup	4.93	81.9	11.3	1.84	43.6	88	261
Scout	4.92	82.4	10.4	1.87	45.4	100	260
Trojan	4.92	81.1	10.2	1.90	47.3	93	263
Espada	4.88	81.4	9.9	2.43	45.1	98	267
Mace	4.87	78.9	10.6	2.27	42.9	95	259
EGA Gregory	4.83	83.0	9.9	2.22	41.7	110	264
Harper	4.83	81.8	10.2	2.29	42.4	100	267
Spitfire	4.83	80.2	11.1	3.54	47.3	95	260
Phantom	4.82	83.2	9.9	2.11	44.1	103	265
Dart	4.72	81.8	11.2	2.53	42.2	95	250
Gazelle	4.71	79.9	8.9	3.38	36.3	103	270
Orion	4.68	78.5	9.1	2.34	43.7	113	272
Corack	4.62	83.0	9.8	2.40	45.7	85	260
QAL2000	4.61	81.1	9.0	2.60	45.9	105	270
Emu Rock	4.59	81.3	10.3	2.87	50.2	87	255
Axe	4.58	82.5	11.0	1.66	46.8	92	252
Gascoigne	4.57	83.2	11.0	2.30	46.7	108	261
Merlin	4.57	83.3	10.7	1.97	47.8	97	255
Elmore CL PLus	4.48	82.7	10.6	1.61	40.6	93	261
Chara	4.46	81.8	10.8	2.13	40.0	97	262
Impala	4.46	81.3	9.6	1.93	41.4	107	261
Derrimut	4.45	83.2	10.0	2.25	39.6	83	262
Barham	4.44	79.0	10.1	2.97	42.7	100	261
Estoc	4.44	82.5	10.7	2.20	41.7	95	269
Yitpi	4.41	82.1	10.4	2.27	43.8	98	267
Lincoln	4.30	82.9	9.6	3.06	46.1	95	259
Grenade CL Plus	4.28	81.8	11.0	1.84	45.0	98	260
Gladius	4.16	82.9	11.1	2.10	46.0	90	263
Sown	18 May 2013						
Harvest	30 November 2013						
Site Mean (t/ha)	4.78						
CV (%)	6.65						
F prob	<0.001						
LSD (t/ha)	0.55						
pH($CaCl_2$)	5.4						
GSR (Apr-Oct)	222mm						

* Heading year day is the calendar day of the year on which the crop heads emerged.
This trial was sprayed with fungicide during August, September and October.



TABLE 6 Yield and quality of wheat varieties (long-season) at Rutherglen during 2013

Variety	Yield (t/ha)	Test weight (kg/hL)	Protein (%)	Screenings <2.0mm (%)	Seed size (g/1000 seeds)	Height (cm)	Heading year day*
Preston	7.35	72.7	11.2	1.4	48.2	100	247
Manning	7.05	73.3	9.6	1.9	42.0	93	291
Gazelle	6.98	73.4	10.4	1.3	39.8	118	266
Beaufort	6.97	73.4	10.5	4.0	43.3	99	267
Forrest	6.93	77.0	10.1	2.5	45.2	117	302
QAL2000	6.89	76.2	10.6	1.6	47.3	110	262
EGA Wedgetail	6.87	73.5	11.2	1.3	42.8	107	273
SQP Revenue	6.87	72.7	9.9	3.5	42.5	99	294
Trojan	6.76	74.7	11.8	1.4	48.9	102	256
Sentinel	6.72	72.2	12.7	1.0	45.3	108	260
Phantom	6.70	76.2	10.9	1.8	49.8	107	260
Bolac	6.51	75.9	11.6	2.5	38.2	104	260
Scout	6.17	77.7	11.7	1.4	47.0	100	252
Elmore CL+	6.16	77.8	11.7	2.1	41.6	103	250
Orion	6.16	72.9	9.5	2.3	48.7	122	265
EGA Gregory	6.12	76.1	12.2	1.6	48.5	113	258
Kellalac	6.00	74.5	10.5	1.6	36.6	105	301
Estoc	5.97	73.7	11.9	2.0	44.8	101	257
Gascoigne	5.79	77.4	12.7	1.4	49.1	108	247
Chara	5.77	74.4	12.3	1.3	41.5	100	255
Lancer	5.60	77.0	12.6	1.9	47.5	90	259
Gauntlet	5.42	75.8	12.1	1.4	46.0	98	250
Mansfield	4.91	75.4	11.6	2.2	34.0	93	300
Sown	26 April 2013						
Harvest	12 December 2013						
Site mean (t/ha)	6.27						
CV (%)	5.0						
F prob	<0.001						
LSD (t/ha)	0.52						
pH($CaCl_2$)	5.9						
GSR (Apr–Oct)	370mm						

* Heading year day is the calendar day of the year on which the crop heads emerged.
This trial was sprayed with fungicide during August, September and October.

TABLE 7 Long-term predicted triticale yields in north east Victoria for 2006–13

Variety	Predicted yield (t/ha)	% of Hawkeye	Site years
Fusion	3.84	106	8
Treat	3.69	102	3
Bogong	3.68	102	14
Crackerjack	3.62	100	4
Hawkeye	3.62	100	16
Canobolas	3.61	100	14
Berkshire	3.61	100	14
Jaywick	3.51	97	16
Chopper	3.47	96	12
Goanna	3.37	93	6
Rufus	3.36	93	12

Variety	Predicted yield (t/ha)	% of Hawkeye	Site years
Tickit	3.35	93	3
Everest	3.35	93	3
Yowie	3.34	92	8
Prime 322	3.31	91	3
Tahara	3.29	91	16
Tuckerbox	3.01	83	10
Tobruk	2.99	83	8
Speedee	2.93	81	4
Credit	2.87	79	3
Kosciuszko	2.77	77	4
Abacus	2.62	72	2

TABLE 8 Yield of triticale varieties at Rutherglen during 2013

Variety	Yield (t/ha)	Test weight (kg/hL)	Protein (%)	Screenings <2.0mm (%)	Seed size (g/1000 seeds)
Bogong	7.69	74.4	10.3	1.7	55.0
Canobolas	7.19	71.0	10.0	4.3	53.6
Hawkeye	7.06	69.0	9.9	3.2	52.0
Fusion	6.89	70.6	10.1	2.8	51.6
Goanna	6.63	70.9	10.3	2.7	45.3
Yukuri	6.51	73.2	10.0	3.6	42.3
Berkshire	6.48	69.6	9.9	3.3	50.1
Jaywick	6.48	63.5	9.8	5.0	46.8
Chopper	6.47	65.7	10.2	2.8	48.0
Yowie	6.42	67.6	10.4	2.5	48.7
Tuckerbox	6.39	69.9	10.3	3.6	41.6
Tahara	6.38	65.7	10.2	2.9	49.1
Rufus	6.28	66.4	10.1	2.9	49.3
Sown	26 April 2013				
Harvest	16 December 2013				
Site mean (t/ha)	6.83				
CV (%)	3.45				
F prob	<0.001				
LSD (t/ha)	0.39				
pH($CaCl_2$)	5.9				
GSR (Apr–Oct)	370mm				

This trial was sprayed with fungicide during August.

TABLE 9 Yield of triticale varieties at Yarrawonga during 2013

Variety	Yield (t/ha)	Test weight (kg/hL)	Protein (%)	Screenings <2.0mm (%)	Seed size (g/1000 seeds)
Fusion	5.43	74.3	10.0	1.41	46.4
Rufus	5.22	71.1	10.0	1.32	45.9
Hawkeye	5.14	74.3	9.9	1.02	46.1
Goanna	4.98	76.2	10.1	1.36	44.3
Jaywick	4.97	73.8	10.1	1.22	43.4
Bogong	4.81	76.6	10.0	1.44	45.0
Berkshire	4.69	77.1	10.0	1.12	50.2
Tahara	4.66	72.5	10.0	1.15	46.6
Canobolas	4.55	75.0	10.0	1.74	45.4
Chopper	4.43	72.3	9.9	1.51	46.3
Yowie	3.25	74.1	10.0	1.17	45.0
Tuckerbox	2.72	73.0	10.0	2.17	38.0
Sown	18 May 2013				
Harvest	1 December 2013				
Site mean (t/ha)	4.74				
CV (%)	12.2				
F prob	<0.001				
LSD (t/ha)	0.88				
pH($CaCl_2$)	5.4				
GSR (Apr–Oct)	222mm				

This trial has a CV of 12.2% indicating high variability across the trial. Make variety selection decisions using information from multiple trials.



TABLE 10 Long-term predicted barley yield in north east Victoria for 2009–13

Variety	Yield (t/ha)	% of Gairdner	Site years
Malting barley			
Charger	3.21	115	4
Commander	3.09	111	8
Henley	3.06	110	5
Granger	3.03	109	3
Navigator	2.98	107	4
Fairview	2.94	105	5
Buloke	2.93	105	8
Scope	2.93	105	5
Bass	2.89	104	6
Westminster	2.88	103	5
Vlamingh	2.80	100	4
Gairdner	2.79	100	8
Baudin	2.73	98	8
Flagship	2.62	94	8
Schooner	2.50	90	8
Feed barley			
Oxford	3.09	111	5
Fathom	3.07	110	4
Fleet	3.07	110	6
Capstan	3.04	109	6
Lockyer	3.03	109	3
Hindmarsh	3.01	108	7
Yarra	2.94	105	5
Keel	2.87	103	5
Hannan	2.76	99	3
Finniss	2.41	86	6
Barley under malt evaluation			
LaTrobe	3.09	111	3
Skipper	2.99	107	4
SY Rattler	2.98	107	5
Wimmera	2.93	105	5
Macquarie	2.89	104	7
Flinders	2.88	103	4

TABLE 11 Yield of barley varieties at Wunghnu during 2013

Variety	Yield (t/ha)
Malting barley	
Fairview	4.16
Henley	4.09
Granger	4.04
Charger	4.03
Scope	3.76
Schooner	3.75
Flagship	3.73
Commander	3.69
Westminster	3.60
Buloke	3.57
Baudin	3.52
Gairdner	3.49
Bass	3.43
Feed barley	
Hindmarsh	3.89
Oxford	3.77
Fathom	3.57
Maritime	3.34
Barley under malt evaluation	
Compass	4.44
SY Rattler	4.00
Flinders	3.95
La Trobe	3.85
Skipper	3.82
Wimmera	3.82
Macquarie	3.76
Sown	3 May 2013
Harvest	28 November 2013
Site mean (t/ha)	3.77
CV (%)	5.6
F prob	<0.001
LSD (t/ha)	0.36
pH($CaCl_2$)	4.7
GSR (Apr–Oct)	223mm

This trial was sprayed with fungicide during August, September and October.

TABLE 12 Long-term predicted oat yield in north east Victoria for 2007–13

Variety	Predicted yield (t/ha)	% of Quoll	Site years
Williams	3.44	115	10
Bannister	3.28	110	10
Echidna	3.09	104	5
Potoroo	3.07	103	7
Wombat	3.02	101	13
Quoll	2.98	100	10
Kojonup	2.95	99	7
Euro	2.90	97	10
Dunnart	2.85	96	15
Possum	2.79	93	15
Yallara	2.70	91	15
Carrolup	2.70	91	3
Mitika	2.68	90	15
Mortlock	2.33	78	5
Numbat	2.26	76	6

TABLE 13 Yield of oat varieties at Yarrawonga during 2013

Variety	Yield (t/ha)	Test weight (kg/hL)	Protein (%)	Screenings <2.0mm (%)	Seed size (g/1000 seeds)
Bannister	4.80	52.6	8.4	12.8	37.4
Wombat	4.78	52.8	9.2	11.6	37.3
Echidna	4.51	51.3	9.5	24.6	37.7
Williams	4.44	54.7	9.5	18.0	35.0
Possum	4.26	52.4	9.3	11.3	36.0
Dunnart	4.15	-	9.0	17.4	37.5
Quoll	4.02	50.8	9.1	19.4	37.1
Mitika	3.94	53.6	9.8	8.1	37.5
Yallara	3.86	-	9.1	19.9	36.5
Numbat	2.20	58.6	9.6	51.1	38.6
Sown	18 May 2013		**pH(CaCl2)**	5.4	
Harvest	1 December 2013		**GSR (Apr–Oct)**	222mm	
Site mean (t/ha)	3.88				
CV (%)	9.06				
F prob	<0.001				
LSD (t/ha)	0.57				

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TABLE 14 Yield of oat varieties at Dookie during 2013

Variety	Yield (t/ha)	Test weight (kg/hL)	Protein (%)	Screenings <2.0mm (%)	Seed size (g/1000 seeds)
Williams	5.41	50.0	8.7	15.81	37.32
Bannister	5.32	54.3	8.0	11.34	37
Dunnart	5.24	-	8.4	16.03	35.9
Wombat	5.15	54.1	9.3	34.23	38.72
Possum	4.93	50.0	9.2	12.65	37.84
Yallara	4.74	50.0	8.9	14.93	39.2
Mitika	4.68	55.4	9.5	8.60	38.7
Echidna	4.55	51.5	9.1	17.45	37.6
Quoll	4.27	50.0	8.8	16.89	37.72
Numbat	2.77	64.2	9.9	74.96	34.06
Sown	14 May 12013		**pH(CaCl2)**	4.6	
Harvest	29 November 2013		**GSR (Apr–Oct)**	298mm	
Site mean (t/ha)	4.58				
CV (%)	4.05				
F prob	<0.001				
LSD (t/ha)	0.28				

TABLE 15 Yield of oat varieties at Rutherglen during 2013

Variety	Yield (t/ha)
Potoroo	4.58
Carrolup	4.48
Williams	4.43
Wombat	4.42
Wandering	4.41
Bannister	4.33
Dunnart	4.31
Kojonup	4.27
Possum	3.52
Yallara	3.20
Mitika	3.02
Sown	26 April 2013
Harvest	1 November 2013
Site mean (t/ha)	3.62
CV (%)	5.0
F prob	<0.001
LSD (t/ha)	0.31
pH($CaCl_2$)	5.9
GSR (Apr–Oct)	370mm

TABLE 16 Long-term predicted yield of conventional canola varieties in north east Victoria for 2009–13

Variety	Predicted yield (t/ha)	% of Garnet	Site years
Nuseed Diamond	2.14	105	2
Hyola 50	2.12	104	4
CB Agamax	2.04	100	3
Hyola 433	2.04	100	2
AV Garnet	2.01	99	4
AV Zircon	1.95	96	2
Victory V3001	1.95	96	2
CB Tango C	1.93	95	2

TABLE 17 Yield of conventional canola varieties (mid-season) at Wunghnu during 2013

Variety	Yield (t/ha)	Oil (%)	Seed protein (%)	Gluc (%)
AV Garnet	1.49	45.8	14.5	6.8
AV Zircon	1.53	46.2	15.2	5.9
CB Agamax	1.53	42.9	16.4	4.5
CB Tango C	1.66	43.9	16.5	4.2
Hyola 50	1.51	44.1	16.6	4.9
Nuseed Diamond	1.6	44.7	15.4	6.4
Victory V3002	1.6	43.5	17.2	7.9
Sown	3 May 2013			
Harvest	15 November 2013			
Site mean (t/ha)	1.55			
CV (%)	6.04			
F prob	<0.001			
LSD (t/ha)	0.15			
pH($CaCl_2$)	4.9			
GSR (Apr–Oct)	223mm			

TABLE 18 Long-term predicted yield of imidazolinone (imi) tolerant canola varieties (mid-season) in north east Victoria during 2009–13

Variety	Predicted yield (t/ha)	% of Hyola 474CL	Site years
Pioneer 45Y86 (CL)	2.23	109	8
Pioneer 44Y84 (CL)	2.19	107	11
Pioneer 44Y87 (CL)	2.19	107	2
Pioneer 45Y88 (CL)	2.19	107	4
Carbine	2.17	106	6
Pioneer 46Y83 (CL)	2.17	106	7
Archer	2.15	105	4
Pioneer 45Y82 (CL)	2.15	105	9
Hyola 474CL	2.04	100	6
Hyola 575CL	2.04	100	8
Hyola 577CL	2.02	99	2
Hyola 676CL	2.02	99	2
Pioneer 46Y78	2.00	98	5
Hyola 571CL	1.98	97	5
Pioneer 43Y85 (CL)	1.96	96	2
Pioneer 45Y77	1.92	94	3
Pioneer 44C79 (CL)	1.63	80	3

TABLE 19 Yield and quality of imidazolinone (imi) tolerant canola varieties (mid-season) at Yarrawonga during 2013

Variety	Yield (t/ha)	Oil (%)	Protein (%)	Gluc (%)
Archer	3.24	41.3	20.5	5
Pioneer 45Y86 (CL)	3.08	41.3	20.8	5.2
Pioneer 45Y88 (CL)	3.00	40.5	20.6	4.4
Pioneer 44Y84 (CL)	2.89	40.8	21.3	5.1
Hyola 474CL	2.88	41.6	20.9	5.8
Hyola 577CL	2.83	41.4	21.0	5.2
Hyola 575CL	2.80	41.2	20.1	4.8
Carbine	2.42	40.2	21.1	5.6
Sown	6 May 2013			
Harvest	18 November 2013			
Site mean (t/ha)	2.84			
CV (%)	5.02			
F prob	<0.001			
LSD (t/ha)	0.23			
pH($CaCl_2$)	6.0			
GSR (Apr–Oct)	222mm			

TABLE 20 Yield and quality of imidazolinone (imi) tolerant canola varieties (mid season) at Wunghnu during 2013

Variety	Yield (t/ha)	Oil (%)	Protein (%)	Gluc (%)
Pioneer 45Y88 (CL)	1.79	42.5	17.1	3.7
Hyola 575CL	1.74	43.7	17.9	6.3
Hyola 474CL	1.73	43.5	17.8	5.1
Pioneer 44Y84 (CL)	1.73	44.0	17.3	4.9
Pioneer 45Y86 (CL)	1.73	44.9	16.7	4.9
Carbine	1.71	43.6	17.1	4.7
Archer	1.69	44.1	16.5	5.4
Hyola 577CL	1.62	44.8	18.2	4.0
Sown	3 May 2013			
Harvest	15 November 2013			
Site mean (t/ha)	1.67			
CV (%)	5.56			
F prob	<0.001			
LSD (t/ha)	0.15			
pH($CaCl_2$)	4.9			
GSR (Apr–Oct)	223mm			



TABLE 21 Long-term predicted yield of triazine tolerant (TT) canola varieties (mid-season) in north east Victoria during 2009–13

Variety	Predicted yield (t/ha)	% of Hyola 444TT	Site years
CB Atomic HT	1.98	116	4
Hyola 559TT	1.98	116	4
CB Nitro HT	1.97	115	4
Hyola 555TT	1.93	113	8
ATR Bonito	1.92	112	4
CB Henty HT	1.92	112	6
Crusher TT	1.92	112	8
Hyola 656TT	1.92	112	4
Hyola 450TT	1.90	111	2
ATR Gem	1.83	107	5
ATR Snapper	1.83	107	6
ATR Stingray	1.83	107	8
CB Jardee HT	1.83	107	11
CB Junee HT	1.83	107	5
ATR Wahoo	1.81	106	4
Hyola 525RT	1.81	106	2
Hyola 751TT	1.81	106	4
Pioneer Sturt TT	1.81	106	4
Jackpot TT	1.80	105	2
CB Tumby HT	1.74	102	5
ATR409	1.73	101	3
Monola 314TT	1.73	101	2
Hyola 444TT	1.71	100	4
Monola 413TT	1.71	100	4
ATR Cobbler	1.69	99	9
Monola 77TT	1.69	99	7
Tawriffic TT	1.69	99	7
CB Mallee HT	1.68	98	4
Monola 704TT	1.68	98	2
Monola 76TT	1.68	98	7
CB Telfer	1.66	97	5
Rottnest TTC	1.66	97	3
Thumper TT	1.66	97	8
CB Scaddan	1.64	96	7
BravoTT	1.62	95	3
Hurricane TT	1.62	95	3
Monola 605TT	1.62	95	5
ATR Marlin	1.61	94	3
Monola 506TT	1.61	94	3
Monola 603TT	1.61	94	2
Fighter TT	1.59	93	2
Bonanza TT	1.54	90	4
CB Tanami	1.50	88	5
Lightning TT	1.47	86	3
Monola 707TT	1.47	86	2
CB Argyle	1.45	85	5

TABLE 22 Yield and quality of triazine tolerant (TT) canola varieties (mid-season) at Yarrawonga during 2013

Varieties	Yield (t/ha)	Oil (%)	Protein (%)	Gluc (%)
CB Henty HT	2.50	41.4	20.6	5.9
ATR Gem	2.49	42.4	20.4	4.8
ATR Bonito	2.47	43.1	20.0	6.0
Hyola 650TT	2.46	39.7	21.8	6.0
ATR Wahoo	2.45	43.8	19.8	4.5
CB Atomic HT	2.44	42.0	21.0	6.3
Hyola 656TT	2.41	42.3	21.2	5.7
CB Jardee HT	2.40	39.5	21.0	4.7
CB Nitro HT	2.40	41.5	21.7	3.8
Hyola 555TT	2.38	41.0	21.1	7.3
Hyola 450TT	2.34	42.7	21.0	6.7
Crusher TT	2.29	39.8	20.1	7.5
ATR Stingray	2.25	41.6	20.7	3.5
Hyola 559TT	2.24	42.5	19.7	6.5
Monola 314TT	2.24	38.8	22.3	3.7
Thumper TT	2.22	41.1	21.6	5.8
Hyola 525RT	2.15	42.3	21.3	5.6
Pioneer Sturt TT	2.06	39.0	21.3	5.3
Monola 413TT	1.97	40.7	21.7	5.8
Monola 605TT	1.83	37.3	23.1	10.2
Sown	6 May 2013			
Harvest	10 November 2013			
Site mean (t/ha)	2.32			
CV (%)	5.87			
F prob	<0.001			
LSD (t/ha)	0.24			
pH($CaCl_2$)	6.0			
GSR (Apr–Oct)	222mm			

TABLE 23 Yield and quality of triazine tolerant (TT) canola varieties (mid-season) at Wunghnu during 2013

Variety	Yield (t/ha)	Oil (%)	Protein (%)	Gluc (%)
ATR Stingray	1.73	44.7	17.3	3.8
CB Nitro HT	1.70	43.3	18.3	4.7
CB Atomic HT	1.67	42.6	18.7	4.2
Crusher TT	1.67	42.4	17.1	5.9
Hyola 555TT	1.67	42.2	18.8	6.6
CB Henty HT	1.65	42.5	17.7	4.9
ATR Bonito	1.63	45.2	16.9	4.0
Hyola 450TT	1.59	44.7	17.8	5.4
Hyola 656TT	1.58	43.6	18.6	5.7
CB Jardee HT	1.57	41.4	17.5	5.2
Hyola 559TT	1.56	44.0	17.9	4.8
Monola 314TT	1.51	41.6	17.6	4.3
ATR Gem	1.50	44.6	16.8	4.4
Hyola 525RT	1.46	43.6	18.0	6.1
Pioneer Sturt TT	1.45	41.8	18.1	5.8
ATR Wahoo	1.43	45.8	16.7	3.1
Monola 413TT	1.37	41.6	18.7	3.5
Thumper TT	1.33	44.6	17.8	5.0
Sown	3 May 2013			
Harvest	15 November 2013			
Site mean (t/ha)	1.57			
CV (%)	5.91			
F prob	<0.001			
LSD (t/ha)	0.15			
pH($CaCl_2$)	4.9			
GSR (Apr–Oct)	223mm			

TABLE 24 Long-term predicted yield of Roundup Ready (RR) canola varieties in north east Victoria during 2009–13

Variety	Predicted yield (t/ha)	% of GT Cobra	Site years
Pioneer 43Y23 (RR)	2.61	115	4
Hyola 500RR	2.54	112	2
Hyola 404RR	2.49	110	6
Nuseed GT-50	2.49	110	6
Pioneer 44Y24 (RR)	2.47	109	6
Hyola 400RR	2.45	108	2
Nuseed GT-41	2.40	106	4
Victory V5002RR	2.38	105	5
Hyola 505RR	2.34	103	5
Pioneer 45Y22 (RR)	2.34	103	7
IH50 RR	2.31	102	6
CB Frontier RR	2.27	100	6
GT Cobra	2.27	100	6
CB Eclipse RR	2.24	99	5
Monola 513GT	2.24	99	4
Pioneer 46Y20 (RR)	2.24	99	3
Victory V5001RR	2.22	98	3
CB Status RR	2.15	95	2
GT Viper	2.13	94	6
GT Cougar	2.09	92	3
GT Mustang	2.06	91	3
GT Scorpion	1.99	88	2
GT Taipan	1.99	88	2

TABLE 25 Yield of Roundup Ready (RR) canola varieties at Yarrawonga during 2013

Variety	Yield (t/ha)	Oil (%)	Protein (%)	Gluc (%)
Pioneer 43Y23 (RR)	2.79	40.8	19.7	4.5
Pioneer 44Y24 (RR)	2.66	41.5	19.9	4.9
Victory V5002RR	2.63	42.4	19.8	8.1
Pioneer 45Y22 (RR)	2.62	41.8	19.7	5.4
CB Frontier RR	2.46	40.3	20.7	3.8
Hyola 500RR	2.46	42.8	20.1	4.0
Hyola 505RR	2.46	43.6	20.2	5.8
Hyola 400RR	2.45	44.6	18.9	6.5
Hyola 404RR	2.41	42.2	20.3	6.8
IH50 RR	2.36	40.4	19.5	5.8
Nuseed GT-50	2.32	41.4	20.0	7.9
Monola 513GT	2.25	43.5	19.9	5.9
GT Cobra	2.19	40.3	21.1	6.2
Nuseed GT-41	2.07	41.5	20.5	10.7
GT Viper	1.77	40.2	20.1	4.3
Sown	6 May 2013			
Harvest	18 November 2013			
Site mean (t/ha)	2.41			
CV (%)	5.64			
F prob	<0.001			
LSD (t/ha)	0.23			
pH($CaCl_2$)	6.0			
GSR (Apr–Oct)	222mm			



TABLE 26 Yield of Roundup Ready (RR) canola varieties at Wunghnu during 2013

Variety	Yield (t/ha)	Oil (%)	Protein (%)	Gluc (%)
Pioneer 43Y23 (RR)	1.98	42.5	17.0	5.0
Hyola 500RR	1.85	46.1	16.7	5.5
Hyola 400RR	1.84	45.7	17.0	5.4
IH50 RR	1.77	42.3	17.7	5.0
Pioneer 45Y22 (RR)	1.76	42.7	17.7	6.2
Hyola 404RR	1.75	44.9	17.3	4.8
Nuseed GT-41	1.73	43.7	17.8	10.8
Pioneer 44Y24 (RR)	1.71	42.2	18.8	5.7
Victory V5002RR	1.70	44.5	17.8	8.1
CB Frontier RR	1.66	41.8	18.0	5.5
Nuseed GT-50	1.63	43.6	16.8	7.1
Monola 513GT	1.59	46.6	16.7	6.2
GT Cobra	1.58	43.6	17.3	4.8
GT Viper	1.34	42.1	18.0	2.6
Sown	3 May 2013			
Harvest	15 November 2013			
Site mean (t/ha)	1.69			
CV (%)	5.5			
F prob	<0.001			
LSD (t/ha)	0.15			
pH($CaCl_2$)	4.9			
GSR (Apr–Oct)	223mm			

TABLE 27 Long-term predicted yield of faba bean varieties in north east Victoria during 2005–12

Variety	Predicted yield (t/ha)	Site years
PBA Rana	2.41	5
Doza	2.46	4
Nura	2.49	7
Fiord	2.54	4
Cairo	2.57	3
Farah	2.59	7
Fiesta FV	2.62	7

TABLE 28 Yield and quality of faba bean varieties at Dookie during 2013

Variety	Yield (t/ha)	100 seed weight (g/100 seeds)
Farah	4.12	72.8
Fiesta VF	3.99	69.1
PBA Warda	3.96	77.9
PBA Rana	3.57	84.2
Nura	3.55	69.0
Sown	8 May 2013	
Harvest	9 December 2013	
Site mean (t/ha)	3.93	
CV (%)	4.34	
F prob	0.0259	
LSD (t/ha)	0.35	
pH($CaCl_2$)	4.8	
GSR (Apr-Oct)	298mm	

TABLE 29 Long-term predicted yield of lupin varieties in north central Victoria during 2009–13

Variety	Predicted yield (t/ha)	% of Mandelup	Site years
Mandelup	2.18	100	5
Jenabillup	2.12	97	5
PBA Gunyidi	2.10	96	4
Coromup	2.04	94	5
PBA Barlock	2.02	93	4
Wonga	1.77	81	5

TABLE 30 Yield and quality of lupin varieties at Diggora (near Elmore) during 2013

Variety	Yield (t/ha)	100 seed weight (g/100 seeds)
PBA Gunyidi	2.64	14.9
Mandelup	2.55	16.1
PBA Barlock	2.55	16.2
Jenabillup	2.44	15.6
Coromup	2.24	15.3
Wonga	2.24	15.1
Sown	29 May 2013	
Harvest	18 December 2013	
Site mean (t/ha)	2.53	
CV (%)	4.41	
F prob	0.0013	
LSD (t/ha)	0.18	
pH($CaCl_2$)	4.6	
GSR (Apr–Oct)	251mm	

Soil microbes and nitrogen availability — the impact of tillage

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Key points

- Tillage, crop rotation and soil moisture significantly impact on the amount of plant-available soil nitrogen (N) available at sowing and throughout the cropping season.
- Clear linkages exist between microbial processes and soil nitrogen pools at sowing in zero-till systems, but not in conventional tillage systems.
- Although stubble retention has many benefits, if strategic tillage is required, doing so after a legume rotation may increase the number of soil microbes available to process the nitrogen-rich legume stubble and increase nitrogen availability at sowing in the following crop.

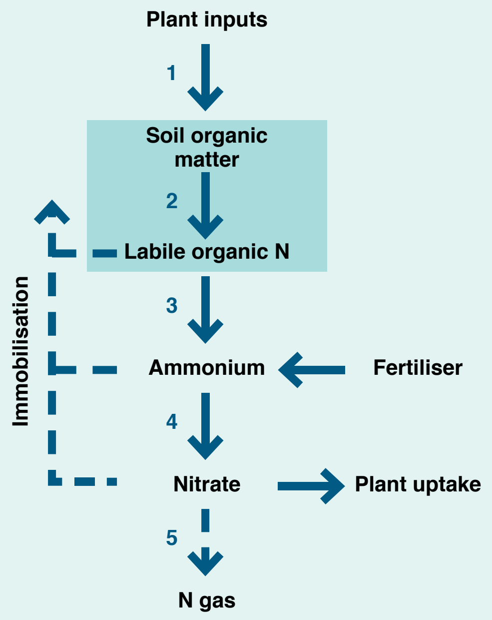
Aim

The aim of this project was to assess how cropping management practices, such as stubble retention, impact on the microbial cycling of nitrogen (N) and carbon (C).

Background

Nitrogen use efficiency is dependent on the ability of soil microbes (e.g. soil bacteria and fungi) to release nitrogen from both soil and fertiliser sources. This project investigated the relationships between the conversion of nitrogen from soil organic matter (SOM) or fertiliser, into plant-available forms (mineral nitrogen), and the microbes involved. It is only through understanding which groups of microbes are driving the nitrogen cycle (see Figure 1), that we can determine how management practices will impact the availability of mineral nitrogen.

Although this project focussed on a cropping soil from Horsham, Victoria (see Table 1), the knowledge generated about the factors that enhance or suppress the conversion of organic nitrogen from plant residues or fertiliser into mineral nitrogen is of value in understanding the processes involved. The following report highlights selected results, rather than going into detail on all aspects of the experimental phase of the project.



Step	Microbial groups	Target enzymes
1 Decomposition	Fungi, bacteria	Laccase; cellulase
2 Depolymerisation	Fungi, bacteria	Laccase; aminopeptidase
3 Mineralisation	Fungi, bacteria	Aminopeptidase
4 Nitrification	Bacteria, archaea	Ammonium monoxygenase; nitrite oxidoreductase
5 Denitrification	Bacteria	Nitrite reductase; nitrous oxide reductase

FIGURE 1 The key processes involved in nitrogen transformations in soil and the microbial enzymes required

TABLE 1 Average soil analysis at Horsham, Victoria

Parameter	0–5 (cm)	5–10 (cm)	10–20 (cm)
pH ($CaCl_2$)	7.6	7.6	7.6
EC (dS/m)	0.21	0.19	0.18
OC (%)	0.97	0.83	0.69
Total C (%)	1.02	0.86	0.75
Mineral N (mg/kg)	36.5	28.6	14.8
Total N (%)	0.14	0.11	0.11
Colwell P (mg/kg)	70.6	54.6	26.7
Total P (mg/kg)	334	281	182



Methods

Soil samples were taken from a long-term cropping experiment at Horsham, Victoria (*Sustainable Cropping Rotations in Mediterranean Environments*; SCRIME, established during 1998), across a range of crop rotations and tillage practices (see Table 2). Samples were collected at five key stages of the growing season: sowing, germination, tillering, flowering, and harvest, in order to track changes in soil nitrogen availability over time and to determine how microbial activity corresponded with changes in soil nitrogen pools.

Soil samples were collected at 0–5, 5–10 and 10–20cm deep from three replicates of each treatment and analysed for a range of soil chemical and microbial parameters. This report outlines the interaction between mineral nitrogen and microbes, which produced specific enzymes. The three enzymes of interest in this study were: laccase, cellobiohydrolase (a cellulase enzyme), and aminopeptidase. These enzymes are important in the initial breakdown of SOM (and plant residues), the breakdown of labile (easily decomposable) SOM, and the release of labile organic nitrogen, respectively.

TABLE 2 Crop rotation and tillage treatments sampled from the SCRIME field site, 2011

Previous crop	Current crop	Tillage treatment
Canola	Wheat	Conventional tillage Zero-till
Wheat	Peas	Conventional tillage Zero-till
Pea	Canola	Conventional tillage Zero-till

* These treatments were not top-dressed with nitrogen through the season

All results were statistically analysed, with statistical significance set at $p < 0.05$. All reported changes due to treatment are statistically significant.

Results

Mineral nitrogen

In all treatments mineral nitrogen concentrations were greatest at sowing due to mineralisation of stubble residue from the previous crop (see Figure 2). There was more mineral nitrogen available at sowing in the conventionally-tilled canola treatment compared with the zero-till treatment due to the incorporation of the stubble residue of the previous legume crop (peas). The greater stubble–soil contact and enhanced microbial communities resulted in increased nitrogen mineralisation.

By germination, mineral nitrogen across all conventionally-tilled treatments had moved deeper than 0–5cm and increased at either 5–10 or 10–20cm depth, and was still greater than the zero-till treatments.

By tillering there was little change in mineral nitrogen between treatments at depth. This indicates that a large amount of nitrogen had been taken up by the crop and/or moved below the measurement zone of 20cm.

Microbial enzymes

The previous crop in the rotation had a significant influence on the amount of microbes capable of producing enzymes present at sowing (see Table 3). For example, where the previous crop was peas, the conventional tillage treatment had more of the required microbes than the zero-till treatments. In contrast, after a canola or wheat crop, the abundance of microbes

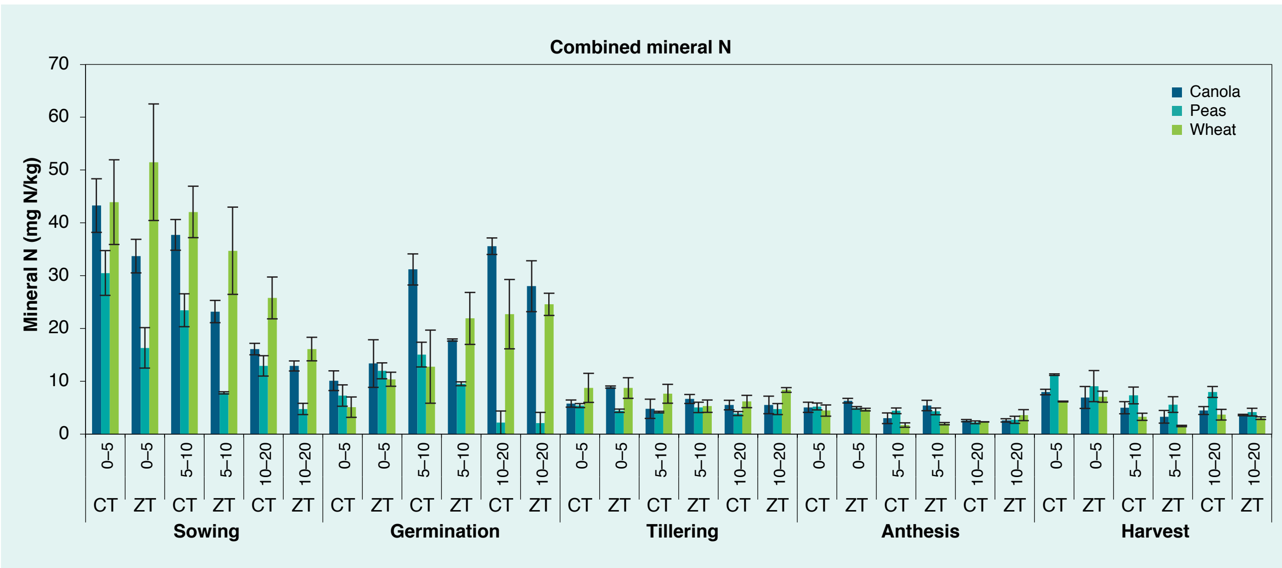


FIGURE 2 Changes in mineral nitrogen with depth at the SCRIME field site, comparing conventional tillage (CT) and zero-till (ZT) across three different crops throughout the 2011 season. Bars are measures of standard error

TABLE 3 Relative abundance of microbes associated with organic matter decomposition in zero-till vs conventional till systems*

Previous crop	Current crop	Sowing	Germination	Tillering	Flowering	Harvest
Canola	Wheat	↑	↑	↑	↑	↑
Wheat	Peas	↑	↑	↑	↑	↓
Peas	Canola	↓	↓	=	=	↑

*↑ indicates increased microbes under zero-till compared with conventional tillage, ↓ indicates decreased microbes under zero-till compared with conventional tillage, and = indicates no difference due to tillage treatment.

producing all three enzymes of interest was higher in zero-till treatments (see Table 3).

This means that the soils of the conventionally-tilled canola treatment (previous crop was peas) had an increased capacity to break down the SOM and plant residues and release labile organic nitrogen, which can then be converted into mineral nitrogen. This result is supported by the mineral nitrogen results, which show increased mineral nitrogen in the conventionally-tilled canola treatment compared with the zero-till treatment.

If the presence of more microbes capable of breaking down organic nitrogen always equals more mineral nitrogen, then more mineral nitrogen should be available in the zero-till treatments following canola and wheat. However, this did not occur (see Figure 2). To understand why this was the case requires not only measuring which microbes are present, but measuring which microbes are active.

The microbes in zero-till treatments were more active than those in the conventional tillage treatments. This increased activity translated to the ability to efficiently process organic nitrogen to mineral nitrogen via the steps outlined in Figure 1. In the year of this field trial, the site had more than three times the annual rainfall in the months leading up to sowing. Under these conditions, the organic nitrogen in the zero-till treatments may been quickly transformed into mineral nitrogen and leached through the wet soil, moving beyond the crop root zone before sowing. Therefore, the increased activity of the microbes meant that the mineral nitrogen had already disappeared from the root zone before the plants needed it.

In comparison, the microbes in the conventional tillage treatments were not so active, or so efficient. This may be due to disruption of the micro-scale soil networks required for microbial movement and communication, resulting in a breakdown of linked nitrogen-cycling processes. The slower processing of the residues in the conventionally-tilled treatments led to the organic nitrogen being mineralised more slowly, so that more mineral nitrogen was available to the crop at sowing (see Figure 2). Therefore, the nitrogen was there when the plants needed it.

However, under 'average' rainfall conditions, and decreased soil moisture contents in the months leading up to sowing, the increased activity of microbes in zero-till systems throughout the season should result in more efficient and timely mineralisation of stubble-derived nitrogen over time, with more mineral nitrogen available at sowing under zero-till systems.

Observations and comments

One of the strengths of this project was that the field sampling was carried out at several key points throughout the growing season. However, the limitation is that it couldn't be reproduced over several years of variable soil moisture and temperatures. Therefore, the applicability of this work over time and across soil types is unknown.

The key outcome from this work is the demonstration of the measurable link between soil mineral nitrogen and the microbes responsible for nitrogen cycling. This has only been possible due to the development of advanced molecular biology techniques.

Understanding how soil microbes control the release of plant-available nitrogen is the starting point to understanding how growers can manipulate these processes to their benefit through management.

As the sensitivity of these techniques, and their application, continues to be increase, they may also provide an alternative means of estimating the amount of soil nitrogen that will become available to the crop during the growing season. Such tests are likely to be more time-effective and cost-effective than current measures of soil nitrogen.

This work was funded by DEPI, Victoria and GRDC through the *Soil Biology Initiative II* project *Managing soil biology to improve nitrogen supply in grain production systems* (DAV 00106).

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Dual-herbicide-tolerant canola integrated weed management performance evaluation

Justin Kudnig
National Canola Technical Manager, Pacific Seeds

Key points

- The hybrid Roundup Ready (RR) canola variety showed the highest yields across three technologies trialled across Australia during 2013.
- Hyola® 525RT® dual herbicide tolerance adds residual weed control to an RR hybrid cropping system.
- Hyola® 525RT® demonstrated competitive performance to industry-leading triazine tolerant (TT) hybrid — Hyola® 559TT
- The combined use of both TT and RR chemistries provided the most effective weed control.

Aim and methodology

During 2013, independent contract researchers carried out a comprehensive weed control and varietal performance trial programme across Australia to evaluate the performance and effectiveness of the triazine tolerant Roundup Ready (RT®) technology in integrated weed management (IWM) programmes.

Nine replicated trials were carried out in typical canola growing regions, with five sites in Western Australia and four in the eastern states. The RT system was compared with triazine tolerant (TT) and Roundup Ready (RR) canola and nine spray regimes were chosen across herbicide systems to mirror typical on-farm spray decisions. The key weed species: annual ryegrass (*Lolium rigidum*) and wild radish (*Raphanus raphanistrum*) were targeted. The aim of this research was to evaluate different combinations of TT and RR herbicides applied at different rates and timings on weed control within each of the three systems and provide growers with appropriate IWM recommendations.

Background

Triazine tolerant Roundup Ready hybrid canola is a new dual-herbicide-tolerant system being commercialised by Pacific Seeds and Monsanto. This technology will be tolerant to both triazine herbicides and Roundup Ready Herbicide with PLANTSHIELD® (RRH), by Monsanto. The RT hybrid canola incorporates one already-approved genetically modified (GM) event – Roundup Ready — and also incorporates cytoplasmic triazine tolerance, which has been developed using conventional breeding.

This combination of herbicide-tolerant traits aims to provide growers with the broad-spectrum knockdown control of RRH, along with the residual activity of the triazine herbicides. Both these herbicide groups have a relatively lower resistance risk profile compared with other herbicide groups, making this herbicide-tolerant system a valuable and timely addition to on-farm IWM.

Roundup Ready canola allows growers to spray two applications of RRH; from emergence to the six-leaf stage. The RT system incorporates the current RR use-pattern along with the ability to spray atrazine and/or simazine as outlined by currently-registered triazine products for use in TT canola.

Results — weed efficacy case studies from Mingenew and Cunderdin trials

The results summary from the trial conducted at Mingenew, WA, which included both of the key weed species — annual ryegrass and wild radish — are shown in Figure 1.

In the RT treatments (treatments 1–3) a range of different spray regimes achieved greater than 90% control of ryegrass and wild radish. The clethodim (Select®) treatment (treatment 4) within the TT canola system provided little ryegrass control, indicating the paddock contained clethodim-resistant ryegrass.

The RT system provided greater control of ryegrass, relative to the TT canola system (treatments 4–6), which was attributed to the RRH application controlling the clethodim-resistant ryegrass.

The RT system also provided improved radish control, relative to the TT canola treatments, due to the additional control of RRH.

Similarly, the RT canola treatments also provided greater radish control relative to the RR canola treatment (treatment 7). This was most likely due to the extended radish control provided by the residual activity of the atrazine and/or simazine.

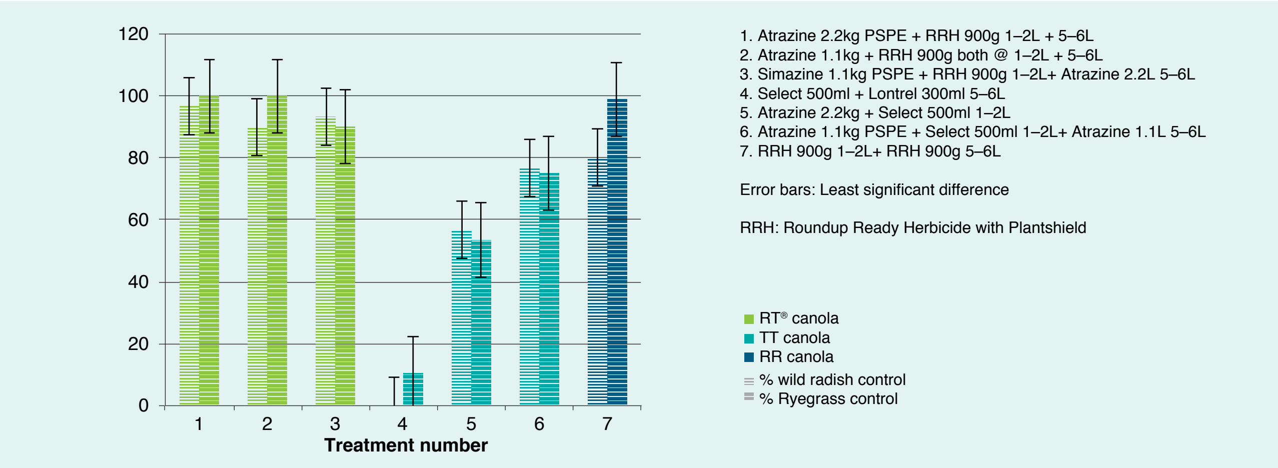

FIGURE 1 Herbicide-tolerant canola systems trial, Mingenew, 2013

At Cunderdin, the RT treatments that included atrazine and/or simazine and RRH (treatments 2-4), had ryegrass control of 95% and above (see Figure 2). The greater control of ryegrass in the RT treatments relative to the TT system was attributed to the RRH, either controlling potentially clethodim-resistant ryegrass and/or the addition of another mode of action providing improved control.

At this site, the RR system (treatment 8), which included two applications of RRH, provided similarly high levels of ryegrass control relative to the RT treatments that included atrazine and/or simazine and RRH. Although the RR system provided high levels of control, the atrazine-alone treatment (treatment 1) in the RT system provided 60% control of ryegrass. This suggests a benefit of adding atrazine to the RR system, providing another mode of action and reducing the potential for the development of glyphosate-resistant ryegrass.

Yield performance

Average yields of the RT hybrid (Hyola® 525RT®) across all nine sites were similar to a current top-performing TT hybrid, Hyola® 559TT (see Figure 3). Hyola® 404RR, one of the top-performing RR canola hybrids outperformed Hyola 525RT and Hyola 559TT in terms of average yield across all sites due to the known inherent lower yield potential associated with germplasm incorporating the TT system.

Summary

Results from the trials suggest the RT system provides an effective tool to control a wide range of weed species, including the key weed species of annual ryegrass and wild radish.

From an IWM perspective, RT canola can be a valuable addition to manage the development of herbicide resistance as it uses two different herbicide modes of action within the cropping season. As with all herbicide resistance management strategies, this system will only be effective if used as one part of a whole IWM strategy, including non-chemical tactics, such as higher plant population competitiveness, autumn tickles, double knocks, windrow burns, weed seed destruction and capture techniques..

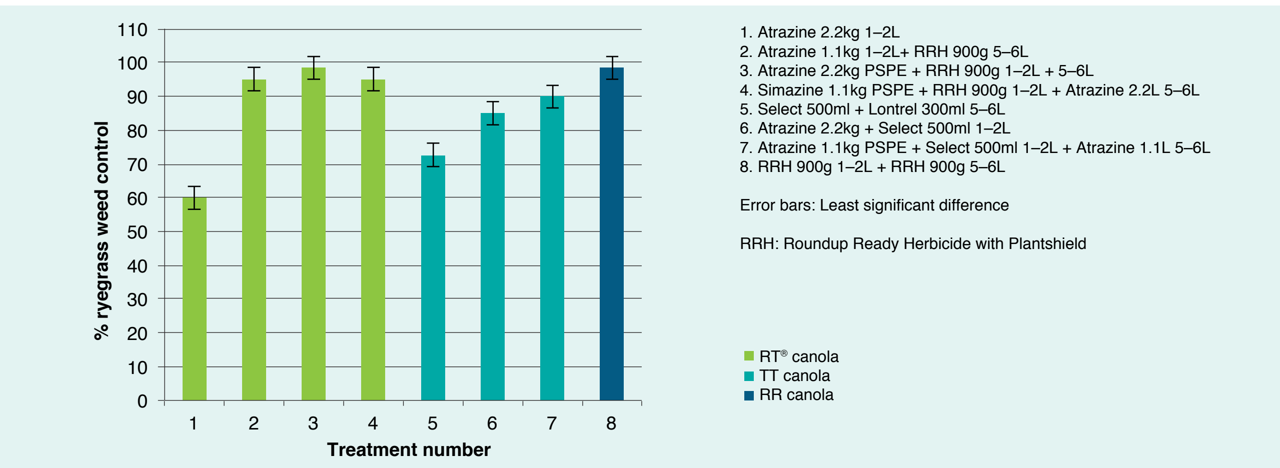

FIGURE 2 Herbicide-tolerant canola systems trial, Cunderdin, 2013

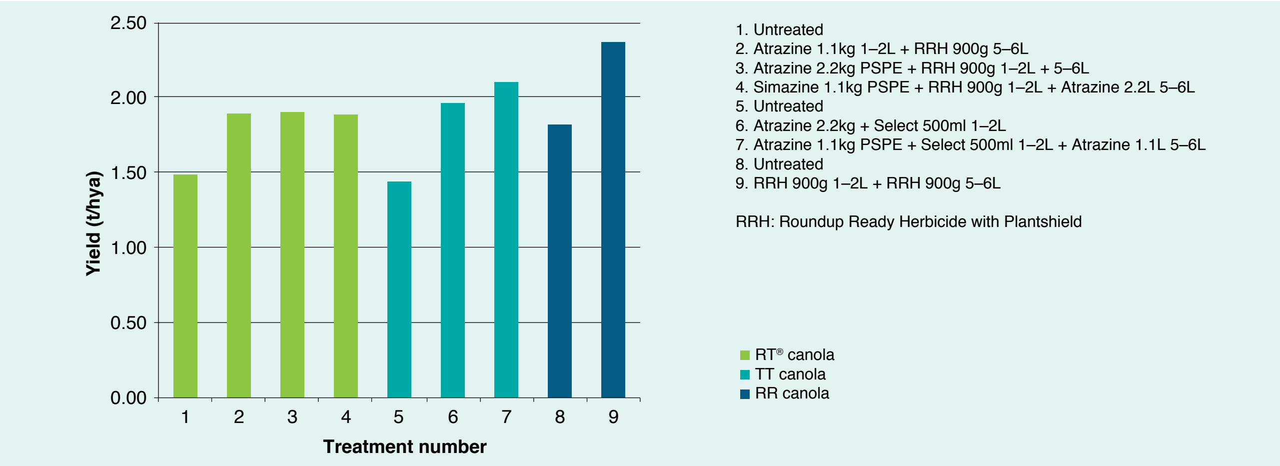

FIGURE 3 Herbicide-tolerant canola systems trials, mean yield performance across nine sites (2013)

Analysed trial results across Australia to date show that the current commercially-available RT canola hybrid, Hyola 525RT has similar yields compared with the current industry-leading commercial TT hybrid, Hyola 559TT.

For further information, visit www.roundupreadycanola.com.au or www.pacificseeds.com.au

Acknowledgements

Matthew Hayes, Monsanto, Eurofins Agrisearch, Kalyx Australia Pty Ltd.

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Effects of crop rotation on phosphorus response in wheat

Lee Menhenett[1], Craig Farlow[1], Charlie Walker[1] and Peter Howie[2]
[1] Incitec Pivot Fertilisers
[2] Melbourne University

Key points

- Higher phosphorus (P) rates (up to 24kg P/ha) were required to maximise yield in wheat following canola compared with wheat following wheat (8kg P/ha).
- Yield responses to phosphorus for a wheat on canola rotation occurred even where Colwell P levels were deemed sufficient in a low-phosphorus-buffering soil.
- Lower phosphorus rates reduced crop vigour, tillering, and dry matter (DM) production resulting in greater weed competition.
- Adjusting phosphorus rates at sowing, based on crop rotation, may be advantageous.
- To capitalise on the investment in phosphorus fertiliser, growers must have nitrogen, weed, pest and disease management right.

Location: 8km SE of Dookie, Victoria

Rainfall:
Annual: 447mm (2013), 551mm (mean all yrs)
GSR: 298mm (2013), 367mm (mean all yrs)
Stored moisture: Dry (<30mm)

Soil:	Trial site A	Trial site B
Type:	Red clay loam	Red clay loam
CEC (meq/100 g)	7.29	10.4
pH ($CaCl_2$):	4.9	4.9
Colwell P:	48mg/kg	60mg/kg
Phosphorus buffering index (PBI)	48	130
DGT# P:	63ug/L	23ug/L
Deep soil nitrogen (80cm):	58kg/ha	61kg/ha
Deep soil sulphur (80cm):	208kg/ha	250kg/ha
Organic carbon (OC):	1.9%	2%
Zinc (DTPA extract):	0.8 mg/kg	1.3 mg/kg

Sowing information:
Variety: Wheat cv. Young
Sowing date: 8 May 2013
Fertiliser: Sowing: 40kg N/ha, in-crop: 40kg N/ha
Sowing equipment: Cone seeder, knife point, press wheel

Row spacing: 29cm

Paddock history:	Trial site A	Trial site B
2012	Wheat	Canola

Plot size: 10m x 1.74m

Replicates: 4

#DGT — Diffuse Gradients in Thin Film: This test is a measure of soil solution phosphorus that is available to plant roots.

Aim

The aim of this trial was to:

- investigate the effect of a canola break crop on wheat response to phosphorus (P) rate compared with wheat following wheat
- assess whether higher phosphorus rates should be applied to wheat following canola and whether phosphorus rates could be reduced in wheat following wheat.

Method

Two trials were established in neighbouring paddocks following previous crops of wheat (site A) or canola (site B). Soil analysis in the wheat on wheat (WOW) trial site for 0–10cm depth indicated a Colwell P of 48mg/kg compared with 60mg/kg in the wheat on canola (WOC) site. Refer to trial site summary details for other soil test information.

The wheat stubble paddock was burnt prior to sowing, while the canola stubble paddock had been grazed with sheep.

Wheat (cv Young) was dry sown at 77kg/ha on 8 May 2013. Six rates of nil, 8kg, 16kg, 24kg, 32kg and 40kg P/ha were applied as mono-ammonium phosphate (MAP) at sowing. Nitrogen was balanced at sowing to supply an equivalent of 40kg N/ha, with a further 40kg N/ha (87kg/ha urea) top dressed on 6 August (first node — GS31), to all plots.

Dry matter (DM) and tiller number assessments occurred 90 days after sowing (DAS), 6 August, on the WOW trial and 111 DAS, 27 August, on the WOC trial. A late frost

occurred on 18 October. Growing season rainfall (GSR) was approximately 298mm. The trial was harvested 3 December, 2013.

Each trial comprised a completely randomised block design with four replicates. Analysis of variance (ANOVA) was undertaken using Genstat® V.16. Least significant difference (LSD) between treatments was determined at the 5% level of significance using Fisher's Protected LSD.

Results

Wheat tiller number and DM production responses to increasing rates of applied phosphorus corresponded with yield effects (see Figures 1 and 2).

Wheat response to phosphorus rate was greater following canola (WOC) than following wheat (WOW).

Dry matter and tiller density assessments between the two trials differed by three weeks, however, apart from the first few weeks after sowing, there were few visual differences between rates above 8kg P/ha in the WOW trial throughout the season. This was in stark contrast to the 2012 trial sown in the same section of paddock following canola where wheat responded similarly to the WOC site during 2013.

In WOW there was a significant DM response between 0 and 16kg P/ha, but no further increase occurred between rates of 16 to 40kg P/ha (see Figure 1a). Similarly there were significant incremental increases in tiller numbers up to 16kg P/ha, with no further increase at higher phosphorus rates. Wheat yield increased significantly between 0 and 8kg P/ha, but yields at rates of 16kg P/ha or above were not statistically different to 8kg P/ha (see Figure 2a). Grain protein decreased significantly between 0 and 16kg P/ha, but was not different between 16 and 40kg P/ha.

In WOC there were significant DM responses between 0 and 24kg P/ha, with DM at 32 and 40kg P/ha

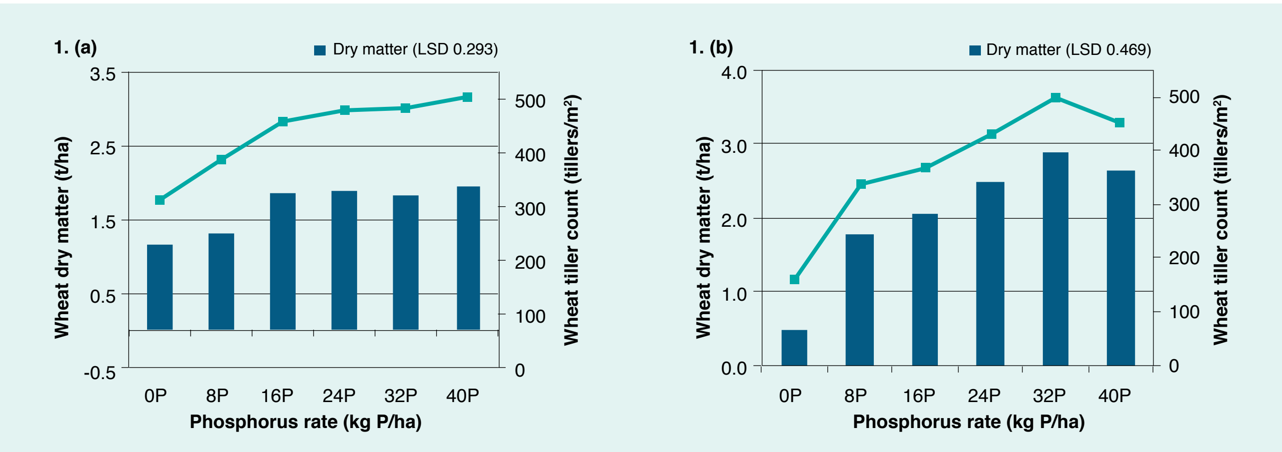

FIGURE 1 Wheat tiller density and dry matter response to phosphorus rate in (a) wheat following wheat (90 DAS) and (b) wheat following canola (111 DAS)

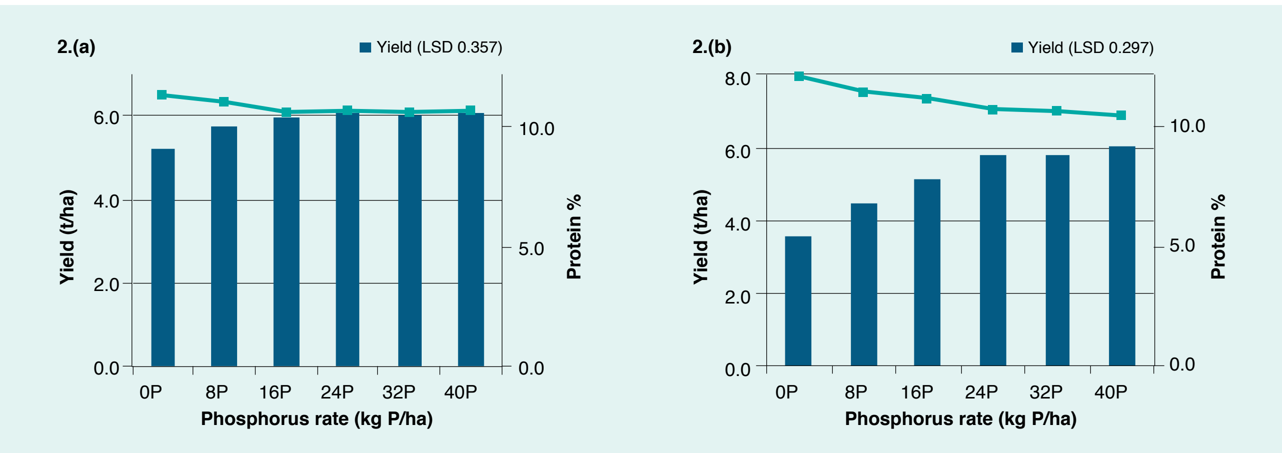

FIGURE 2 Wheat yield and grain protein response to phosphorus rate in (a) wheat following wheat and (b) wheat following canola

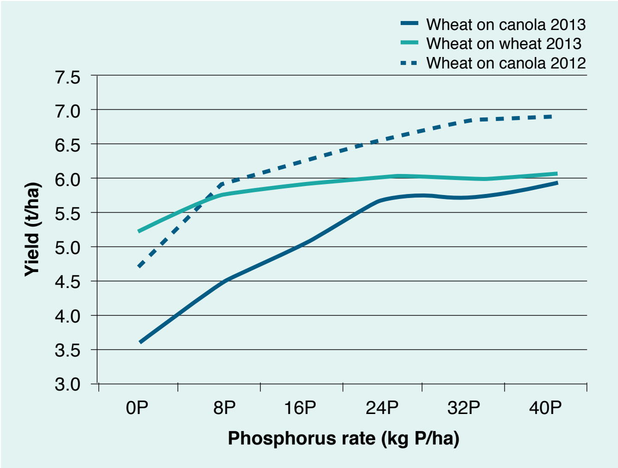

FIGURE 3 Effect of phosphorus rate on wheat yield response during 2012 and 2013*
* The 2012 trial (WOC) was in the same paddock as the WOW in 2013.

significantly higher than 16kg P/ha, but not 24kg P/ha (see Figure 1b). Similarly there were significant, almost incremental, increases in tiller numbers up to 32kg P/ha. Wheat yield increased incrementally between 0 and 24kg P/ha, with no further increase at higher phosphorus rates (see Figure 2b). Grain protein decreased between 0 and 24kg P/ha, but was not significantly different between 24 and 40kg P/ha.

Observations and comments

Soil test values indicate the likelihood of a response to applied fertiliser. A Colwell P value above the critical range indicates there is unlikely to be a yield response to fertiliser phosphorus. Critical Colwell P values for different crops and soil types have been established using phosphorus rate trial results from south-eastern Australia in the *Better Fertiliser Decisions for Cropping* database, (www.bfdc.com.au).

Interrogation of the BFDC database indicates the critical Colwell P level (90% relative yield) in wheat following wheat from 235 phosphorus rate trials across NSW, Victoria and SA is 27mg/kg (critical range 23–32). However, for wheat following canola the critical Colwell P level is 40mg/kg (range 16–100), albeit from a smaller data set (30 phosphorus rate trials) and hence, lower reliability.

Soil samples (0–10cm depth) collected at Dookie before sowing indicated Colwell P levels of 48mg/kg for the WOW site and 60mg/kg for the WOC site, which were at or above critical phosphorus levels for wheat. While a DGT phosphorus level of 63 for the WOW site suggested adequate phosphorus and 23ug/L for the WOC site was in the responsive range, there is insufficient data in the BFDC database to explore the effect of crop rotation on critical DGT phosphorus levels at this time.

During the past two seasons, fertiliser trials conducted at Dookie in WOC in neighbouring paddocks have shown a much greater rate response to applied phosphorus (see broken red line for 2012 and solid red line for 2013 in Figure 3) than observed in WOW (green line, 2013 season only).

Wheat yields were slightly higher in the WOW trial during 2013 compared with WOC in the same year. Although in near neighbouring paddocks, in the WOC trial (west-facing slope), a mid-October frost had some impact on yield and grain quality, with a lower test weight due to a proportion of blackened, shrivelled grain, compared with the WOW (east-facing slope). Annual ryegrass control at the WOC site was also more challenging, particularly in the less competitive plots where lower phosphorus rates were applied.

Wheat grown after brassica crops normally yields more than wheat grown after wheat. This is largely attributed to depleted inoculum levels of soil-borne cereal pathogens following the brassica crop. Given potential root disease suppression benefits and sufficient soil phosphorus reserves, the magnitude of the phosphorus response in WOC in two consecutive years in different paddocks at Dookie continues to indicate a crop rotation effect yet to be fully understood.

Whether this relates to the specific crop, herbicide system (triazine tolerant), microbial contribution, soil type or other factors, requires further examination. Reduced mycorrhizal colonisation in WOC may be a factor. Canola does not support arbuscular mycorrhizal fungi, the symbiotic fungi that can increase the uptake of phosphorus and other nutrients in exchange for carbohydrates from the host plant. Reduced phosphorus foraging of wheat at lower phosphorus rates and a reduced drain on carbohydrates at higher phosphorus rates could explain the steepness of this response in WOC during both 2012 and 2013.

Crop phosphorus comprises both fertiliser and soil profile phosphorus uptake, and is controlled by both soil and climatic factors. A recent study by McBeath *et al* (2011), found that the amount of phosphorus fertiliser used by wheat increased with rainfall but was not directly related to whether the soil was initially deficient or sufficient in phosphorus. When sufficient phosphorus was present in the subsoil, the use of subsoil phosphorus increased with the addition of phosphorus fertiliser, suggesting the phosphorus fertiliser stimulated early development and

root growth into the subsoil. The subsoil phosphorus status of soils at Dookie is included in ongoing research at Dookie during 2014.

While the 2012 WOC and 2013 WOW trials were grown in a similar section of the same paddock and grown under favourable seasonal conditions in both years, it is not possible to say whether yield potential was higher in the WOC situation between different years. Further investigation of crop rotation effects on phosphorus nutrition will continue during 2014–15 with a rotation trial established within a neighbouring paddock. Established in the current 2014 season, the response of canola to phosphorus rates following wheat is being examined in the same paddock as previous trials.

Acknowledgements

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