RiverinePlains

Research for the Riverine Plains 2016

A selection of research relevant to agriculture in the Riverine Plains

Farmers inspiring farmers

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Research for the Riverine Plains 2016

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 the 2016 edition of *Research for the Riverine Plains*. This year we have collected a range of articles covering topics relevant to farming in the region, 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 crop management in retained stubble systems, the importance of stubble management on frost risk, nitrogen (N) timing and efficiency, and the role of soil moisture in managing nitrogen.

In addition to research carried out by Riverine Plains Inc, we have also included results from other research organisations and industry bodies, which 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), which enables us to contribute to national research initiatives, while delivering research outcomes that address local issues.

A special thanks to the Riverine Plains Inc staff and committee for their contribution to this publication. Thanks also to sub-editor Catriona Nicholls and graphic designer Josephine Eynaud for producing a professional publication, which presents technical information in a manner that is easy to interpret and understand.

We hope you enjoy reading *Research for the Riverine Plains 2016*, and we wish you all the best for the 2016 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 2015 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

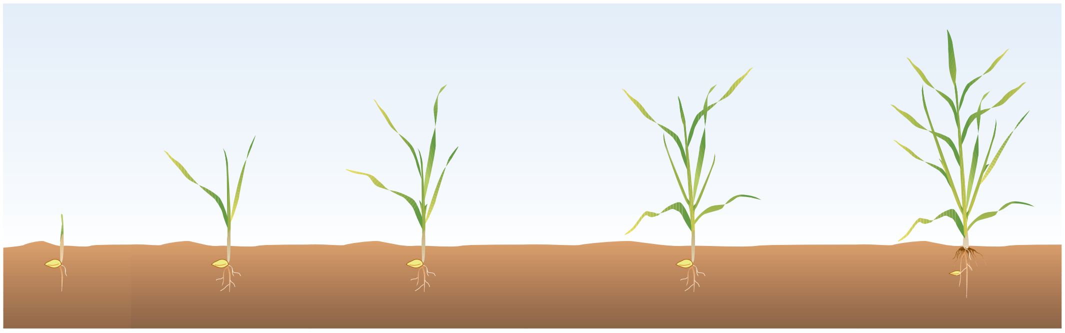
The most commonly used growth stage key for cereals is the:

- 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)

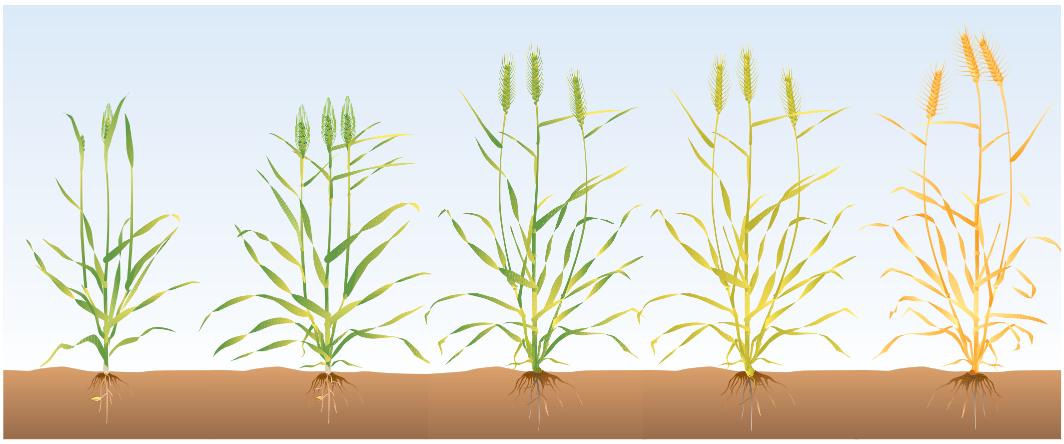
Within each of the 10 development phases there are 10 individual growth stages, for example, in the seedling stage:

- GS11 describes the first fully unfolded leaf
- GS12 describes two fully unfolded leaves
- GS13 describes three fully unfolded leaves
- GS19 describes nine 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

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 four plots then divided by four) of each variety accounts for variations in soil type.

Statistical tests, for example, analysis of variance (ANOVA) and, least significant difference (LSD), are used to measure the difference between the averages. 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		Average 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, take care 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.

A word from the Chairman

GRDC Stubble Project *paddock walk, Dookie, July 2015.*

John Bruce

Chairman, Riverine Plains Inc

Welcome to the 2016 edition of *Research for the Riverine Plains*.

I was reminded the other day that Riverine Plains Inc has been running for nearly 17 years. During those 17 years we have grown from a small group of like-minded farmers into the nationally recognised organisation we are today. This is an amazing achievement and it highlights the vision of those who founded the group that we continue to deliver value for our network of members, sponsors and funders.

Farmer-driven research underpins sound decision making, and sound decision making is what Riverine Plains Inc is all about. Our annual trial book is testament to this and brings together the results from research carried out by Riverine Plains Inc, as well as a quality collection of other locally-relevant research. We hope this information gets you thinking and perhaps encourages you to try something different in the future.

Extensive extension

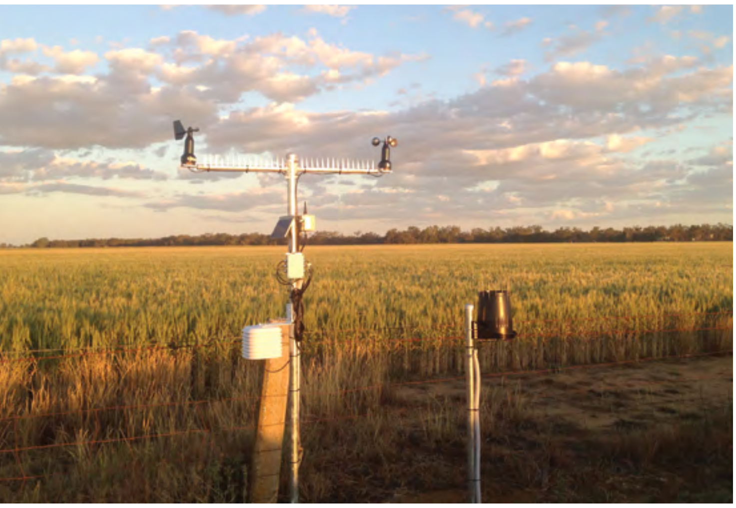
The 2015/16 year was another busy period for Riverine Plains Inc, with a comprehensive extension program running throughout the year.

During June 2015, we were given the green light by the Grains Research and Development Corporation (GRDC) to extend the existing GRDC stubble project — *Maintaining Profitable Farming Systems with Retained Stubble in the Riverine Plains Region* — to measure in-canopy temperature across different stubble management systems. With stem frost an issue during the recent past, this work was both timely and highly relevant. The network of weather stations with soil moisture probes, which are accessible on our website, is also a great resource for local growers.

Our winter events program kicked off with the August *In-season Update*, with more than 100 people hearing about insect pests, canola seed size, fungicide over-use and the state of agriculture in the United Kingdom. The *Update* is a regular fixture on our calendar and it was pleasing to see so many participants getting value out of the day.

A silverleaf nightshade workshop was run in conjunction with the *In-season Update,* in partnership with Murrumbidgee Landcare, to address best management practices for control of this challenging weed. This workshop was delivered on a small scale and covered a range of control options.

Farmers inspiring farmers



Rand Weather Station.

Sykesy's Buraja Day meeting, February 2016.

The first in our series of paddock walks for the *GRDC Stubble Project* at each of the four focus farm sites at Yarrawonga, Dookie, Corowa and Henty was held during July. More than 100 people attended the walks and heard how the various stubble treatments influenced establishment and early vigour.

During September, we took 19 growers on a study tour to Western Australia to hear about the latest developments in managing herbicide resistance. The tour included a mix of farm and grower-group visits, with a visit to the Metro Grain Centre and the Australian Herbicide Resistance Initiative (AHRI) facilities. This tour was supported by the GRDC's *Grower and Adviser Development Program*.

The *Nitrogen Efficiency Field Day* was also held during mid-September and featured some of the research Riverine Plains Inc has been carrying out in our partnership with FAR Australia and the Sustainable Agriculture Victoria: Fast-Tracking Innovation, an initiative made possible with the support of the Foundation for Rural and Regional Renewal (FRRR) together with the William Buckland Foundation. The 40 attendees heard the latest research information on the cycling of nitrogen (N) in cropping systems and the key processes responsible for nitrogen losses. The day also covered strategies for improving efficiency and the importance of fertiliser type.

During September we also announced a new project to install six weather stations at strategic weather 'black spots', which exist between Wagga Wagga and Corowa. Funding for the project is provided by Riverina and Murray Local Land Services (LLS) through the Australian Government's National Landcare Program. The network is up and running and is available via the Riverine Plains Inc website. This is another terrific initiative our members value highly.

The second in the series of *GRDC Stubble Project* paddock walks was held during October led by Nick Poole, with a total of 50 attendees across the four sites.

After a dry spring, those attending the *Gerogery Agronomy Field Day* on 5 November braved the rain to hear about new canola, cereal and lucerne varieties and blackleg resistance, sustainable grazing management and dual-purpose wheat varieties. This was the first time Riverine Plains Inc had hosted the day (on behalf of Murray LLS) and we look forward to our involvement again during spring 2016.

Kicking off 2016

Riverine Plains Inc started its 2016 events calendar with a soil pit event at Rutherglen, during mid-January. The day was part of the *Soil Moisture Probe Network Project*, supported by the North East Catchment Management Authority (NECMA) with funding from the Australian Government's National Landcare Programme and Sustainable Agriculture Victoria: Fast-Tracking Innovation, an initiative made possible with the support of the FRRR together with the William Buckland Foundation. The soil pits revealed the variability of the soils, which led to some interesting discussions around soil limitations, the possible side-effects of soil disturbance and the performance of last year's crops.

During February 2016, Riverine Plains was again proud to support *Sykesy's Buraja Day*, continuing the tradition the late John Sykes initiated. More than 100 people packed into the Buraja Hall for this traditional planning and review day and heard from a range of local and guest speakers.

We also partnered with Craig Day from 'Spray Safe and Save' during February to run a successful sprayer day at Rennie. The day was organised as part of the *GRDC*

Stubble Project and was attended by close to 100 people. Craig delivered a thorough and informative workshop on boomspray set-up for effective herbicide delivery, covering nozzle selection, drift reduction, herbicide selection and rates and recent changes to regulations. The emphasis of the day was on achieving effective spray coverage in stubble and we received excellent feedback about the hands-on knowledge Craig shared.

February was also *GRDC Grains Research Update* time. This year about 130 growers, advisors and sponsors attended the day at Corowa. A great line-up of speakers covered topics including windrowing vs direct heading of canola, trace element deficiencies, wheat phenology and controlled traffic farming (CTF). A range of Riverine Plains Inc projects was discussed, along with a great summary of last year's herbicide resistance study tour to WA.

Following on from our highly-successful strategic tillage day during 2015, Riverine Plains Inc ran a *Seeder Day* at Barooga and Dookie during March, again as part of the *GRDC Stubble Project*. More than 100 attendees saw a range of disc and tined seeders in action, and heard about their overall performance.

Valuable support

Putting together such an extensive program of events would simply not be possible without the input of our volunteer committee, our staff and our members and sponsors. Thank you to all those who contributed to and attended these events — your support is greatly appreciated.

The Riverine Plains Inc committee is responsible for establishing the research and extension priorities for the group, and ensuring we operate within the requirements of the law. This is no small task and I would like to thank each committee member for the time they have put in during the past 12 months. At the October 2015 AGM the committee voted to adopt a new, modernised constitution to replace the existing model constitution. The review of our existing constitution was a major undertaking and I would like to thank Clare Robinson and Michelle Pardy for their time and efforts on this project.

Riverine Plains Inc continues to be involved with a number of research projects, with the *GRDC Stubble Project*, the *Nitrous Oxide Project* (led by FAR Australia), the *Harvest Weed Seed Project* (led by Southern Farming Systems) and the *Innovative Approaches to Managing Sub-soil Acidity in the Southern Region Project* (led by Charles Sturt University) all continuing. We continue to monitor the LLS weather stations and have also started a new, small-scale project with the Goulburn Broken CMA — *Refining Deep Soil Nitrogen Testing to Reduce Environmental Losses*.

We wrapped up the GRDC-funded *Soil Carbon Project* during 2015, with the final report now complete. We will be releasing a *Soil Carbon Report* for growers in the coming months. The *Soil Moisture Probe Network Project* has also now been completed.

Congratulations to all those involved in developing, running and writing up these projects, and to our farmer hosts for their support. It truly is a team effort and one that is greatly valued by our members, sponsors and the wider community.

I would also like to thank all of the sponsors who support Riverine Plains. Their contributions allow us to deliver many of the services we run for the benefit of our members and is greatly valued. We also appreciate the support shown by our sponsors at events and by their input into the group. Many of our sponsors have been with us for

GRDC Grains Research Update, Corowa, February 2016.

Seeder Day, Barooga, March 2015.

a long time and we have also welcomed several new sponsors during the past 12 months. We look forward to growing these relationships into the future.

On behalf of the committee and our members, I would also like to thank all our staff for the passion and dedication they show in their work for Riverine Plains Inc. The Riverine Plains Inc office is now home to Executive Officer, Fiona Hart, Finance Officer, Kate Coffey, Extension Officer, Cassandra Schefe and Communications Officer, Michelle Pardy. They each have a specialised role and this has streamlined the operations of Riverine Plains so our administration runs efficiently. I would like to acknowledge the key role Allison Courtney (Research Officer) played in developing the research program of Riverine Plains Inc, and wish her well as she moves on to focus on her new family and running the farm. I also acknowledge and thank Dr Bill Slattery for his work during the past three years as Project Officer for the *Soil Carbon Project* and wish him all the best for the future.

I would also like to recognise the ongoing support provided by funding bodies such as the GRDC, the Australian Government Department of Agriculture, Sustainable Agriculture Victoria: Fast-Tracking Innovation, an initiative made possible with the support of the FRRR together with the William Buckland Foundation, Murray LLS, Riverina LLS, NECMA and Goulburn Broken Catchment Management Authority (GBCMA). Their financial support is essential in enabling locally-based research to continue.

Research for the Riverine Plains is our flagship publication, and an enormous amount of effort goes into bringing you this work. Thank you to all the people and organisations who have contributed articles for this year's edition. I particularly thank Cassandra Schefe for her role in collating and editing this publication and also Fiona Hart for her involvement.

We trust you will enjoy the read and find value in the reports contained within. All the best for the 2016 season.

John Bruce
Chairman

MURRAY LOCAL LAND SERVICES

WHAT DO WE DO?

INTEGRATED SERVICES COVERING AGRICULTURE, NATURAL RESOURCE MANAGEMENT, BIOSECURITY, TRAVELLING STOCK RESERVES, AND EMERGENCY MANAGEMENT

MURRAY LOCAL LAND SERVICES

Murray LLS delivers services that add value to local industries, enhance natural resources, protect agriculture from pests and disease, and help communities prepare and respond to emergencies like fire and flood.

SERVICES & ADVICE

- Agricultural production
- Natural resource management
- Biosecurity & Livestock Health
- Emergency management

PARTNERSHIPS

We collaborate with a wide range of farmers, land managers (public and private), producer groups, Landcare, Local Government, special interest groups, other government agencies, and the wider community, such as the Aboriginal communities and schools, to undertake projects and activities which support healthy productive landscapes and resilient communities.

LOCAL MANAGEMENT

Murray LLS is managed by local people on local boards, working closely with farmers, land managers and communities. The Board of Murray LLS has responsibility for governance and strategic direction of the organisation. The Murray Local Community Advisory Group (LCAG) gives advice to the Board on ways to effectively connect and work in partnership with the community. Chaired by Mr. Anthony Piggin (Corowa), it complements the Murray Aboriginal Technical Group which advises the Board on ways to support and work with Aboriginal communities in our region.

INCOME

Funds to work with landholders and local communities come from investment by the NSW and Australian Governments and our ratepayer base.

AGRICULTURAL PRODUCTION

Murray LLS provides agricultural advice to assist farmers increase their productivity and profitability in an environmentally and socially sustainable way. We work closely with industry, producer groups and Landcare, to link farmers with research and practical information. Our specialisations include irrigation systems, cropping, pastures, livestock management, land capability and seasonal condition reporting.

NATURAL RESOURCE MANAGEMENT

We work with community, Landcare and industry groups to develop and deliver projects that improve the management of native vegetation, wetlands, flora and fauna habitat, water quality, and soil health, that underpin productive agricultural businesses and communities.

BIOSECURITY & LIVESTOCK HEALTH

We provide biosecurity services relating to animal and plant pests and diseases including management, control and eradication; preparedness, response and recovery from animal and plant pest and disease emergencies; chemical residue prevention control and management; and movement of stock. This contributes to confidence in the safety of livestock and livestock products, international market access and environmental health.

TRAVELLING STOCK RESERVES & ROUTES

Our management of TSRs aims to balance the needs of travelling or grazing stock and the conservation of native species. Our work includes: authorising and monitoring stock movements, recreation and apiary site use; controlling noxious weeds, pest animals and insects; maintenance of fencing, watering points and holding yards.

EMERGENCY MANAGEMENT

Murray Local Land Services, works in collaboration with the Department of Primary Industries to manage livestock disease emergencies and biosecurity events involving plants, animals and pest insects such as locust plagues. We work alongside other agencies to provide vital support in emergencies where agricultural industries are impacted, such as floods and bushfire.

Contact us: **1300 795 299** or at **www.murray.lls.nsw.gov.au**

2016 — the year in review

Sue Briggs
Land Services Officer — Sustainable Agriculture, Murray Local Land Services

The Bureau of Meteorology (BoM) 2015 forecast for an El Nino event saw an increase in the area sown to barley and reduced canola plantings. The promising start to the season ended in another spring of below-average rainfall and record-breaking temperatures. Early-sown crops generally tolerated the conditions better than later-sown crops, ending the year with average yields.

Temperature effects

The 2015 cropping season was not only dictated by rainfall — minimum and maximum temperatures also played a crucial role in crop performance and yield (Figure 1). The above-average minimum temperatures during April, along with above-average rainfall, resulted in an early start to the cropping season and widespread germination.

There was an 11% reduction in frost events throughout the 2015 growing season (April – October) however June was the exception, with a 15% increase in the number of frost events compared with the long-term average. This contributed to lower-than-average minimum temperatures, slowing the development of later-sown crops.

The region experienced above-average minimum and maximum temperatures from October to December. The BoM reported the warmest October on record across Australia and the region experienced 16 days that were 5–10 degrees above the long-term average. The impact of the heat-wave event during early October varied across the region, depending on crop growth stage. The full impact was not realised until harvest.

Fluctuating rainfall

The 2015 season started with the highest rainfall event for the year occurring during mid-January, contributing moisture to the dry subsoil (Figure 2). The above-average rainfall during April provided ideal topsoil moisture for sowing and crop germination. Above-average rainfall between May and August provided valuable subsoil moisture across the region, with some areas experiencing waterlogging.

The cumulative 12-month rainfall and growing season rainfall (GSR: April–October) were both slightly higher than the long-term average at Albury (Figure 3). However, the total rainfall for September and October was 38mm, which was 63% below the long-term average of 103mm. The low rainfall, combined with higher-than-average temperatures, resulted low topsoil moisture at a critical time. It was the higher-than-average rainfall between April and August, and resultant stored soil moisture, that got crops through to harvest.

At Corowa, the 12-month cumulative and GSR was higher than the long-term average by 100mm and 37mm respectively (Figure 4). The September and October rainfall totalled 54mm, which was 49% below the average of 105mm.

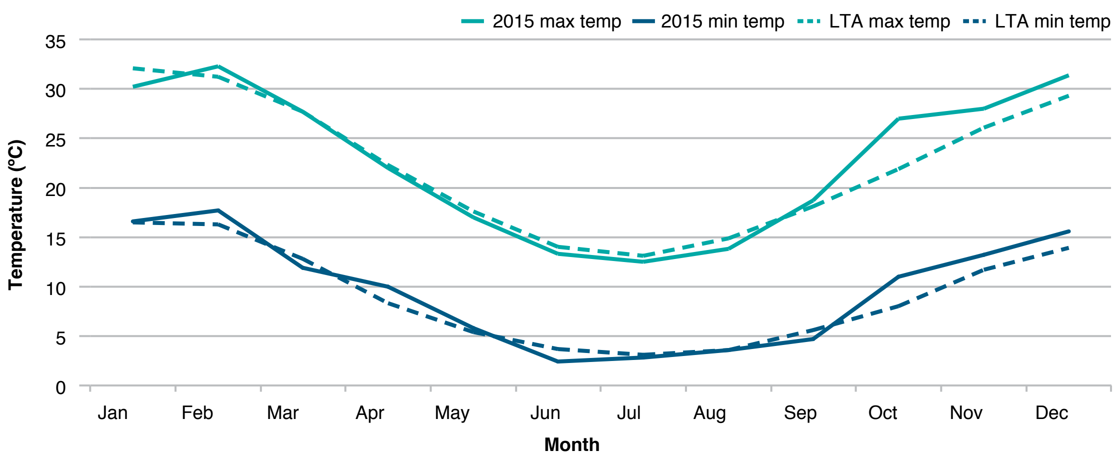


FIGURE 1 Minimum and maximum temperatures for 2015, compared with the long-term average (LTA) at Albury Airport weather station (BOM No: 72160)

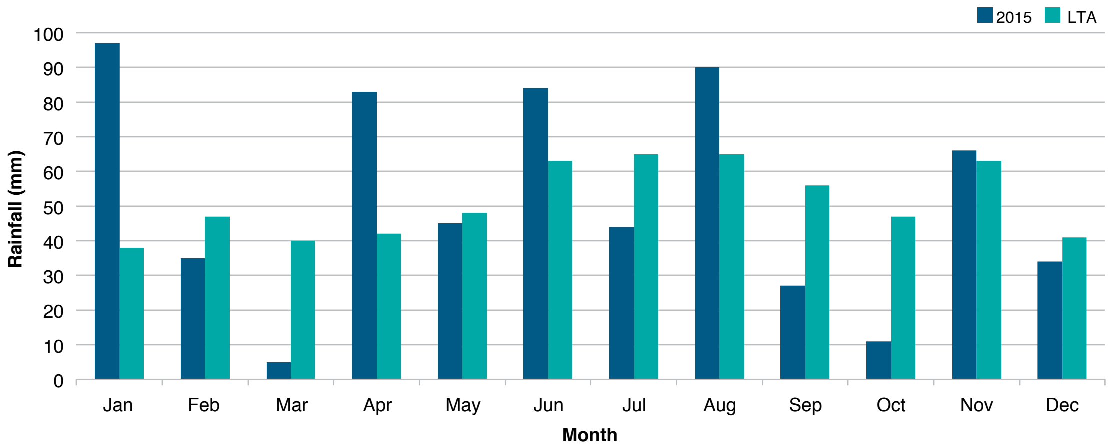


FIGURE 2 Monthly rainfall for 2015, compared with the long-term average (LTA) at Albury Airport (No. 72160)

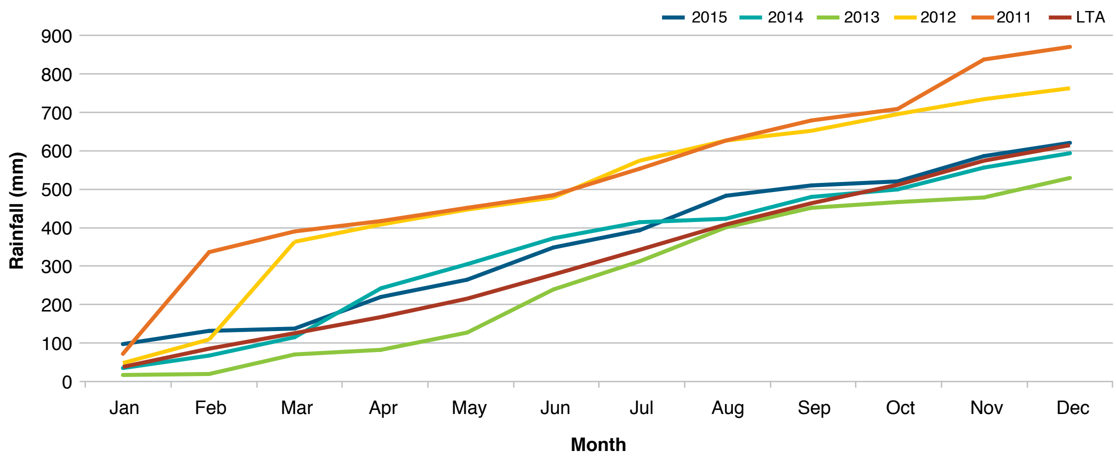


FIGURE 3 2015 Cumulative rainfalls at Albury Airport (No: 72160)

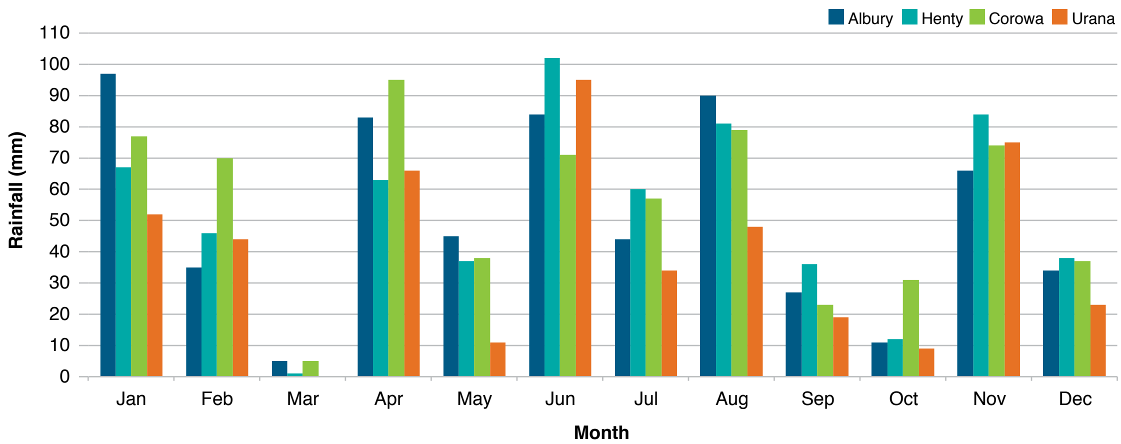


FIGURE 4 Monthly rainfall for 2015, Albury, Henty, Corowa and Urana

The rainfall fell in two significant events at the start and end of a seven-week dry period, which, combined with the above-average temperatures, negatively impacted crop performance.

This trend was reflected across the region. Henty and Urana experienced higher-than-average 12-month cumulative and GSR, however Henty received only 44% of the average September and October rainfall, while Urana received only 35%, a total of only 28mm for spring.

The November storms damaged mature unharvested crops and delayed harvest in some areas. The year ended with average crop yields, although experiences varied at the individual farm level, depending on how well individual paddocks got through the hot, dry spring.

Pest incursions during 2015

The 2015 season saw some notable pests during the crop establishment phase, in particular Bryobia mites and weevils. The warm temperatures and rainfall during April were ideal for Bryobia mites and the infestation was widespread and prevalent. The mites persisted longer than they have during other years, impacting newly-emerging crops and retarding development. The cooler June conditions saw the impacts diminish. Various weevil species caused problems to seedlings and establishing crops into June, with damage continuing through to August in some areas.

Many other common pests were absent or only present in local hot spots during the 2015 cropping season. This may be due to the premature finish to the 2014 cropping season and an increased number of beneficial natural enemies, which seem to reduce spring populations and egg carryover through to autumn.

Mid-August saw reports of cereal aphids in large numbers on cereal crops and with the higher September and October temperatures, the population and number of infested sites increased across the region. However, by mid-October there were reports of beneficial insects controlling the aphids.

This information was compiled from weather data sourced from Bureau of meteorology and the PestFact reporting service provided by CESAR Australia http://cesaraustralia.com/sustainable-agriculture/pestfacts-south-eastern/

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MIN-TILL

Maintaining profitable farming systems with retained stubble in the Riverine Plains region — project overview

Dr Cassandra Schefe[1], Adam Inchbold[1], Nick Poole[2], Michael Straight[2], Tracey Wylie[2]

[1] Riverine Plains Inc

[2] FAR Australia

Introduction

The *Maintaining Profitable Farming Systems with Retained Stubble in the Riverine Plains Region Project* is managed by Riverine Plains Inc, supported by FAR Australia and funded by the Grains Research and Development Corporation (GRDC) as part of an overarching national initiative focussed on maintaining the profitability of stubble-retained systems. This project started during 2013 and will run until June 2018.

Objectives

The project seeks to:

- investigate, demonstrate and extend cultural practices that will assist growers to adopt no-till stubble retention (NTSR) in medium and higher-rainfall environments;
- build on findings from the previous Riverine Plains Inc *Water Use Efficiency (WUE)* project; and
- extend the frontier of agronomic knowledge for crops grown in NTSR systems.

Background

It is widely accepted that as rainfall increases across cropping landscapes, the amount of stubble retention decreases. This often is because growers perceive that growing high-yielding crops in stubble-retained systems is more difficult than growing them in paddocks where the previous crop residue is removed (mainly through burning). It is also true to say that much agronomic knowledge has been gleaned from trials not carried out under a modern NTSR system, leaving a potential knowledge gap. These issues ring true for growers in the Riverine Plains area.

By addressing the negative impacts and perceptions of NTSR systems, advancing the agronomic frontier and building the capacity of growers and advisors working in these systems it is anticipated more growers across the Riverine Plains area will adopt them, and the WUE of these systems will increase. Adoption of an NTSR system, or improving an existing NSTR system, is estimated to result in at least $50/ha of extra income from cropping each year. Additionally, a cost saving of about $60/ha/yr can be achieved through either reduced nutrient loss, normally seen in stubble removal, and/or a more appropriate allocation of inputs under an NTSR system.

Research

The research component of the Riverine Plains Inc *Maintaining Profitable Farming Systems with Retained Stubble in the Riverine Plains Region Project* is comprised of a series of large and small plot trials. The first trials were established during 2014.

Using large-scale trials (focus farms) the research team is evaluating the impact of a single-year, one-off change in stubble management. The result of these trials will help to determine if periodic active management of stubble in an NTSR system increases the sustainability and profitability of the system across the rotation. As different stubble management approaches are likely to perform better under different seasonal conditions, the four years of trials (2014–17) will provide information on crop performance under a range of seasonal climatic conditions.

The focus farm trials in 2014 were located at Henty, Coreen/Redlands and Yarrawonga, New South Wales and Dookie, Victoria (Figure 1). The only change during 2015 was that a site near Corowa, NSW was used rather than Coreen/Redlands, in order to maintain the same rotation position.

As a key component of this project is to identify the long-term impact of a one-off change in management, the sites used during 2014 were returned to the farmer for commercial cropping, with new sites (in the same rotation position) established during 2015. These sites are referred to as ‘time replicate 1’ and ‘time replicate 2’.

As 2015 is the second year of the project, the trial reports include both the experimental results from the 2015 trials, with yields also measured on the 2014 sites, to understand if the 2014 change in stubble management has influenced the performance of the following 2015 commercial crop.



FIGURE 1 Locations of large block (focus farm) trials 2015

The results from the focus farm trials can be found on page 12.

A series of small plot trials has been established to address specific aspects of management in an NTSR system, in order to optimise the NTSR production system in the Riverine Plains region. The results from these trials have also been reported in this publication.

The small plot trials carried out during 2015 were:

1. early sowing and the interaction with row spacing and variety in first wheat under full stubble retention (Barooga, Yarrawonga), page 34;
2. interaction between fungicide program and in-crop nitrogen timing for the control of yellow leaf spot (YLS) in early-sown wheat (Corowa), page 42;
3. the interaction between plant growth regulator (PGR) and nitrogen application in early-sown first wheat (Dookie), page 48; and
4. monitoring the performance of nitrogen application to wheat under full stubble retention (Yarrawonga, Dookie), page 52.

Outcomes

The overarching outcome from this project will be to increase the adoption of NTSR systems across the Riverine Plains region. This will be achieved through increasing the profitability and sustainability of NTSR cropping systems by developing regional guidelines specific to the region, enabling growers and advisers to use rotational cultural control measures to enhance the sustainability of their NTSR farming systems.

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Active stubble management to enhance residue breakdown and subsequent crop management — focus farm trials

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Background

This report presents the results from the large plot focus farm trials of the *Maintaining Profitable Farming Systems with Retained Stubble in the Riverine Plains Region Project*, as described in the project overview on pages 10–11.

Method

Different methods of stubble management were trialled in four large (farm-scale) replicated trials during 2014 and 2015. All results were statistically analysed using analysis of variance (ANOVA), with means separated using the unrestricted least significant difference (LSD) procedure. The different trial treatments are outlined in Table 1.

As the trial sites are moved each year to reflect a one-off change in the system, each year of trials is referred to as a 'time replicate':

- 2014 trial site: time replicate 1
- 2015 trial site: time replicate 2.

After each year of field trials the site is returned to the farming co-operator and blanket-sown with a crop of their choice, as described in Table 2. The yield of the subsequent crop is also measured, to determine whether a one-off strategic change has any long-term impacts through the rotation.

TABLE 1 Stubble management project trial details, 2015 (time replicate 2)

Trial details	Trial 1 Corowa	Trial 2 Yarrawonga	Trial 3 Dookie	Trial 4 Henty
Treatments				
NTSR (control)	✓	✓	✓	✓
NTSR + 40kg extra nitrogen at sowing	×	✓	×	✓
Cultivate	One pass	One pass	One pass	One pass
Cultivate + 40kg N/ha at sowing	One pass	One pass	×	One pass
Burn stubble	✓	✓	✓	×
NTSR — long stubble	×	38cm	42cm	×
NTSR — short stubble	×	15cm	15cm	×
NTSR — straw mown and removed	×	✓	✓	×
NTSR — stubble mulched and retained	×	×	×	✓
NTSR — stubble mulched + 40kg extra nitrogen at sowing	×	×	×	✓
NTSR — faba beans sown for forage	✓	×	×	×
NTSR — faba beans sown for grain	✓	×	×	×
Trial plot dimensions	40 x 15m	40 x 18m	40 x 18m	40 x 15m
Farm drill used for trial	Aus seeder DBS D-300 tine seeder	Aus seeder DBS Tine knife point	Simplicity Seeder/ knife point	John Deere 1590 disc seeder
Stubble loading (t/ha)	6.4	6.3	8.7	8.3
Stubble height (cm)	35	38	15	50
Soil type description	Red brown earth	Self-mulching red loam over grey clay	Red clay	Red brown earth
Row spacing (cm)	30	32	33.3	19
Crop and rotation position	Second wheat	Wheat following barley	Second wheat	Monola following triticale



TABLE 2 Site details for 2015 crops sown onto 2014 stubble management trial sites (time replicate 1)

Trial details	Trial 1 Daysdale#	Trial 2 Yarrawonga	Trial 3 Dookie	Trial 4 Henty
Treatments				
Crop type/variety	Wheat/Corack	Barley/Latrobe	Canola/43Y23	Oats/Matika
Paddock burnt	×	✓	✓	×
Farmer harvested	×	✓	✓	✓
Plot harvester	✓	×	×	×
Trial plot dimensions	40 x 15m	40 x 18m	40 x 15m	40 x 15m
Farm drill used for trial	Aus seeder DBS D-300 tine seeder	Aus seeder DBS Tine knife point	Simplicity Seeder/knife point	John Deere 1590 disc seeder
Stubble loading (t/ha)	6.1	6.4	7.4	7.9
Stubble height (cm)	26	35	30	47
Soil type description	Heavy grey clay	Self-mulching red loam over grey clay	Red clay	Yellow podzol-yellow brown earth
Row spacing (cm)	30	32	33.3	19
Crop and rotation position	Third wheat	Barley following wheat	Canola following wheat	Oats following wheat

The site was relocated from a paddock near Daysdale in 2014 to a paddock near Corowa in 2015 in order to maintain the required rotation position.

Trial 1: Corowa, NSW

Sowing date: 7 May 2015

Rotation: Second wheat

Variety: Wheat cv Mace, faba beans cv Fiesta

Stubble: Wheat (various treatments applied)

Stubble load at sowing: 6.4t/ha

Rainfall:

GSR: 329mm (April – October)

Summer rainfall: 152mm

Soil nitrogen at sowing: 50kg N/ha NTSR (control) and 54kg N/ha multidisc (0–60cm)

Key points

- There were significant differences in dry matter (DM) accumulation, nitrogen (N) uptake, disease control and yield between treatments.
- Burning stubble increased wheat dry matter (DM), but limited yield, likely due to earlier senescence causing lower harvest indices (HI).
- Growing faba beans, instead of a second wheat, increased the yield of the following wheat by about 2t/ha compared with growing a third wheat using no-till full stubble retention (NTSR).
- Wheat following faba beans resulted in significantly higher protein compared with third wheat with more than 50kg N/ha additional nitrogen offtake in the grain.
- Cultivation in the 2014 trial resulted in significantly higher yields during 2015 compared with burning.

Results

i) Establishment and crop structure

With sufficient moisture levels at sowing there were no differences in crop establishment at three and six weeks after sowing with no increase in plant numbers between the two assessments (Table 3). Rates of tillering were relatively low and uniform at 2.3–2.4 tillers per plant when assessed at the end of tillering/start of stem elongation (GS31). There was also no difference in head numbers between treatments, which was about 300/m^2.

ii) Dry matter production and nitrogen uptake

Where the previous wheat stubble was burnt the DM production at flowering was greater than with the NTSR and cultivated plots (Table 4). At harvest there were no significant differences in DM production between burning and NTSR. Similar trends were apparent in the nitrogen uptake figures with more nitrogen present in the burn treatment and the treatment receiving an extra 40kg N/ha at sowing. The higher nitrogen content in the burnt treatment was not statistically superior to the NTSR (Table 5 and Figure 1). Nitrogen uptake did not increase in the crop canopy after flag leaf emergence (GS39).

iii) Disease levels

Yellow leaf spot (YLS) caused by the pathogen *Pyrenophora tritici repentis* was present at high levels early in the season but never exceeded 5–10% on flag-2, the first of the important leaves. Under these conditions burning the previous wheat stubble gave significantly better disease control in the lower crop canopy (flag-3 to flag-5) when assessed at stem elongation (GS31 and GS39). There were no significant differences in disease

TABLE 3 Plant counts 1 June 2015, two-leaf stage (GS12); plant counts 24 June 2015, one-tiller stage (GS21); tiller counts 15 July 2015, first node (GS31) and head counts 19 November, harvest (GS99)

	Crop growth stage			
	GS12	GS21	GS31	GS99
Treatment	Plants/m²	Plants/m²	Tillers/m²	Heads/m²
NTSR (control)	114^{a}	114^{a}	270^{a}	312^{a}
Cultivated (one pass)	118^{a}	113^{a}	265^{a}	321^{a}
Cultivated (one pass) + 40kg N/ha	114^{a}	115^{a}	276^{a}	294^{a}
Burnt	126^{a}	131^{a}	295^{a}	297^{a}
Mean	**118**	**118**	**277**	**306**
LSD	28	32	54	85

Figures followed by different letters are regarded as statistically significant.

TABLE 4 Dry matter 15 July 2015, first node (GS31); 9 September 2015, flag leaf fully emerged (GS39); 9 October 2015, mid-flowering (GS65) and 19 November, harvest (GS99)

	Dry matter (t/ha)			
	GS31	GS39	GS65	GS99
NTSR (control)	0.66^{a}	3.81^{ab}	6.94^{b}	8.90^{a}
Cultivated (one pass)	0.71^{a}	3.47^{b}	7.59^{b}	9.12^{a}
Cultivated (one pass) + 40kg N/ha	0.70^{a}	4.42^{a}	8.01^{ab}	8.77^{a}
Burnt	0.73^{a}	4.35^{a}	9.34^{a}	8.79^{a}
Mean	**0.70**	**4.01**	**7.97**	**8.90**
LSD	0.18	0.69	1.45	1.89

Figures followed by different letters are regarded as statistically significant.

TABLE 5 Nitrogen uptake in crop 15 July 2015, first node (GS31); 9 September 2015, flag leaf fully emerged (GS39); 9 October 2015, mid-flowering (GS65) and 19 November, harvest (GS99)

	Nitrogen uptake in dry matter (kg N/ha)			
	GS31	GS39	GS65	GS99
NTSR (control)	32^{a}	77^{bc}	70^{a}	79^{a}
Cultivated (one pass)	33^{a}	67^{c}	68^{a}	61^{a}
Cultivated (one pass) + 40kg N/ha	32^{a}	98^{a}	89^{a}	87^{a}
Burnt	35^{a}	83^{ab}	94^{a}	79^{a}
Mean	**33**	**81**	**80**	**77**
LSD	10	16	26	42

Figures followed by different letters are regarded as statistically significant.

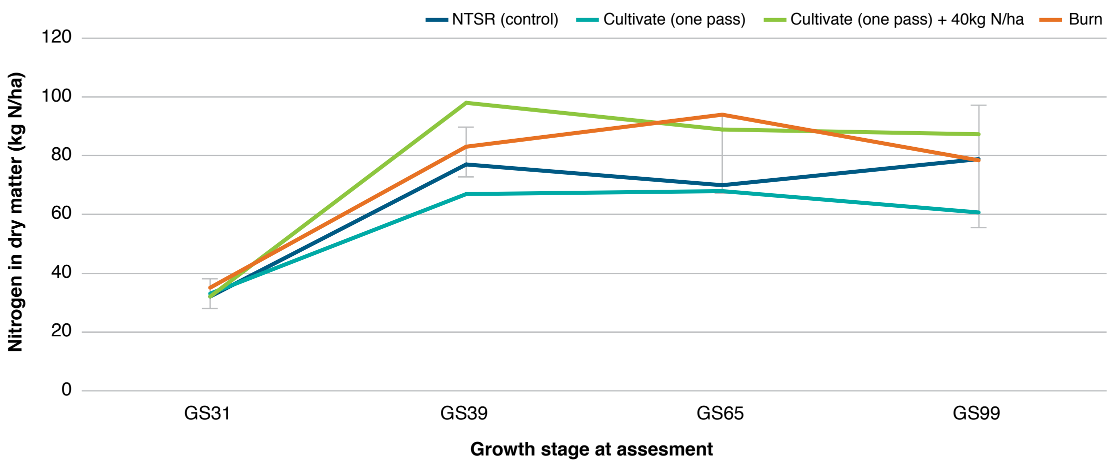


FIGURE 1 Nitrogen uptake in dry matter across the four stubble management treatments



levels due to other stubble management treatments (Table 6 and Table 7).

iv) Green leaf retention differences

The largest visual differences in the large block plots were observed during mid-October after a period of extreme heat (35–37°C) during the first week of October. The NTSR plots were visibly greener at this stage than the burn plots and observations at grain fill suggested the burn plots were slightly more developmentally advanced. How the stubble treatments affect the timing of crop phenology will be studied in more detail during the 2016 season.

v) Yield and grain quality

The trial was harvested on 25 November 2015. The different stubble management treatments resulted in significantly different yields (Table 8). Where stubble was burnt the yields were significantly lower than cultivated crops, which received 40kg N/ha before sowing. There were no significant yield advantages of any stubble treatments over the NTSR control treatments at this site.

TABLE 6 Yellow leaf spot severity and incidence of the two newest fully-emerged leaves (flag-4, flag-5) assessed 15 July 2015, first-node stage (GS31)

	YLS (%) at GS31			
	Severity (% leaf area infected)		Incidence (% leaves infected)	
	Flag-4	Flag-5	Flag-4	Flag-5
NTSR (control)	1.93[a]	5.83[ab]	75[a]	85[a]
Cultivated (one pass)	2.20[a]	5.78[ab]	88[a]	95[a]
Cultivated (one pass) + 40kg N/ha	2.30[a]	6.58[a]	78[a]	95[a]
Burnt	0.18[b]	0.68[b]	15[b]	48[b]
Mean	**1.65**	**4.71**	**64**	**81**
LSD	1.55	5.90	30	23.28

Figures followed by different letters are regarded as statistically significant.

TABLE 7 Yellow leaf spot severity and incidence on the three newest fully-emerged leaves (flag-1, flag-2, flag-3) assessed 9 September 2015, flag leaf fully emerged (GS39)

	YLS (%) at GS39					
	Severity (% leaf area infected)			Incidence (% leaves infected)		
	Flag-1	Flag-2	Flag-3	Flag-1	Flag-2	Flag-3
NTSR (control)	0.2[a]	2.8[a]	35.4[a]	18[a]	88[a]	100[a]
Cultivated (one pass)	0.2[a]	6.3[a]	42.2[a]	15[a]	80[ab]	100[a]
Cultivated (one pass) + 40kg N/ha	0.2[a]	2.9[a]	28.2[a]	23[a]	76[ab]	100[a]
Burnt	0.3[a]	1.4[a]	12.9[b]	25[a]	63[b]	98[a]
Mean	**0.2**	**3.3**	**29.7**	**20**	**77**	**99**
LSD	0.2	5.5	15.1	23	19	4

Figures followed by different letters are regarded as statistically significant.

TABLE 8 Wheat yield, protein, test weight, screenings, harvest index (HI) and thousand seed weight (TSW) 25 November 2015, at harvest (GS99)

	Yield and quality					
	Yield (t/ha)	Protein (%)	Test weight (kg/hl)	Screenings (%)	HI (%)	TSW (g)
NTSR (control)	4.33[ab]	10.9[a]	78.8[a]	3.5[a]	42.8[ab]	31.3[b]
Cultivated (one pass)	4.18[ab]	11.4[a]	78.7[a]	3.2[a]	40.4[b]	36.1[a]
Cultivated (one pass) + 40kg N/ha	4.69[a]	11.5[a]	78.7[a]	3.5[a]	46.8[a]	28.9[b]
Burnt	3.77[b]	11.4[a]	79.8[a]	3.6[a]	37.7[b]	35.2[a]
Mean	**4.24**	**11.3**	**79.0**	**3.5**	**41.9**	**32.9**
LSD	0.67	1.2	1.8	1.2	5.9	3.2

Figures followed by different letters are regarded as statistically significant.

The only significant difference in grain quality was a lower thousand seed weight (TSW) when extra nitrogen was applied at sowing.

The faba bean treatments, when cut for forage on 23 October, had a DM yield of 3.5t/ha. The bean crop taken through to grain harvest yielded 1.4t/ha and was harvested on the same day as the wheat treatments.

vi) Combined results over two years

The results from this focus farm across the past two years show that for both 2014 and 2015 the rank order of treatments has been similar, although with significant differences in yield only recorded during 2015 (Figure 2). Despite benefits in terms of earlier DM accumulation and disease control (YLS) from burning, no yield advantage has been observed over NTSR at this trial site.

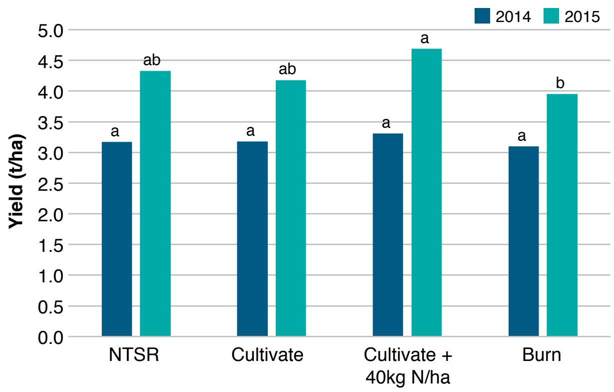


FIGURE 2 Yield data from the Daysdale (red brown earth) and Corowa (heavy grey clay) trials for 2014 and 2015 — cv Whistler in 2014 and cv Mace in 2015.

Yield bars for the same year with different letters are regarded as statistically different.

Notes: The two trials were carried out in the same region, but not on the same trial site. During 2014 the cultivation treatments were established with two passes while a single pass was used in 2015.

vii) 2014 stubble management treatments — influence on 2015 wheat yields

The stubble management trial has not only been set up to examine the influence of different stubble management techniques on the subsequent crop, but to assess whether there are any rotational effects on these crops. For example, whether burning or cultivating between the first and second wheat crop impact yield performance the year after the second wheat. Table 9 shows the performance of a commercial wheat crop (cv Corack) sown during 2015 into the 2014 stubble management trial.

The stubble management carried out during the 2014 stubble management trial, where a second wheat crop and faba beans were grown, significantly influenced the commercial crop established in 2015. The 2015 wheat crop was established using NTSR. Wheat yields following faba beans yielded 2t/ha more than a third continuous wheat crop. Higher yields were clearly associated with greater nitrogen availability as wheat protein was significantly higher following faba beans. The nitrogen offtake in grain following faba beans equated to 111kg N/ha (average of forage and grain faba bean treatments) versus 57kg N/ha in the third wheat established with NTSR. Light cultivation during 2014 offered no advantage to NTSR crops during 2015, although burning during 2014 resulted in significantly lower-yielding 2015 crops than cultivating during 2014. Screenings from the 2015 harvest following burning during 2014 were significantly higher.

TABLE 9 Wheat yield, protein, test weight and screenings at Daysdale, 2015

2014 stubble treatments	2015 yield and quality			
	Yield (t/ha)	Protein (%)	Test weight (kg/hL)	Screening (%)
Burnt	3.38^{c}	9.1^{b}	82.7^{b}	5.8^{a}
NTSR (control)	3.54^{bc}	9.2^{b}	83.6^{a}	4.8^{b}
Cultivated	3.82^{b}	9.7^{b}	82.9^{ab}	4.7^{b}
Cultivated + 40kg N/ha	3.61^{bc}	9.4^{b}	82.7^{b}	4.4^{b}
Faba beans (forage)	5.62^{a}	11.4^{a}	82.8^{b}	3.7^{c}
Faba beans (grain)	5.66^{a}	11.1^{a}	83.1^{ab}	3.5^{c}
Mean	**4.27**	**10.0**	**83.0**	**4.5**
LSD	0.39	0.8	0.7	0.6

Figures followed by different letters are regarded as statistically significant.



Trial 2: Yarrawonga, Victoria

Sowing date: 13 May 2015
Rotation: Second cereal
Variety: Young
Stubble: Barley (various treatments applied)
Stubble load at sowing: 6.3t/ha
Rainfall:
GSR: 266mm (April–October)
Summer rainfall: 120mm
Soil nitrogen at sowing: 98kg N/ha NTSR (control) and 60kg N/ha multidisc (0–60cm)

Key points

- Retaining short stubble with no-till full stubble retention (NTSR — short stubble) resulted in significantly higher wheat yields than where stubble was burnt, cultivated with extra nitrogen (N) or straw removed.
- No-till full stubble retention with long stubble (NTSR — long stubble), and to a lesser extent NTSR — short stubble, gave better green leaf retention than other stubble management treatments; a result that may be linked to slower development earlier in the season.
- The stubble treatments set up during the 2014 season (burning, cultivating, removing straw) had no impact on the yield of the following barley crop compared with the NTSR control, although removing straw during 2014 produced significantly superior barley crops in 2015 compared with cultivating the straw.

Results

i) Establishment and crop structure

The different stubble management treatments did not influence plant establishment, however the NTSR — long stubble (control) crops had less vigour compared with where straw was removed, cultivated, burnt or where stubble was kept short (NTSR — short stubble) (Table 10). By the start of stem elongation (GS31) the NTSR — long stubble treatments had significantly fewer tiller numbers per square metre compared with the straw removed, cultivation and burn treatments. The differences in tillering did not result in any significant difference in head number.

ii) Dry matter production

The lower tiller number recorded with NTSR — long stubble at first node (GS31) correlated to less dry matter (DM) accumulation, which was also seen in the NTSR — short stubble treatment (Table 11). However the lag in DM production with NTSR treatments was not apparent at the harvest assessment, indicating later compensation in these treatments. The burn treatment had significantly higher DM than the NTSR — long stubble treatment up to and including flowering (GS65).

The differences in DM accumulation at first node (GS31) were related to nitrogen uptake in the crop canopy, with significantly higher nitrogen content where there was more DM (Table 12). Again there were few differences in nitrogen contents of the canopy at later assessments, although an extra 40kg N/ha at sowing did result in more nitrogen in the crop at harvest.

TABLE 10 Plant counts and vigour 2 June 2015, one-leaf stage (GS11); plant counts 25 June 2015, three-leaf stage (GS13); tiller counts 6 August 2015, first-node stage (GS31) and head counts 25 November, harvest (GS99)

	Crop growth stage				
	Plants/m^2	Vigour	Plants/m^2	Tillers/m^2	Heads/m^2
Treatment	GS11		GS13	GS31	GS99
NTSR — long stubble (control)	167^{a}	6.0^{b}	165^{a}	338^{d}	289^{a}
NTSR — long stubble + 40kg N/ha	178^{a}	6.0^{b}	175^{a}	354^{cd}	294^{a}
NTSR — short stubble	164^{a}	8.0^{a}	163^{a}	379^{bcd}	313^{a}
Straw removed	185^{a}	8.0^{a}	185^{a}	406^{bc}	300^{a}
Cultivated (one pass)	179^{a}	8.0^{a}	177^{a}	440^{ab}	314^{a}
Cultivated (one pass) + 40kg N/ha	177^{a}	8.0^{a}	181^{a}	471^{a}	289^{a}
Burnt	185^{a}	9.0^{a}	188^{a}	486^{a}	301^{a}
Mean	**176**	**7.5**	**177**	**411**	**300**
LSD	31	0.8	29	64	45

Figures followed by different letters are regarded as statistically significant.

TABLE 11 Dry matter 6 August 2015, first node (GS31); 15 September 2015, flag leaf fully emerged (GS39); 7 October 2015, mid-flowering (GS65) and 17 November, harvest (GS99)

Treatment	Dry matter (t/ha)			
	GS31	GS39	GS65	GS99
NTSR — long stubble (control)	0.86^{b}	4.01^{b}	6.52^{b}	6.88^{a}
NTSR — long stubble + 40kg N/ha	1.01^{b}	4.61^{ab}	7.40^{a}	6.79^{a}
NTSR — short stubble	1.00^{b}	4.21^{ab}	6.84^{ab}	6.82^{a}
Straw removed	1.36^{a}	4.61^{ab}	6.80^{ab}	6.81^{a}
Cultivated (one pass)	1.37^{a}	5.01^{a}	6.78^{ab}	7.05^{a}
Cultivated (one pass) + 40kg N/ha	1.50^{a}	4.84^{ab}	6.71^{ab}	7.14^{a}
Burnt	1.34^{a}	4.87^{a}	7.42^{a}	6.92^{a}
Mean	**1.21**	**4.60**	**6.92**	**6.91**
LSD	0.27	0.85	0.73	1.01

Figures followed by different letters are regarded as statistically significant.

TABLE 12 Nitrogen uptake in crop 6 August 2015, first node (GS31); 15 September 2015, flag leaf fully emerged (GS39); 7 October 2015, mid-flowering (GS65) and 17 November, harvest (GS99)

Treatment	Nitrogen uptake in biomass (kg N/ha)			
	GS31	GS39	GS65	GS99
NTSR — long stubble (control)	47.0^{b}	121^{a}	117^{a}	90^{ab}
NTSR (long) + 40kg N/ha	54.0^{b}	122^{a}	120^{a}	86^{b}
NTSR — short stubble	56.0^{b}	113^{a}	111^{ab}	98^{ab}
Straw Removed	77.0^{a}	114^{a}	95^{b}	91^{ab}
Cultivated (one pass)	74.0^{a}	116^{a}	101^{ab}	81^{b}
Cultivated (one pass) + 40kg N/ha	82.0^{a}	125^{a}	108^{ab}	109^{a}
Burnt	74.0^{a}	117^{a}	111^{ab}	77^{b}
Mean	**66.3**	**118**	**109**	**90**
LSD	13.3	26	20	22

Figures followed by different letters are regarded as statistically significant.

iii) Green leaf retention at the early grain-fill stage

During mid-October there were large visual differences in the treatment blocks with the NTSR blocks being greener, but with slightly less-developed grain. These differences followed a period of extreme heat (35–37°C) during the first week of October that 'cooked' many of the crops. The burn blocks were notably more senesced with more-developed grain when observed during mid-October.

iv) Soil water monitoring

Monitoring of deep soil moisture at this site indicated water was unavailable to the crop below 50cm, which may help explain the premature senescence in the crop following the dry spring and excessive heat events during October.

v) Grain yield and quality

The trial was harvested on 25 November 2015. There were statistical differences in grain yield and quality as a result of stubble management. Despite a lag in DM accumulation in the NTSR — short stubble treatment, it significantly out yielded the burn treatment (3.35t/ha versus 2.93t/ha). The premature senescence of the burn treatment is evident in the higher level of screenings (averaged 21%) compared with the NTSR — short stubble treatment.

Visual differences in green leaf retention due to different stubble management treatments photographed 13 October 2015 (NTSR — long stubble plot in the foreground). Inset: Grain from burn plots (left) and NTSR — long stubble plots (right).

TABLE 13 Wheat yield, protein, test weight, screenings, harvest index (HI) and thousand seed weight (TSW) 25 November 2015, at harvest (GS99)

Treatment	Yield and quality					
	Yield (t/ha)	Protein (%)	Test wt (kg/hL)	Screenings (%)	HI (%)	TSW (g)
NTSR — long stubble (control)	3.13^{ab}	15.6^{ab}	78.8^{ab}	19.9^{ab}	42.8^{a}	21.1^{a}
NTSR — long stubble + 40kg N/ha	3.20^{ab}	15.6^{abc}	78.5^{ab}	21.0^{ab}	44.0^{a}	21.1^{a}
NTSR — short stubble (2015 only)	3.35^{a}	14.8^{d}	79.2^{a}	17.7^{b}	46.8^{a}	22.3^{a}
Straw removed	3.03^{b}	14.9^{bcd}	78.3^{ab}	22.6^{ab}	41.7^{a}	21.1^{a}
Cultivated (one pass)	3.10^{ab}	14.8^{cd}	79.0^{ab}	19.1^{b}	41.0^{a}	21.3^{a}
Cultivated (one pass) + 40kg N/ha	3.05^{b}	15.7^{a}	78.9^{ab}	22.0^{ab}	40.0^{a}	21.3^{a}
Burnt	2.93^{b}	15.0$^{a\text{-}d}$	77.9^{b}	25.2^{a}	39.8^{a}	20.8^{a}
Mean	**3.11**	**15.2**	**78.7**	**21.1**	**42.3**	**21.3**
LSD	0.29	0.8	1.2	5.7	7.7	1.5

Figures followed by different letters are regarded as statistically significant.

vi) Two-year results — yield

In two trials set up in the same crop rotation position on different paddocks during 2014 and 2015, changing stubble management only had a significant effect on yield during 2015 (Figure 3). There was a trend during the 2014 season, when ground conditions were wetter at establishment, for those treatments that removed or cultivated straw to perform better than during 2015. The lag in DM production observed with NTSR compared with other treatments was evident in both years, persisting up to flowering in both 2014 and 2015. The DM results indicate a growth compensation occurred in the NTSR treatments later in the season from flowering to grain fill.

vii) 2014 stubble management treatments — influence on 2015 barley yields

Different stubble management treatments carried out during autumn 2014 resulted in no significant differences in 2014 second wheat yields but did produce significant differences in the commercial barley crop yields during 2015 (Table 14). Retaining the stubble, but removing the straw during 2014, then burning wheat stubble during 2015 resulted in significantly higher barley yields compared with cultivating during 2014 and burning wheat stubble during 2015. This treatment however was not significantly greater than NTSR or burning in both years.

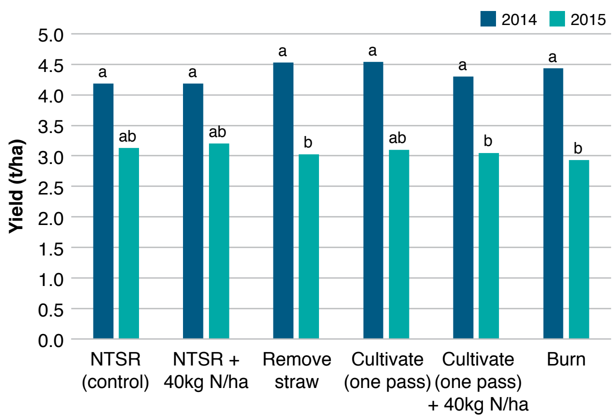


FIGURE 3 Yield data (cv Young) from the Yarrawonga trials during 2014 and 2015

Yields for the same year with different letters are regarded as statistically different. Refer to Table 14 for NTSR — short stubble result (2015 only), which completes the dataset.

TABLE 14 Barley yield in the 2015 commercial crop following different stubble management treatments set up in the 2014 stubble management site and the 2014 wheat yield

2014 stubble management treatments (all blocks were burnt before the 2015 crop)	2014 second wheat yield (t/ha)	2015 barley yield (t/ha)
Burnt	4.43^{a}	2.60^{ab}
NTSR — long stubble (control)	4.18^{a}	2.49^{ab}
NTSR — long stubble + 40kg N/ha	4.18^{a}	2.70^{ab}
Straw removed	4.53^{a}	2.73^{a}
Cultivated (one pass)	5.54^{a}	2.43^{b}
Cultivated + 40kg N/ha	4.30^{a}	2.40^{b}
Mean	**4.36**	**2.56**
LSD	0.46	0.30

Figures followed by different letters are regarded as statistically significant.

Trial 3: Dookie, Victoria

Sowing date: 12 May 2015

Rotation: Second wheat

Variety: Mace

Stubble: Wheat (various treatments applied)

Stubble load at sowing: 8.7t/ha

Rainfall:
GSR: 233mm (April–October)
Summer rainfall: 76mm

Soil nitrogen at sowing: 56kg N/ha NTSR (control), 35kg N/ha multidisc in 0–60cm (21 April 2015)

Key points

- Heat and moisture stress during spring resulted in average yields of 2.4t/ha compared with 5.5t/ha for the equivalent trial and rotation position during 2014.
- There were no differences in the 2015 yields due to stubble management, all stubble treatments resulted in low yields, high screenings and high protein levels.
- There were visual differences in green leaf retention due to stubble management and evidence of slightly delayed maturity in the no-till stubble retention (NTSR) treatments.
- Although the NTSR— long stubble treatment decreased yields during 2014, this effect was not seen under the more stressful conditions of 2015.
- Canola sown during 2015 across the 2014 trial site yielded significantly higher in the 2014 long stubble treatment, presumably due to either water or nitrogen (N) saving.

Results

i) Establishment and crop structure

Removing or burning straw resulted in significantly higher crop vigour and tiller numbers at first node (GS31), although at harvest there were no significant differences in head numbers between any of the stubble treatments (Table 15).

ii) Dry matter production and nitrogen uptake in the crop canopy

Despite having the same plant populations, where straw was removed or burnt there were 0.75–1.0t/ha extra dry matter (DM) production by flag leaf emergence (GS39), compared with the NTSR and cultivation treatments (Table 16). After flag leaf emergence (GS39) there were no differences in DM. The same trends in DM production correlated to nitrogen uptake into the crop canopy with more nitrogen present in crops with more DM (straw removed and burnt blocks). Nitrogen content in the crop canopy peaked at the flag leaf growth stage (GS39), while DM production peaked at the end of flowering (GS69) (Table 17).

iii) Disease levels

Yellow leaf spot (YLS) was assessed at first node (GS31) and flag leaf emergence (GS39) with low levels recorded in the trial on both occasions. There were no significant differences at first node (GS31) but at flag leaf emergence (GS39) there was evidence of higher levels of YLS in the long stubble compared with the short stubble, straw removed and burnt treatments (Table 18).

iv) Green leaf retention

Following the heat shock during early October the plots showed visual differences in green leaf retention with the NTSR plots being greener than the burnt plots.

The grain in the NTSR plots also appeared to be less physiologically mature than grain taken from the burn plots.

TABLE 15 Plant counts and vigour 10 June 2015, two-leaf stage (GS12); plant counts 23 June 2015, one-tiller stage (GS21); tiller counts 29 July 2015, first-node stage (GS31) and head counts 20 November, harvest (GS99)

	Crop growth stage				
	Plants/m^2	Vigour	Plants/m^2	Tillers/m^2	Heads/m^2
	GS12		GS21	GS31	GS99
NTSR — long stubble	154^{a}	8.3^{b}	153^{ab}	298^{b}	317^{a}
NTSR — short stubble	143^{a}	9.0^{a}	141^{b}	309^{b}	333^{a}
Cultivated (one pass)	143^{a}	9.0^{a}	151^{ab}	349^{ab}	340^{a}
Straw removed	146^{a}	8.8^{a}	146^{ab}	389^{a}	354^{a}
Burnt	163^{a}	9.0^{a}	162^{a}	394^{a}	325^{a}
Mean	**150**	**9.0**	**151**	**348**	**334**
LSD	25	0.5	21	76	60

Figures followed by different letters are regarded as statistically significant.



TABLE 16 Dry matter 29 July 2015, first node (GS31); 11 September 2014, flag leaf fully emerged (GS39); 9 October, end of flowering (GS69) and 20 November, harvest (GS99)

	Dry matter (t/ha)			
	GS31	GS39	GS69	GS99
NTSR — long stubble	0.92^{bc}	3.67^{b}	6.67^{a}	6.35^{a}
NTSR — short stubble	0.89^{c}	3.66^{b}	6.82^{a}	6.87^{a}
Cultivated (one pass)	0.92^{bc}	3.86^{b}	6.56^{a}	6.76^{a}
Straw removed	1.13^{ab}	4.75^{a}	6.72^{a}	6.66^{a}
Burnt	1.15^{a}	4.46^{a}	6.77^{a}	6.74^{a}
Mean	**1.00**	**4.08**	**6.71**	**6.68**
LSD	0.22	0.59	0.63	0.63
Figures followed by different letters are regarded as statistically significant.				

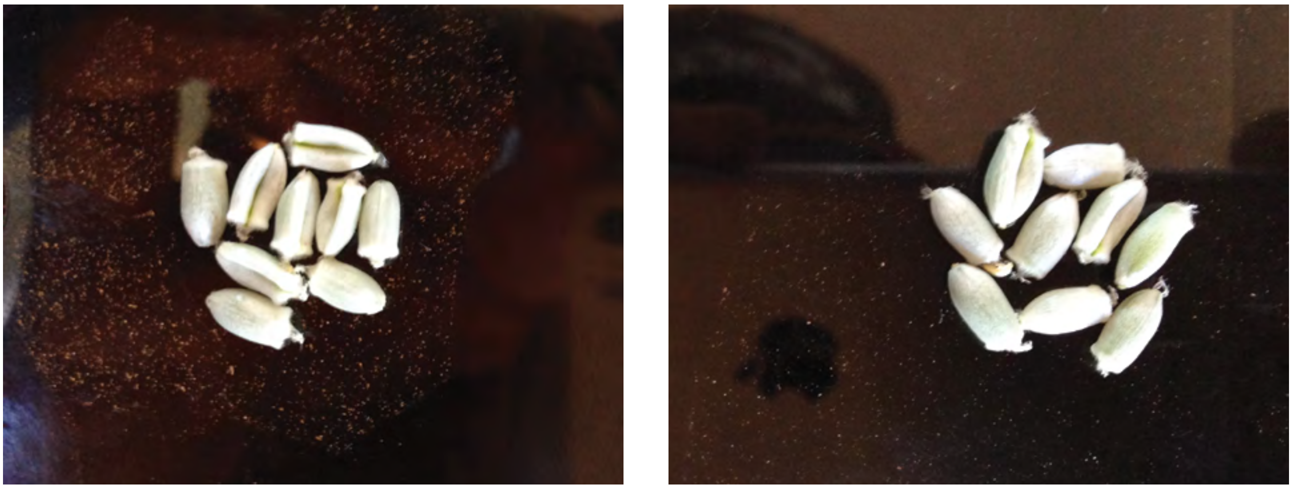
TABLE 17 Nitrogen uptake in dry matter 29 July 2015, first node (GS31); 11 September 2014, flag leaf fully emerged (GS39); 9 October, end of flowering (GS69) and 20 November, harvest (GS99)

	Nitrogen uptake (kg/ha)			
	GS31	GS39	GS69	GS99
NTSR — long stubble	39^{ab}	90^{abc}	81^{a}	89^{ab}
NTSR — short stubble	35^{b}	87^{bc}	84^{a}	82^{ab}
Cultivated (one pass)	33^{b}	79^{c}	73^{a}	85^{ab}
Straw removed	44^{a}	103^{a}	76^{a}	90^{a}
Burnt	44^{a}	94^{ab}	83^{a}	74^{b}
Mean	**39**	**91**	**79**	**84**
LSD	8	13	12	16
Figures followed by different letters are regarded as statistically significant.				

TABLE 18 Yellow leaf spot severity and incidence of the two newest fully-emerged leaves (flag-2, flag-3) assessed 11 September 2015, flag leaf fully emerged (GS39)

	Severity (% leaf area infected)		Incidence (% leaves infected)	
	Flag-2	Flag-3	Flag-2	Flag-3
NTSR — long stubble	1.3^{a}	5.6^{a}	70.0^{a}	83.3^{ab}
NTSR — short stubble	0.5^{b}	2.7^{bc}	36.7^{b}	83.3^{ab}
Cultivated (one pass)	0.6^{b}	3.8^{ab}	50.0^{ab}	86.7^{a}
Straw removed	0.3^{b}	1.5^{c}	34.1^{b}	65.2^{b}
Burnt	0.6^{b}	2.7^{bc}	56.7^{ab}	80.0^{ab}
Mean	**0.6**	**3.3**	**49.5**	**79.7**
LSD	0.6	1.9	27.3	19.7
Figures followed by different letters are regarded as statistically significant.				

Green leaf retention differences resulting from the 2015 stubble management treatments at Dookie. Outlined block on right is NTSR — long stubble, and the slightly less green block outlined to the left is NTSR — short stubble. In other plots where straw was removed or cultivated the crops were more senesced. Note: two replicates further up the paddock showing similar differences. (Drone image from Tony Ludeman, with thanks).



Physiological development of grain from NTSR — long stubble treatment on the left and from burn blocks on the right observed 13 October 2015 — cv Mace.

v) Yield and grain quality

The trial was harvested on 27 November 2016. There were no statistical differences in grain yield with all treatments showing high levels of screenings (averaged almost 50%) (Table 19). The only significant differences were measured in the grain quality. Grain protein from NTSR — long stubble treatments was significantly higher than the other treatments, including NTSR — short stubble. When straw was removed the screenings were increased relative to the NTSR — short stubble treatment

vi) Two-year results — yield data

The results from this focus farm across the past two years have shown the main difference in crop productivity has been associated with long stubble in NTSR (Figure 4). The heat stress experienced during early October 2015, with resultant low yields, may have negated any treatment differences compared with 2014. The differences in green leaf retention associated with NTSR were the most visual differences recorded during 2015, but were not



TABLE 19 Wheat yield, protein, test weight, screenings, harvest index (HI) and thousand seed weight (TSW) 27 November 2015, at harvest (GS99)

	Yield and quality					
	Yield (t/ha)	Protein (%)	Test weight (kg/hL)	Screenings (%)	HI (%)	TSW (g)
NTSR — long stubble	2.41[a]	15.0[a]	69.8[a]	45.8[ab]	33.2[a]	17.3[a]
NTSR — short stubble	2.52[a]	13.6[b]	70.6[a]	43.7[b]	32.1[a]	17.1[a]
Cultivated (one pass)	2.39[a]	12.9[c]	68.1[ab]	47.3[ab]	31.1[a]	16.4[a]
Straw removed	2.32[a]	13.5[bc]	66.4[b]	57.7[a]	30.5[a]	16.1[a]
Burnt	2.49[a]	13.3[bc]	68.6[ab]	50.3[ab]	32.4[a]	16.5[a]
Mean	**2.42**	**13.6**	**68.7**	**49.0**	**31.9**	**16.7**
LSD	0.22	0.6	2.8	12	4.1	1.9

Figures followed by different letters are regarded as statistically significant.

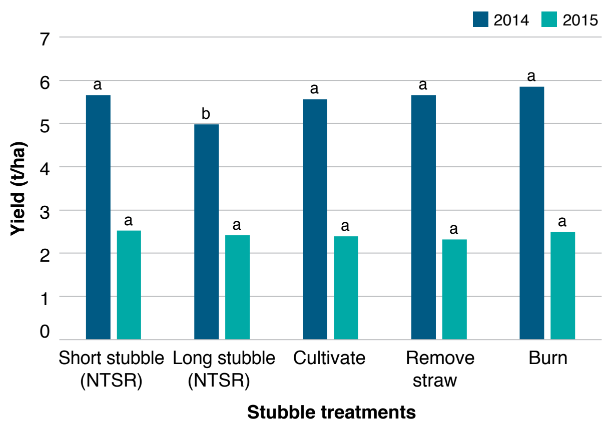


FIGURE 4 Yield data from the Dookie wheat-on-wheat trials, 2014 and 2015 — cv Corack (2014) and cv Mace (2015)

Yield bars for the same year with different letters are regarded as statistically different

Notes: The two trial sites were on the same farm in the same rotation position, but not on the same trial site. During 2014 the cultivation treatments were carried out twice and during 2015 a single pass was carried out.

evident in 2014 when yields were almost double at this site There was also evidence that longer stubble in the NTSR blocks retarded the phenological development of the crop at this site during 2015, which may explain why despite the increased green leaf retention relative to other blocks the NTSR — long stubble treatment conferred no significant yield benefit. The influence of stubble length on subsequent crop development will be studied in more detail during 2016.

vii) 2014 trial treatments — 2015 canola yield data

The 2014 stubble management trial at the Dookie focus farm was sown to a commercial crop of canola during 2015. The 2014 second-wheat trial stubbles were burnt in preparation for the canola crop. The NTSR — long stubble plots that produced the lowest wheat yields during 2014 produced significantly higher canola yields than the burnt plots from 2014 (Table 20). It is unclear if the higher yields in the 2015 canola crop were the result of moisture and/or nutrient saving due to the lower-yielding wheat the season before.

TABLE 20 2015 Canola yields grown on the 2014 second wheat blocks where different stubble management treatments were performed

2014 stubble management (2015 all trial blocks burnt)	2014 second wheat yield	2015 canola yield
Burn	5.85[a]	1.2[b]
NTSR — long stubble	4.98[b]	1.4[a]
NTSR — short stubble	5.66[a]	1.3[ab]
Straw removed	5.66[a]	1.3[ab]
Cultivated (one pass)	5.56[a]	1.4[ab]
Mean	**5.54**	**1.3**
LSD	0.45	0.2

Figures followed by different letters are regarded as statistically significant.

Trial 4: Henty, NSW

Sowing date: 21 April 2015
Rotation: Monola following triticale/arrowleaf clover
Variety: 314 TT Monola
Stubble: Triticale (various treatments applied)
Stubble load at sowing: 8.3 t/ha
Rainfall:
GSR: 391mm (April–October)
Summer rainfall: 114mm
Soil nitrogen at sowing: 44kg N/ha NTSR (control), 37kg N/ha cultivate 0–60cm (21 April 2015)

Key points

- A highly variable trial with no significant differences in monola dry matter (DM) accumulation, nitrogen (N) uptake or yields due to stubble management.
- The 2014 cultivation treatments carried out before sowing the canola crop during the first year of the project significantly increased the yield of the following oat crop established using no-till stubble retention (NTSR).
- The yield increase in the following oat crops was reflected in significantly more biomass accumulation by the flag leaf.

Results

i) Establishment and crop structure

There were no significant differences in crop establishment in terms of crop and weed plant populations, which were highly variable. However, extra nitrogen applied at sowing improved crop vigour where cereal straw was cultivated (Table 21).

ii) Dry matter production and nitrogen uptake in the crop canopy

The different stubble management treatments produced no differences in DM production, as the waterlogging through winter resulted in large variation between replicates (Table 22). The variable nature of the DM data is also represented in the nitrogen uptake data (Table 23).

iii) Disease levels

Although there was a high level of blackleg (phoma) incidence in the trial (more than 70% of plants at each assessment timing showed infection across all treatments) infection severity never exceeded more than 20%. Significant differences in blackleg levels were recorded due to stubble management in the trial at mid-flowering only (Figure 5) with mulched stubble plus 40N being more severely infected than NTSR.

iv) Yield and grain quality

Periodic waterlogging produced highly variable yields with no significant differences due to stubble management (Table 24). The moisture content of the oilseed was higher with NTSR. Extra nitrogen at sowing significantly decreased oil content in the NTSR plots.

v) 2014 stubble management treatments — influence on 2015 oat yields cv Matika

The 2014 canola stubble management trial at the Henty focus farm was sown to a commercial crop of oats during 2015 using NTSR. From the exact same areas in the trial the 2015 oat yields were recorded to assess if the 2014 stubble management treatments put in place before the canola had any rotational effect on the following oat crop. The 2014 stubble management treatments set up before canola produced significant differences in the following 2015 oat crop (Table 25). The 2014 cultivation

TABLE 21 Plant counts, vigour and weed counts 21 May 2015, three leaves unfolded (GS13) and plant counts 5 August 2015, yellow bud stage (GS59)

	Canopy composition			
	GS13			GS59
Treatment	Plants/m²	Vigour	Weeds/m²	Plants/m²
NTSR (control)	42^{ab}	4.0^{b}	2.0^{a}	29^{ab}
NTSR + 40kg N/ha	43^{ab}	5.0^{b}	4.0^{a}	35^{ab}
Mulched	34^{b}	5.0^{b}	2.0^{a}	24^{b}
Mulched + 40kg N/ha	39^{ab}	5.0^{b}	2.0^{a}	36^{ab}
Cultivated (one pass)	59^{a}	7.0^{a}	6.0^{a}	33^{ab}
Cultivated (one pass) + 40kg N/ha	62^{a}	8.0^{a}	6.0^{a}	42^{a}
Mean	**47**	**5.7**	**3.8**	**33**
LSD	23	0.7	6.2	17

Figures followed by different letters are regarded as statistically significant.



TABLE 22 Dry matter 2 July 2015, green bud stage (GS51); 5 August 2015, yellow bud stage (GS59); 27 August, full flowering (GS65); 8 September 2015, 50% pods reached final size (GS75); 8 October 2015, 10% pods ripe (GS81) and 17 November 2015, harvest (GS99)

Treatment	Dry matter (t/ha)					
	GS51	GS59	GS65	GS75	GS81	GS99
NTSR (control)	0.90[a]	2.04[a]	2.78[a]	4.91[a]	6.38[a]	4.79[a]
NTSR + 40kg N/ha	1.07[a]	2.18[a]	2.84[a]	3.98[a]	6.67[a]	3.52[a]
Mulched	0.95[a]	2.04[a]	2.60[a]	5.29[a]	6.47[a]	3.88[a]
Mulched + 40kg N/ha	0.96[a]	2.33[a]	2.87[a]	4.54[a]	7.79[a]	4.04[a]
Cultivated (one pass)	1.07[a]	2.20[a]	2.69[a]	4.52[a]	6.21[a]	3.27[a]
Cultivated (one pass) + 40kg N/ha	1.22[a]	2.23[a]	3.09[a]	4.38[a]	5.60[a]	3.54[a]
Mean	**1.03**	**2.17**	**2.81**	**4.60**	**6.52**	**3.84**
LSD	0.46	0.83	0.98	2.38	3.53	1.55

Figures followed by different letters are regarded as statistically significant.

TABLE 23 Nitrogen uptake in dry matter 2 July 2015, green bud stage (GS51); 5 August 2015, yellow bud stage (GS59); 27 August, full flowering (GS65); 8 September 2015, 50% pods reached final size (GS75); 8 October 2015, 10% pods ripe (GS81) and 17 November 2015 harvest (GS99)

Treatment	Nitrogen uptake (kg N/ha)					
	GS51	GS59	GS65	GS75	GS81	GS99
NTSR (control)	30[b]	83[a]	47[a]	80[a]	68[a]	42[a]
NTSR + 40kg N/ha	44[ab]	71[a]	50[a]	64[a]	79[a]	44[a]
Mulched	39[ab]	65[a]	47[a]	80[a]	61[a]	48[a]
Mulched + 40kg N/ha	36[ab]	78[a]	58[a]	76[a]	81[a]	66[a]
Cultivated (one pass)	34[ab]	82[a]	55[a]	87[a]	67[a]	43[a]
Cultivated (one pass) + 40kg N/ha	50[a]	85[a]	55[a]	76[a]	57[a]	51[a]
Mean	**39**	**77**	**52**	**77**	**69**	**49**
LSD	17	29	17	43	54	31

Figures followed by different letters are regarded as statistically significant.

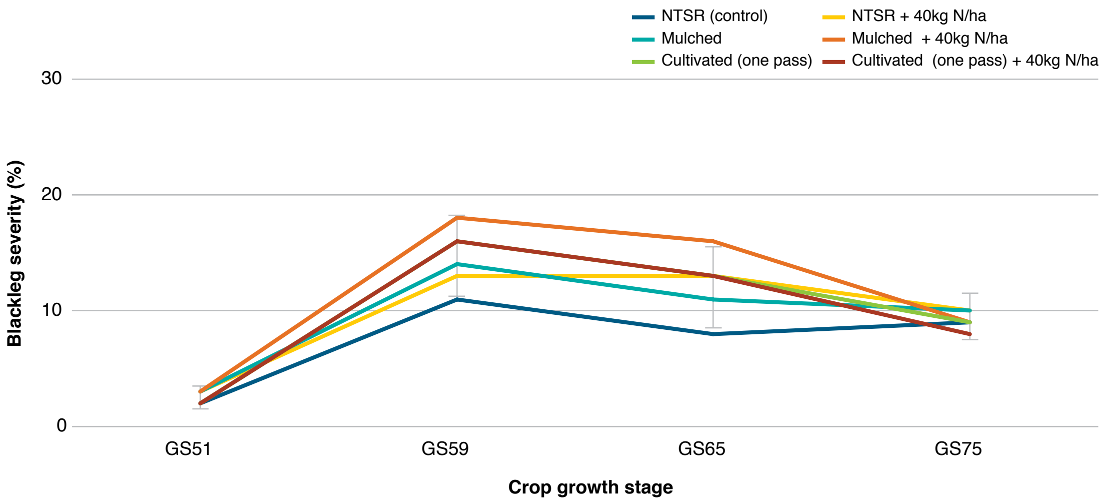


FIGURE 5 Blackleg severity of the whole plant 2 July 2015, green bud stage (GS51); 5 August 2015, yellow bud stage (GS59); 27 August, full flowering (GS65) and 8 September 2015, 50% pods reached final size (GS75)

Error bars presented as a measure of LSD

TABLE 24 Monola yield, oil, protein and moisture 28 November 2015, harvest (GS99)

Treatment	Yield and quality			
	Yield (t/ha)	Oil (%)	Protein (%)	Moisture (%)
NTSR (control)	1.24^{a}	44.5^{a}	19.1^{b}	5.4^{a}
NTSR + 40kg N/ha	1.32^{a}	41.0^{b}	21.7^{a}	5.1^{ab}
Mulched	1.44^{a}	43.6^{a}	20.6^{ab}	5.0^{b}
Mulched + 40kg N/ha	1.39^{a}	43.6^{a}	20.4^{ab}	4.8^{b}
Cultivated (one pass)	1.43^{a}	44.3^{a}	20.3^{ab}	4.9^{b}
Cultivated (one pass) + 40kg N/ha	1.35^{a}	43.7^{a}	20.8^{ab}	4.8^{b}
Mean	**1.36**	**43.4**	**20.5**	**5.0**
LSD	0.63	1.6	1.7	0.4

Figures followed by different letters are regarded as statistically significant.

TABLE 25 2015 oat yields recorded on the 2014 Henty stubble management site

2014 stubble management treatments	2014 canola yields	2015 oat yields
NTSR (control)	2.02^{c}	2.71^{b}
NTSR + 40kg N/ha	2.42^{ab}	3.24^{ab}
Mulched	2.29^{abc}	3.21^{ab}
Mulched + 40kg N/ha	2.21^{bc}	3.29^{ab}
Cultivated	2.48^{ab}	3.48^{a}
Cultivated + 40kg N/ha	2.63^{a}	3.49^{a}
Mean	**2.34**	**3.24**
LSD	0.36	0.71

Figures followed by different letters are regarded as statistically significant.

blocks with and without nitrogen significantly increased oat yields in the year following compared with the NTSR treatments. There was also a non-significant trend that oat yields following mulching were higher than NTSR.

The 2014 cultivation carried out before the canola significantly increased the yield of the 2015 oat crop both with and without additional nitrogen at sowing (applied at sowing during autumn 2014). This yield increase was reflected in DM increases (Table 26).

TABLE 26 2015 oat dry matter following the 2104 Henty stubble management treatments — assessed early booting (GS41), 8 September 2015

2014 stubble management treatments	Dry matter GS41
	(t/ha)
NTSR (conrol)	6.03^{bc}
NTSR + 40kg N/ha	5.75^{c}
Mulched	6.30^{bc}
Mulched + 40kg N/ha	6.57^{bc}
Cultivated	7.39^{b}
Cultivated + 40kg N/ha	9.72^{a}
Mean	**6.96**
LSD	1.55

Figures followed by different letters are regarded as statistically significant.

Acknowledgements

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- Yarrawonga: Telewonga Pty Ltd
- Dookie: Ludeman Brothers
- Henty: Peter Campbell

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Does stubble retention influence in-canopy temperature and frost risk?

Dr Cassandra Schefe[1], Michael Straight[2], Adam Inchbold[1], Nick Poole[2]

[1] Riverine Plains Inc

[2] FAR Australia

Key points

- Stubble management can influence in-canopy temperatures.
- Long stubble gets colder than short stubble.
- All stubble management treatments experienced very cold minimum temperatures; any differences in frost risk due to management in the Riverine Plains region is not yet known.

Background

The *Maintaining Profitable Farming Systems with Retained Stubble in the Riverine Plains Region* project is primarily focussed on maintaining the profitability of stubble-retained systems. However, since the establishment of the project growers have frequently asked about the influence of retained stubble on frost risk. While there is a perception retained stubble will decrease in-canopy temperatures and increase the risk and severity of frost, most frost-related research has been done in Western Australia in regions of lower yields and lower stubble loads than those experienced in the Riverine Plains region.

Additional project funding was secured from the Grains Research and Development Corporation (GRDC) during 2015 to measure the impact of different stubble treatments on in-canopy temperatures at three large-plot stubble trial sites for the 2015–17 field plot trials. This funding links the project into the GRDC *National Frost Initiative*, with all data generated being submitted into the national frost research database for review and analysis.

Aim

The aim of this work is to understand the impact of stubble retention on in-canopy temperatures and associated risk of frost in cropping environments with high yields and high stubble loads.

Method

The Corowa, New South Wales, and Yarrawonga and Dookie, Victoria, stubble management trials were chosen for this work, as they are all on a second-wheat rotation and are located on flat, relatively uniform frost-prone positions in the landscape. The treatments are listed in Table 1, along with the specific temperature monitoring that was carried out during the 2015 season (June – November) at each site. Temperature was monitored for all four replicates of each treatment, at each site.

The no-till stubble retention (NTSR) — short and NTSR — long stubble treatments at Yarrawonga and Dookie (Table 1) were chosen as long stubble was shown to decrease tillering in the 2014 Dookie trial. This may be due to decreased temperature and/or decreased light interception, and may be related to frost risk.

The in-crop temperature monitoring was carried out using Tinytags, which are battery-operated sensors that

TABLE 1 Sites, selected treatments and temperature monitoring carried out during 2015

Site	Treatments	Measurements
Corowa, NSW	• Stubble retained (NTSR) • Stubble burnt • Stubble incorporated	• Loggers (30cm height and moved to 60cm height on 9 September 2015)
Yarrawonga, Victoria	• NTSR — long stubble (38cm) • NTSR — short stubble (15cm) • Stubble burnt • Stubble incorporated	• Loggers (30cm height and moved to 60cm height on 9 September 2015)
Dookie, Victoria	• NTSR — long stubble (42cm) • NTSR — short stubble (15cm • Stubble burnt • Stubble incorporated	• Loggers (30cm height and moved to 60cm height on 9 September 2015) • Loggers at 5cm height • Loggers buried 5cm below the soil surface.

record the temperature every 15 minutes, which were downloaded at intervals through the season (Figure 1). As these sensors are un-shielded from direct sunlight, they will measure higher daytime temperatures than those recorded at a weather station, where the temperature sensor is shaded.

A weather station with a 1m deep soil moisture probe was also located adjacent to each site to provide local climatic information to support the temperature data.

The temperature data was statistically analysed using Genstat, with statistical significance determined at 5% variance. Measures of least significant difference (LSD) were used to determine which treatments were significantly different.

Results

The following results are for the temperature loggers installed at 30cm height, which were moved up to 60cm height on the 9 September 2015.

Site 1. Corowa, NSW

The overall temperature profile for the Corowa site is shown in Figure 2, with little difference clearly evident between the three stubble treatments. The amount of data presented in this graph makes it difficult to identify clear trends, however it is useful to look at the extremes of cold and heat experienced within the canopy throughout the season.

As the temperature loggers are not shaded, the recorded maximum temperatures are higher than those measured at a weather station. The minimum temperatures are also colder than those measured by a weather station, more accurately reflecting the air temperatures to which the growing plant is exposed. The coldest minimum temperature during the measuring period was -6.5°C in the standing stubble treatment at 5:30am on 4 August 2015.

Frost risk is determined by the duration and severity of frost events; the amount of time the crop experiences sub-zero temperatures, and how cold it actually gets.

FIGURE 1 Tinytag temperature loggers installed in the NTSR — short stubble treatment at Dookie, 23 June 2015
Note: The 5cm and 30cm loggers are attached to the PVC tube, with the pink flagging tape showing the location of the logger buried 5cm under the soil surface.

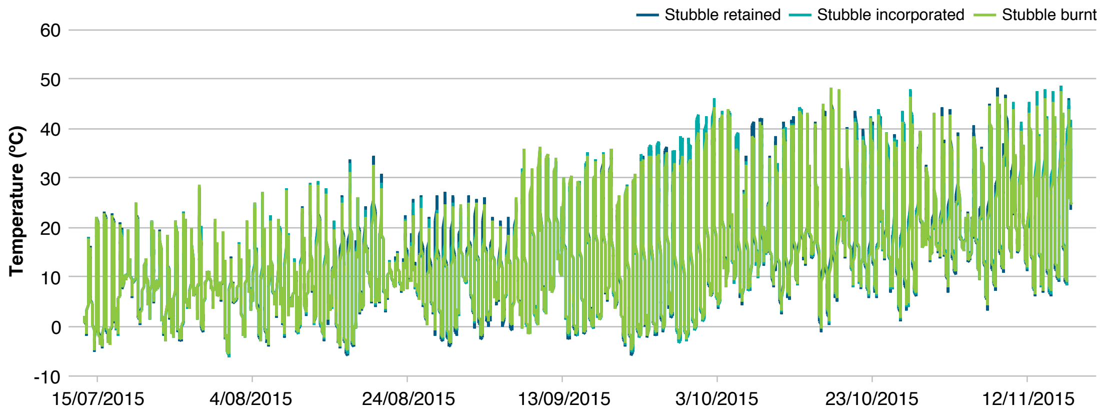

FIGURE 2 The in-canopy temperatures measured at the Corowa site from 17 July – 18 November 2015

The minimum temperatures were analysed to determine if the stubble treatments influenced the amount of time the crop experienced temperatures below zero (time threshold). As seen in Figure 3, during the period measured, the stubble retained (NTSR) treatment was exposed to a significantly longer amount of time at zero and each degree below, compared with the burnt and cultivated treatments, which largely held similar temperatures.

Site 2. Yarrawonga, Victoria

The Yarrawonga site showed a similar spread of temperatures as the Corowa site, with the coldest minimum temperature -6.4°C again measured on 4 August at 7:30am (Figure 4).

The Yarrawonga site had NTSR — long stubble and NTSR — short stubble treatments. These showed that while stubble burning lessened the time below each temperature threshold compared with the other treatments, the incorporated and NTSR — short stubble treatments recorded similar temperatures (Figure 5). The NTSR — long stubble treatment only increased the time below each temperature threshold compared with the incorporated and NTSR — short stubble treatments, at the 0, -1 and -6 °C temperature thresholds. Within the other temperature ranges there was no difference between the incorporated, NTSR — long and NTSR — short stubble treatments.

The fact the NTSR — short stubble treatment recorded similar temperatures to the incorporated treatment indicates stubble height is a significant factor in temperature regulation. The difference between the burnt and the incorporated/NTSR — short stubble treatments may be due to increased minimum temperatures in the burnt treatment before canopy closure, through greater heat absorption onto a darker surface.

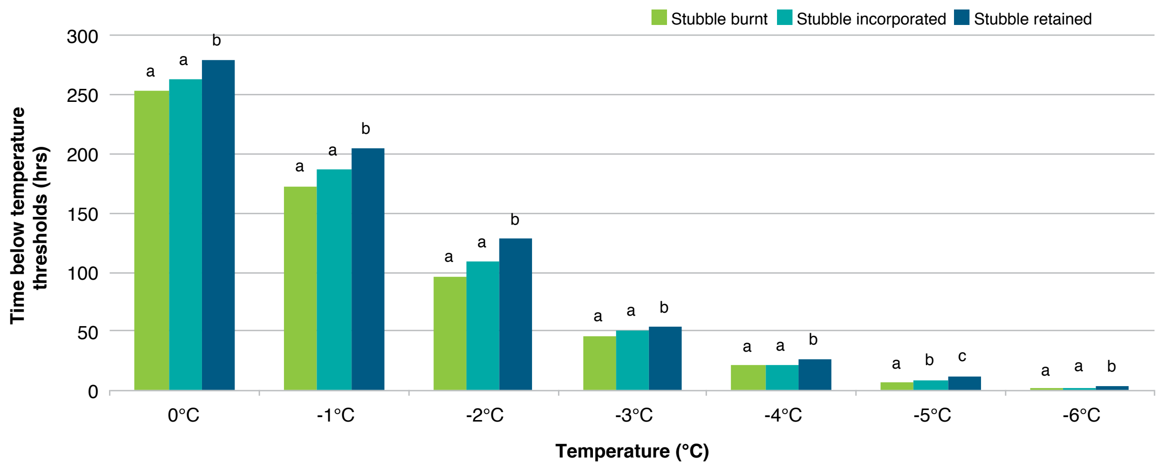

FIGURE 3 The effect of stubble treatment on the duration of in-canopy temperatures at zero and each degree below, at the Corowa site

Letters denote statistical significance between treatments at each temperature.



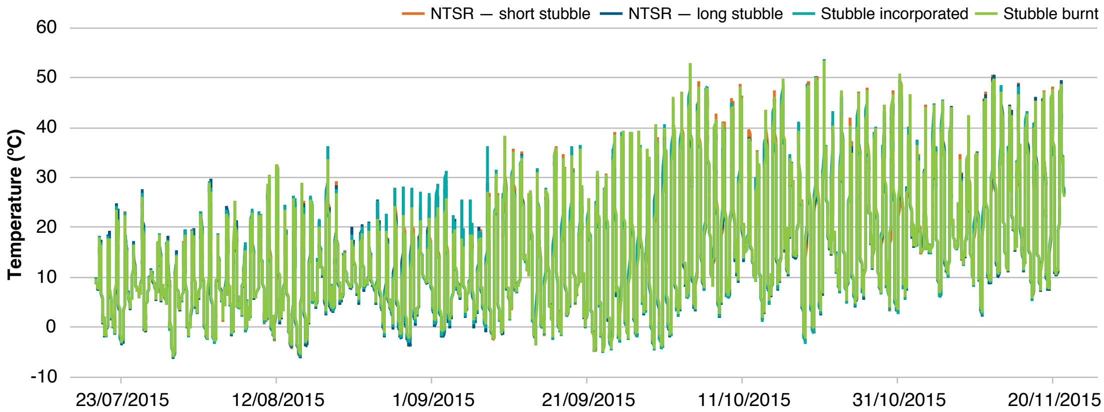

FIGURE 4 The in-canopy temperatures measured at the Yarrawonga site from 17 July – 18 November 2015

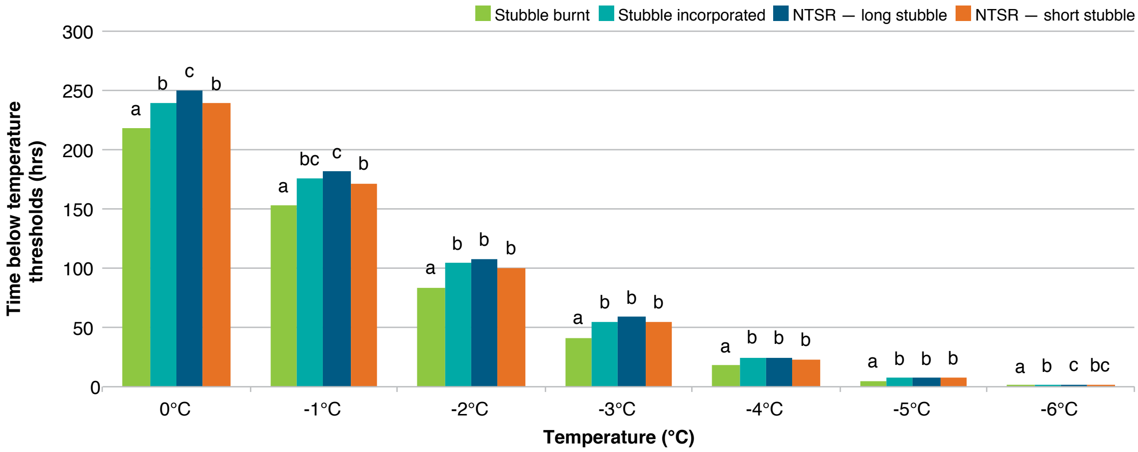

FIGURE 5 The effect of stubble treatment on the duration of in-canopy temperatures at zero and each degree below, at the Yarrawonga site

Letters denote statistical significance between treatments at each temperature.

Site 3. Dookie, Victoria

The Dookie site recorded the coldest minimum temperature of the three sites, with a minimum of -7.0°C at 8:00am on 4 August 2015 (Figure 6).

The burnt and incorporated treatments recorded similar average times below each temperature threshold at the Dookie site, while the NTSR — long stubble treatment was generally significantly colder, with more time at each minimum temperature (Figure 7). The NTSR — short stubble treatment was generally in the middle and was not statistically different to any of the other treatments at all temperature thresholds except -5 and -6°C.

Comparison of temperature recorded at different positions at Dookie

As noted in Table 1, the Dookie site was instrumented with temperature loggers at heights of 30cm, 5cm and 5cm beneath the soil surface. While data analysis of the 5cm and buried loggers is continuing, a key message to come out of this work is how the temperatures varied at the different logging positions.

As shown in the example of NTSR — short stubble in Figure 8, the 5cm loggers measured comparable temperatures to the 30cm loggers early during the season. As expected clear differences became evident as the plants grew taller (above the 5cm loggers), the 5cm loggers didn't reach the extremes of cold or heat of the 30cm loggers.

The buried loggers showed even less variation in temperature through the season (Figure 8). While the 30cm logger plummeted to -7°C on the morning of 4 August 2015, the minimum temperature recorded in the buried logger was 2.7°C, which was the lowest recorded temperature for the whole recording period.

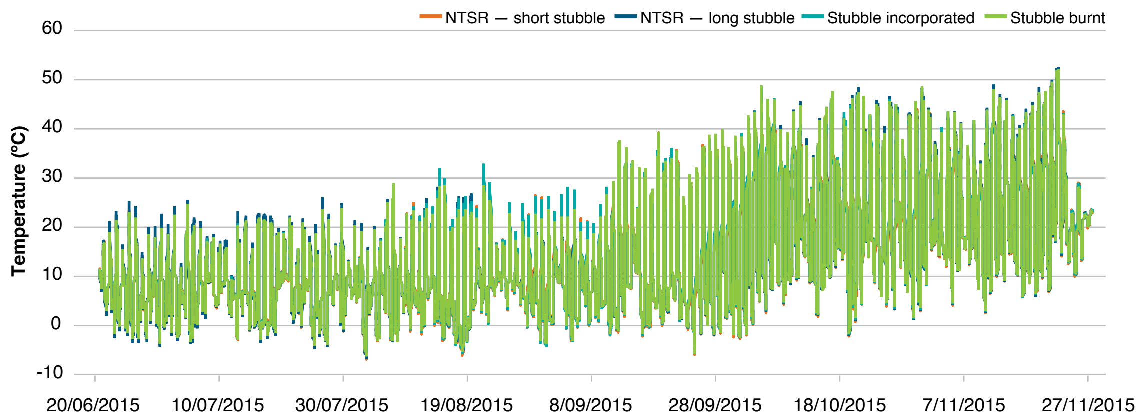

FIGURE 6 In-canopy temperatures at the Dookie site from 24 June – 24 November 2015

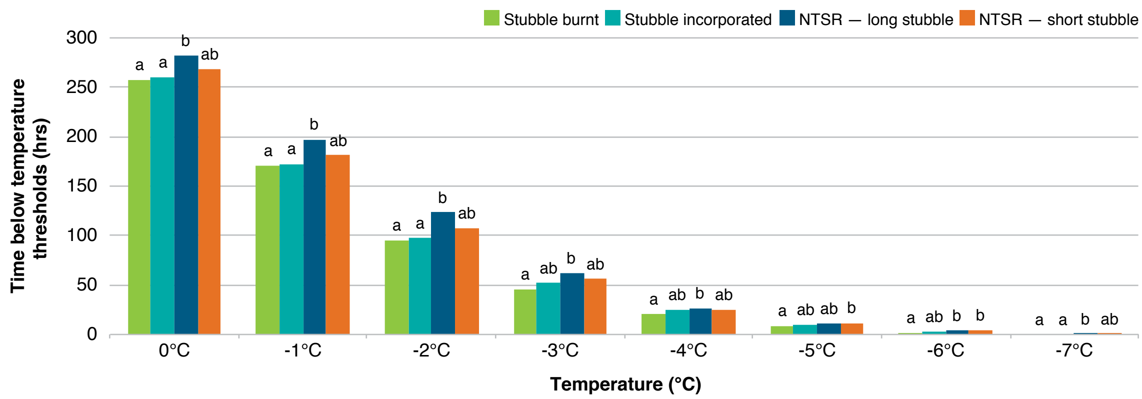

FIGURE 7 The effect of stubble treatment on the duration of in-canopy temperatures at zero and each degree below, at the Dookie site

Letters denote statistical significance between treatments at each temperature.

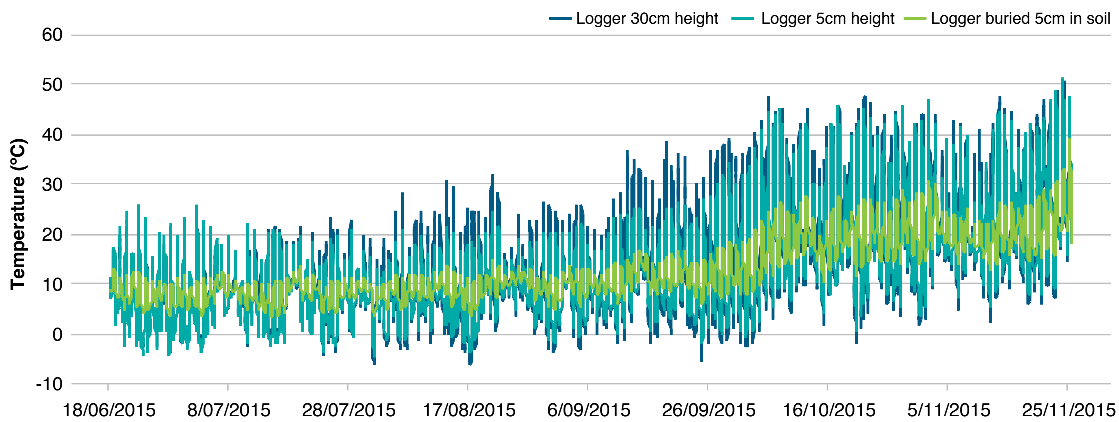

FIGURE 8 A comparison of recorded temperatures when temperature loggers were positioned 30cm above the soil, 5cm above the soil and buried 5cm below the soil surface in the NTSR — short stubble treatment at the Dookie site

Observations and comments

As a general comment, the NTSR — short stubble treatment (15cm high) seems to offer an acceptable compromise in terms of frost risk management between retaining stubble and other management practices (burning and incorporation) — a theme which continues with the plant growth and yield measurements recorded (and reported in other sections of this publication). The NTSR — short stubble treatment seemed to provide all the benefits of full stubble retention (NTSR), while being easier to manage and less likely to cause issues at sowing than the NTSR — long stubble (38–42cm). While statistically significant differences in minimum temperatures were measured when stubble was retained or retained high (NTSR — long stubble) at all three sites, the physiological importance of this difference on the plant's exposure to frost is as yet unknown, due to the lack of frosts during flowering. Rather than extreme frost events; there were extreme heat events during October 2015.

For the 2016 season all three sites have temperature loggers 5cm above the soil surface, and all monitoring started immediately post-sowing. This approach is being employed to better understand the influence of stubble on near-surface temperatures and the effect on plant establishment and early vigour. As temperature monitoring will be carried out for both the 2016 and 2017 seasons, at the end of the project we will understand more about the role of stubble management on frost risk in the Riverine Plains region.

Acknowledgements

This project is funded by the Grains Research and Development Corporation (GRDC). Many thanks to the *GRDC National Frost Initiative* team for advice on frost temperature monitoring, frost damage assessment and statistical support. Thanks also to the farmer co-operators Tomlinson Ag, Telewonga Pty Ltd and the Ludemann Brothers.

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Early sowing and the interaction with row spacing and variety in first wheat crops under full stubble retention

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FAR Australia in conjunction with Riverine Plains Inc

Key points

- Two wheat trials sown during mid-April 2015 showed no difference in grain yield or quality as a result of being grown on 22.5cm, 30cm and 37.5cm row spacings, when averaged across four varieties (Bolac, Lancer, Trojan and Wedgetail).
- Although crops grown on a 22.5cm row spacing produced more dry matter (DM), this did not correspond to increased yield.
- The results were identical to that seen with wheat sown in mid-April 2014.
- There were no differences in yields of the four wheat varieties, although Bolac produced higher screenings than the other three varieties in both trials.
- There was no difference in overall water use efficiency (WUE) between narrow and wide row spacing, although calculated water losses (soil evaporation, drainage or unused water) were greater with the wide spacing than the narrow spacing.

Previous row spacing findings

Results from the Riverine Plains Inc *Water Use Efficiency (WUE)* project (2009–13) demonstrated that wheat grown on a narrow row spacing (22.5cm) was higher yielding than equivalent crops sown in wider rows (30–37.5cm). Trials sown for the *WUE* project were established on crops sown in the mid May – early June sowing window, prompting research questions as to whether wider row spacings would be more successful if crops were sown earlier.

During 2014, first-year results showed no difference in grain yield or quality as a result of row spacing from 22.5–37.5cm, when crops were sown in mid-April, despite lower DM production with wider rows.

Method

To confirm the 2014 results, two trials were established in 2015 under the Riverine Plains Inc stubble project: *Maintaining Profitable Farming Systems with Retained Stubble in the Riverine Plains Region (2013–18)*. The two trials were conducted in the same locations as 2014: one in Barooga, New South Wales and the other in Yarrawonga, Victoria.

Four varieties, Wedgetail (winter wheat), Trojan (mid-fast spring wheat), Lancer and Bolac (slow spring wheats) were sown at identical sowing rates per unit area at three row spacings: 22.5cm, 30cm and 37.5cm. The trials were sown on 15 April as split plot designs with row spacing as the main plot and variety as the sub plot, replicated four times. All management, including starter fertiliser, was the same across the trials for the remainder of the season.

Trial 1: Barooga, NSW

Sowing date: 15 April 2015
Rotation: First wheat after canola
Varieties: Bolac, Lancer, Trojan and Wedgetail
Stubble: Canola, unburnt
Rainfall:
GSR: 201mm (April – October)
Summer rainfall: 107mm
Soil mineral nitrogen: 58kg N/ha (0–60cm)

Results

i) Establishment and crop structure

The narrow row spacing (22.5cm) produced significantly more tillers per unit area compared with wider rows (Table 1). This difference carried through to head numbers, with between 35–55 more heads with the narrow row spacing.

Averaged across the three row spacings, Wedgetail and Bolac produced significantly more heads than Lancer and Trojan, with Trojan producing significantly fewer heads than all the other varieties. There were no significant interactions between row spacing and variety, with all four varieties responding to increasing row width in the same way in regards to their crop structure (Figure 1).



TABLE 1 Plant counts 6 May 2015, two leaves unfolded (GS12), tiller counts 9 July 2015, targeted first node* (GS30–31) and head counts 18 November 2015, harvest (GS99)

Row spacing (cm)	Canopy structure (m^2)		
	Plants	Tillers*	Heads
22.5	110^{b}	356^{a}	331^{a}
30	127^{a}	306^{b}	297^{b}
37.5	112^{ab}	274^{b}	275^{b}
Mean	**116**	**312**	**301**
LSD	16	32	32
Variety			
Wedgetail	113^{a}	386^{a}	338^{a}
Bolac	113^{a}	328^{b}	320^{ab}
Lancer	116^{a}	271^{c}	293^{b}
Trojan	123^{a}	264^{c}	254^{c}
LSD	18	37	36

Figures followed by different letters are regarded as statistically significant.
* Actual growth stages at tiller assessment to account for varietal differences; Bolac GS31, Wedgetail GS30, Trojan GS31, Lancer GS31.

TABLE 2 Dry matter 9 July 2015, first node* (GS30–31), 23 September 2015, targeted start of flowering^ (GS59–65) and 18 November 2015, harvest (GS99)

Row spacing (cm)	Dry matter (t/ha)		
	GS30–31	GS59–61	GS99
22.5	1.31^{a}	9.07^{a}	10.27^{a}
30	1.35^{a}	8.42^{ab}	9.23^{b}
37.5	1.29^{a}	8.01^{b}	8.46^{b}
Mean	**1.32**	**8.50**	**9.32**
LSD	0.19	0.75	0.99
Variety			
Wedgetail	1.34^{ab}	7.20^{c}	9.35^{a}
Bolac	1.27^{b}	8.84^{ab}	8.94^{a}
Lancer	1.14^{b}	8.50^{b}	9.32^{a}
Trojan	1.52^{a}	9.46^{a}	9.66^{a}
LSD	0.22	0.87	1.15

Figures followed by different letters are regarded as statistically significant.
* Actual growth stages at tiller assessment to account for varietal differences: Bolac GS31, Wedgetail GS30, Trojan GS31, Lancer GS31.
^ Actual growth stages at GS61 assessment to account for varietal differences: Trojan GS65, Bolac GS61, Lancer GS61, Wedgetail GS59.

ii) Dry matter production and nitrogen uptake

The increased tiller numbers with the narrow row spacing did not result in an increase in DM production at first node (GS31). However the narrow row spacing produced significantly more DM at flowering (GS59–65) and harvest (GS99) compared with the wider row spacings (Table 2). At the wider row spacings of 30cm and 37.5cm there were no significant differences in DM production but there was a trend for the 30cm row spacing to produce more DM than the 37.5cm spacing.

Trojan initially produced more DM than the other varieties at first node (GS31) and flowering (GS59–65), however by harvest (GS99) this difference was not significant.

Nitrogen uptake was increased with the narrow row spacing at flowering (GS61) and harvest (GS99) compared with crops grown in wider rows (Table 3). While Trojan had a higher uptake of nitrogen compared with Lancer at first node (GS31), by the start of flowering (GS61) there were no differences between varieties.

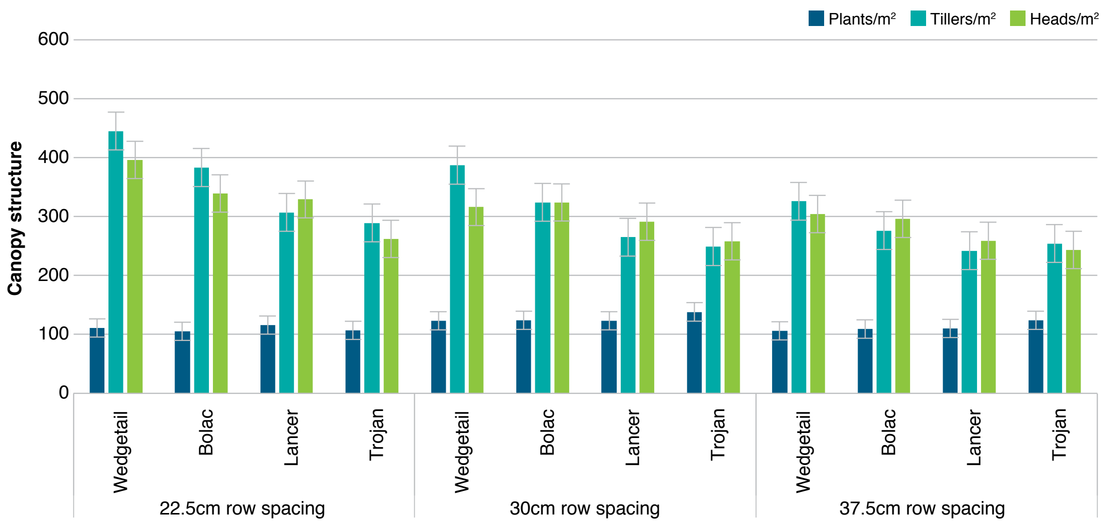

FIGURE 1 Canopy structure across all row spacing and variety treatments. Plant counts 6 May 2015, two leaves unfolded (GS12), tiller counts 9 July 2015, targeted first node (GS31*) and head counts 18 November 2015, harvest (GS99)
*Actual growth stages at tiller assessment to account for varietal differences: Bolac GS31, Wedgetail GS30, Trojan GS31, Lancer GS31.
Error bars are a measure of LSD

TABLE 3 Nitrogen uptake in dry matter 9 July 2015, first node* (GS31), 23 September 2015, targeted start of flowering^ (GS61) and 18 November 2015, harvest (GS99)

Row spacing (cm)	Nitrogen uptake in dry matter (kg N/ha)		
	GS30–31	GS59–61	GS99
22.5	46^{a}	112^{a}	102^{a}
30	46^{a}	100^{ab}	77^{b}
37.5	43^{a}	93^{b}	78^{b}
Mean	**45**	**102**	**86**
LSD	6	13	18
Variety			
Wedgetail	46^{ab}	98^{a}	87^{a}
Bolac	44^{ab}	100^{a}	82^{a}
Lancer	41^{b}	102^{a}	87^{a}
Trojan	49^{a}	108^{a}	83^{a}
LSD	6	16	18

Figures followed by different letters are regarded as statistically significant.

* Actual growth stages at tiller assessment to account for varietal differences: Bolac GS31, Wedgetail GS30, Trojan GS31, Lancer GS31.

^ Actual growth stages at GS61 assessment to account for varietal differences: Trojan GS65, Bolac GS61, Lancer GS61, Wedgetail GS59.

TABLE 4 Yield, protein, test weight and screenings at 27 November 2015, harvest (GS99)

Row spacing (cm)	Yield and quality			
	Yield (t/ha)	Protein (%)	Test weight (kg/hL)	Screenings (%)
22.5	4.17^{a}	9.8^{a}	77.2^{a}	7.1^{a}
30	4.20^{a}	9.6^{a}	77.8^{a}	6.7^{a}
37.5	4.23^{a}	9.9^{a}	77.4^{a}	7.1^{a}
Mean	**4.20**	**9.8**	**77.5**	**7.0**
LSD	0.50	0.5	0.9	1.2
Variety				
Wedgetail	3.91^{a}	9.6^{b}	76.7^{b}	5.3^{b}
Bolac	4.18^{a}	9.7^{b}	76.0^{b}	11.9^{a}
Lancer	4.28^{a}	10.3^{a}	79.0^{a}	5.1^{b}
Trojan	4.44^{a}	9.5^{b}	78.2^{a}	5.7^{b}
LSD	0.57	0.6	1.0	1.4

Figures followed by different letters are regarded as statistically significant.

iii) Grain yield and quality

There were no differences in grain yield or grain quality due to the different row spacings (Figure 2 and Table 4).

Although there were no significant differences in grain yield, the trends in yield followed DM production at flowering (GS59–61). Trojan had the highest DM at this stage and yielded 4.44t/ha, while Wedgetail had the lowest DM, yielding 3.91t/ha. The protein level recorded with Trojan suggested that nitrogen fertiliser applied may have been suboptimal. Lancer had significantly higher protein than the other varieties, while Bolac had the highest screenings.

iv) Water use efficiency calculations

While there were no differences in WUE due to row spacings, as the grain yield from the widest row spacing (37.5cm) was derived from significantly less DM, the harvest index (HI) of the wider-row-spaced crops was significantly higher (Table 5). The calculated transpiration of crops grown on wide row spacings was also less than the narrow rows, resulting in a greater transpiration efficiency (TE) in wide rows.

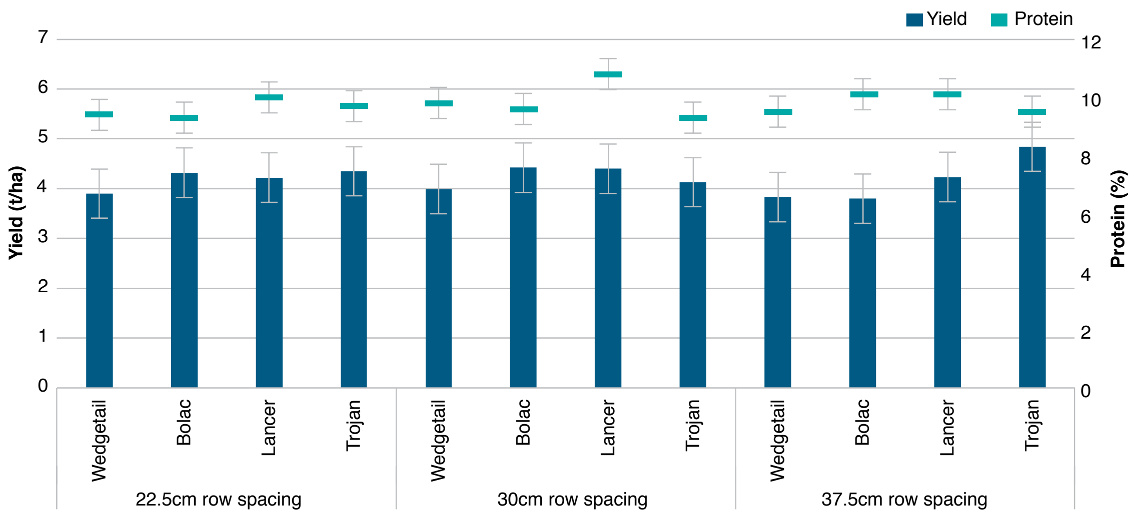

FIGURE 2 Yield and protein at 27 November 2015, harvest (GS99)

Error bars are a measure of LSD



TABLE 5 Average biomass at harvest, yield (0% moisture), harvest index (HI), calculated water use efficiency (WUE), calculated transpiration, calculated evaporation/drainage and transpiration efficiency (TE)

Row spacing (cm)	Biomass[1] (t/ha)	Yield[1] (t/ha)	HI[2] (%)	WUE[3] (kg/mm)	Transpiration[4] (mm)	Evaporation[5] (mm)	TE[6] (kg/mm)
22.5	10.27	3.65	36.1	15.3	186.7	51.4	19.8
30.0	9.23	3.67	40.3	15.4	167.8	70.4	22.1
37.5	8.46	3.70	44.6	15.5	153.8	84.4	24.5
Mean	**9.32**	**3.68**	**40.3**	**15.4**	**169.4**	**68.7**	**22.2**
LSD	0.99	0.43	5.9	1.8	18.1	18.1	3.2

GSR (April–October) 201mm plus calculated soil water available on 1 April (37.4mm) — total 238mm

1. All harvest biomass and grain yield calculations are based on DM content (i.e. 0% moisture, rather than grain at 12.5% moisture as in section iii of this report).
2. Harvest index (HI) is calculated by dividing the final harvest yield by the final harvest biomass.
3. Water use efficiency (WUE) is calculated by dividing grain yield by the available soil water (mm).
4. Transpiration through the plant was based on a maximum 55kg biomass/ha.mm transpired for wheat.
5. Soil evaporation, drainage, or unused water is calculated as the water that remains unaccounted after transpiration water has been subtracted from available soil water (stored in the fallow plus GSR).
6. Transpiration efficiency (TE) is calculated by dividing the final harvest yield per mm. water transpired through the plant.

v) Results from two years of trials at Barooga

This early-sown trial (mid-April) has now run for two years in the same rotation position, but different paddocks. While the narrow-row-spaced crops had higher DM production across both years there has been no differences in grain yield due to row spacing (Figure 3).

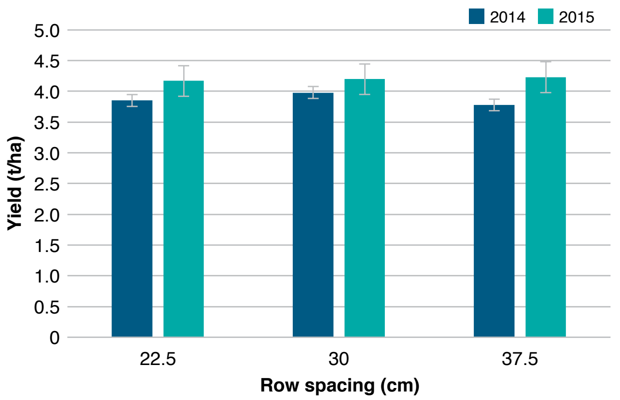

FIGURE 3 Influence of row spacing on grain yield in early-sown first wheat (average of four varieties) across 2014 and 2015 at Barooga, NSW

Trial 2: Yarrawonga, Victoria

Sowing date: 15 April 2015
Rotation: First wheat after canola
Variety: Bolac, Lancer, Trojan and Wedgetail
Stubble: Canola unburnt
Rainfall:
GSR: 266mm (April–October)
Summer rainfall: 120mm
Soil mineral nitrogen: 74kg N/ha (0–60cm)

Results

i) Establishment and crop structure

Row spacing produced the same patterns of tiller response as seen in Trial 1 at Barooga, NSW with wider rows resulting in lower tiller and head numbers despite similar plant populations of 158–171 plants/m^2 (Figure 4 and Table 6).

Trojan produced significantly fewer head numbers than Wedgetail and Bolac, despite having a slightly higher plant population. In both the Barooga and Yarrawonga row spacing trials Trojan showed reduced tillering characteristics relative to the other varieties investigated.

TABLE 6 Plant counts 7 May 2015, two leaves unfolded (GS12), tiller counts 8 July 2015, targeted first node (GS30–32*) and head counts 16 November 2015, harvest (GS99)

Row spacing (cm)	Crop structure (m^2)		
	Plants	Tillers*	Head
22.5	171^{a}	348^{a}	413^{a}
30	158^{a}	304^{b}	363^{b}
37.5	162^{a}	282^{c}	364^{b}
Mean	**164**	**311**	**380**
LSD	14	22	32
Variety			
Wedgetail	155^{b}	341^{a}	382^{b}
Bolac	165^{ab}	336^{a}	446^{a}
Lancer	156^{b}	277^{b}	357^{bc}
Trojan	178^{a}	292^{b}	337^{c}
LSD	16	25	37

Figures followed by different letters are regarded as statistically significant.

*Actual growth stages at tiller assessment to account for varietal differences: Bolac GS31, Wedgetail GS30, Trojan GS32, Lancer GS31.

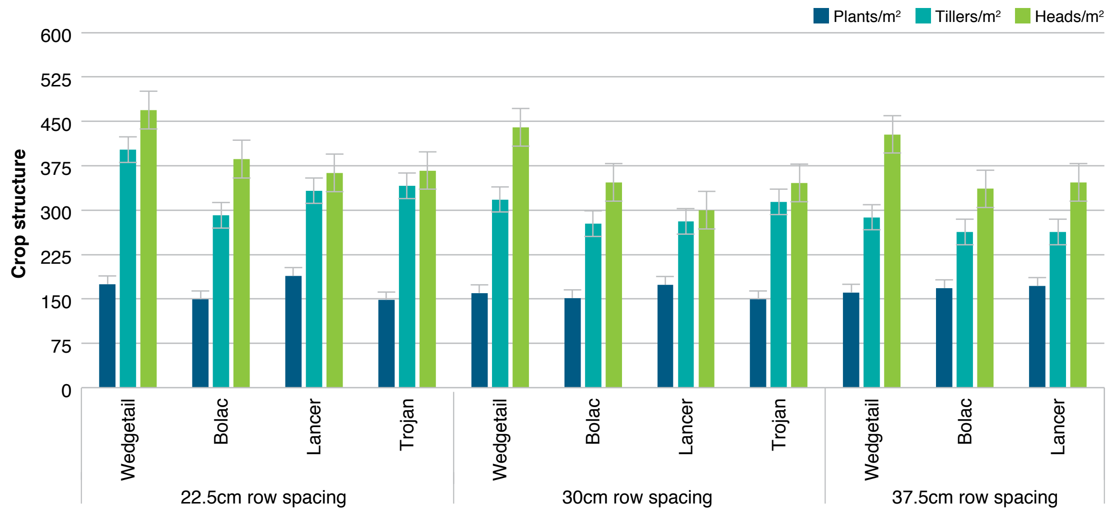

FIGURE 4 Plant counts 7 May 2015, two leaves unfolded (GS12), tiller counts 8 July 2015, targeted first node (GS31*) and head counts 16 November 2015, harvest (GS99)

*Actual growth stages at tiller assessment to account for varietal differences; Bolac GS31, Wedgetail GS30, Trojan GS32, Lancer GS31.

ii) Dry matter production and nitrogen uptake

The 22.5cm row spacing produced significantly more DM than the 37.5cm row spacing at flowering (GS59–65), and was greater than both the 30cm and 37.5cm row-spaced crops at harvest (GS99) (Table 7).

Bolac and Trojan consistently produced higher DM throughout the season. At the pre-harvest assessments the increased DM may be due to Bolac and Trojan being slightly more advanced in growth stage.

Row spacing did not have any effect on nitrogen uptake. Bolac and Trojan had greater nitrogen uptake at first node (GS31), however by start of flowering (GS61) all varieties had similar values (Table 8).

iii) Grain yield and quality

Row spacing had no effect on grain yield when averaged across the four varieties, despite significant differences in DM at harvest (Figure 5 and Table 9). There were also no significant effects on grain quality. Screening levels were high (about 20%) across all row-spacing treatments.

TABLE 7 Dry matter production 8 July 2015, first node* (GS31), 23 September 2015, targeted start of flowering^ (GS61) and 16 November 2015, harvest (GS99)

Row spacing (cm)	Dry matter (t/ha)		
	GS30–32	GS59–65	GS99
22.5	1.49[a]	9.47[a]	9.49[a]
30	1.49[a]	9.12[ab]	8.49[b]
37.5	1.47[a]	8.67[b]	8.42[b]
Mean	**1.48**	**9.09**	**8.80**
LSD	0.19	0.65	0.50
Variety			
Wedgetail	1.37[b]	8.40[b]	8.08[b]
Bolac	1.65[a]	9.88[a]	9.32[a]
Lancer	1.24[b]	8.20[b]	8.59[b]
Trojan	1.68[a]	9.85[a]	9.21[a]
LSD	0.217	0.747	0.582

Figures followed by different letters are regarded as statistically significant.

* Actual growth stages at tiller assessment to account for varietal differences: Bolac GS31, Wedgetail GS30, Trojan GS32, Lancer GS31.

^ Actual growth stages at GS61 assessment to account for varietal differences: Trojan GS65, Bolac, GS59 Lancer GS61, Wedgetail GS55.

TABLE 8 Nitrogen uptake in biomass 8 July 2015, first node* (GS31), 23 September 2015, targeted start of flowering^ (GS61) and 16 November 2015, harvest (GS99)

Row spacing (cm)	Nitrogen uptake in biomass (kg N/ha)		
	GS30–32	GS59–65	GS99
22.5	56[a]	114[a]	91[a]
30	54[a]	113[a]	87[a]
37.5	55[a]	114[a]	82[a]
Mean	**55**	**114**	**87**
LSD	7	14	36
Variety			
Wedgetail	51[b]	118[a]	75[a]
Bolac	61[a]	119[a]	87[a]
Lancer	50[b]	106[a]	95[a]
Trojan	59[a]	111[a]	89[a]
LSD	8	16	22

Figures followed by different letters are regarded as statistically significant.

* Actual growth stages at tiller assessment to account for varietal differences: Bolac GS31, Wedgetail GS30, Trojan GS32, Lancer GS31.

^ Actual growth stages at GS61 assessment to account for varietal differences: Trojan GS65, Bolac GS59, Lancer GS61, Wedgetail GS55.

TABLE 9 Yield, protein, test weight and screenings at 24 November 2015 harvest (GS99)

Row spacing (cm)	Yield and quality			
	Yield (t/ha)	Protein (%)	Test weight (kg/hL)	Screenings (%)
22.5	3.33[a]	13.0[a]	75.7[a]	19.3[a]
30	3.22[a]	13.3[a]	75.7[a]	19.2[a]
37.5	3.25[a]	13.7[a]	75.4[a]	20.5[a]
Mean	**3.27**	**13.3**	**75.6**	**19.7**
LSD	0.31	1.1	1.6	9.1
Variety				
Wedgetail	3.23[a]	13.8[a]	74.3[b]	17.7[b]
Bolac	3.32[a]	13.3[a]	74.3[b]	30.9[a]
Lancer	3.28[a]	13.5[a]	78.0[a]	10.5[b]
Trojan	3.25[a]	12.7[a]	75.8[b]	19.5[b]
LSD	0.36	1.3	1.9	10.5

Figures followed by different letters are regarded as statistically significant.

There were no varietal differences in yield or protein, however Bolac had significantly higher screenings (30%) than the other varieties.

The sharp end to the season at this site may have prevented the higher harvest DM in the narrow-row-spaced crop from finishing during the grain fill period, which is supported by lower harvest index (Table 10).

iv) Water use efficiency calculations

There were no significant differences in WUE although there was a trend for wide rows to be more efficient than narrow row spacing in terms of water passing through the plant (transpiration efficiency — TE). However more water was calculated to have been lost or left unused in wider rows as the overall WUE was similar at the three row spacing (Table 10).

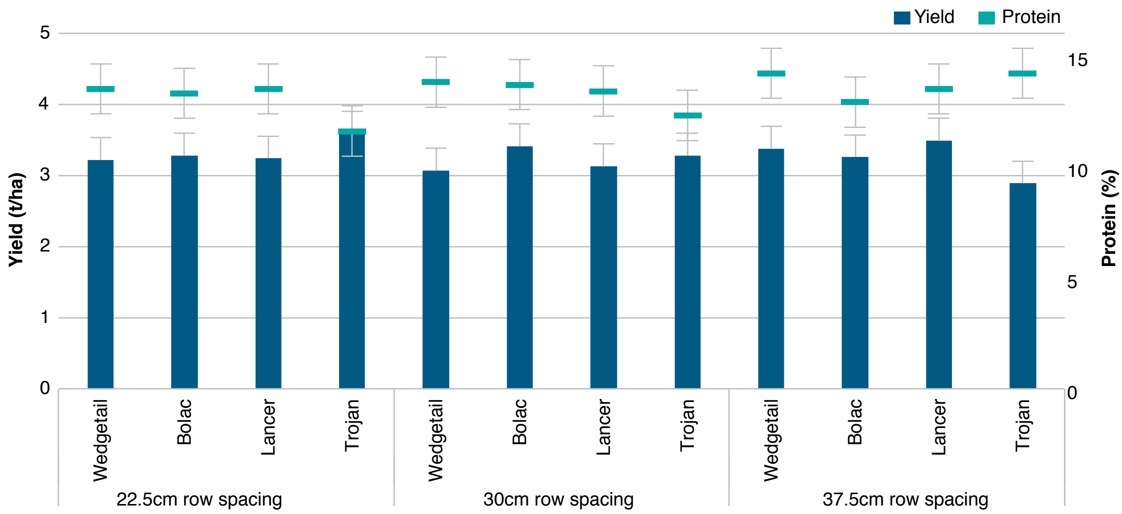

FIGURE 5 Influence of row spacing and cultivar on yield and protein
Error bars are a measure of LSD

TABLE 10 Average biomass at harvest, yield (0% moisture), harvest index (HI), calculated water use efficiency (WUE), calculated transpiration, calculated evaporation/drainage and transpiration efficiency (TE)

Row spacing (cm)	Biomass[1] (t/ha)	Yield[1] (t/ha)	HI[2] (%)	WUE[3] (kg/mm)	Transpiration[4] (mm)	Evaporation[5] (mm)	TE[6] (kg/mm)
22.5	9.49	2.92	30.8	9.5	172.5	135.3	17.0
30.0	8.49	2.82	33.2	9.2	154.4	153.5	18.3
37.5	8.42	2.85	34.2	9.3	153.1	154.8	18.8
Mean	**8.80**	**2.86**	**32.8**	**9.3**	**160.0**	**147.9**	**18.0**
LSD	0.50	0.27	3.0	0.9	9.1	9.1	1.6

GSR (April–October) 266mm plus calculated soil water available on April 1 42mm — total 308mm

1. All harvest biomass and grain yield calculations are based DM content (i.e. 0% moisture, rather than grain at 12.5% moisture as in section iii of this report).
2. Harvest index (HI) is calculated by dividing the final harvest yield by the final harvest biomass.
3. Water use efficiency (WUE) is calculated by dividing grain yield by the available soil water (mm).
4. Transpiration through the plant was based on a maximum 55kg biomass/ha.mm transpired for wheat.
5. Soil evaporation, drainage, or unused water is calculated as the water that remains unaccounted after transpiration water has been subtracted from available soil water (stored in the fallow plus GSR).
6. Transpiration efficiency (TE) is calculated by dividing the final harvest yield per mm. water transpired through the plant.

v) Results from two years of trials at Yarrawonga

The early-sown row spacing trial (mid-April) at Yarrawonga has now run for two years in the same rotation position after canola, in different paddocks. In both 2014 and 2015 the narrow-row-spaced crops produced more DM, however there have been no differences in grain yield in either year (Figure 6). This result is the same as that seen at the Barooga, NSW trial.

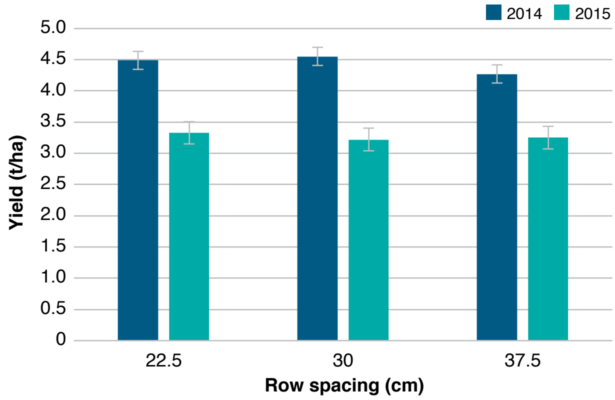

FIGURE 6 Influence of row spacing on grain yield in early-sown first wheat (average of four varieties) in 2014 and 2015, Yarrawonga, Victoria

Results in early-sown crops are different to results generated in later-sown crops (late May/early June) studied as part of the *WUE* project, where narrow row spacing produced more DM, which led to more yield. This indicates that row spacing is less important in determining wheat yield when crops are sown early, compared with crops sown later.

Acknowledgements

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 (2013–18)*.

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Interaction between fungicide program and in-crop nitrogen timing for the control of yellow leaf spot (YLS) in early-sown wheat

Nick Poole and Michael Straight
FAR Australia in conjunction with Riverine Plains Inc

Key points

- The level of yellow leaf spot (YLS) *Pyrenophora tritici repentis* control achieved with fungicides applied at the tillering (GS22) and third node stage (GS33) in wheat-on-wheat was poor (less than 50% in most assessments).
- Fungicide applied at third node stage (GS33) was more effective at preventing YLS infection on the top three leaves of the crop than when applied at tillering (GS22).
- Fungicide applied at third node stage (GS33) generated a significant (0.44t/ha) yield increase over the untreated crop, while the equivalent fungicide applied at tillering (GS22) gave no yield benefit.
- Applying fungicide at both tillering (GS22) and third node stage (GS33) offered no advantage over a single application at GS33.
- Nitrogen application at tillering (GS22) or first node (GS31) had no effect on yield.
- There was no significant difference in product performance between Tilt® (propiconazole) and Prosaro® (prothioconazole and tebuconazole).

Location: Corowa, NSW
Sowing date: 12 May 2015
Rotation: Second wheat
Variety: Gregory
Stubble: Wheat unburnt
Rainfall:
GSR: 329mm (April – October)
Summer rainfall: 152mm

Method

The trial examined the influence of two nitrogen timings: 40kg N/ha applied at tillering (GS22) or first node (GS31) (Table 1) and four fungicide strategies (untreated, fungicide at tillering — 17 July, third node — 11 September, and fungicide at both timings) on levels of YLS as part of the Riverine Plains Inc *Maintaining Profitable Farming Systems with Retained Stubble in the Riverine Plains Region Project*.

The trial was set up in a block of commercial wheat (cv Gregory) in a wheat-on-wheat rotation position as a balanced split–split plot design, with nitrogen timing as the main plot (Table 1) and fungicide timing as the sub plot and fungicide product as the sub-sub plot, replicated four times.

For each of the fungicide strategies, two fungicides were evaluated at their full rates at both timings: Tilt 0.5L/ha and Prosaro 0.3L/ha. A full list of nitrogen and fungicide treatments is presented in Table 2.

Data has been statistically analysed using analysis of variance (ANOVA), with means separated using the unrestricted least significant difference (LSD) procedure.

The crop had a plant population of 143 plants/m^2 and a tiller population of 295 tillers/m^2 when assessed at the third node stage (GS33) on 11 September, after the final fungicide application.

TABLE 1 Nitrogen application rates and timings

	12 May 2015 (sowing)	15 July 2015 (GS22)	12 August 2015 (GS31)	Total nitrogen applied
	(kg N/ha)			
Tillering timing	6	40	Nil	46
First node timing	6	Nil	40	46



TABLE 2 Treatment list

Treatment	Active ingredient (g/ha ai)		Fungicide timing (mL/ha) GS22	Fungicide timing (mL/ha) GS33	Nitrogen timing (kg N/ha) GS22	Nitrogen timing (kg N/ha) GS31
1	Untreated				40	
2	Untreated					40
3	Prosaro	Prothioconazole (63) and tebuconazole (63)	300		40	
4	Prosaro	Prothioconazole (63) and tebuconazole (63)	300			40
5	Prosaro	Prothioconazole (63) and tebuconazole (63)		300	40	
6	Prosaro	Prothioconazole (63) and tebuconazole (63)		300		40
7	Prosaro	Prothioconazole (126) and tebuconazole (126)	300	300	40	
8	Prosaro	Prothioconazole (126) and tebuconazole (126)	300	300		40
9	Untreated#				40	
10	Untreated#					40
11	Tilt	Propiconazole (250)	500		40	
12	Tilt	Propiconazole (250)	500			40
13	Tilt	Propiconazole (250)		500	40	
14	Tilt	Propiconazole (250)		500		40
15	Tilt	Propiconazole (500)	500	500	40	
16	Tilt	Propiconazole (500)	500	500		40

#The trial is a balance split–split plot design; hence the replication of the 40kg N/ha at GS22 untreated with fungicide and 40kg N/ha at GS31 untreated with fungicide treatments (9 and 10).

TABLE 3 Yellow leaf spot severity and incidence assessed 20 July 2015 two–three tillers (GS22–23) on the newest fully-emerged leaves (flag-6, flag-7 and flag-8)

GS22–23	YLS (%) Flag-6	YLS (%) Flag-7	YLS (%) Flag-8
Disease severity	1.0	8.4	72.3
Disease incidence	52.5	97.5	100

Results

i) Disease assessment data

At the first fungicide application timing (GS22) there was a high level of disease incidence on the lowest leaves (Table 3).

When assessed at third node (GS33) before the second fungicide application timing, there was little evidence of earlier treatment effects (Table 4).

TABLE 4 Yellow leaf spot severity (% leaf area infected) and incidence (% of leaves infected) assessed 11 September 2015 third node stage (GS33), on the second newest fully-emerged leaf (flag-2, flag-3 and flag-4)

Nitrogen timing	YLS (%) Flag-2 Severity	YLS (%) Flag-2 Incidence	YLS (%) Flag-3 Severity	YLS (%) Flag-3 Incidence	YLS (%) Flag-4 Severity
GS22	1.0^{a}	70.0^{a}	7.3^{a}	98.3^{a}	44.0^{a}
GS31	1.1^{a}	62.0^{b}	7.8^{a}	97.5^{a}	49.3^{a}
Mean	**1.1**	**66.0**	**7.6**	**97.9**	**46.7**
LSD	0.3	7.5	2.4	2.3	6.9
Fungicide timing					
Untreated control	1.1^{a}	65.4^{a}	8.2^{a}	99.2^{a}	54.7^{a}
GS23	0.9^{a}	66.7^{a}	6.9^{a}	96.7^{a}	38.5^{b}
LSD	0.4	10.6	3.3	3.3	9.8
Product					
Prosaro	1.2^{a}	70.8^{a}	8.7^{a}	98.3^{a}	47.3^{a}
Tilt	0.9^{b}	61.2^{b}	6.4^{a}	97.5^{a}	46.0^{a}
LSD	0.3	7.5	2.4	2.3	6.9

Figures followed by different letters are regarded as statistically significant.
Note: The newest emerged leaf (flag-1) had no disease as very newly emerged.

Later-applied nitrogen (at GS31) decreased YLS incidence on flag-2, but the difference was small. Fungicide applied during tillering (GS22–23) gave a small reduction in YLS severity on the top three leaves assessed, but the difference was only significant on flag-4.

At flag leaf emergence the impact of the later spray at third node (GS33) was evident in the YLS infection levels recorded on flag-1, flag-2 and flag-3, however only poor control (less than 50%) was achieved (Table 5). No differences in product performance were recorded at this assessment.

Disease assessments at head emergence (GS59) showed a significant decrease in YLS severity and incidence on flag-1 and flag-2 when fungicides were applied at both tillering and third node stage (GS23 and GS33) compared with the untreated control (Table 6, Figure 1). There was no difference between the two-spray program and the single application at the third node stage (GS33) on disease severity.

Early nitrogen application decreased YLS severity on flag-2, however the differences were only small.

TABLE 5 Yellow leaf spot severity and incidence assessed 24 September 2015 flag leaf just visible (GS37) on the newest fully-emerged leaf (flag-1, flag-2 and flag-3)

GS37	YLS (%)					
	Flag-1		Flag-2		Flag-3	
Nitrogen timing	**Severity**	**Incidence**	**Severity**	**Incidence**	**Severity**	**Incidence**
GS22	0.5[a]	51.3[a]	2.4[a]	95.6[a]	11.7[a]	100.0[a]
GS31	0.5[a]	48.4[a]	2.2[a]	92.5[a]	13.1[a]	100.0[a]
Mean	**0.5**	**49.9**	**2.3**	**94.1**	**12.4**	**100.0**
LSD	0.1	11.0	0.4	4.8	2.9	-
Fungicide timing						
Untreated control	0.6[a]	56.3[a]	2.9[a]	97.5[ab]	16.3[a]	100.0[a]
GS23	0.6[a]	58.1[a]	2.8[a]	99.4[a]	14.2[a]	100.0[a]
GS33	0.5[ab]	46.3[ab]	2.0[b]	92.5[bc]	9.5[b]	100.0[a]
GS23 and 33	0.4[b]	38.8[b]	1.5[b]	86.9[c]	9.6[b]	100.0[a]
LSD	0.2	15.6	0.5	6.8	4.0	-
Product						
Prosaro	0.5[a]	49.7[a]	2.3[a]	95.9[a]	11.7[a]	100.0
Tilt	0.5[a]	50.0[a]	2.3[a]	92.2[a]	13.1[a]	100.0
LSD	0.1	11.0	0.4	4.8	2.9	-

Figures followed by different letters are regarded as statistically significant.

TABLE 6 Yellow leaf spot severity and incidence assessed 9 October 2015 head completely emerged (GS59) on the second newest fully-emerged leaf (flag-1, flag-2) and green leaf retention (GLR) on flag-3

	YLS (%)				GLR (%)
	Flag-1		Flag-2		Flag-3
Nitrogen timing	**Severity**	**Incidence**	**Severity**	**Incidence**	**GLR**
GS22	1.3[a]	81.3[a]	7.2[b]	97.2[a]	40.9[a]
GS31	1.5[a]	83.4[a]	10.5[a]	97.5[a]	34.3[a]
Mean	**1.4**	**82.4**	**8.9**	**97.4**	**37.6**
LSD	0.3	8.9	2.0	2.7	6.8
Fungicide timing					
Untreated control	1.6[ab]	87.5[a]	12.3[a]	99.4[a]	27.3[b]
GS23	1.7[a]	88.1[a]	11.5[a]	98.8[a]	32.6[b]
GS33	1.3[bc]	80.6[ab]	6.2[b]	98.1[a]	45.3[a]
GS22 and 33	1.0[c]	73.1[b]	5.4[b]	93.1[b]	45.3[a]
LSD	0.4	12.5	2.8	3.8	9.7
Product					
Prosaro	1.3[a]	80.9[a]	8.9[a]	97.2[a]	37.7[a]
Tilt	1.5[a]	83.8[a]	8.8[a]	97.5[a]	37.6[a]
LSD	0.3	8.9	2.0	2.7	6.8

Figures followed by different letters are regarded as statistically significant.



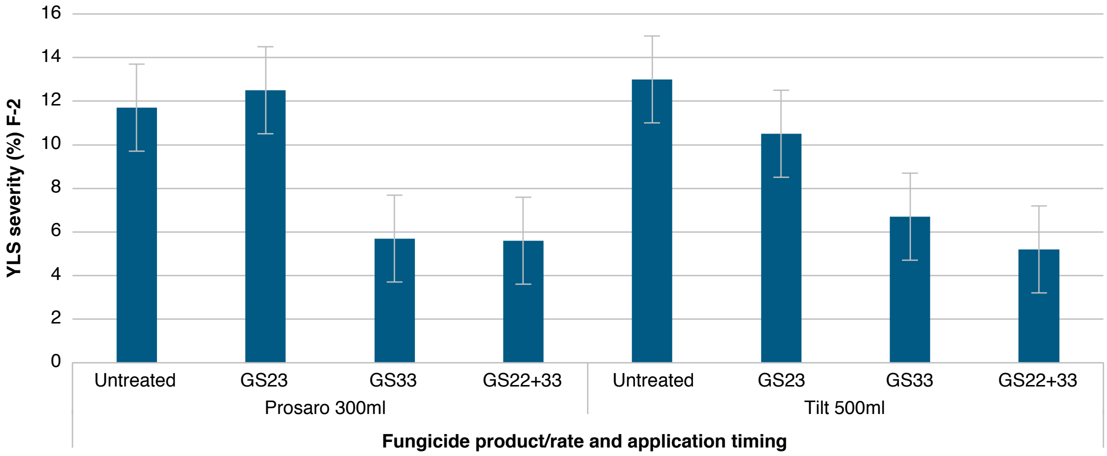

FIGURE 1 Interaction between fungicide application timing* and product on YLS severity (flag-2), assessed head emergence (GS59), 9 October 2015

*Mean of two nitrogen application timings

The error bars are a measure of LSD

Green leaf retention assessed at the watery ripe stage (GS71) showed there to be a significantly greater percentage of the leaf area of flag-3 to be greener where fungicide was applied at the third node stage.

Crop canopy greenness (measured as crop reflectance with the Greenseeker®) was significantly increased by applying fungicide at the third node stage (GS33) compared with the untreated control, however the differences were small (Table 7).

ii) Yield and quality results

Influence of nitrogen timing

The timing of nitrogen application (main dose applied at the tillering or first node stage) did not influence yield or grain quality (Table 8). There was a small but significant reduction in screenings when nitrogen was applied at the first node stage (GS31).

Influence of fungicide timing and product

Applying fungicide at tillering (GS22) did not increase yields (Table 8). However, when applied at the third node stage (GS33) there was a significant yield increase over the untreated control and the tillering applications (averaged across two products and nitrogen timings).

There were no yield or quality differences measured between Tilt and Prosaro. In this trial both products partially controlled the disease, which rarely scored above 50% control (Figure 2).

TABLE 7 NDVI 11 September 2015 third node stage (GS33), 24 September 2015 flag leaf just visible (GS37), 9 October 2015 head fully emerged (GS59) and 21 October 2015, grain watery ripe (GS71)

Treatment	NDVI			
Nitrogen timing	**GS33**	**GS37**	**GS59**	**GS71**
GS22	0.43[a]	0.54[a]	0.59[a]	0.51[a]
GS31	0.43[a]	0.55[a]	0.58[a]	0.49[a]
Mean	**0.43**	**0.54**	**0.59**	**0.50**
LSD	0.03	0.04	0.04	0.03
Fungicide timing				
Untreated control	0.40[b]	0.53[b]	0.57[b]	0.49[b]
GS23	0.43[ab]	0.51[b]	0.58[b]	0.47[b]
GS33	0.45[a]	0.60[a]	0.63[a]	0.54[a]
GS23 and 33	0.43[ab]	0.55[ab]	0.58[b]	0.50[ab]
LSD	0.04	0.06	0.05	0.04
Product				
Prosaro	0.43[a]	0.55[a]	0.59[a]	0.50[a]
Tilt	0.42[a]	0.54[a]	0.59[a]	0.50[a]
LSD	0.03	0.04	0.04	0.03

Figures followed by different letters are regarded as statistically significant.

TABLE 8 Yield, protein, test weight and screenings at 26 November 2015, harvest (GS99)

Treatment	Grain yield and quality			
Nitrogen timing	**Yield (t/ha)**	**Protein (%)**	**Test weight (kg/hL)**	**Screenings (%)**
GS22	3.81[a]	11.4[a]	82.0[a]	3.4[a]
GS31	3.64[a]	11.5[a]	81.8[a]	3.1[b]
Mean	**3.73**	**11.5**	**81.9**	**3.3**
LSD	0.19	0.2	0.6	0.2
Fungicide timing				
Untreated control	3.57[b]	11.4[ab]	82.0[a]	3.3[a]
GS23	3.62[b]	11.3[b]	82.2[a]	3.3[a]
GS33	3.97[a]	11.6[ab]	82.2[a]	3.2[a]
GS23 and 33	3.74[ab]	11.7[a]	81.3[a]	3.2[a]
LSD	0.26	0.3	0.9	0.3
Product				
Prosaro	3.65[a]	11.6[a]	81.7[a]	3.3[a]
Tilt	3.80[a]	11.4[a]	82.1[a]	3.2[a]
LSD	0.19	0.2	0.6	0.2

Figures followed by different letters are regarded as statistically significant.

Conclusions

For the third year in succession there have been responses to foliar fungicides for YLS control, despite yields being below 4t/ha during 2015 (3t/ha the two previous seasons) and disease levels being relatively low (less than 20% on the top three leaves).

Previous years of the trial have challenged current wisdom in two respects; firstly that fungicide application for YLS gives little value when applied at late tillering, and secondly, despite low levels of disease on the top three leaves there were yield responses to fungicide application. On balance it is the later of the two fungicide applications at GS32–33 that has been more effective for YLS control, although in previous years a two-spray program has performed better than one fungicide.

Overall, the yield differences are small (0.05–0.4t/ha) this season. At $300/t such yield increases would generate gross income increases of $15–$120/ha. Allowing for cost of fungicide and application at $9/ha (approximately $15/ha with Tilt and $29/ha for Prosaro) the maximum

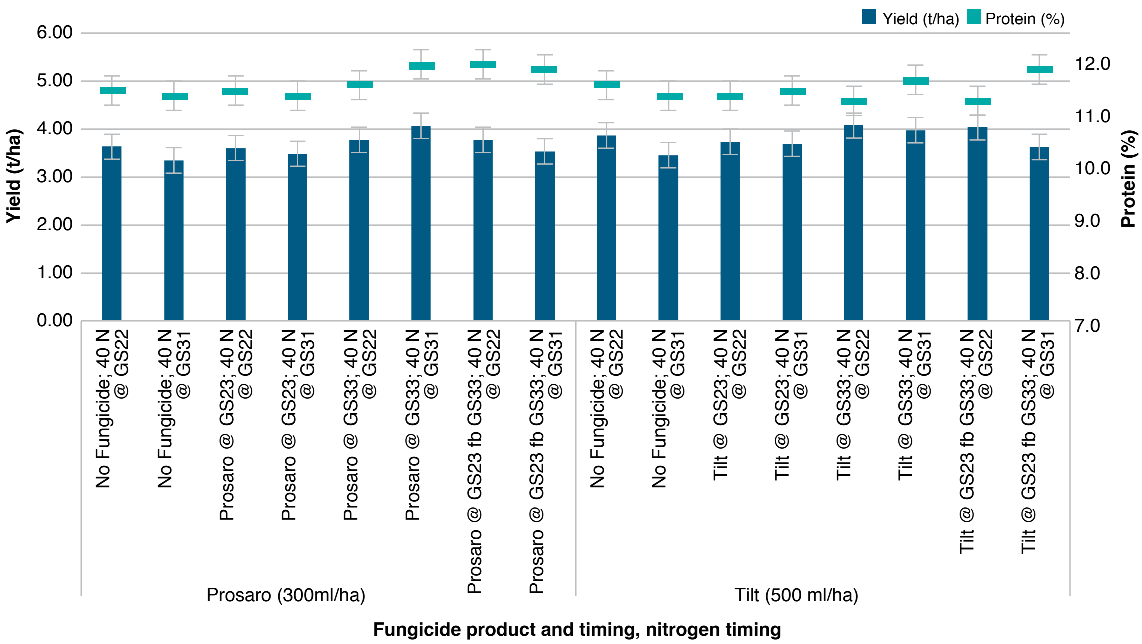

FIGURE 2 Influence of fungicide strategy and nitrogen timing on yield and protein, 26 November 2015

*The error bars are a measure of LSD



Application details:

T1 Application 17/07/2015

Application description		Application equipment	
Application date	17/7/15	Nozzle brand	Lechler
Actual growth stage at application	GS23	Nozzle type	AI110
Crop height (cm)	10 cm	Nozzle size	01
Method/equipment used	Hand boom	Nozzle spacing (cm)	50
Soil moisture	Moist	Boom height above crop(cm)	50
Air temperature (oC)	10	Operating pressure (kPa)	300
Cloud cover (%)	35	Ground speed (km/h)	4.8
Relative humidity (%)	67	Spray volume (L/ha)	100
Wind velocity (kph) (start/finish)	0-5		
Wind direction (start/ finish)	W		
Dew presence (Y/N)	N		
Crop cover (%)			

T2 Application 11/09/2015

Application description		Application equipment	
Application date	11/9/15	Nozzle brand	Lechler
Actual growth stage at application	GS33	Nozzle type	AI110
Crop height (cm)	40cm	Nozzle size	01
Method/equipment used	Hand boom	Nozzle spacing (cm)	50
Soil moisture	Moist	Boom height above crop(cm)	50
Air temperature (ºC)	17	Operating pressure (kPa)	300
Cloud cover (%)	20	Ground speed (km/h)	4.8
Relative humidity (%)	60	Spray volume (L/ha)	100
Wind velocity (kph) (start/finish)	0 to 5		
Wind direction (start/ finish)	N		
Dew presence (Y/N)	N		
Crop cover (%)			

return on input was approximately 8:1 and 4:1 respectively for the late fungicide application (GS32–33), which was the most successful program. The tillering application of fungicide on its own was not cost effective this year.

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

Location: Dookie, Victoria

Sowing date: 19 May 2015
Rotation: First wheat after canola
Variety: Trojan
Stubble management: Canola unburnt
Rainfall:
GSR: 233mm (April–Oct)
Summer rainfall: 76mm

Key points

- With an average yield of almost 3t/ha, increasing the rate of nitrogen (N) applied (40 and 80 extra kilograms N/ha) did not affect dry matter (DM) accumulation, crop height or final yield of first wheat following canola.
- Applying a plant growth regulator (PGR) (chlormequat + Moddus) decreased crop height, but did not influence DM or grain yield.
- Although differences were small, the PGR application significantly decreased screenings and increased test weight.
- Applying the PGR also decreased crop reflectance, measured as normalised difference vegetation index (NDVI), during stem elongation (GS39); a result also observed during 2013 and 2014.
- The lower NDVI readings suggest PGR altered the greenness of the crop canopy or the orientation of the leaves, decreasing the crop reflectance.

Method

A commercial crop of wheat, cv Trojan, sown 19 May 2015, was fertilised with three different rates of nitrogen (142, 188 and 222kg N/ha) applied as granular urea fertiliser (46% N). The nitrogen was applied as detailed in Table 1. Nitrogen treatments then received a single application of PGR (chlormequat + Moddus) at the second-node stage (GS32) as outlined in Table 2.

Results

i) Dry matter accumulation

Increasing nitrogen application above the farm standard and applying a PGR had no significant effect on crop DM when assessed at booting (GS43), watery ripe grain fill (GS71) and harvest (GS99) (Table 3). However, there was a significant interaction of the two factors on DM at harvest (Figure 1). The interaction between PGR and nitrogen timing suggested that at the highest rate of nitrogen DM increased with PGR, which was not seen with no PGR applied.

ii) Crop reflectance using normalised difference vegetation index

The additional nitrogen applied above the farm standard did not increase the NDVI recorded with the Greenseeker® after the third node (GS33) assessment (Figure 2 and Table 4). As was seen during 2014, the PGR application resulted in a slight decrease in NDVI. This may be due to the PGR treatment making the leaves more erect in the crop canopy, resulting in less crop reflectance, however the differences were very small being significant on only one occasion post application in 2015.

iii) Crop height

The application of PGR significantly decreased crop height by 5cm (Table 5). However, as the additional nitrogen did not affect crop height, there was no interaction between factors.

TABLE 1 Nitrogen application rates and timings Dookie, Victoria

Nitrogen treatment	19 May 2015 (sowing) (kg N/ha)	3 July 2015 (kg N/ha)	24 July 2015 (GS23) (kg N/ha)	31 July 2015 (kg N/ha)	12 August 2015 (kg N/ha)	Total nitrogen applied (kg N/ha)
Standard nitrogen applied	4	46	Nil	46	46	**142**
Standard + 40kg N/ha	4	46	40	46	46	**182**
Standard + 80kg N/ha	4	46	80	46	46	**222**

TABLE 2 PGR application details

		Application equipment	GS32
		Nozzle brand	Agrotop
		Nozzle type	Air inducted flat fan
Crop height (cm)	40	Nozzle size	AirMix 11001
Equipment	CO_2 pressurised backpack sprayer with hand boom	Nozzle spacing (cm)	50
Soil moisture	Moist	Boom height above crop(cm)	50
Air temperature (°C)	13.8	Operating pressure (kPa)	260
Cloud cover (%)	98		
Relative humidity (%)	61.1	Spray volume (L/ha)	100
Droplet size	Medium		

TABLE 3 Dry matter 24 September 2015, flag leaf fully emerged (GS39), 15 October 2015, start of grain fill (GS71) and 20 November 2015, harvest (GS99)

	DM (t/ha)		
Nitrogen treatment	**GS39**	**GS71**	**GS99**
Standard (142kg N/ha)	8.11^{a}	11.22^{a}	10.74^{a}
Standard + 40kg N/ha	8.76^{a}	11.66^{a}	11.10^{a}
Standard + 80kg N/ha	8.71^{a}	11.32^{a}	10.55^{a}
Mean	**8.53**	**11.40**	**10.80**
LSD	0.67	0.78	1.08
PGR treatment			
Untreated control	8.61^{a}	11.44^{a}	11.03^{a}
Moddus + chlormequat	8.45^{a}	11.36^{a}	10.57^{a}
LSD	0.55	0.64	0.88
Figures followed by different letters are regarded as statistically significant.			

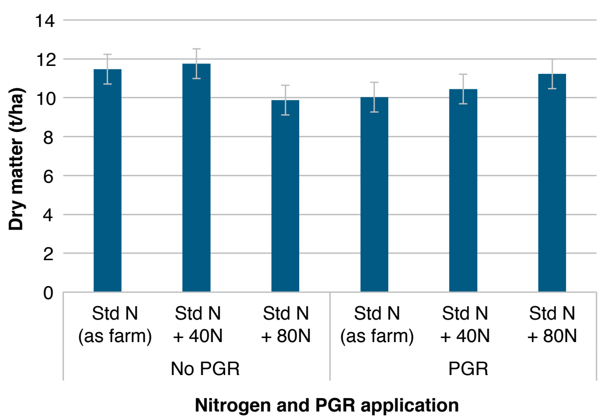

FIGURE 1 Interaction between nitrogen rate and PGR application on dry matter production 27 November, harvest (GS99)

The error bars are a measure of LSD.

iv) Yield and quality

Nitrogen effect

Additional nitrogen did not affect yield, although test weight increased and screenings were lower with the highest nitrogen application (Table 6). The low yields and high protein levels indicate the optimum nitrogen application for this site was lower than the farm standard of 142kg N/ha, which meant the extra nitrogen had no positive effect on yield in this trial.

PGR effect

PGR application resulted in significantly higher test weight and reduced screenings, but yield was not affected.

Nitrogen x PGR interaction

The interaction between additional nitrogen and PGR was not significant in terms of yield and grain quality (Figures 3 and 4).

TABLE 4 NDVI readings measured 25 August, second node (GS32), 11 September, third node (GS33), 24 September, flag leaf fully emerged (GS39) and 15 October, start of grain fill (GS71)

Treatment	NVDI reading (scale 0–1)			
Nitrogen treatment	**GS32**	**GS33**	**GS39**	**GS71**
Standard (142kg N/ha)	0.57[a]	0.68[b]	0.76[a]	0.45[a]
Standard + 40kg N/ha	0.59[a]	0.71[a]	0.78[a]	0.46[a]
Standard + 80kg N/ha	0.58[a]	0.70[ab]	0.78[a]	0.46[a]
Mean	**0.58**	**0.70**	**0.77**	**0.46**
LSD	0.02	0.05	0.04	0.03
PGR treatment				
Untreated control	0.58[a]	0.71[a]	0.78[a]	0.47[a]
Moddus + chlormequat	0.58[a]	0.69[a]	0.76[b]	0.45[a]
LSD	0.03	0.02	0.01	0.03

Figures followed by different letters are regarded as statistically significant.

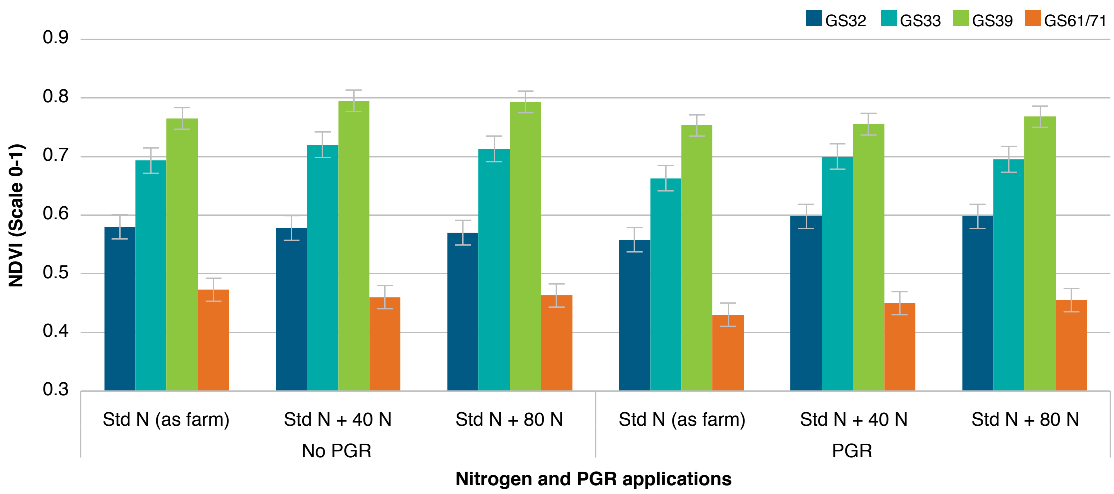

FIGURE 2 Interaction between nitrogen rate and PGR application on NDVI (0–1 scale) GS32–GS71
The error bars are a measure of LSD

TABLE 5 Crop height at harvest (GS99), 27 November 2015

Treatment	Height (cm)
Nitrogen treatment	
Standard (142kg N/ha)	67.3[a]
Standard + 40kg N/ha	67.2[a]
Standard + 80kg N/ha	67.2[a]
Mean	**67.2**
LSD	1.8
PGR treatment	
Untreated control	69.7[a]
Moddus + Chlormequat	64.7[b]
LSD	1.5

Figures followed by different letters are regarded as statistically significant.

Conclusions

For the second year in succession there have been no yield benefits to the application of PGR (chlormequat + Moddus), although there was evidence in 2015 that PGR application reduced screenings and increased test weight. Although there has been a trend for PGR application to reduce final harvest dry matter in both 2014 and 2015 the reduction has not been significant.

Acknowledgements

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 Mark Harmer Dookie, Victoria.

TABLE 6 Yield, protein, screenings and test weight at harvest (GS99), 27 November 2015

Treatment	Yield and quality			
Nitrogen treatment	**Yield (t/ha)**	**Protein (%)**	**Test weight (kg/hL)**	**Screenings (%)**
Standard (142kg N/ha)	3.05[a]	17.0[a]	79.7[b]	12.5[b]
Standard + 40kg N/ha	2.96[a]	17.2[a]	79.1[b]	15.7[a]
Standard + 80kg N/ha	2.86[a]	17.2[a]	80.6[a]	8.4[c]
Mean	**2.96**	**17.1**	**79.8**	**12.2**
LSD	0.21	0.8	0.9	3.0
PGR treatment				
Untreated control	2.91[a]	17.2[a]	78.9[b]	14.8[a]
Moddus + chlormequat	3.00[a]	17.1[a]	80.7[a]	9.6[b]
LSD	0.17	0.7	0.7	2.5

Figures followed by different letters are regarded as statistically significant.

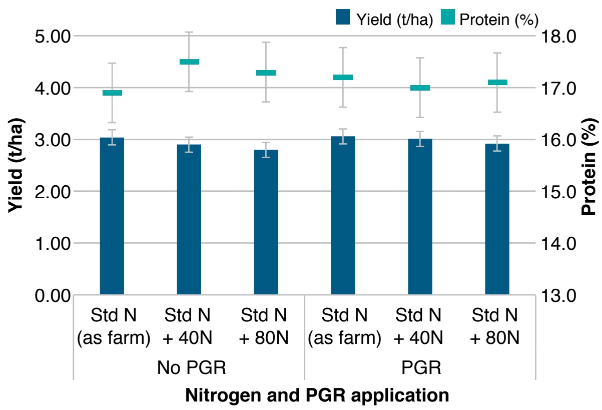

FIGURE 3 Influence of nitrogen application and PGR application on yield and protein

The error bars are a measure of LSD

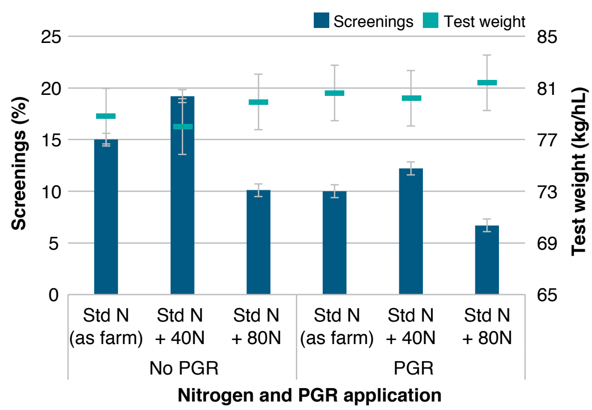

FIGURE 4 Influence of nitrogen application and PGR application on screenings and test weight

The error bars are a measure of LSD

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Monitoring the performance of nitrogen application to wheat under full stubble retention

Nick Poole and Michael Straight
FAR Australia in conjunction with Riverine Plains Inc

Key points:

- At both Yarrawonga and Dookie, Victoria, there was no yield response to nitrogen (N) application, with yields of 4.34t/ha and 3.88t/ha respectively.
- Although there was no yield response, there was significantly higher dry matter (DM) production and greater nitrogen offtake as a result of applying nitrogen at both sites.
- The maximum nitrogen offtake in the unfertilised crops at both sites equated (approximately) to the level of available nitrogen at the start of the season during April (assessed 0–60cm).
- The normalised difference vegetation index (NDVI) response index (NDVI of fertilised/NDVI of unfertilised plots equated to 1.25) assessed at first node stage (GS31) and the subsequent divergence of NDVI scores between fertilised and unfertilised crops suggested that both sites would benefit from additional nitrogen, however late moisture stress and high temperatures compromised any potential yield response.
- The NDVI canopy scores taken at Dookie during October 2015 from the 120kg N/ha plots clearly show a more rapid senescence than unfertilised crops (control) or those crops fertilised with 60kg N/ha.

Methodology

Two trials were set up under the Riverine Plains Inc stubble project: *Maintaining Profitable Farming Systems with Retained Stubble in the Riverine Plains Region (2013–18)* at Yarrawonga and Dookie, Victoria. They were set up in an established wheat crop, sown 22 April at Yarrawonga and 19 May at Dookie. The trials were run according to host farmer standard paddock practice except for nitrogen application.

Nitrogen was hand spread across the plots at three rates, 0, 60 and 120kg N/ha using two split-dose strategies. The first strategy was based on 50% of the nitrogen dose targeted at sowing (GS00) and 50% at the start of stem elongation (GS30). The second strategy was based on timings where 50% of the nitrogen rate was applied at the start of stem elongation (GS30) and 50% was applied at third node stage (GS33).

Trial 1: Yarrawonga, Victoria

Sowing date: 22 April 2015
Rotation: First wheat after canola
Variety: Trojan
Stubble: Canola unburnt
Rainfall:
GSR: 266mm (April–October)
Summer rainfall: 120mm
Soil mineral nitrogen: 84kg N/ha (0–60cm 21 April 2015)

Results

The application rates and timings of nitrogen applied to the trial are presented in Table 1. Since the effectiveness of nitrogen is clearly influenced by subsequent rainfall Table 2 presents the rainfall data for the five days following application and the next rainfall event greater than 5mm. The early stem elongation (GS30) application was the most affected by dry conditions following application.

i) Establishment and crop structure

Crops receiving either 30kg N/ha or 60kg N/ha at sowing produced significantly higher tiller numbers compared with the unfertilised crop. However at harvest (GS99) there were no differences in the final head numbers due to the rate of nitrogen applied (Table 3).

TABLE 1 Nitrogen application rates and timings at Yarrawonga, Victoria, 2015

Treatment	23 April 2015 (GS00) (kg N/ha)	29 June 2015 (GS30) (kg N/ha)	23 July 2015 (GS33) (kg N/ha)	Total nitrogen applied (kg N/ha)
1	-	-	-	nil
2	-	-	-	nil
3	30	30	-	60
4	-	30	30	60
5	60	60	-	120
6	-	60	60	120

Note: To maintain trial balance the trial included two untreated treatments.



TABLE 2 Rainfall measured for five days following each nitrogen application

	Five days rainfall following nitrogen application (mm)					Date of rainfall >5mm after application
Application 1: 23 April	23 April	24 April	25 April	26 April	27 April	
	0	4.2	8.6	0.4	0.2	25 April (2 days)
Application 2: 29 June	29 June	30 June	1 July	2 July	3 July	
	0.2	0	0.2	0	0.4	11 July (13 days)
Application 3: 23 July	23 July	24 July	25 July	26 July	27 July	
	0.2	6.8	3	1	0	24 July (2 days)

TABLE 3 Tiller counts 28 August, flag leaf fully emerged (GS39); head counts and crop height 16 November, harvest (GS99)

Nitrogen rate (kg N/ha)	Crop structure		
	GS39	GS99	
	Tillers (m^2)	Heads (m^2)	Height (cm)
0	307^{b}	279^{a}	73^{b}
60	370^{a}	318^{a}	76^{ab}
120	415^{a}	327^{a}	77^{a}
Mean	**364**	**308**	**75**
LSD	55	50	3
Nitrogen timing			
GS00 and **GS30**	372^{a}	314^{a}	75^{a}
GS30 and **GS33**	355^{a}	303^{a}	76^{a}
LSD	45	41	3
Figures followed by different letters are regarded as statistically significant.			

The highest rate (120kg N/ha) significantly increased crop height (by 4cm) compared with the nil plots. The timing of nitrogen did not have any significant impact on tiller numbers, head numbers or crop height.

ii) Dry matter production and nitrogen uptake

The 120kg N/ha rate produced significantly more DM at the flag leaf fully emerged stage (GS39) and the start of flowering (GS61), compared with where no nitrogen was applied. However at harvest (GS99) both rates of nitrogen (60, 120kg N/ha) produced higher biomass production than the unfertilised plots (Table 4). Again the timing of application did not affect DM production.

Nitrogen uptake in the crop was assessed at the same time as DM and also showed nitrogen uptake to be significantly greater where nitrogen was applied at all three crop stages assessed (GS33, GS39 and GS99). However at the start of flowering (GS61) only the highest rate of nitrogen applied had significantly greater nitrogen uptake (143.5kg N/ha) with the unfertilised plots showing the least nitrogen uptake (94.4 kg N/ha) (Table 5).

At the third node stage (GS33) there was significantly more nitrogen in the crop, an increase of 13.7kg N/ha, where the nitrogen was split between sowing (GS00) and start of stem elongation (GS30). However this effect was reversed at the start of flowering (GS61) where there was 12.5kg/ha more nitrogen when the

TABLE 4 Dry matter 12 June, early tiller (GS22); 29 June, stem elongation (GS30); 18 August, third node stage (GS33); 28 August, flag leaf emergence (GS39); 30 September, start of flowering (GS61) and 16 November, harvest (GS99)

Nitrogen rate (kg N/ha)	Dry matter (t/ha)					
	GS22	GS30–31	GS33	GS39	GS61	GS99
0	0.38	0.65	3.64^{a}	3.79^{b}	8.79^{b}	8.77^{b}
60	0.40	0.92	3.82^{a}	4.28^{ab}	9.51^{ab}	10.26^{a}
120	0.46	0.89	3.94^{a}	4.5^{a}	10.5^{a}	10.35^{a}
Mean	**0.41**	**0.82**	**3.80**	**4.19**	**9.60**	**9.79**
LSD			0.49	0.65	1.12	0.86
Nitrogen timing						
GS00 and **GS30**	0.41	0.82	3.80^{a}	4.15^{a}	9.58^{a}	9.96^{a}
GS30 and **GS33**			3.80^{a}	4.23^{a}	9.61^{a}	9.63^{a}
LSD			0.40	0.53	0.92	0.70

Figures followed by different letters are regarded as statistically significant.
Note. Since nitrogen wasn't applied at the time of application no LSD values are presented for GS22 and GS30.

TABLE 5 Nitrogen uptake 12 June, early tiller (GS22); 29 June, stem elongation (GS30); 18 August, third node stage (GS33); 28 August, flag leaf emergence (GS39); 30 September, start of flowering (GS61) and 16 November, harvest (GS99)

Nitrogen rate (kg N/ha)	Nitrogen uptake (kg N/ha)					
	GS22	GS30-31	GS33	GS39	GS61	GS99
0	19.5	32.5	77.0^{b}	74.6^{b}	94.5^{b}	75.7^{b}
60	21.2	46.7	101.8^{a}	103.1^{a}	116.5^{ab}	112.2^{a}
120	24.4	47.1	111.8^{a}	116.0^{a}	143.5^{a}	115.2^{a}
Mean	**21.7**	**42.1**	**96.9**	**97.9**	**118.1**	**101.0**
LSD			11.7	16.7	35.2	17.8
Nitrogen timing						
GS00 and **GS30**	21.7	42.1	103.7^{a}	97.9^{a}	111.9^{b}	98.2^{a}
GS30 and **GS33**			90.0^{b}	97.9^{a}	124.4^{a}	103.8^{a}
LSD			9.5	13.6	9.8	14.5

Figures followed by different letters are regarded as statistically significant.
Note. Since nitrogen wasn't applied at the time of application no LSD values are presented for GS22 and GS30.

timing was split between start of stem elongation (GS30) and the third node stage (GS33). There was however no significant difference at harvest (GS99) in nitrogen uptake in the crop.

iii) Normalised Difference Vegetation Index (NDVI)

Crop reflectance measurements taken with a GreenSeeker® showed significant differences in NDVI readings (crop reflectance measurement used as a surrogate canopy greenness reading) between the two different nitrogen application timings when measured at stem elongation (GS30), flag leaf emergence (GS39) and 17 days after flowering (Table 6). The early split timing (GS00 and GS30) was significantly greener (higher NDVI reading) at both stem elongation (GS30) and flag leaf emergence (GS39) than the later split timing crop. This changed 17 days after flowering where the later split timing of nitrogen was significantly greener.

Both rates of nitrogen applied were significantly greener than where no nitrogen was applied across all assessment timings (Table 6, Figure 1). At the start of stem elongation (GS30), flag leaf emergence (GS39) and flowering (GS61), the 120kg N/ha treatment was significantly greener than the 60kg N/ha treatment. At the flowering assessment (GS61) the NDVI readings for the earlier split of nitrogen were statistically significant, but this was not case with other four assessments.

iv) Yield and grain quality

Increased DM in the 120kg N/ha treatments at both timings did not increase grain yields (Table 7, Figure 2). The hard finish to the season, with little rainfall during September and October, combined with high temperatures at the start of October, decreased the yield potential and negated the need for higher rates of nitrogen. The crop yielded 4.45t/ha where 60kg N/ha

TABLE 6 NDVI (scale 0–1), 30 June, stem elongation (GS30); 19 August, third-node stage (GS33); 28 August, flag leaf emergence (GS39); 29 September, start of flowering (GS61) and 16 October (GS61 + 17 days)

Nitrogen rate (kg N/ha)	NDVI (scale 0–1)				
	GS30	GS33	GS39	GS61	GS61 + 17 days
0	0.39^{b}	0.51^{c}	0.54^{c}	0.40^{c}	0.26^{b}
60	0.41^{a}	0.58^{b}	0.63^{b}	0.51^{b}	0.29^{a}
120	0.41^{a}	0.64^{a}	0.67^{a}	0.57^{a}	0.30^{a}
Mean	**12.7**	**0.40**	**0.58**	**0.61**	**0.50**
LSD	3.27	0.02	0.05	0.03	0.03
Nitrogen timing					
GS00 and **GS30**	0.41^{a}	0.59^{a}	0.63^{a}	0.50^{a}	0.27^{b}
GS30 and **GS33**	0.40^{b}	0.57^{a}	0.60^{b}	0.49^{a}	0.29^{a}
LSD	0.01	0.04	0.03	0.03	0.01

Figures followed by different letters are regarded as statistically significant.

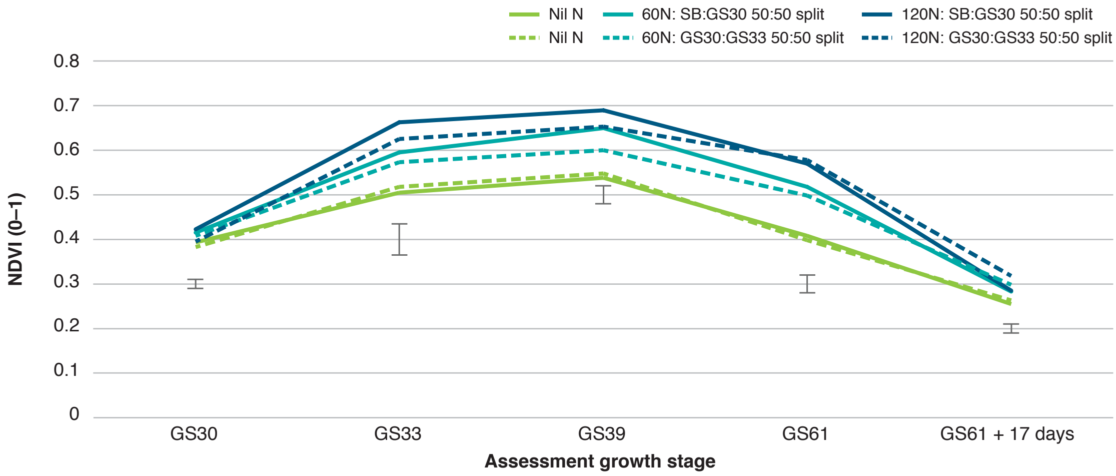

FIGURE 1 Influence of applied nitrogen timing and rate on NDVI (scale 0–1)*

The error bars are a measure of LSD.

TABLE 7 Yield, test weight, protein and screenings at harvest (GS99), 24 November 2015

Nitrogen rate (kg N/ha)	Yield and quality			
	Yield (t/ha)	**Test weight (kg/hL)**	**Protein (%)**	**Screenings (%)**
0	4.34[ab]	78.0[a]	8.6[c]	7.3[c]
60	4.45[a]	78.4[a]	11.2[b]	11.1[b]
120	4.23[b]	75.9[b]	14.1[a]	19.8[a]
Mean	**4.34**	**77.4**	**11.3**	**12.7**
LSD	0.22	1.34	0.7	3.27
Nitrogen timing				
GS00 and **GS30**	4.39[a]	77.5[a]	11.2[a]	12.4[a]
GS30 and **GS33**	4.29[a]	77.3[a]	11.4[a]	13.0[a]
LSD	0.18	1.1	0.6	2.7

Figures followed by different letters are regarded as statistically significant.

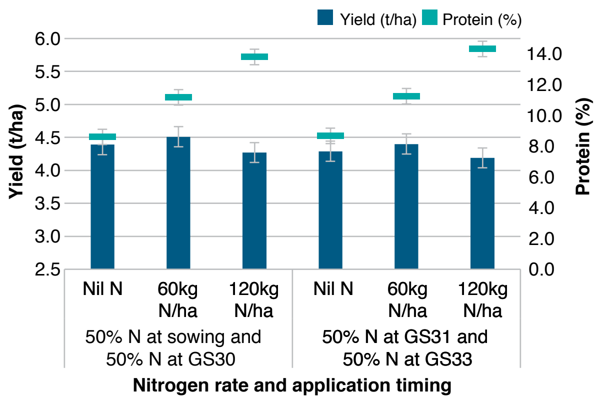

FIGURE 2 Grain yield and protein results, 24 November Yarrawonga, Victoria

The error bars are a measure of LSD

was applied (averaged across both split timings), which was significantly more than the 120kg N/ha treatment, which yielded 4.23t/ha (Table 7). Grain protein increased significantly as nitrogen rate increased, however screenings also increased with increased nitrogen. Test weight was less at the 120kg N/ha rate compared with the other nitrogen treatments.

There were no differences between the two nitrogen timing strategies for yield, test weight, protein or screenings (Table 7).

Trial 2: Dookie, Victoria

Sowing date: 19 May 2015
Rotation: First wheat after canola
Variety: Corack
Stubble: Canola unburnt
Rainfall:
GSR: 386mm
Summer rainfall: 78mm
Soil mineral nitrogen: 61kg N/ha

Results

The application rates and timings of nitrogen applied to the trial are presented in Table 8 with the rainfall surrounding application outlined in Table 9. The conditions for uptake of nitrogen at the Dookie site were more challenging than at Yarrawonga, since there were no rainfall events exceeding 5mm for more than 50 days following the GS33 application.

i) Establishment and crop structure

The application of 120kg N/ha significantly increased tiller production but not final head number relative to unfertilised crops (Table 10). The height of the crop canopy at harvest (GS99) was not increased with additional nitrogen. Varying the timing of the nitrogen application did not affect tiller numbers, head numbers or crop height.

TABLE 10 Tiller counts 24 September, flag emergence (GS39), head counts and crop height 20 November, harvest (GS99)

Nitrogen rate (kg N/ha)	GS39	GS99	
	Tillers (m^2)	Heads (m^2)	Height (cm)
0	325^{b}	278^{a}	72.8^{a}
60	349^{ab}	270^{a}	72.3^{a}
120	377^{a}	289^{a}	71.4^{a}
Mean	**350**	**279**	**72.2**
LSD	45	42	1.5
Nitrogen timing			
GS00 and **GS30**	366^{a}	285^{a}	72.0^{a}
GS30 and **GS33**	335^{a}	273^{a}	72.3^{a}
LSD	37	35	1.9

Figures followed by different letters are regarded as statistically significant.

ii) Dry matter production and nitrogen uptake

There were clear differences in crop DM production between crops with nil nitrogen and where the crop was fertilised, with 120kg N/ha producing significantly more DM at each assessment, except the start of grain fill/milky ripe (GS71) (Table 11). At flag leaf emergence (GS39) crops with 120kg N/ha applied had significantly more DM than crops with 60kg N/ha.

Timing of nitrogen application did not affect DM production across any of the assessment timings.

Nitrogen uptake followed similar trends to DM production with no differences in nitrogen uptake due to the timing of

TABLE 8 Nitrogen application rates and timings at Dookie, Victoria, 2015

Treatment	19 May (sowing) (kg N/ha)	26 May (GS00) (kg N/ha)	11 August (GS30) (kg N/ha)	11 September (GS33) (kg N/ha)	Total nitrogen applied (kg N/ha)
1	4.4	-	-	-	4.4
2	4.4	-	-	-	4.4
3	4.4	30	30	-	64.4
4	4.4	-	30	30	64.4
5	4.4	60	60	-	124.4
6	4.4	-	60	60	124.4

Note: To maintain trial balance the trial included two untreated treatments.

TABLE 9 Rainfall measured for five days following each nitrogen application

	Five days rainfall following nitrogen application (mm)					Date of rainfall >5mm after application
Application 1: 26 May	27 May	28 May	29 May	30 May	31 May	
	0	0	0.5	1	0	5 June (11 days)
Application 2: 11 August	11 August	12 August	13 August	14 August	15 August	
	1.6	0.2	2.8	0	0	27 August (17 days)
Application 3: 11 September	11 September	12 September	13 September	14 September	15 September	
	0	0	0	0	2	2 November (53 days)



TABLE 11 Dry matter 24 July, mid-tillering (GS23); 11 August, first node stage (GS31); 11 September, third node stage (GS33); 22 September, flag leaf emergence (GS39); 22 September, grain fill (GS71); and 20 November, harvest (GS99)

Nitrogen rate (kg N/ha)	Dry matter (t/ha)					
	GS23	GS31	GS33	GS39	GS71	GS99
0	0.41	0.64	1.8^{b}	3.5^{c}	6.0^{a}	7.8^{b}
60	0.45	0.75	2.1^{a}	4.1^{b}	6.4^{a}	10.2^{a}
120	0.42	0.76	2.1^{a}	4.6^{a}	6.0^{a}	9.7^{a}
Mean			**2.0**	**4.0**	**6.1**	**9.2**
LSD			0.2	0.5	0.6	1.3
Nitrogen timing						
GS00 and **GS30**	0.43	0.72	2.0^{a}	4.0^{a}	6.3^{a}	9.4^{a}
GS31 and **GS33**			2.0^{a}	4.1^{a}	6.0^{a}	9.1^{a}
LSD			0.2	0.4	0.5	1.0

Figures followed by different letters are regarded as statistically significant.

TABLE 12 Nitrogen uptake 24 July, mid-tillering (GS23); 11 August, first node stage (GS31); 11 September, third node stage (GS33); 22 September, flag leaf emergence (GS39); 22 September, grain fill (GS71); and 20 November, harvest (GS99)

Nitrogen rate (kg N/ha)	Nitrogen uptake (kg N/ha)					
	GS23	GS31	GS33	GS39	GS71	GS99
0	19.4	29.8	47.6^{b}	54.1^{c}	62.6^{c}	51.0^{b}
60	21.3	35.3	59.2^{a}	75.0^{b}	75.9^{b}	97.1^{a}
120	20.5	37.3	66.1^{a}	100.9^{a}	86.3^{a}	97.6^{a}
Mean			**57.6**	**76.7**	**74.9**	**81.9**
LSD			7.7	9.0	8.5	21.6
Nitrogen timing						
GS00 and **GS30**	20.4	34.1	59.9^{a}	77.1^{a}	75.7^{a}	85.9^{a}
GS31 and **GS33**			55.4^{a}	76.2^{a}	74.2^{a}	77.8^{a}
LSD			6.3	7.3	6.9	14.5

Figures followed by different letters are regarded as statistically significant.

application (Table 12, Figure 3). At flag leaf emergence (GS39) and grain fill (GS71) the nitrogen uptake increased significantly with the addition of each nitrogen rate, with 120kg N/ha having the greatest amount of nitrogen accumulated in the crop.

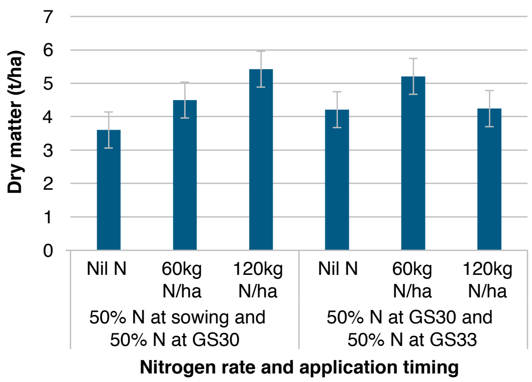

FIGURE 3 The effect of nitrogen application rate and timing on dry matter at harvest (GS99) at Dookie, 2015

iii) Normalised Difference Vegetation Index (NDVI)

The greenness of the crop canopy at the third node stage (GS33), flag leaf emergence (GS39), grain fill (GS71) and 12 days after the start of grain fill (GS71 + 12 days) (measured with a GreenSeeker) was significantly greater where nitrogen had been applied than where left untreated (Table 13). The crop treated with 120kg N/ha was the greenest throughout the assessment period. At grain fill (GS71) the crop greenness started to even out because of the dry and hot weather conditions (Figure 4).

The early split of nitrogen (GS00 and GS30) was significantly greener, from first node (GS31) until flag leaf was fully emerged (GS39) reflecting the higher nitrogen rates applied before third node stage (GS33) (Table 13).

At the start of stem elongation (GS31) the difference in NDVI readings between crops fertilised with nitrogen at sowing and the untreated crops gave an indication of how responsive the site might be to nitrogen application at each timing. This is referred to as the response index (RI). For example, at the third node stage (GS33)

TABLE 13 NDVI (scale 0–1), 11 August, first node stage (GS31); 11 September, third node stage (GS33); 22 September, flag leaf emergence (GS39); 15 October, start of grain fill (GS71) and 12 days after grain fill (GS71 + 12 days)

Treatment	NDVI (scale 0–1)				
Nitrogen rate (kg N/ha)	GS31	GS33	GS39	GS71	GS71+12d
0	0.37^{a}	0.45^{c}	0.50^{c}	0.38^{b}	0.24^{b}
60	0.39^{a}	0.53^{b}	0.58^{b}	0.41^{b}	0.27^{a}
120	0.39^{a}	0.57^{a}	0.67^{a}	0.43^{a}	0.29^{a}
Mean	**0.38**	**0.52**	**0.58**	**0.41**	**0.27**
LSD	0.03	0.03	0.04	0.03	0.02
Nitrogen timing					
GS00 and **GS30**	0.40^{a}	0.54^{a}	0.60^{a}	0.41^{a}	0.27^{a}
GS33 and **GS33**	0.37^{b}	0.49^{b}	0.56^{b}	0.41^{a}	0.27^{a}
LSD	0.02	0.02	0.03	0.02	0.02

Figures followed by different letters are regarded as statistically significant.

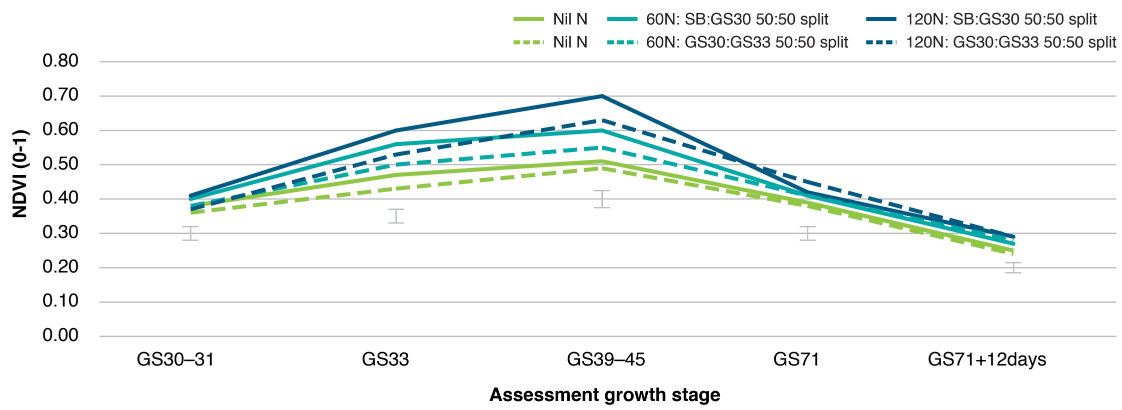

FIGURE 4 Influence of applied nitrogen timing and rate on NDVI (scale 0–1)
The error bars are a measure of LSD.

120kg N/ha produced an NDVI score of 0.57 compared with 0.45 for the untreated crop. In this case the RI was 1.26 (0.57/0.45 = 1.26), with a similar RI at Yarrawonga of 1.25 (0.64/0.51 = 1.25). These simple calculations indicate the yield response to nitrogen at Dookie was likely to be similar to that at Yarrawonga, albeit at a slightly lower level of background fertility.

iv) Yield and grain quality

Applying the highest rate of nitrogen (120kg N/ha) significantly decreased yield with a 0.18t/ha yield penalty compared with the untreated and 60kg N/ha treatments (Table 14, Figure 5).

TABLE 14 Yield, test weight, protein and screenings 24 November 2015, harvest (GS99)

Treatment	Grain yield and quality			
Nitrogen rate (kg N/ha)	Yield (t/ha)	Protein (%)	Test weight (kg/hL)	Screenings (%)
0	3.93^{a}	10.2^{b}	84.2^{a}	4.2^{b}
60	3.96^{a}	11.9^{a}	82.8^{b}	4.9^{b}
120	3.75^{b}	13.2^{a}	81.5^{c}	7.2^{a}
Mean	**3.88**	**11.8**	**82.8**	**5.4**
LSD	0.13	1.4	1.1	1.4
Nitrogen timing				
GS00 and **GS30**	3.9^{a}	12.0^{a}	82.8^{a}	5.4^{a}
GS33 and **GS33**	3.9^{a}	11.5^{a}	83.0^{a}	5.4^{a}
LSD	0.1	1.1	0.9	1.2

Figures followed by different letters are regarded as statistically significant.



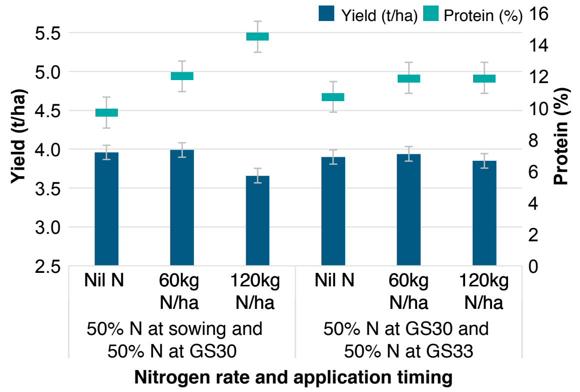

FIGURE 5 Grain yield and protein 24 November 2015, harvest (GS99)

The errors bars are a measure of LSD

Crops receiving 120kg N/ha also produced significantly lower test weights than the untreated crops and the 60kg N/ha treatment.

Grain protein was significantly less in the untreated crops compared with those where nitrogen was applied.

Screenings were significantly higher (by 2.3%) in the 120kg N/ha treatment compared with the other treatments.

As with the Yarrawonga trial, the timing of nitrogen did not influence yield or grain quality.

Conclusions

At both the Yarrawonga and Dookie sites the NDVI scores (a measurement of crop reflectance) indicated additional nitrogen was required. This was supported by strong DM growth responses as a result of nitrogen application. However, hot conditions between ear emergence (GS59) and the end of flowering (GS69) resulted in no yield advantage. At the Yarrawonga site applying the higher rates of nitrogen may still have been advantageous if the crop was cut for hay, as the fertilised crops had greater biomass.

Acknowledgements

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Management strategies for improved productivity and reduced nitrous oxide emissions for wheat following peas and canola

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Key points

- Nitrous oxide (N_2O) emissions during the 2015 growing season were indicative of nitrogen (N) losses of up to 9kg N/ha following canola and 6kg N/ha following peas, compared with 50kg N/ha and 58kg N/ha respectively during 2014.
- The highest N_2O emissions were recorded during July following rain after nitrogen application, however soil moisture never reached the levels witnessed during the 2014 winter.
- Wheat crops following peas yielded 4.04t/ha–4.49t/ha while wheat following canola yielded 4.04t/ha–4.31t/ha.
- The unfertilised wheat crop following peas yielded 4.42t/ha and produced the most profitable return with the lowest N_2O emissions.
- Despite the low protein of wheat following canola, with no nitrogen applied (except 8.8kg N/ha MAP), this crop was still more profitable than fertilised crops, which had significantly increased screenings.

Background

Nitrous oxide (N_2O) is an important greenhouse gas due to its high global warming potential (GWP), which means it can trap heat in the atmosphere, contributing to global warming. It is produced by soil microbial activity and is increased in the presence of nitrogen (N) fertilisers, high levels of organic residues and livestock waste, especially when soil conditions are anaerobic (void of oxygen — O), such as occurs with waterlogging. Recent research has revealed a range of reduction strategies that may benefit growers, both environmentally and economically.

In addition to producing N_2O, soils also release dinitrogen (N_2) gas through denitrification, particularly under waterlogged conditions. The total quantity of nitrogen lost as dinitrogen gas is up to 20–30 times greater than the nitrogen lost as N_2O, however dinitrogen is difficult to measure as it makes up a large proportion of the gas in the Earth's atmosphere. In comparison, as N_2O comprises only a small component of atmospheric nitrogen, it is technically easier to monitor changes in emissions due to management.

Aim

The aim of this ongoing project (2013–17) is to measure and demonstrate on-farm strategies that can reduce N_2O and improve nitrogen use efficiency by trialling four key practices:

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

Location: Yarrawonga, Victoria

Plot size: 13.75m x 25m

Sowing date: 22 April 2015

Crop: Wheat (cv Trojan)

Fertiliser: MAP (11:52:0) @ 80kg /ha at sowing (8.8 kg N/ha). All in-season nitrogen applications as specified by treatments

Paddock history (2014): Canola/peas

Methodology

Two wheat trials were established adjacent to one another on two different crop histories (2014 — canola and field peas) and experienced identical management (with the exception of nitrogen). During 2014 the canola and field pea blocks were sown side-by-side.

Each trial was a factorial design with six nitrogen treatments and four replicates, two previous crop histories (canola or field pea) and six nitrogen treatments. During 2014 the canola and field pea blocks were sown adjacent to each other on similar soil and using identical management (with the exception of nitrogen).

During 2015 the trial was sown with Trojan wheat. Six nitrogen treatments were applied as incorporated by sowing (IBS) on 22 April, first node (GS31) on 10 July and flag leaf just visible (GS37) on 19 August.

1. Nil nitrogen applied
2. 40 kg N/ha applied as urea at first node (GS31)
3. 80kg N/ha applied as urea at first node (GS31)
4. 80kg N/ha as urea incorporated by sowing (IBS)
5. 80kg N/ha applied as Entec urea (nitrification inhibitor) at first node (GS31)
6. Real time tactical (RTT) treatment — determined using a Greenseeker® to measure crop canopy greenness. The rate for the ex-canola trial was 35kg N/ha as urea split across first node (GS31) and flag leaf just visible (GS37) stages. The rate for the ex-field pea trial was 24kg N/ha as urea split across the same growth stages (GS31 and GS37).*

** The (RTT) treatment (#6) used the difference in normalised difference vegetative index (NDVI) readings at GS30-31 from the nil nitrogen (#1) and IBS treatment (#4) in order to calculate the responsiveness of the soil to nitrogen application. As a result only 24kg N/ha was applied following peas and 35kg N/ha following canola*

Note: All treatments had 8.8kg N/ha applied at sowing with the monoammonium phosphate (MAP), including the nil control.

Soil assessments

A number of measurements were taken throughout the season including N_2O monitoring in treatments 1 (nil), 3 (80kg N/ha at GS31) and 4 (80kg N/ha IBS).

Sampling of N_2O emissions occurred once each week during the growing season and twice per week after sowing and the first node stage (GS31) nitrogen applications for three weeks. Soil nitrogen was assessed in both the ex-canola and ex-field pea trials just before sowing (21 April) and in-season at the second node stage (GS32) (7 August) at depths 0–30cm and 30–60cm.

Crop structure assessments

Two fixed marker points were used for crop structure assessments, with 2m of crop row assessed at each point. Plant establishment, tiller and head number were all assessed at these fixed marker points.

Dry matter (DM) and nitrogen content were sampled at stem elongation (GS30) and first node (GS31) for treatments 1 and 4 only and at second node (GS32), flag leaf fully emerged (GS39), flowering (GS65) and harvest (GS99) for all treatments.

Grain yield and quality

The trial was harvested on 24 November 2015. All plots were assessed for grain yield, protein, test weight and screenings (<2.0mm screen).

Results and discussion

i) Soil nitrogen status

The ex-pea and ex-canola trial sites were sampled for soil nitrogen the day before sowing, with similar levels of mineral (available) soil nitrogen present in each site (Table 1).

Before the in-crop nitrogen application at first node (GS31) during spring, the amount of mineral nitrogen had decreased in the unfertilised plots, particularly in the 0–30cm depth.

ii) Crop structure

There were few significant differences in crop structure due to nitrogen management, however first node (GS31) urea applications resulted in significantly greater head numbers following both peas (40kg N/ha only) and canola (Figures 1 and 2). Despite the later timing and lower nitrogen rates applied, crop structure in the RTT treatment was similar to the other nitrogen strategies, suggesting greater soil mineral nitrogen levels than that measured at second node (GS32) (see Table 1).

iii) Dry matter

There were few significant differences in DM accumulation between the different nitrogen treatments, again suggesting a reasonable level of fertility following both peas and canola (Figures 3 and 4). Following peas it was the lower levels of applied nitrogen with the 40kg N/ha and RTT at first node (GS31) that tended to increase DM at harvest relative to the nil nitrogen and 80kg N/ha applications. There were no clear trends in DM production following canola. With both trials there were no significant differences in DM production due to the nitrogen strategy.

TABLE 1 Soil mineral nitrogen for ex-pea and ex-canola, sampled pre-sowing (21 April 2015) and in-season (7 August 2015)

Previous crop	Sampling depth (cm)	Pre-season	In-season	
		Nil N	Nil N	80kg N/ha IBS
		Mineral N (kg/ha)		
Peas	0–30	69.4	10.0	16.4
	30–60	24.6	21.7	12.9
	Total	**94.0**	**31.7**	**29.3**
Canola	0–30	59.2	7.3	45.4
	30–60	24.9	5.8	5.9
	Total	**84.1**	**13.1**	**51.3**

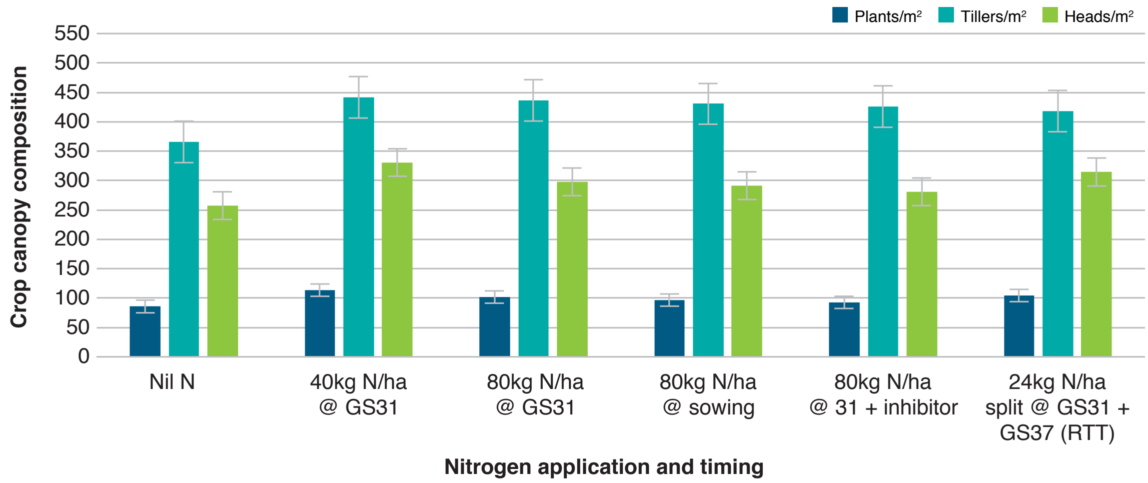

FIGURE 1 Plant, tiller and final head numbers for Trojan wheat *following peas* for all nitrogen treatments

The error bars are a measure of LSD

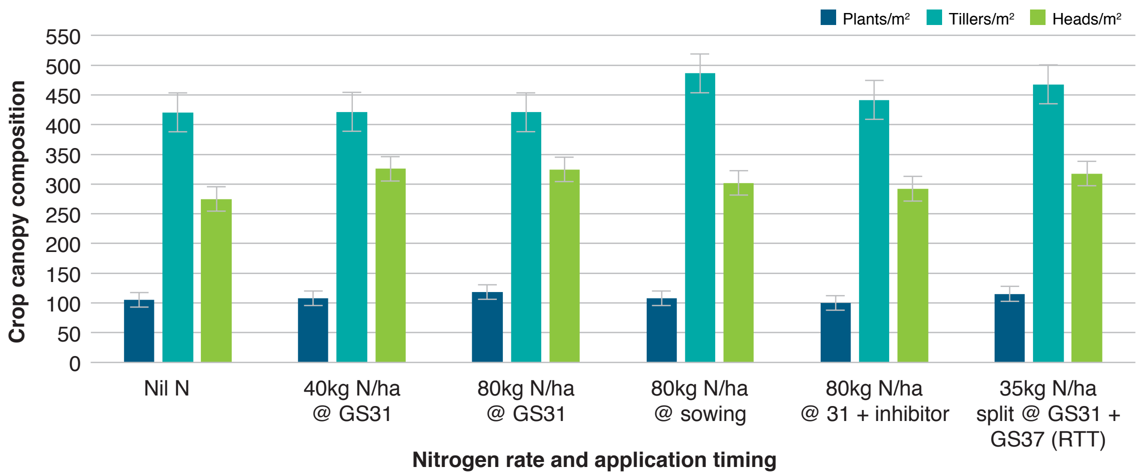

FIGURE 2 Plant, tiller and final head numbers for Trojan wheat *following canola* for all nitrogen treatments

The error bars are a measure of LSD

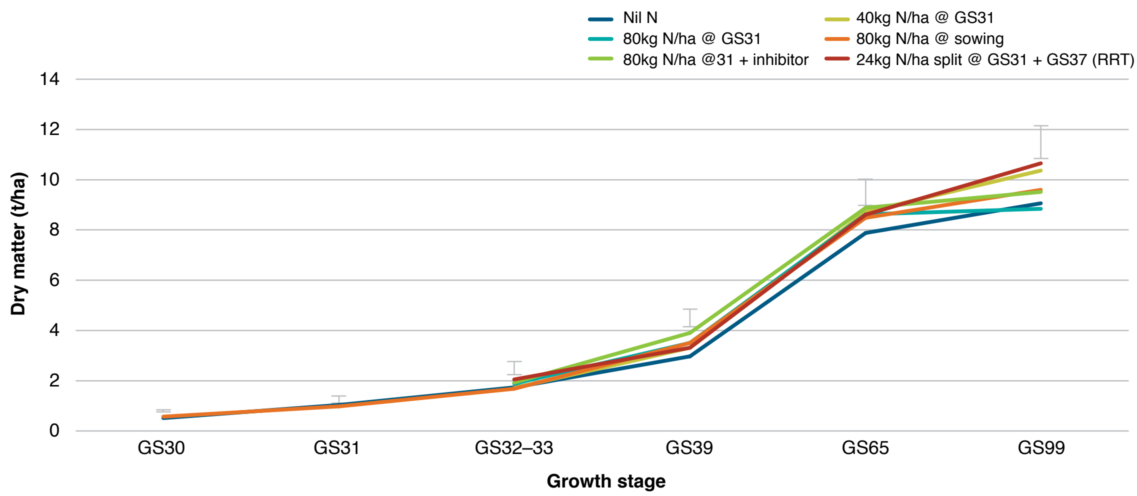

FIGURE 3 Dry matter production of Trojan wheat *following peas* for all nitrogen treatments

The error bars are a measure of LSD

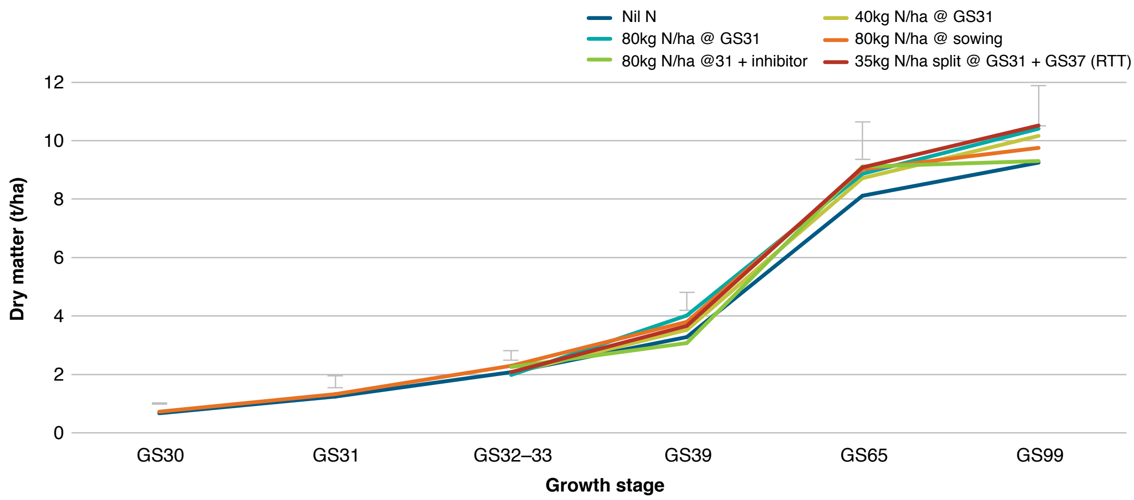

FIGURE 4 Dry matter production of Trojan wheat *following canola* for all nitrogen treatments
The error bars are a measure of LSD

iv) Nitrogen uptake

Despite few significant differences in DM accumulation there was a clear trend indicating greater nitrogen uptake into the crop canopy where fertiliser was applied (Tables 2 and 3). The unfertilised crop following peas had a nitrogen content of approximately 100kg N/ha, which was not significantly different to those crops receiving nitrogen fertiliser. The unfertilised crop following canola had accumulated 80kg N/ha at harvest (GS99), which was significantly less than the RTT treatment, which had a split dose of 35kg N/ha between the first node (GS31) and flag leaf just visible (GS37) stages.

TABLE 2 Nitrogen uptake in biomass *following peas* 29 June 2015, stem elongation (GS30); 13 July 2015, first node (GS31); 7 August 2015, second–third node (GS32–33); 28 August 2015, flag leaf fully emerged (GS39); 7 October 2015, mid-flowering (GS65); and 18 November 2015 harvest (GS99)

Treatment	GS30	GS31	GS32–33	GS39	GS65	GS99
Nil nitrogen	23^{b}	44^{a}	51^{a}	65^{c}	92^{c}	101^{a}
40kg N/ha @ GS31			58^{a}	84^{bc}	135^{a}	141^{a}
80kg N/ha @ GS31			63^{a}	105^{ab}	115^{abc}	113^{a}
80kg N/ha @ sowing	27^{a}	46^{a}	53^{a}	89^{abc}	104^{bc}	114^{a}
80kg N/ha @31 + inhibitor			65^{a}	113^{a}	120^{ab}	123^{a}
24kg N/ha split @ GS31 + GS37 (RTT)			68^{a}	81^{bc}	95^{bc}	121^{a}
Mean	**25**	**45**	**60**	**90**	**110**	**119**
LSD	20	10	20	26	27	42

Figures followed by different letters are regarded as statistically significant.

TABLE 3 Nitrogen uptake in biomass *following canola* 29 June 2015, stem elongation (GS30); 13 July 2015, first node (GS31); 7 August 2015, second–third node (GS32–33); 28 August 2015, flag leaf fully emerged (GS39); 7 October 2015, mid-flowering (GS65); and 18 November 2015, harvest (GS99)

Treatment	GS30	GS31	GS32–33	GS39	GS65	GS99
Nil nitrogen	32^{b}	49^{a}	69^{a}	67^{b}	76^{b}	83^{b}
40kg N/ha @ GS31			72^{a}	79^{ab}	98^{ab}	101^{ab}
80kg N/ha @ GS31			76^{a}	97^{a}	108^{a}	105^{ab}
80kg N/ha @ sowing	34^{a}	56^{a}	76^{a}	84^{ab}	96^{ab}	108^{ab}
80kg N/ha @31 + inhibitor			75^{a}	82^{ab}	112^{a}	95^{ab}
35kg N/ha split @ GS31 + GS37 (RTT)			75^{a}	82^{ab}	112^{a}	117^{a}
Mean	**33**	**52**	**74**	**82**	**100**	**101**
LSD	3	15	14	19	28	29

Figures followed by different letters are regarded as statistically significant.

TABLE 4 Summary of yield and quality for Trojan wheat sown *following peas* harvested 24 November 2015

Treatment	Yield and quality				
	Yield (t/ha)	Protein (%)	Test weight (kg/hL)	Screenings (%)	HI (%)
Nil nitrogen	4.42^{ab}	10.6^{d}	79.4^{a}	7.6^{b}	48.9^{a}
40kg N/ha @ GS31	4.29^{ab}	12.3^{c}	78.9^{ab}	10.0^{a}	41.7^{a}
80kg N/ha @ GS31	4.04^{b}	14.5^{a}	77.6^{ab}	16.3^{a}	46.0^{a}
80kg N/ha @ sowing	4.36^{ab}	13.7^{ab}	76.9^{b}	14.8^{a}	45.5^{a}
80kg N/ha @ 31 + Inhibitor	4.47^{a}	12.9^{bc}	78.5^{ab}	11.0^{ab}	47.2^{a}
24kg N/ha split @ GS31 + GS37 (RTT)	4.49^{a}	12.5^{bc}	78.0^{ab}	10.9^{ab}	42.4^{a}
Mean	**4.34**	**12.7**	**78.2**	**11.8**	**45.3**
LSD	0.41	1.2	2.4	6.7	7.3

Figures followed by different letters are regarded as statistically significant.

v) Grain yield and quality

There was no yield benefit in applying nitrogen where wheat followed peas, however there was a significant increase in grain protein of between 1.7–3.8% due to the application of nitrogen fertiliser (Table 4). The RTT treatment gave the best results of the applied nitrogen strategies using a late two-split (GS31 and GS37) of 24kg N/ha. However, as the unfertilised plots measured comparable yield and with 10.5% grain protein with the lowest screenings, this was the most profitable approach.

The grain yield of the unfertilised crop was significantly less than when 80kg N/ha was applied at sowing, with no difference between any other treatments (Table 5). There were no differences in yield between the different application strategies, however only crops that received 80kg N/ha had protein levels high enough to qualify for Australian Premium White (APW) (although they also had screenings exceeding 10%).

vi) Nitrous oxide emissions

Nitrous oxide emissions were at least five-fold less than those measured during 2014 when the winter period was excessively wet. The emissions equated to less than 0.5kg N_20/ha for the growing season (Table 6). Considering that N_20 emissions indicate higher losses as N_2, maximum indicative losses would still only equate to 6–9kg N/ha over the growing season. Following both peas and canola, emissions were highest where nitrogen was applied at first node (GS31), the canola emissions were 6–9kg N/ha. After peas the total nitrogen losses following the same nitrogen treatment were 4–6kg N/ha during the growing season. The lowest emissions came from crops where no nitrogen was applied— as would be expected (Figures 5 and 6).

TABLE 6 Total nitrous oxide emissions for the period 22 April–9 November 2015 for nil, 80kg N/ha IBS or applied at first node (GS31) for wheat sown after field peas and canola at Yarrawonga

Previous crop	Treatment	g N_2O/ha/season
Peas	Nil nitrogen	80
	80kg N/ha IBS-	166
	80kg N/ha GS31	198
Canola	Nil nitrogen	112
	80kg N/ha IBS	195
	80kg N/ha GS31	300

TABLE 5 Summary of yield and quality for Trojan wheat sown *following canola* harvested 24 November 2015

Treatment	Yield and quality				
	Yield (t/ha)	Protein (%)	Test weight (kg/hL)	Screenings (%)	HI (%)
Nil nitrogen	4.04^{b}	8.5^{d}	78.5^{a}	6.2^{c}	43.8^{ab}
40kg N/ha @ GS31	4.24^{ab}	10.3^{cd}	78.1^{a}	8.6^{bc}	41.7^{ab}
80kg N/ha @ GS31	4.11^{ab}	13.4^{a}	75.0^{b}	17.5^{a}	39.5^{b}
80kg N/ha @ sowing	4.31^{a}	11.3^{bc}	78.2^{a}	13.4^{ab}	44.5^{ab}
80kg N/ha @ 31 + Inhibitor	4.24^{ab}	12.1^{ab}	77.8^{a}	12.4^{abc}	45.6^{a}
35kg N/ha split @					
GS31 + GS37 (RTT)	4.28^{ab}	9.9^{cd}	78.4^{a}	8.7^{bc}	41.2^{ab}
Mean	**4.20**	**10.9**	**77.7**	**11.1**	**42.7**
LSD	0.27	1.8	2.3	6.7	5.3

Figures followed by different letters are regarded as statistically significant.

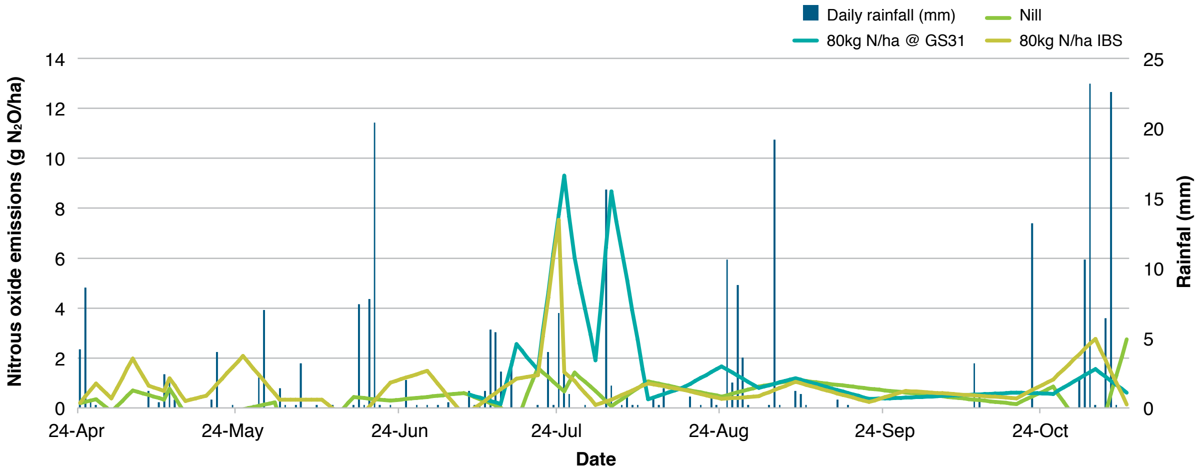

FIGURE 5 Nitrous oxide emissions for the period of 4 May–9 December for nitrogen fertiliser treatments for wheat *following peas* at Yarrawonga, 2015

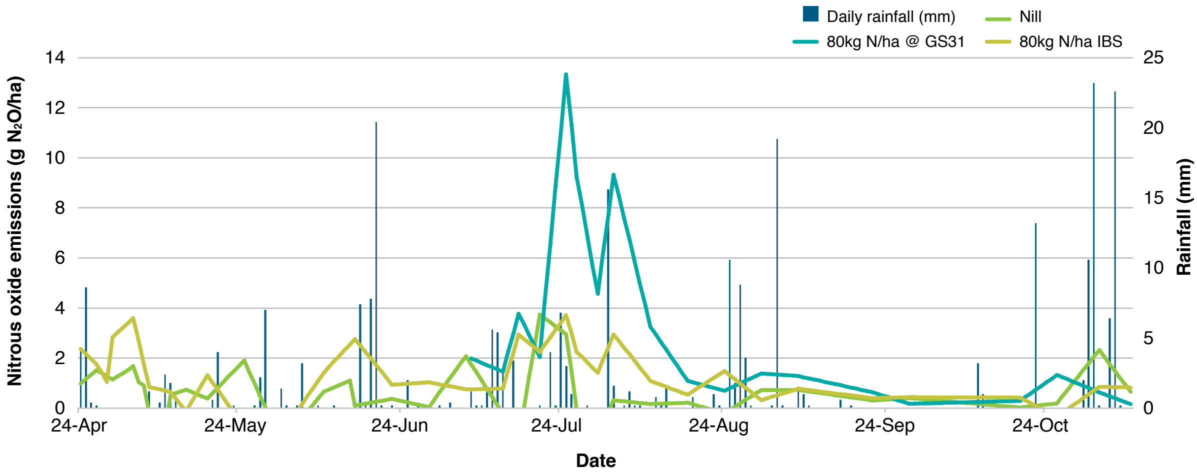

FIGURE 6 Nitrous oxide emissions for the period of 4 May–9 December for nitrogen fertiliser treatments for wheat *following canola* at Yarrawonga, 2015

Interestingly, peak emissions coincided with first node (GS31) application during July and a period where it rained on 13 of the next 20 days (Figure 7).

FIGURE 7 Average soil moisture in the top 12cm of the soil sampled on 20th day of each month) at Yarrawonga, 2015

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Thanks go to the Inchbold Family, Yarrawonga, Victoria.

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Seasonal soil moisture and nitrogen availability

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Key points

- Soils in the Rutherglen region of Victoria are highly variable.
- Most soils across the region increase in clay content in the subsoil, which has a limited capacity to supply water to plant roots.
- The distribution of plant-available nitrogen (nitrate-nitrogen) throughout these soils is variable, with some soils having a high concentration of nitrogen (N) near the soil surface, while others store nitrogen at depth.
- Sampling for deep soil nitrogen (DSN) by combining all soil from 0–60cm depth does not give a clear picture of where nitrogen is located throughout the profile.

Background

During June 2015 the North East Catchment Management Authority (NECMA) with funding from the Australian Government's National Landcare Programme, enabled Riverine Plains Inc to install and monitor soil moisture probes in cropping paddocks at 11 sites across the Rutherglen region of Victoria through the *Soil Moisture Probe Network Project*.

The objective of this project was for growers to understand how knowledge of stored soil moisture can inform their decisions about applying fertiliser. For example, if the soil profile has sufficient moisture, growers might decide to apply enough nitrogen during spring to satisfy the full crop requirement. However, if there is limited stored soil moisture, growers might only apply a smaller amount of fertiliser, as the crop would be entirely dependent on opportune rainfall events to take it through to harvest.

In addition, measurements of DSN post-harvest and pre-sowing means the amount of nitrogen mineralised during summer can be accounted for when planning the nitrogen strategy for the following season.

The Sustainable Agriculture Victoria: Fast-Tracking Innovation initiative made possible with the support of the Foundation for Rural and Regional Renewal (FRRR) together with the William Buckland Foundation allowed the sampling of DSN (broken into incremental depth samples) at each of these sites. By connecting the results from soil nitrogen sampling to soil moisture status, growers can predict if the stored nitrogen will be available to the crop through the year, or if it will be lost through leaching (due to accumulation of nitrogen at depth under high soil moisture conditions).

Aim

The aim of this project was to increase our understanding of nitrogen availability and movement across, and between, seasons and to appreciate how nitrogen availability is intimately related to soil moisture status.

Method

Soil moisture probes were installed at 11 sites across the Rutherglen region during June 2015. Probes were removed during harvest (November 2015) and in preparation for sowing (late March 2016).

Each probe measured up to four depth intervals (10, 30, 50 and 90cm below the soil surface), with values logged every two hours. The data was manually downloaded from each probe on a regular basis. Gaps in the dataset occurred if the probe was damaged.

Deep soil nitrogen sampling was carried out at each of the soil moisture probe locations during June and December 2015, and April 2016 (Figure 1). The June sampling was carried out at a time when many growers across the region undertake DSN sampling to identify how much nitrogen they need to apply to meet crop demand through spring. The December sampling, post-harvest, provided a measure of post-crop residual nitrogen, and the April sampling provided information on the amount of nitrogen lost or mineralised (becoming more plant-available) during the summer months; ready for sowing.

Sampling at each of the 11 soil moisture probe sites consisted of one core sample, which was split into increments (0–10, 10–20, 20–30, 30–60 and 60–100cm) before being submitted to the laboratory for analysis of mineral nitrogen (nitrate + ammonium) and total nitrogen (includes organic and inorganic forms — i.e. the total nitrogen soil bank).

FIGURE 1 Locations of the 11 soil moisture probes installed across the Rutherglen area

By measuring both mineral nitrogen and total nitrogen growers can appreciate the role of organic forms of nitrogen in cycling and mineralisation processes.

As the nitrogen samples collected were not replicated, they cannot be statistically analysed. As such, the results presented provide an indication of nitrogen availability, however as they are sampled from one point in the paddock, there is the possibility the results are not representative of the rest of the paddock.

Results

Soil moisture and available nitrogen

Please note the graphs included in this section have not been plotted on a common axis, so take care when comparing the values between sites.

The laboratory results for the ammonium fraction were highly variable and potentially unreliable. As such, they have been excluded from the analysis, with just the nitrate-nitrogen fraction of mineral nitrogen being presented.

The monthly rainfall data for Rutherglen is presented in Figure 2 to provide context to the soil moisture results presented. While there was plentiful rainfall during winter, spring was dry. The rainfall during December and January contributed to replenishing stored soil moisture, however there was little follow-on rainfall during February and March.

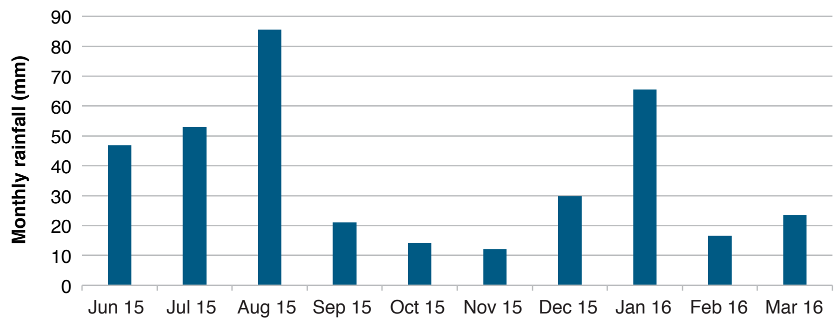

FIGURE 2 Monthy rainfall recorded at Rutherglen, June 2015–March 2016

Location: Springhurst/Lilliput

2014 crop and stubble practice: Wheat, stubble burnt

2015 crop and yield: Wheat, 3.9t/ha

2015 nitrogen applied: 9kg N/ha MAP, 37kg N/ha urea

Timing of 2015 in-crop nitrogen application: Mid-June

2015 stubble management (post-harvest): Stubble burnt

Soil moisture was non-limiting throughout most of the 2015 cropping season at Springhurst/Lilliput, Victoria, until the season dried off during September, at which point soil moisture started to withdraw down to 50cm. Rainfall during November wet the profile somewhat, to a depth of 30cm, however the soil had dried out in the top 10cm layer by sowing (Figure 3).

The June 2015 nitrogen sampling showed a large bulge of nitrate (plant-available nitrogen) at 30–100cm depth, which is likely due to accumulation of nitrogen over time, (Figure 4). This bulge largely disappeared by the post-harvest sampling, with limited nitrogen remaining by the pre-sowing sampling. While the crop may have used some of this DSN, it is likely at least some of the nitrogen in the 60–100cm layer was lost through leaching while soil moisture levels were high throughout the season.

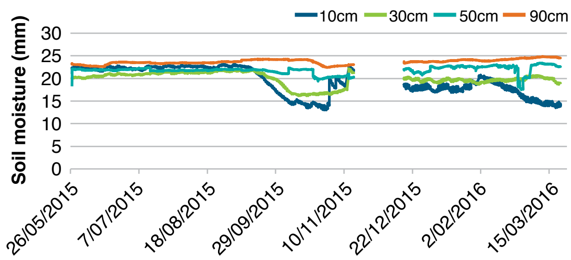

FIGURE 3 Soil moisture levels at Springhurst/Lilliput, Victoria June 2015–March 2016

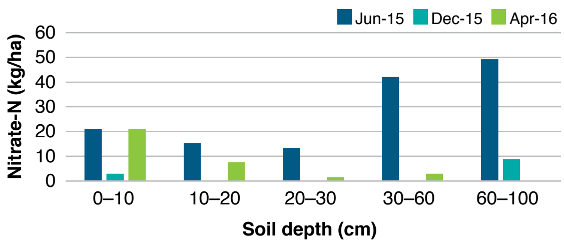

FIGURE 4 Plant-available (nitrate) soil nitrogen levels, at Springhurst /Lilliput, Victoria June 2015–April 2016

Location: East Rutherglen

2014 crop and stubble practice: Canola, stubble burnt

2015 crop and yield: Wheat, 5t/ha

2015 nitrogen applied: 8kg N/ha MAP, 101kg N/ha urea

Timing of 2015 in-crop nitrogen application: Late July, early August

2015 stubble management (post-harvest): Stubble burnt

The East Rutherglen site maintained high soil moisture levels through the season, until mid-September 2015 when the season turned dry (Figure 5). While the 10cm soil layer showed strong extraction of stored soil moisture, only a small change is seen at 30cm, due to the high subsoil clay content at this site. However, the large decrease in plant available soil nitrogen (nitrate-nitrogen) from June to December 2015 (post-harvest) indicates plants were extracting nutrients (and therefore water) to a depth of at least 60cm.

The June 2015 nitrate-nitrogen sampling showed a large amount of nitrogen (170kg N/ha) at the 0–10cm depth before 101kg N/ha was applied as urea during late July/ early August (Figure 6). This indicates plants potentially had access to 271kg N/ha during late winter. As it was quite wet at this time, it is likely some of this nitrogen was lost as gaseous-nitrogen due to denitrification (gaseous-nitrogen loss), while the rest was taken up by the crop. Conversely, the lack of change in DSN (60–100cm) indicates that while the crop may not have used this nitrogen, it is unlikely to have leached deeper due to the high clay content at this site. Summer mineralisation resulted in almost 40kg N/ha available to the following crop.

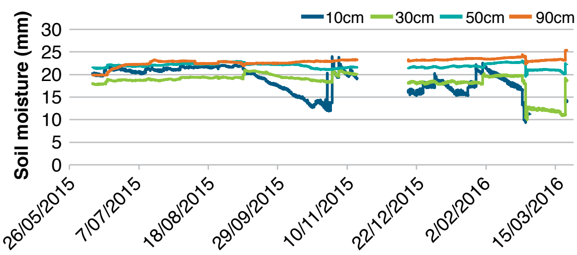

FIGURE 5 Soil moisture levels at East Rutherglen, Victoria June 2015–March 2016

* The sharp drop in soil moisture in late February is due to a damaged probe.

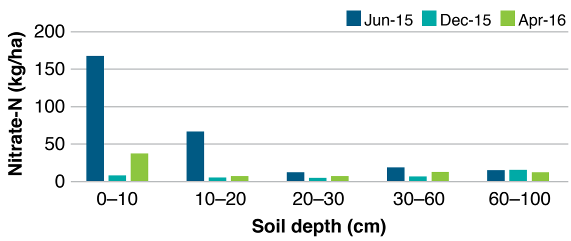

FIGURE 6 Plant-available soil nitrogen levels, at East Rutherglen, Victoria June 2015–April 2016

Location: Wahgunyah

2014 crop and stubble practice: Canola, stubble burnt

2015 crop and yield: Wheat, 4.25t/ha

2015 nitrogen applied: 46kg N/ha urea, 27L N/ha Sulsa (liquid urea — 100L/ha of product applied)

Timing of 2015 in-crop nitrogen application: Granular urea during June, liquid during August

2015 stubble management (post-harvest): Stubble burnt

The Wahgunyah site maintained high soil moisture through the season until mid-September, at which point the crop started to run the soil moisture levels down (Figure 7). Although a soil pit was not available at this site, it appears to be free draining and lighter textured down to at least 50cm, with plants accessing moisture down to 50cm with ease. The fact the 50cm layer had a large range between the upper and lower limits (field capacity and permanent wilting point) indicates a lighter texture, compared with the previous site at East Rutherglen, which is known to have a high clay content.

The June nitrate-nitrogen samples show an accumulation in the 0–10cm soil layer, with little nitrogen at depth (Figure 8). As plants can freely extract water down to at least 50cm, it is likely the crop extracted nutrients from that layer also, which is supported by the absence of detectable nitrate-nitrogen in the 30–60cm soil layer. The lack of change in nitrate-nitrogen levels at the 60–100cm layer indicates plants are not extracting from that layer, which is supported by Figure 6, indicating the deep soil layer may be high in clay, with little penetration extraction of water or nutrients by plant roots.

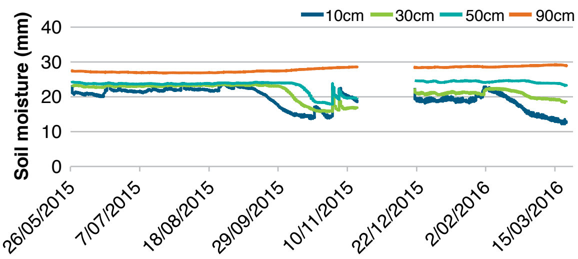

FIGURE 7 Soil moisture levels at Wahgunyah, Victoria June 2015–March 2016

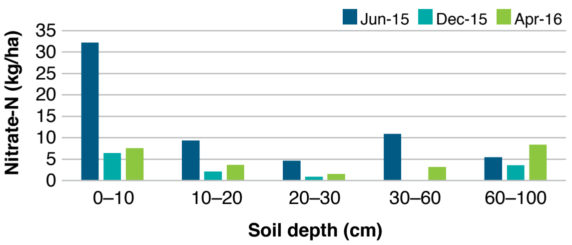

FIGURE 8 Plant-available soil nitrogen levels, at Wahgunyah, Victoria June 2015–April 2016

Location: Browns Plains

2014 crop and stubble practice: Canola, stubble burnt in windrows

2015 crop and yield: Wheat, 5t/ha

2015 nitrogen applied: 87kg N/ha urea

Timing of 2015 in-crop nitrogen application: June, September

2015 stubble management (post-harvest): Stubble burnt

The 10cm soil moisture sensor at Browns Plains was faulty, so is not shown in Figure 9. The remaining data shows plants were extracting moisture down to a depth of at least 50cm and likely a bit deeper, while the 90cm layer shows a heavy clay layer with minimal potential to extract water (Figure 9).

Figure 10 shows nitrogen distributed to depth during June, with the highest concentration in the 10–20cm soil layer. It appears plants were extracting nutrients through the profile, based on the low levels of nitrate-nitrogen present during December, and may have almost depleted all nutrient reserves by harvest. Mineralisation during the summer months has provided some nitrate-nitrogen prior to sowing, although this is primarily only in the 0–10cm layer, as would be expected.

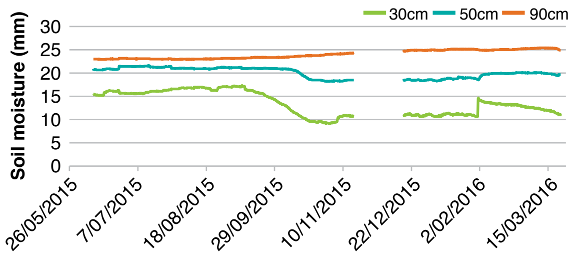

FIGURE 9 Soil moisture levels at Browns Plains, Victoria June 2015–March 2016

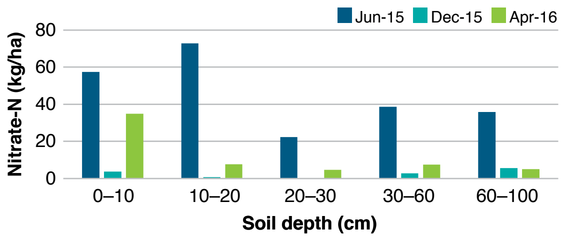

FIGURE 10 Plant-available soil nitrogen levels, at Browns Plains, Victoria June 2015–April 2016

Location: Cornishtown

2014 crop and stubble practice: Wheat, stubble burnt

2015 crop and yield: Wheat, 5t/ha

2015 nitrogen applied: 58kg N/ha urea

Timing of 2015 in-crop nitrogen application: Late June

2015 stubble management (post-harvest): Stubble burnt

The soil moisture graph from the Cornishtown site (Figure 11) indicates a soil profile that gradually increases in clay content with depth, based on the staged decrease in soil moisture at each depth from late September to the start of November, with the November rain event only impacting on the 10cm layer.

This correlates well with the nitrate-nitrogen values (Figure 12). While there was measurable nitrate-nitrogen to depth during June, although probably less than optimum in the 0–10cm layer, the crop depleted the nutrient stores to depth by harvest. However, the stores of nitrogen in the topsoil were replenished with summer mineralisation of nitrogen.

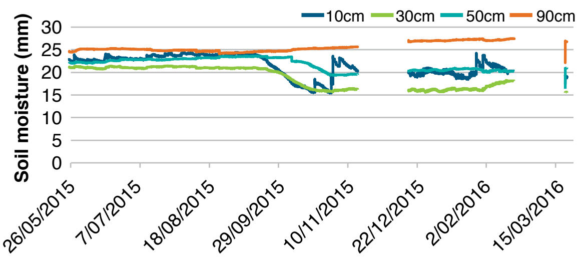

FIGURE 11 Soil moisture levels at Cornishtown, Victoria June 2015–March 2016

* Soil moisture sensor not working during early March 2016.

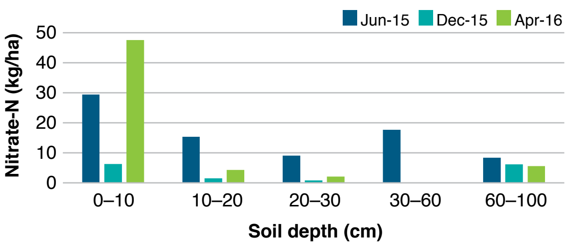

FIGURE 12 Plant-available soil nitrogen levels, at Cornishtown, Victoria June 2015–April 2016

Location: Carlyle

2014 crop and stubble practice: Canola, stubble burnt in windrows

2015 crop and yield: Wheat, cut for hay 5t/ha

2015 nitrogen applied: 74kg N/ha urea

Timing of 2015 in-crop nitrogen application: Late June, August

2015 stubble management (post-harvest): Stubble burnt

The crop at the Carlyle site appears to have had limited access to soil moisture (Figure 13), with the 0–10cm sensor being the only one to show clear change with rainfall or crop water extraction. This indicates the site is located on a heavy clay, and/or has a high amount of run-off — both of which would limit the amount of rainfall infiltrating to depth. This suggestion is supported by the nitrate-nitrogen values shown in Figure 14, which reveal the nitrogen is mostly stored in the 0–10 and 10–30cm layers, with only minimal nitrogen moving down to 60cm. As most of the nitrate-nitrogen is in the topsoil layers, this, with additional in-crop nitrogen, are likely being utilised by the crop. However it is likely that significant denitrification occurred on this site during the wet winter, which may have been subject to prolonged waterlogging due to its inability to drain water. The amount of nitrate-nitrogen mineralised during summer was surprisingly low, suggesting the soil sample may have been taken from an area of bare ground, from which there was limited organic matter (OM) to drive the mineralisation process.

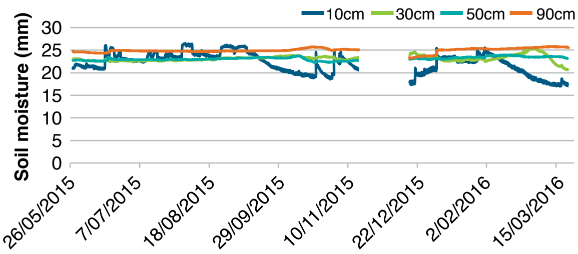

FIGURE 13 Soil moisture levels at Carlyle, Victoria June 2015–March 2016

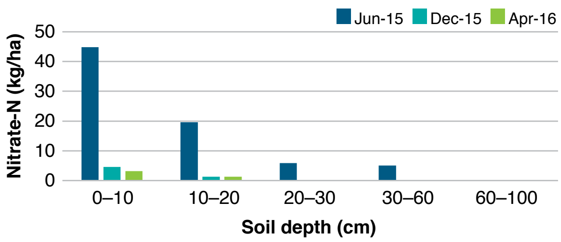

FIGURE 14 Plant-available soil nitrogen levels, at Carlyle, Victoria June 2015–April 2016

Location: Indigo

2014 crop and stubble practice: Wheat, stubble burnt

2015 crop and yield: Feed wheat, 3.5t/ha

2015 nitrogen applied: 10kg N/ha MAP, 46kg N/ha urea

Timing of 2015 in-crop nitrogen application: July

2015 stubble management (post-harvest): Stubble burnt

The Indigo site looks to be quite free draining down to at least 30cm, as shown by the 10cm and 30cm depths in Figure 15, showing similar soil moisture storage. The range in soil moisture storage (difference from wet to dry) in the 10cm and 30cm layers, and the rapidity with which the profile wet and drained, indicates this soil is likely to have a high gravel content. While infiltration decreased down to 50cm, there were still some plant roots at depth, as seen by water extraction by the crop during early October 2015 after the 10cm and 30cm layers were depleted of soil moisture.

The soil nitrate-nitrogen values shown in Figure 16 support this observation. The even distribution of nitrogen through the profile during June indicates easy movement of nutrients down the profile, while the lack of measurable nitrogen post-harvest indicates the crop used this nitrogen within season, with leaching of nutrients below the measured depth also possible. Movement of mineralised nitrogen over summer was also measured, with the 10–20cm depth recording as much nitrate-nitrogen as is in the surface 0–10cm layer.

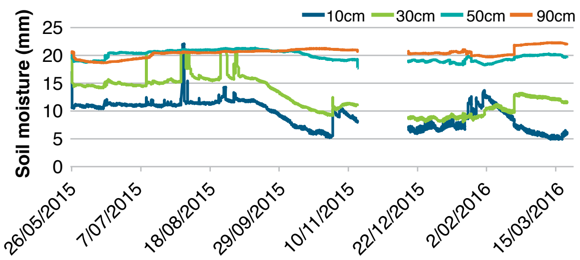

FIGURE 15 Soil moisture levels at Indigo, Victoria June 2015–March 2016

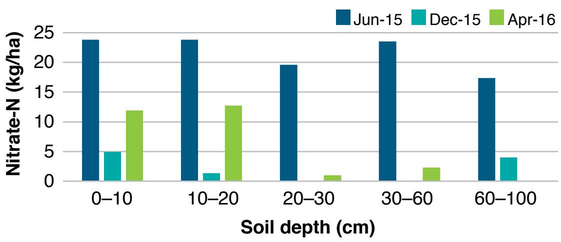

FIGURE 16 Plant-available soil nitrogen levels, at Indigo, Victoria June 2015–April 2016

Location: Norong Central

2014 crop and stubble practice: Wheat, stubble burnt

2015 crop and yield: Wheat, 3t/ha

2015 nitrogen applied: 8kg N/ha MAP, 92kg N/ha urea

Timing of 2015 in-crop nitrogen application: Late July, late August

2015 stubble management (post-harvest): Stubble burnt

The Norong Central site appeared to be waterlogged most of the winter, as shown by the 10cm depth layer having a higher soil moisture content than the deeper layers (Figure 17). This can only occur if the topsoil has a greater clay content than the subsoil, and so can hold more water (which is unlikely), or if the soil is saturated, with free-standing water. Saturation is likely, as the 30cm layer also held more water than it would otherwise.

While the soil moisture results indicate that the plant roots may not have gone much past the 30cm layer, due to the wet conditions, the nitrate-nitrogen at depth was decreased by harvest, by plants or through losses to depth (Figure 18). Moreover, although nitrogen supply at depth was replenished during summer, presumably through mineralisation, the amount measured at depth is surprising given most mineralisation processes occur in the top 0–10cm layer of soil, with limited movement to depth. One possibility may be that the location for the April sampling was a stock camp during the summer months.

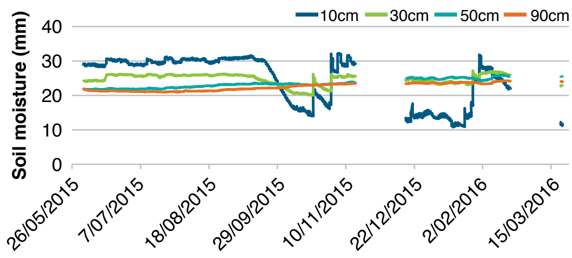

FIGURE 17 Soil moisture levels at Norong Central, Victoria June 2015–March 2016

*Soil moisture sensors not working in early March 2016.

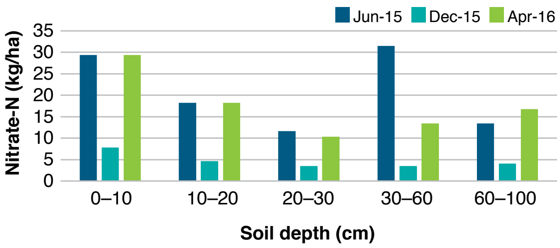

FIGURE 18 Plant-available soil nitrogen levels, at Norong Central, Victoria June 2015–April 2016

Location: Norong

2014 crop and stubble practice: Wheat, stubble burnt

2015 crop and yield: Wheat, 4t/ha

2015 nitrogen applied: 9kg N/ha MAP, 74kg N/ha Urea

Timing of 2015 in-crop nitrogen application: June, August

2015 stubble management (post-harvest): Stubble burnt

The soil moisture profile at Norong showed a high capacity to store and release moisture from the 10cm depth, due to a light-textured topsoil (Figure 19). However, there was likely a large texture change into the subsoil, with a large increase in clay content. This would explain why the moisture release range of the 30cm and 50cm soil layers is similar, and relatively small (small difference between wet and dry moisture levels). The decline in soil moisture in the 30cm and 50cm depth during mid-October indicates plants were accessing to this depth, with the nitrate-nitrogen values supporting the soil moisture results (Figure 20). While some nitrogen may be lost to depth, it is likely plants used most of the nitrogen.

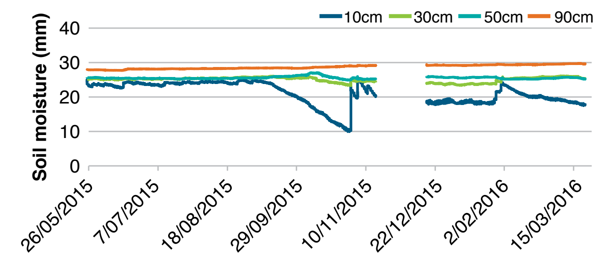

FIGURE 19 Soil moisture levels at Norong, Victoria June 2015–March 2016

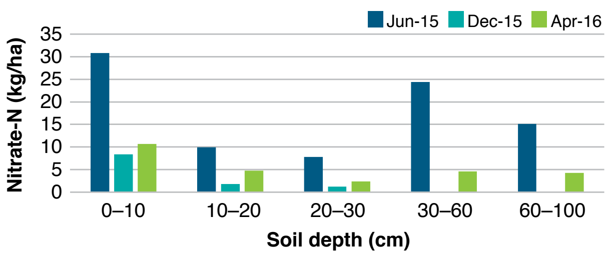

FIGURE 20 Plant-available soil nitrogen levels, at Norong, Victoria June 2015–April 2016

Location: Dugays Bridge

2014 crop and stubble practice: Lucerne, two-way disc before cropping

2015 crop and yield: Wheat, 2.5t/ha

2015 nitrogen applied: 18kg N/ha DAP

Timing of 2015 in-crop nitrogen application: None applied

2015 stubble management (post-harvest): Stubble burnt

The Dugays Bridge soil moisture probe indicates this site is likely to be free draining, which would be expected as it is close to the Murray River (Figure 21). As such, it is unknown if there is any lateral water movement from the river at the 50cm and 90cm deep soil layers. However, when the 10cm and 30cm sensors started drawing moisture during September, the 50cm sensor showed slight drawdown, as did the 90cm sensor. This indicates roots were accessing water at depth.

The nitrate-nitrogen results (Figure 22) show the crop accessed almost all available nitrogen reserves by harvest, with little nitrogen remaining in the profile at the end of the season. The poor mineralisation of nitrate-nitrogen during summer indicates most of the 'potentially mineralisable nitrogen' fraction in the total soil nitrogen bucket was accessed. This means the 2016 crop would require larger nitrogen inputs to meet its yield potential.

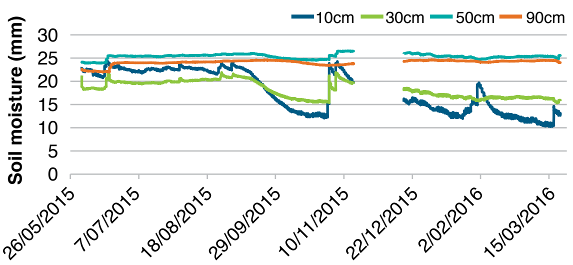

FIGURE 21 Soil moisture levels at Dugays Bridge, Victoria June 2015–March 2016

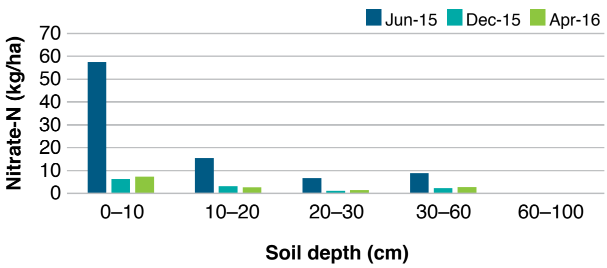

FIGURE 22 Plant-available soil nitrogen levels, at Dugays Bridge, Victoria June 2015–April 2016

Location: South-west Rutherglen

2014 crop and stubble practice: Canola, stubble burnt in windrows

2015 crop and yield: Wheat, 4.9t/ha

2015 nitrogen applied: 10kg N/ha MAP, 46kg N/ha urea

Timing of 2015 in-crop nitrogen application: July

2015 stubble management (post-harvest): Stubble burnt

The soil moisture profile of the South-west (SW) Rutherglen site indicates this soil had plentiful capacity to store and release water for plant growth, with plants accessing moisture down to at least 50cm, if not deeper (Figure 23).

The increase in nitrate-nitrogen down to 60cm indicates nitrogen can be easily leached in this soil (Figure 24). While plants are likely to take up most of this nitrogen, as roots accessed this depth, there is potential for nitrogen to be lost deeper in the soil profile. This is seen from the April sampling, where the nitrate-nitrogen values increased at the 60–100cm soil depth. This demonstrates the ability of this soil to move nutrients to depth.

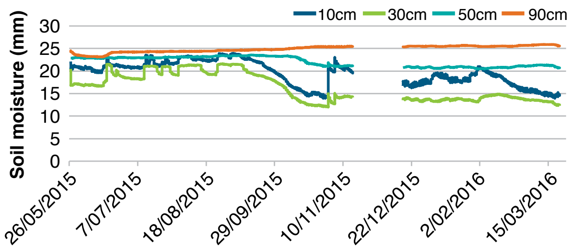

FIGURE 23 Soil moisture levels at South-west Rutherglen, Victoria June 2015–March 2016

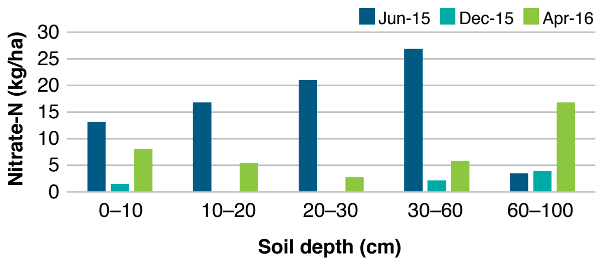

FIGURE 24 Plant-available soil nitrogen levels, at South-west Rutherglen, Victoria June 2015–April 2016

Importance of incremental depth sampling

The accepted practice for sampling DSN is to take a core soil sample down to 60cm or 100cm, homogenise the sample and take a subsample from that for laboratory analysis. This effectively provides an average nitrogen sample for the whole core. While this provides an indicator of stored nitrogen across the whole season, it doesn't provide any information on when the plants will be able to access this nitrogen.

The incremental depth sampling was carried out to help growers appreciate the averaged deep nitrogen sample has limitations.

Feedback to date from this project is that some growers are already changing the way they carry out their sampling, with the soil core being broken up into at least two increments (0–30cm and 30–60cm) to better understand where the nitrogen is stored.

Splitting cores into more than two increments would become cost-prohibitive, however even the simple change to two increments can provide useful information on nutrient availability, resulting in more informed decision-making and greater environmental stewardship.

Two examples from the June 2015 dataset are shown in Table 1 and Table 2 to demonstrate the value of incremental sampling.

Based on the 0–100cm depth average of 56kg N/ha at East Rutherglen in Table 1, a grower may decide to apply more nitrogen to the crop soon after sowing. However, based on the 0–30 and 30–100cm averages, which show plentiful nitrogen in the surface soil available for plant uptake, the grower may decide to apply less nitrogen early in the season, reserving some for topdressing later during the season if the conditions (and soil moisture availability) allow, as there is little nitrogen available at depth for plants to access through spring.

The Springhurst/Lilliput site has a larger amount of nitrate-nitrogen at depth than the east Rutherglen (Table 2).

TABLE 1 Example of the value of incremental soil sampling from East Rutherglen, 2015

Depth (cm)	Nitrate-nitrogen (kg/ha)	Average soil nitrate-nitrogen levels across incremental depths	
0–10	168.0		
10–20	67.2	Average 0–30cm = **82**kg/ha	
20–30	12.7		Average 0–100cm = **56**kg/ha
30–60	18.9	Average 30–100cm = **17**kg/ha	
60–100	15.1		

TABLE 2 Examples of the value of incremental soil sampling from Springhurst/Lilliput, 2015

Depth (cm)	Nitrate-nitrogen (kg/ha)	Average soil nitrate-nitrogen levels across incremental depths	
0–10	21.0		
10–20	15.4	Average 0–30cm = **17**kg/ha	
20–30	13.4		Average 0–100cm = **28**kg/ha
30–60	42.0	Average 30–100cm = **46**kg/ha	
60–100	49.3		

If a grower used the results from the 0–100cm sample (28kg N/ha), a decision could be made to apply a lot of nitrogen early during the season due to a perceived nitrogen deficit through the profile. However, if the core was split into the 0–30cm and 30–100cm layers, the grower would identify the shortfall of nitrogen in the top layers, but also see there is some nitrogen sitting at depth, which could contribute to finishing the crop off in a favourable season without additional nitrogen being applied.

Total nitrogen vs available nitrogen

The results presented to date mostly focus on the available soil nitrogen (measured as nitrate-nitrogen), which is the form of nitrogen crops access during the growing season. Another form of plant-available nitrogen is 'mineral nitrogen', which includes both nitrate (NO_3) and ammonium (NH_4) forms of nitrogen, which is a more complete measure of available nitrogen. However, as some of the ammonium results received during this project were questionable, the ammonium results were omitted.

A key part of the nitrogen story for crop production is the cycling of nitrogen through organic (plant matter, decaying roots, microbial biomass) and inorganic (nitrate, ammonium) forms. To this end, we measured the total soil nitrogen in addition to the available/nitrate-nitrogen to understand the size of the complete soil nitrogen 'bucket', which is already in the soil, additional to any fertiliser applied.

The real challenge lies in estimating the nitrogen *mineralisation* rate — the rate at which the organic (plant unavailable) nitrogen is transformed into plant-available forms. The mineralisation process depends heavily upon environmental factors including temperature and moisture, and also varies according to the type and amount of plant residue present on the ground.

A comparison of total nitrogen vs plant-available nitrogen is presented in Figure 25. Figure 25 illustrates an accumulation of organic nitrogen (represented as total-nitrogen minus nitrate-nitrogen) in the 0–10cm layer, which is expected as this is where most of the nutrient-cycling microbes are located.

To provide context as to the size of this organic nitrogen 'bucket', nitrate-nitrogen is plotted alongside, and barely registers on the scale of this graph.

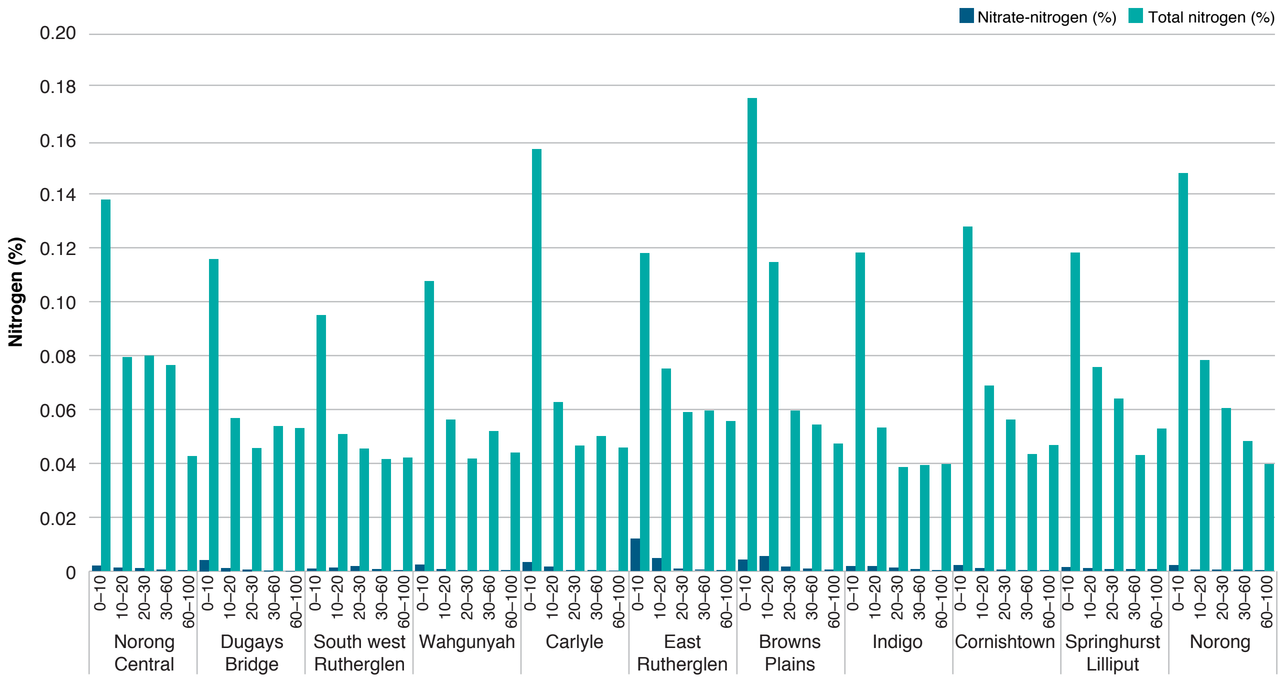

FIGURE 25 A comparison of total nitrogen vs plant-available (nitrate) nitrogen



Observations and comments

Although all of the sites for this project lie within the Rutherglen region, there is a range of soil types. However, the duplex, texture-contrast soil type dominates, with a sharp increase in clay content in the subsoil. This means water is strongly held in this zone and is only extracted for plant use after the topsoil layers are depleted of moisture.

The sites vary in both the amount of nitrate-nitrogen stored in the soil, and the depth at which it is stored. As the traditional DSN measure doesn't account for the distribution of nitrogen, it is worth considering splitting DSN samples into two increments — a 0–30cm and a 30+cm depth sample. This will provide more accurate information on the availability of nitrogen as the season progresses, supporting better and more timely fertiliser application decisions.

The nitrate-nitrogen component is only a small proportion of the total soil nitrogen, with the large pool of soil organic nitrogen being responsible for the ongoing cycling and mineralisation throughout the season and during summer.

While the soil moisture results presented here show a dry soil profile going into the 2016 season, as this report is being written the ground outside has turned to mud, thanks to the fantastic rain received during early May. With between 60–80mm rainfall across the region, it certainly will go a long way towards refilling the soil profile!

Acknowledgements

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'Topping up' wheat with foliar phosphorus — formulation testing

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Key points

- Previous work suggests it is possible to increase phosphorus (P) uptake in wheat plants using foliar phosphorus if the leaves are not too deficient and a surfactant is used in the formulation — however dry matter (DM) and grain yield responses have not been consistent.
- No positive grain yield responses to foliar phosphorus were measured in this field trial.

Introduction

Recent surveys of cropping soils for levels of available phosphorus suggest many soils have marginal to adequate supplies due to accumulation from previous fertiliser applications. In areas with marginally-deficient soils, where the crop requirements for additional fertiliser are small and highly dependent on seasonal rainfall, there could be opportunities to optimise the management of fertiliser phosphorus. We have been investigating whether an in-season phosphorus top-up by foliar application is a possible management strategy in soils with marginal to adequate phosphorus status.

Early work, using phosphoric acid as the source of phosphorus, showed it is possible to increase phosphorus uptake in wheat plants using foliar application if the leaves are not too deficient and a surfactant is used in the formulation. Our research also suggested applications just before booting (GS45) increased the leaf uptake of foliar applied phosphorus compared with early applications (at tillering — GS22) and resulted in increases of DM and/or grain yield.

The efficiency of foliar applications of phosphorus depends on a range of factors, including soil phosphorus availability, timing of application, fertiliser rate of application/formulation, and environmental conditions. These factors do not influence plant responses independently, rather through their interactive effects. Although earlier studies and grower interaction indicated phosphoric acid was the most likely candidate for foliar phosphorus fertiliser source, consistent yield responses under controlled and field conditions have been elusive. For this reason it was imperative to investigate whether different sources of phosphorous may be more effective at increasing wheat grain yield.

Formulation testing in a growth room experiment

Method

In an experiment under controlled conditions (20°C/15°C day/night cycle of 12h each) the efficacy of a range of formulations, both commercial and laboratory-grade phosphorus sources, was evaluated in combination with three different adjuvants (Table 1) for total and foliar phosphorus uptake, foliar phosphorus translocation and plant growth response.

Plants were grown in a highly-phosphorus-responsive soil with basal nutrients added before sowing to produce a soil with marginal phosphorus status. Foliar fertilisers labelled with ^{33}P (radioisotope form of phosphorus that can be tracked) were applied at flag leaf visible growth stage (GS37) as 2µL drops, with an application rate equivalent to 2kg P/ha in 100L/ha total volume, such that the plant recovery of foliar-applied phosphorus could be directly measured.

Results

The commercial products, PeKacid® and Pick®, and laboratory reagents, sodium phosphate and ammonium phosphate, in combination with different adjuvants showed increases in plant biomass at flowering (GS68) compared with the nil foliar control. Although the plants fertilised with phosphoric acid had a high level of foliar phosphorus recovery (data not shown) they did not show an increase in biomass (Figure 1).

Formulation testing in the field

Method

The promising responses to some products in the growth room led to the development of two field-based experiments to test the effect of selected formulations on wheat yield under field conditions during 2015. Two sites with marginally phosphorus-deficient soils were selected for replicated field trials based on soil analyses and/or plant responses to phosphorus (SAGIT project UA1115 — *Reassessing the Value of Phosphorus Replacement Strategies on Fixing Soils*). These sites were Pinery in

TABLE 1 Characteristics of phosphorus sources and adjuvants tested in a pot experiment under controlled conditions

Phosphorus sources	pH of formulation (P source + adjuvant)	N	P	K
		% w/w		
Phosphoric acid[TG] (PA)	1.4	0	26.9	0
PeKacid® (PeK)	2.2	0	26.5	16.7
Monoammonium phosphate (MAP[AR])	4.3	12.2	27.0	0
Maxi-Phos 16 Neutral® (Maxi Phos®)	4.3	7.8	12.5	0
Potassium phosphate[AR]	4.4	0	22.8	28.7
Sodium phosphate[AR] (NaP)	6.5	0	22.5	0
Pick 15–42® (Pick®)	8.7	0	9.4	26.3
Adjuvants				
Hasten® (H)	Esterified vegetable oil, non-ionic surfactant			
LI700® (L)	Acidifying, penetrating surfactant			
Spreadwet 1000® (S)	Non-ionic surfactant			

[TG] technical grade; [AR] analytical reagent

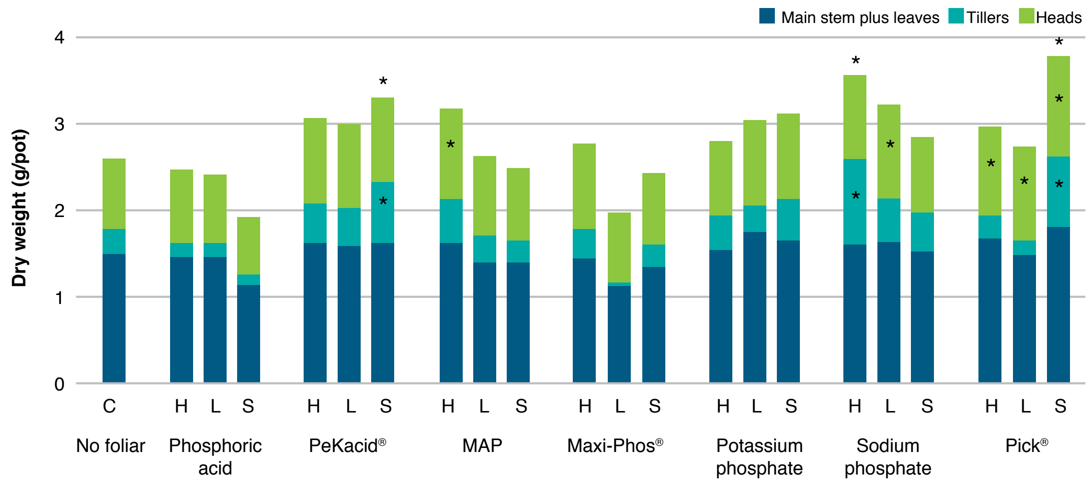

FIGURE 1 Dry weight of wheat plants grown in a soil with marginal phosphorus status

* Indicates biomass (total, heads or tillers) higher than the control (C) ($p \leq 0.05$)

Note: Foliar fertilisers labelled with ^{33}P were applied at flag leaf visible stage (GS37) as 2μL drops, with an application rate equivalent to 2kg P/ha in 100L/ha total volume. Foliar fertilisers were applied with different adjuvants, labelled as H, L and S for Hasten, LI700 and Spreadwet1000, respectively

the Mid North and Sherwood in the Upper South East of South Australia.

A total of 10 formulations were tested under field conditions (Table 2) and compared with nil foliar fertiliser controls at two levels of starter soil phosphorus (starter soil phosphorus was added as MAP and nitrogen was balanced across all plots with urea).

There were two timings for foliar phosphorus sprays — at stem elongation (second node visible [GS32] at Pinery and sixth node visible [GS36] at Sherwood) and boots

TABLE 2 Foliar phosphorus sources, adjuvants and combined formulations used at Pinery and Sherwood, SA, 2015

Phosphorus sources	Adjuvants	Foliar phosphorus formulations	
Phosphoric acid (**PA**)	Hasten® (**H**)	PA–H	PA–S
PeKacid® (**PeK**)	Spreadwet® (**S**)	PeK–H	PeK–S
Mono ammonium phosphate (**MAP**)		MAP–H	MAP–S
Sodium phosphate (**NaP**)		NaP–H	NaP–S
Pick® (**Pick**)		Pick–H	Pick–S
		C (control, no added foliar P)	

swollen (booting [GS45] at Pinery and booting to early flowering [GS45–55] at Sherwood). The application rate was equivalent to 2kg P/ha in 100L/ha total volume. Adjuvants were mixed at label recommended rates.

There were four replicate plots per treatment, with a total of 168 plots. Wheat (variety Mace — reportedly responsive to phosphorus; McDonald *et al* 2015) was sown in 2m x 7m plots at 150plants/m^2.

Grain yield was the final indicator of crop response to foliar phosphorus but additional measurements included: in-season performance of the plants through plant tissue nutrient levels, normalised difference vegetation index (NDVI) measurements, and biomass at flowering (GS68). At maturity, whole plants above ground were hand-harvested to measure harvest index (HI), grain yield and phosphorus content. Plots were subsequently machine harvested.

Results

Soil tests before the trial indicated phosphorus deficiency (DGT-P 9µg/L and 5µg/L for Pinery and Sherwood respectively). Soil tests post-sowing supported this and confirmed the addition of soil starter phosphorus had increased soil phosphorus test values (Table 3). In-season plant tissue analyses indicated marginal status for phosphorus (~0.2% total phosphorus) at the time of foliar phosphorus application (data not shown).

At both sites, plant growth responses based on NDVI measurements and biomass at flowering (GS68) showed a positive, significant effect of soil starter phosphorus (Table 3). Plant growth differences between the two rates of starter phosphorus were smaller at Pinery and decreased at both sites as the season progressed (Table 3) but they lead to a significant increase in grain yield (Table 4). There was no effect of foliar applied phosphorus on any of the plant growth parameters measured. Statistical analysis (ANOVA) was performed for all varieties to test for an effect of foliar phosphorus, soil starter phosphorus and timing of application. As there was no effect of foliar phosphorus or timing, means for each soil starter phosphorus rate are given.

Discussion

In agreement with the literature, recorded responses to foliar phosphorus were sporadic and difficult to predict. After completing several growth room studies and being able to trace that some foliar formulations have been taken up by the plant, increased the total amount of plant phosphorus uptake, increased biomass at flowering (GS68), or increased grain yield, the ability to achieve a consistent and predictable positive effect on wheat in the field appears elusive. Insufficient in-season rainfall (period of stress in spring at Pinery, overall low rainfall at Sherwood, Figure 2) may have

TABLE 3 Results from soil phosphorus analyses at the two-leaf growth stage (GS12) at Pinery and Sherwood, SA 2015

Site	Starter soil P (kg/ha)	Colwell P (mg/kg)	DGT P (µg/L)	PBI	NDVI GS32–36	NDVI GS45–55	Biomass at flowering (t/ha)
Pinery	0	30[a]	12[a]	100[a]	0.45[a]	0.67[a]	4.2[a]
	12	65[b]	73[b]	98[a]	0.53[b]	0.72[b]	4.9[b]
	LSD	16.8	41.6	5.1	0.03	0.02	0.26
Sherwood	0	14[a]	5[a]	33[a]	0.33[a]	0.44[a]	2.1[a]
	15	36[b]	71[b]	30[a]	0.48[b]	0.51[b]	3.1[b]
	LSD	11.7	37.0	3.5	0.02	0.02	0.21

Figures followed by different letters are regarded as statistically different.
NDVI taken at the two timings for foliar application (GS32–36, GS45–55), and biomass at flowering. Means and least significant differences (LSD) are shown.

TABLE 4 Wheat grain yield, phosphorus concentration and protein, crop harvest index (HI) and relative yield at maturity at Pinery and Sherwood, SA 2015

Site	Soil starter P (kg/ha)	Grain yield (t/ha)	Grain P concentration (%)	Grain protein	HI	Relative yield (max/nil)*
Pinery	0	2.9[a]	0.33[a]	14.1[a]	0.43[a]	1.1
	12	3.1[b]	0.29[a]	12.7[a]	0.42[b]	
	LSD	0.53	0.05	1.8	0.01	n/a
Sherwood	0	0.75[a]	0.26[a]	14.9[a]	0.37[a]	1.5
	15	1.09[b]	0.27[a]	14.2[a]	0.37[a]	
	LSD	0.30	0.05	1.6	0.01	n/a

Figures followed by different letters are regarded as statistically different.
Means and least significant differences (LSD) are shown. * Maximum yield obtained/yield obtained with no added phosphorus; n/a, not applicable.

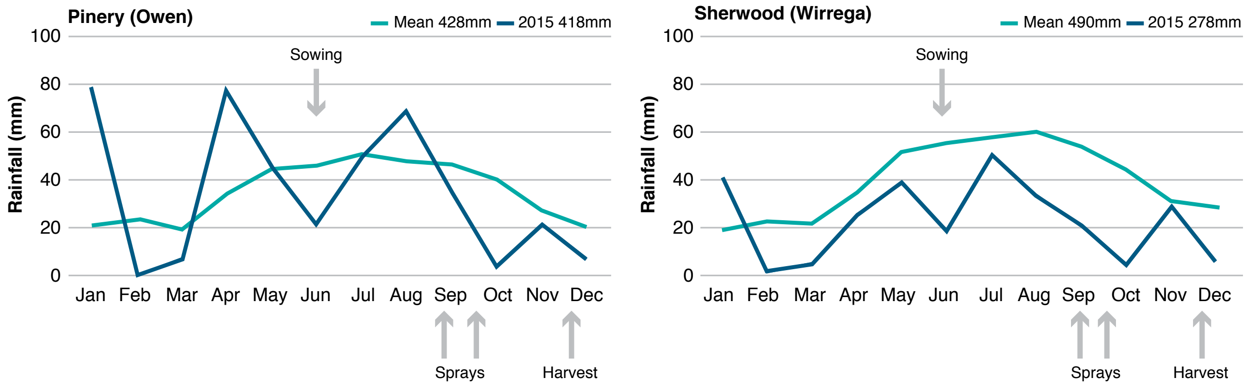

FIGURE 2 Monthly average (based on ~100 year records) and 2015 rainfall from the nearest Bureau of Meteorology weather station (brackets)

been a limiting factor for the crop to benefit from foliar phosphorus top-ups during 2015.

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Canola response to nitrogen rate, splits and timings

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Key points

- There was no yield response in canola to a range of nitrogen (N) rate applications.
- There was little effect on canola yield of timing (two-leaf, bud initiation, early flowering) or splitting of nitrogen applications.
- The oil percentage decreased at 80kg N/ha, with higher nitrogen rates having a lower incremental effect.
- Results confirm the importance of carrying out a nitrogen budget before applying fertiliser.

Location: 8km SE of Dookie, Victoria

Rainfall:
Annual: 398.9mm (2015), 551mm (mean all years)
GSR: 232.7mm (2015), 367mm (mean all years)
Stored moisture: 22mm (dry)

Soil:
Type: Red clay loam
CEC: 10.4meq/100g
pH ($CaCl_2$): 4.5
Colwell P: 51mg/kg
Phosphorus buffering Index (PBI): 150
DGT# phosphorus: 39ug/L
Deep soil nitrogen (0–80cm): 115kg/ha
Deep soil sulphur (80cm): 125kg/ha
Organic carbon (OC): 1.9%
Zinc (DTPA extract): 0.75mg/kg

Sowing information:
Sowing date: 27 April 2015
Fertiliser: Sowing: MAP 73kg/ha
Variety: Canola ATR Bonito
Sowing equipment: Cone seeder, knife point, press wheel

Row spacing: 29cm

Paddock history:
2014: Wheat

Plot size: 10m x 1.74m

Replicates: Four

DGT – Diffuse gradients in thin film: this test is a measure of soil solution phosphorus available to plant roots.

Aim

To investigate canola yield and quality response to nitrogen rate, split applications and timing of application based on growth stage.

Method

Canola (cv ATR Bonito) was sown into burnt wheat stubble with adequate moisture at a rate of 2.5kg/ha on 28 April 2015. Sixteen treatment rates of 0, 40, 80, 160 and 240kg N/ha were applied as urea at three growth stage timings (two leaf (GS1.02), bud initiation (GS3.0) and 30% flower (GS4.3) as single or split applications (Table 1).

The trial comprised a completely randomised block design with four replicates. Analysis of variance (ANOVA) was used, with least significant difference (LSD) between treatments determined at the 5% level of significance using Fisher's Protected LSD.

Deep soil analysis at the trial site for 0–80cm indicated starting mineral nitrogen of 115kg/ha in the soil profile (refer to trial site summary details for other soil test information).

Growing season rainfall (GSR) was approximately 233mm (Figure 1). The trial was harvested 11 November 2015.

Results

Canola yield was not influenced by nitrogen rate, application timing or splits in application over the growing season (Table 2).

Oil content was significantly lower with nitrogen applied at 80kgN/ha, regardless of application timing, compared with the control (Table 2). As illustrated in Figure 2, the effect of reduced oil content in response to nitrogen application was greatest with the first 40kg N/ha applied, (-1.8% oil), with a smaller decrease in oil content with each subsequent nitrogen application. While trending lower, there was no significant difference in oil content or oil yield with 120–240kg/ha of applied nitrogen.

Splitting the nitrogen and the timing of application had little effect on oil content at the same nitrogen rate (Table 2). The trend for lower oil content with earlier nitrogen application timings was not statistically significant. However, oil yield per hectare was significantly lower with applications of 80kg N/ha applied earlier at the two leaf to bud initiation timings or splits compared with the control. There was no effect of nitrogen rate on grain test weights.

TABLE 1 Nitrogen treatment rate, splits and timings

Treatment No.	Nitrogen treatment (applied as urea) (kg N/ha)	Topdress two leaf (T2L) (kg N/ha)	Topdress bud initiation (TBI) (kg N/ha)	Topdress at 30% flower (TFL) (kg N/ha)	Total nitrogen applied (kg N/ha)
1	Nil nitrogen	0			0
2	40	40			40
3	40+40	40	40		80
4	0+40+40		40	40	80
5	80	80			80
6	0+80		80		80
7	0+0+80			80	80
8	40+80	40	80		120
9	40+40+40	40	40	40	120
10	0+80+40	0	80	40	120
11	80+80	80	80		160
12	0+80+80		80	80	160
13	80+80+80	80	80	80	240

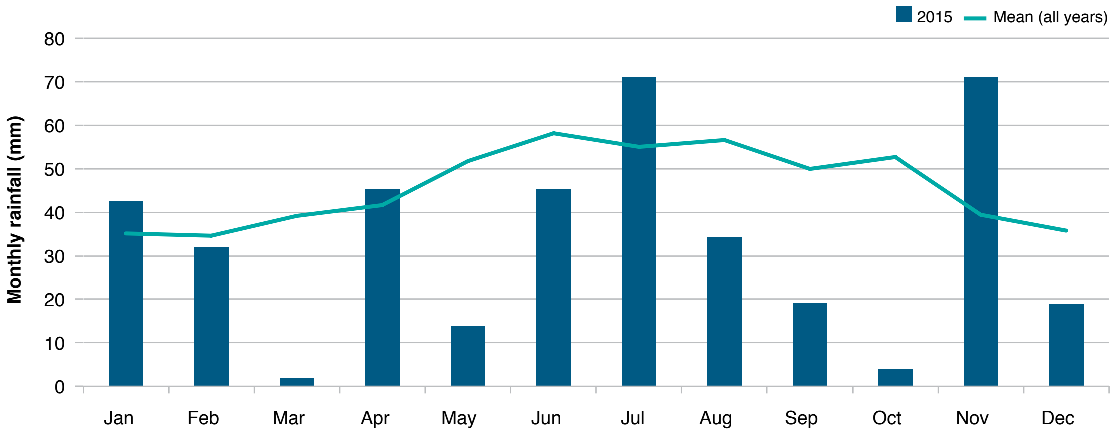

FIGURE 1 Mean and 2015 monthly rainfall at Dookie

Increasing the nitrogen rate decreased the canola oil content while increasing the protein content. The combined sum of oil and protein content remained constant at about 61% (Table 3). Protein response to nitrogen appears to be more influenced by nitrogen rate than splits or timings. Grain nitrogen recovery (GNR) was calculated from the total yield and protein, which showed no consistent effect in response to nitrogen rate, timings or splits.

Observations and comments

The 2015 season started with minimal stored moisture. Average April rainfall allowed canola to establish, however by the end of winter the rainfall was 64mm below average and remained well below average throughout spring.

After average September temperatures, hot conditions were experienced during October, with temperatures up to 5°C above the long-term average.

The water use efficiency (WUE) for the trial was calculated using an average trial yield of 1.8t/ha, stored moisture and GSR of 255mm, less 100mm evaporation, resulting in 11.6kg grain/mm moisture. This compares with 12kg grain/mm for 2014 where the average yield was 3.3t/ha and GSR moisture was 373mm (stored moisture not mentioned for 2014).

With a starting soil mineral nitrogen (0–80cm depth) of 115kg N/ha and a further 66kg N/ha of mineralised nitrogen, calculated from a GSR of 233mm and an organic carbon (OC) value of 1.9%, the total nitrogen

TABLE 2 Effect of nitrogen rate, splits and timings on canola yield, oil content, oil yield and test weight*

Total nitrogen applied (kg N/ha)	Timing	Yield (t/ha)	Oil content (%)	Oil yield (kg/ha)	Test weight (kg/hL)
0	Nil nitrogen	1.84[a]	42.9[a]	790.1[a]	69.3[a]
40	T2L	1.85[a]	41.1[ab]	759.9[ab]	69.3[a]
80	T2L	1.69[a]	39.9[be]	672.8[bd]	69.9[a]
80	T2L+TBI	1.74[a]	39.4[bf]	686.7[bd]	69.8[a]
80	TBI	1.74[a]	39.1[cf]	680.1[bd]	69.3[a]
80	TBI+TFL	1.82[a]	40.2[bd]	731.4[ac]	69.7[a]
80	TFL	1.84[a]	40.8[bc]	753.5[ab]	69.2[a]
120	T2L+TBI	1.71[a]	38.5[df]	658.2[cd]	69.3[a]
120	T2L+TBI+TFL	1.82[a]	38.8[df]	708.8[ad]	70.4[a]
120	TBI+TFL	1.70[a]	39.0[cf]	662.4[cd]	70.0[a]
160	T2L+TBI	1.68[a]	38.0[f]	636.4[d]	69.5[a]
160	TBI+TFL	1.80[a]	38.2[ef]	686.5[bd]	69.6[a]
240	T2L+TBI+TFL	1.68[a]	37.9[f]	638.7[d]	69.1[a]
LSD (P = 0.05)		0.186	1.8	88.1	0.931
p value.		0.385	<0.001	0.018	0.215
CV%		7.4	3.2	8.8	0.9

Figures followed by different letters are regarded as statistically significant.
T2L = topdressed at two-leaf stage TBI = topdressed at bud initiation TFL = topdressed at 30% flower
• Means followed by the same letter are not significantly different at P=0.05. Oil yield is calculated from grain yield (kg/ha) x oil%.

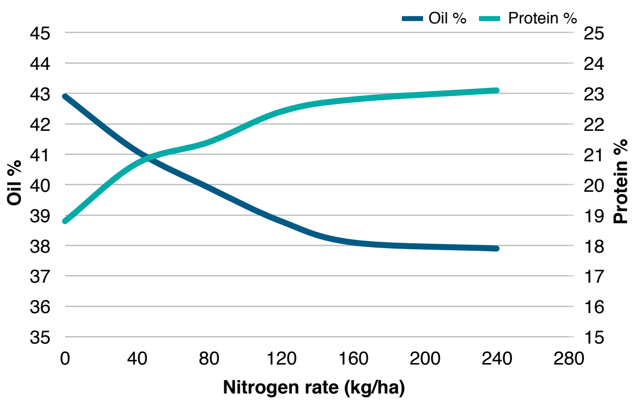

FIGURE 2 Effect of nitrogen rate on mean canola oil and protein content*
* Mean of nitrogen application rates for different splits and timings

available to the crop with no allowance for losses was estimated at 181kg N/ha, based on:

Total mineral nitrogen for crop = [OC (%) x GSR x 0.15] + starting mineral nitrogen

Nitrogen demand, based on a yield of 1.8t/ha and 21.5% protein was estimated at 185kg N/ha.

Nitrogen demand = yield (t/ha) x protein (%) x protein factor (1.6) x efficiency (33%)*

** Protein factor is used to convert grain protein % back to nitrogen in the grain i.e. canola protein is 16% nitrogen.*

The lack of difference between the total mineral nitrogen available for the crop (181kg N/ha), and the crop demand (185kg N/ha) explains the lack of a yield response to applied nitrogen and highlights the importance of nitrogen budgeting in determining fertiliser applications.

A basic analysis of incremental returns from yield and oil responses over the control, less the cost of fertiliser, is provided in Table 4. The risk:reward ratio is calculated using the gross return per hectare above the control divided by the cost of nitrogen. As there was no nitrogen response to yield, and increasing nitrogen rates decreased oil content, any additional nitrogen applied was an added cost. This again highlights the importance of carrying out deep soil nitrogen sampling and nitrogen budgeting before applying fertiliser.

In summary, while there was no yield benefit from nitrogen rate, and little effect of timing or application splits in this trial, it highlights the importance of matching nitrogen inputs with water availability and crop yield potential. This generally requires tactical applications of nitrogen as the season unfolds based on regular revision of nitrogen budgets.



TABLE 3 Effect of nitrogen rate, splits and timings on canola protein content, combined oil and protein content, and grain nitrogen recovery*

Total nitrogen applied (kg N/ha)	Timing	Protein (%)	Oil + protein (%)	Grain nitrogen recovery (kg/ha)
0	Nil nitrogen	18.8^{f}	61.7^{a}	55.3
40	T2L	20.7^{e}	61.8^{a}	61.1
80	T2L	21.6^{be}	61.5^{a}	58.7
80	T2L+TBI	21.9^{ad}	61.3^{a}	60.8
80	TBI	21.7^{be}	60.8^{a}	60.2
80	TBI+TFL	21.3^{a}	61.5^{a}	61.9
80	TFL	20.7^{de}	61.5^{a}	60.9
120	T2L+TBI	22.6^{ab}	61.1^{a}	61.5
120	T2L+TBI+TFL	22.3^{ac}	61.1^{a}	64.9
120	TBI+TFL	22.2^{ac}	61.2^{a}	60.0
160	T2L+TBI	22.8^{ab}	60.8^{a}	61.1
160	TBI+TFL	22.7^{ab}	60.9^{a}	65.4
240	T2L+TBI+TFL	23.1^{a}	61.0^{a}	62.1
LSD		1.200	1.1	6.1
p value		<0.001	0.745	0.213
CV%		4.0	1.3	7.0

Figures followed by different letters are regarded as statistically significant.
T2L = topdressed at two-leaf stage TBI = topdressed at bud initiation TFL = topdressed at 30% flower
* Means followed by the same letter are not significantly different at P=0.05. Grain nitrogen recovery is yield (t/ha) x protein % x 1.6.

TABLE 4 Incremental returns from applied nitrogen

Total nitrogen applied (kg N/ha)	Nitrogen cost ($/ha)	Timing	Yield (t/ha)	Canola price on farm ($/t)	Oil (%)	Oil premium/ discount ($/t)	Gross return including oil ($/ha)	Return net of nitrogen vs control ($/ha)	Risk reward ratio ($/kgN)
0	0	nil	1.84	517	42.9	6.79	965.33	0	0
40	48	T2L	1.85	517	41.1	-7.17	943.22	-70.11	-0.46
80	96	T2L+TBI	1.74	517	39.4	-20.16	864.55	-196.77	-1.05
80	96	TBI+TFL	1.82	517	40.2	-14.15	914.17	-147.15	-0.53
80	96	T2L	1.69	517	39.9	-16.29	846.73	-214.59	-1.24
80	96	TBI	1.74	517	39.1	-22.30	859.21	-202.11	-1.11
80	96	TFL	1.84	517	40.8	-9.11	935.64	-125.68	-0.31
120	144	T2L+TBI	1.71	517	38.5	-26.95	836.10	-273.22	-0.90
120	144	T2L+TBI+TFL	1.82	517	38.8	-25.01	896.83	-212.50	-0.48
120	144	TBI+TFL	1.70	517	39.0	-23.27	837.14	-272.19	-0.89
160	192	T2L+TBI	1.68	517	38.0	-31.41	814.53	-342.80	-0.79
160	192	TBI+TFL	1.80	517	38.2	-29.66	876.75	-280.58	-0.46
240	288	T2L+TBI+TFL	1.68	517	37.9	-32.18	816.49	-436.84	-0.52

Assumptions: $517/t canola on farm; 1.5% oil premium/1% above 42% base grade; urea $550/t on farm
[1] Risk reward calculated from the net $ return (over no nitrogen) divided by the cost of nitrogen application

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Harvest weed seed control: annual ryegrass seed retention levels in south-eastern Australia wheat crops

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Key points

- Herbicide-resistant annual ryegrass (*Lolium rigidum*) is increasingly becoming a challenge for growers across southern Australia.
- Harvest weed seed control (HWSC) — the collection and/or destruction of weed seeds at harvest — is a non-chemical control method, which can be used to reduce the seedbank of weeds such as annual ryegrass.
- A major premise of HWSC is that the targeted weed species retain a high proportion of their total seed production at crop maturity.
- An investigation into the height at which the bulk of annual ryegrass seed is located within a wheat crop found 80% (range of 48–100%) of the seed was more than 10cm above the soil surface and 69% (range of 23–100%) was more than 20cm above the soil surface.

Background

A significant proportion of crops across the cereal-growing regions of southern Australia contain herbicide-resistant annual ryegrass populations, with many of these populations resistant to multiple herbicide modes of action (MoA).

Many of the major annual weeds of Australian cropping systems, including annual ryegrass, retain their seed at maturity. Growers can capitalise on this inherent weakness by adopting harvest weed seed control (HWSC) as a non-chemical weed control strategy to reduce seedbank inputs for a range of weed species.

A major principle of all HWSC systems is that the proportion of weed seeds collected at the front of the harvester is a measure of the efficiency by which seeds are prevented from entering the seedbank.

Growers in Western Australia have widely adopted HWSC as a result of the high levels of herbicide resistance found across the WA cropping zone. Adoption has been slower in south-eastern Australia for a number of reasons; one of which has been the lack of localised data on how to optimise these weed-control systems.

Aim

This study aimed to address the lack of local data regarding HWSC, particularly the height at which annual ryegrass seed is located within a wheat crop. The height of the seed within the crop determines the harvest height required to collect most weed seeds and demonstrates the maximum potential benefit from HWSC systems in south-eastern Australia.

Method

During 2013, 46 wheat crops were sampled at maturity (first opportunity to harvest) across southern New South Wales and Victoria (Figure 1). Wheat and annual ryegrass plants were collected from four, 1m^2 quadrats at five cutting heights: 0, 10, 20, 30 and 40cm above the soil surface. Additionally, any seed, seed heads and plant material that had fallen from plants were also collected. The number of wheat and ryegrass plants was counted in each quadrat.

The samples were then sorted to separate wheat and ryegrass plant material. For each sampling height the crop and weed dry matter (DM) production and grain yield were determined, from which the percentage of wheat and ryegrass seed collected above each of the harvest heights was calculated for each site.

For each parameter measured, the lowest and highest 15 sites were then determined and the mean (average) percentage of ryegrass collected above each harvest height was also determined for these sub-samples of sites. Standard errors were then calculated for the overall mean, lowest 15 sites and highest 15 sites to observe differences between these categories.

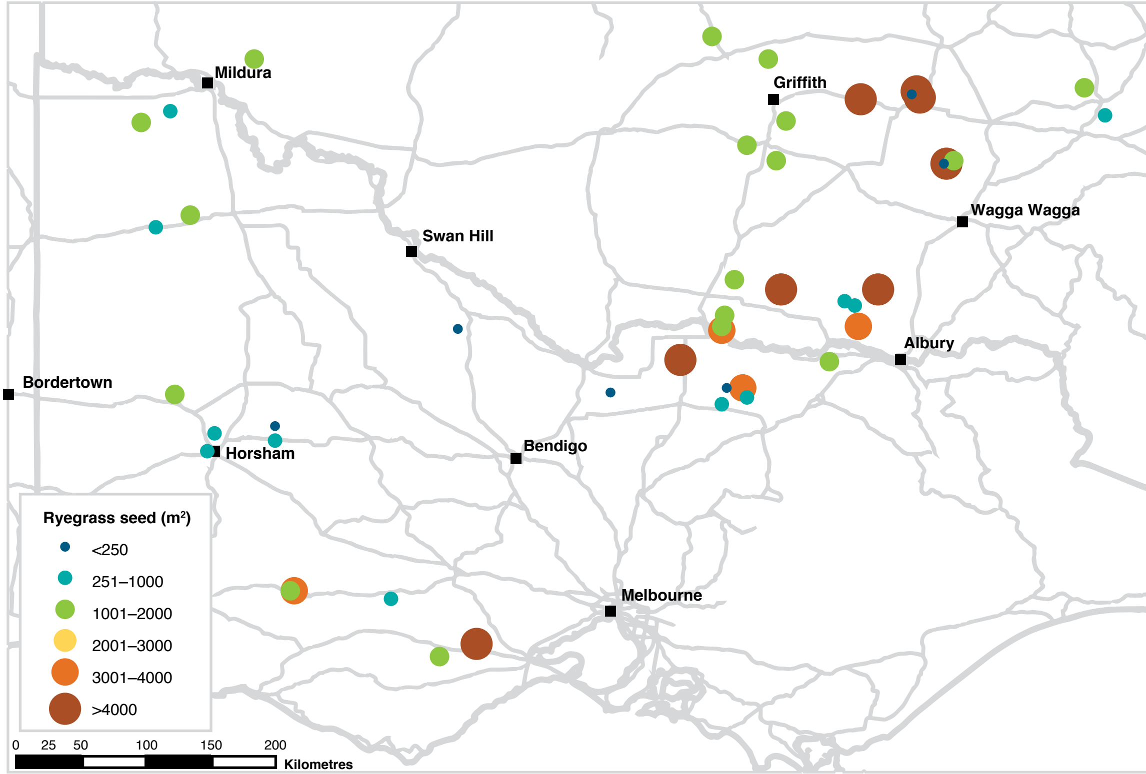

FIGURE 1 Location of paddocks sampled across Victoria and southern NSW to determine annual ryegrass seed retention height at wheat crop maturity, showing ryegrass seed densities at each site

Results

The mean wheat density across all sites was 65.6 plants/m^2 producing 8.6t/ha of DM and 3.68t/ha of grain with a mean harvest index (HI) of 41.3%.

The average number of annual ryegrass plants recorded was 8.5/m^2, producing 168kg/ha DM and 1889 seeds/m^2, or approximately 18.9 million seeds per hectare (Table 1).

Overall, 93% of the ryegrass seed had been retained by the plants at the time of sampling, with a mean of 80% (range of 48–100%) retained more than 10cm above the soil surface and 69% (range of 23–100%) more than 20cm above the soil surface.

At a 15cm harvest height there was no difference in the proportion of ryegrass seed collected between the average, lowest and highest yielding sites (Figure 2a).

TABLE 1 Wheat and ryegrass production at 46 sites across south-eastern Australia

	Mean	Minimum	Median	Maximum
Wheat				
Plants/m^2	65.6	13.0	65.6	122.3
Dry matter (t/ha)	8.6	1.6	8.2	16.4
Yield (t/ha)	3.7	0.5	3.2	8.6
Harvest index (%)	41.3	16.7	41.6	57.5
Ryegrass				
Plants/m^2	8.5	1.0	4.3	50.8
Dry matter (kg/ha)	168	6	90	1145
Seed production (seed/m^2)	1889	87	1254	7192

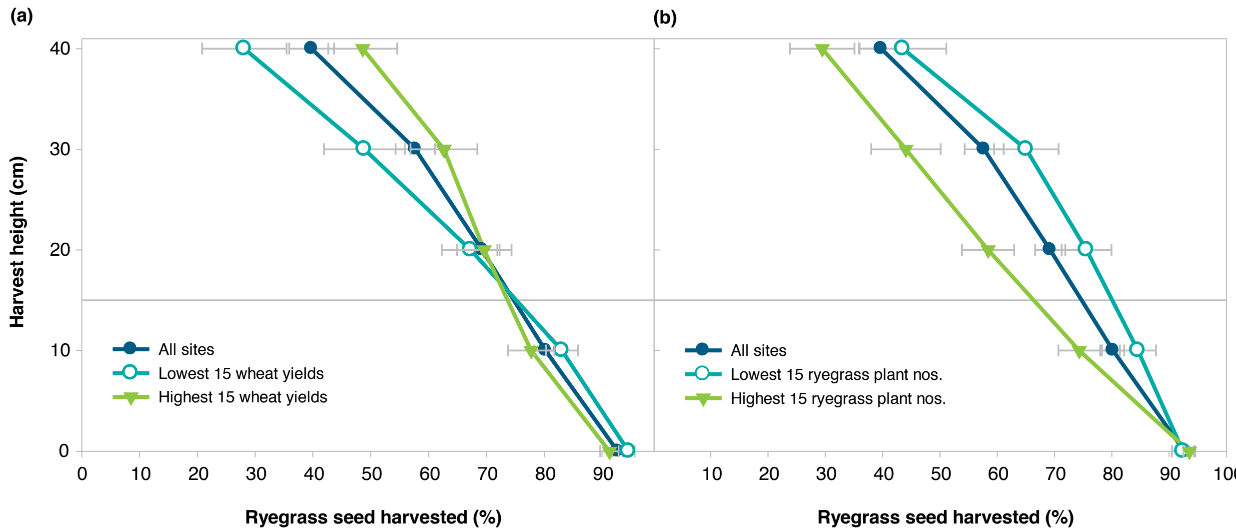

FIGURE 2 Percentage of annual ryegrass seed located above five harvest heights (0, 10, 20, 30 and 40cm) for wheat yield (a) and ryegrass plant number (b)

Note: Lines represent the mean (± SE) for all sites, the 15 lowest-yielding sites and the 15 highest-yielding sites for each parameter. The horizontal line indicates a 15cm harvest height, the standard for HWSC in WA.

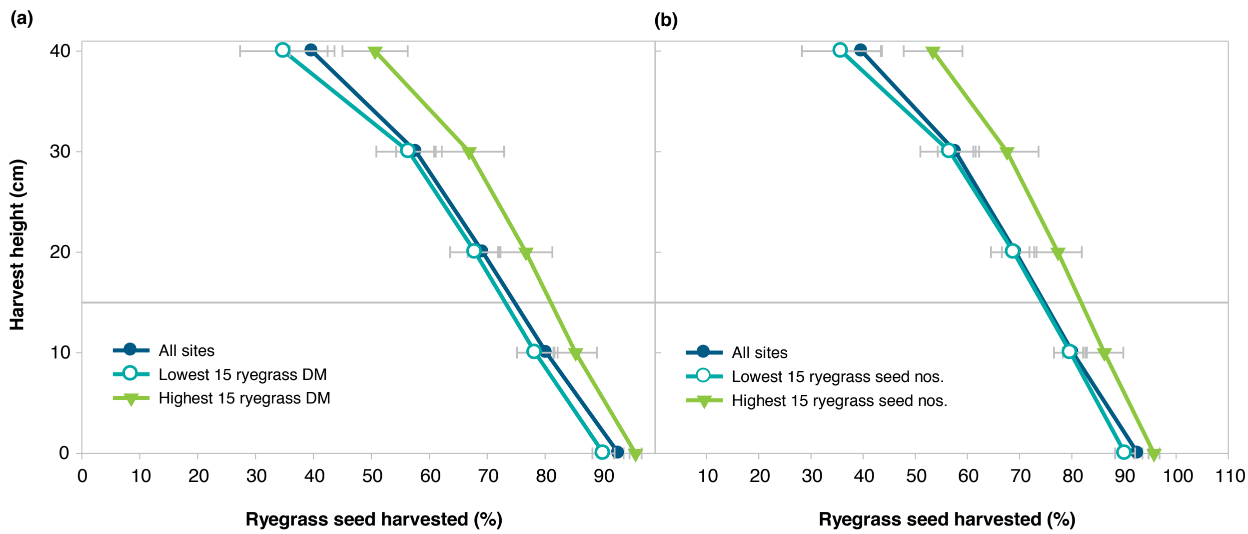

FIGURE 3 Percentage of annual ryegrass seed located above five harvest heights (0, 10, 20, 30 and 40cm) for ryegrass DM (a) and ryegrass seed production (b)

Note: Lines represent the mean (± SE) for all sites, the 15 lowest-yielding sites and the 15 highest-yielding sites for each parameter. The horizontal line indicates a 15cm harvest height, the standard for HWSC in WA.

However, a higher percentage of ryegrass seed was found above both 30 and 40cm harvest heights in the higher-yielding crops compared with both the overall mean and the lowest-yielding crops (Figure 2a). A similar finding was also recorded for the sites with the lowest and highest wheat DM production.

In the paddocks with the highest annual ryegrass plant densities, less seed (66.4%) was found above a 15cm harvest height compared with the paddocks with the lowest annual ryegrass plant densities (80.1% above 15cm harvest height) (Figure 2b). Conversely, high annual ryegrass DM production (Figure 3a), or annual ryegrass seed production (Figure 3b), resulted in higher percentages of seed found at all heights compared with the overall mean. There were minimal differences between the low-wheat-yielding paddocks and the average-wheat-yielding paddocks.

Lowering the harvesting height by 10cm resulted in a greater than 10% increase in the amount of ryegrass seed collected. The associated increase in wheat DM collected was less than 10% and at least 90% of this was straw or leaf material — not chaff or grain (Table 2).



TABLE 2 Proportion of total wheat dry matter production, wheat grain yield and annual ryegrass seed yield from different harvest heights in the crop canopy for 46 sampling sites across Victorian and NSW*

Harvest height (cm)	Wheat DM^ t/ha (%)	Wheat yield^ t/ha (%)	Ryegrass seed^ Total seed number (%)
40	5.83 (68.0)	3.58 (97.5)	847 (47.4)
30	0.77 (7.8)	0.05 (1.4)	302 (16.9)
20	0.62 (7.2)	0.01 (0.4)	207 (11.6)
10	0.66 (7.6)	0.01 (0.3)	207 (11.6)
0	0.80 (9.4)	0.02 (0.4)	223 (12.5)

* Dry matter and seeds found on the soil surface excluded from calculations.
^ Numbers in brackets indicate percentage of total DM, wheat grain yield or ryegrass seed present at each height in the canopy.

Observations and comments

The high retention of annual ryegrass seed on upright tillers at harvest indicates that 75% of total annual ryegrass seed is collected at a harvest height of 15cm. However, there was considerable variation in annual ryegrass seed retention height associated with wheat biomass production. The optimum conditions for annual ryegrass seed collection occurs in higher-yielding crops, with greater levels of DM production forcing annual ryegrass plants to grower taller to compete for light and consequently producing seed higher in the crop canopy.

A major concern raised by growers when discussing HWSC systems is the need to harvest lower than normal, dramatically slowing the harvest operation. As observed in this study most of the wheat grain (98%) was located more than 40cm above the soil surface, however most annual ryegrass seed (88%) occurred more than 10cm above the soil surface. At a 40cm harvest height about 5.8t/ha of biomass (60% of which is grain) is processed. Most of the additional crop material entering the harvester when harvesting at 10cm, instead of 40cm, is straw and leaf material only (Table 2), which requires minimal processing when compared with wheat heads.

This research has shown that HWSC systems have the potential to be a useful non-chemical control tool for NSW and Victorian growers to reduce both weed seed burdens and the reliance on herbicides. However, the large variability shown in this experiment demonstrates the effectiveness of HWSC will vary depending upon location, crop yield and ryegrass density.

Sponsors

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Nationwide field survey for herbicide residues in soil

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Key points

- Glyphosate, trifluralin and diflufenican residues, plus the glyphosate metabolite aminomethylphosphonic acid (AMPA), can accumulate to agronomically-significant levels in certain soils.
- The risk to soil biological processes is generally minor when herbicides are used at label rates and given sufficient time to dissipate before re-application.
- Given the frequency of glyphosate application, and the persistence of trifluralin and diflufenican, further research is needed to define soil type-specific critical thresholds for these chemicals to avoid potential negative impacts to soil function and crop production.
- Strategies to avoid herbicide residue accumulation and potential damage include: routine rotation of pre-emergent herbicides, reliable record keeping to help identify potential residue issues, and organic matter (OM) addition to help tie-up bioavailable residues and stimulate microbial activity.

Aim

Information about herbicide residue levels in Australian cropping soils is scarce due to the high cost of herbicide residue analysis. Here we report on the results of a national field survey of herbicide residues in 40 cropping soils before sowing and pre-emergent herbicide application during 2015. We discuss the relevance of these residues to soil biological processes and crop health, with a focus on those herbicides most frequently detected.

Method

A total of 40 paddocks was surveyed, including 12 from Western Australia, 15 from South Australia, 10 from New South Wales and three from Queensland.

Eight of the survey sites were located in southern NSW in an area between Wagga Wagga, Young and Ardlethan. Two sites in northern NSW were located in the Coonamble area.

Topsoil (0–10cm) pH (H_2O) ranged from 5.4–7.5 in southern NSW and 7.3–8.2 in northern NSW. Subsoil (10–30cm) pH (H_2O) ranged from 5.4–7.0 in southern NSW and 8.8–8.9 in northern NSW.

Soil sampling was undertaken to provide a representative snapshot of herbicide residue levels in cropping soils at the start (April–May) of the 2015 growing season before pre-emergent herbicides were applied. Composite soil samples (12 subsamples) were taken from a randomly-chosen 50m by 50m grid in each paddock, at two depths (0–10 and 10–30 cm). Samples were analysed for traces of 15 commonly-used herbicides using advanced analytical techniques developed and validated specifically for this project.

Results and comments

Which herbicides remain in soil?

The soil survey of 40 different paddocks from around Australia detected residues of 11 chemicals out of the 15 analysed (Figure 1). Glyphosate and its primary break-down product (metabolite) AMPA were the most commonly-detected residues, with AMPA residues present in every topsoil sample taken.

Trifluralin residues were also detected in more than 75% of the paddocks surveyed, both in topsoil and

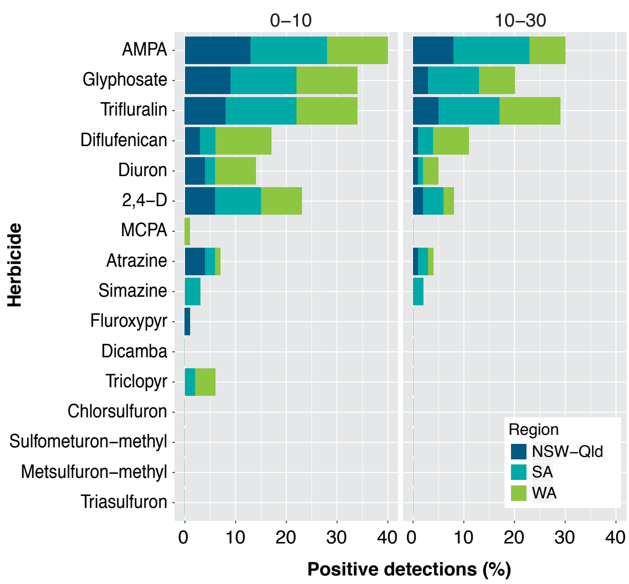

FIGURE 1 Number of positive detections of herbicides and the glyphosate metabolite AMPA in soil samples from 40 grain cropping paddocks around Australia



in the 10–30cm subsoil layer, indicating some vertical movement despite the strong tendency of trifluralin to remain close to the site of application. This is possibly the result of cultivation, however, leaching or movement of particle-bound trifluralin may also occur on lighter-textured soils with low OM content.

Diflufenican and diuron residues were frequently detected in samples from WA paddocks, but less so in NSW, Qld and SA.

Interestingly, despite known application of triasulfuron and metsulfuron-methyl in many of the surveyed paddocks, neither of these residual herbicides was detected in any of the samples tested. This probably reflects their low rates of application, close to the limit of analytical detection. It should be noted that sulfonylurea (SU) herbicides may still have some residual activity at levels below the limit of (currently available) analytical detection. By contrast, the lack of detection of frequently applied MCPA reflects its relatively short persistence in soil.

By multiplying herbicide concentrations (mg/kg) by soil bulk density (kg/dm) and area, we estimated the total load of herbicide in the 0–30 cm soil profile for each paddock (Table 1). The average and maximum estimated loads of glyphosate, trifluralin, diflufenican and diuron were all significantly higher in paddocks in WA compared with those in SA, NSW and Qld. This likely reflects the lighter soil types, lower OM, dry summers and cool winters, which contribute to lower microbial activity and constrained herbicide breakdown. The higher load of atrazine in SA paddocks is probably a consequence of the higher persistence of s-triazine herbicides in alkaline soils; while the higher values for 2,4-D in the NSW and Qld soil profiles was due to a high value in a single paddock, which had recently been sprayed.

Notably, in a number of paddocks (especially in WA but also in other states), we found a higher load of glyphosate than was applied in the previous spray, indicating that some glyphosate and its metabolite AMPA has accumulated over time. Although the half-life of glyphosate is relatively rapid (10–40 days), a significant portion of the glyphosate (and AMPA) is bound to soil and much less accessible for continued degradation by soil microbes. This, combined with the high frequency of glyphosate use, can lead to a build-up of glyphosate and AMPA in soil.

Accumulation of trifluralin was also apparent in a number of paddocks in WA. It should be reiterated that these levels represent the total loads, rather than the bioavailable fraction. Aging of residues in soil results in stronger binding over time, and a reduction in bioavailability, so any biological effect can be difficult to predict. This is discussed in more detail in the following sections.

TABLE 1 Residue loads (average and maximum) of herbicide active ingredients (a.i.) in the 0–30cm soil profile of paddocks by region

	Estimated average load across all sites (kg a.i./ha)*			Estimated maximum load detected (kg a.i./ha)*		
Herbicide	**NSW–Qld**	**SA**	**WA**	**NSW–Qld**	**SA**	**WA**
AMPA	0.91	0.95	0.92	1.92	1.97	2.21
Glyphosate	0.56	0.48	0.79	2.05	1.05	1.75
Trifluralin	0.08	0.11	0.53	0.14	0.26	1.34
Diflufenican	0.01	0.03	0.04	0.02	0.05	0.09
Diuron	0.14	0.05	0.17	0.16	0.05	0.29
2,4-D	0.20	0.02	0.01	1.00	0.05	0.02
MCPA	0	0	0	0	0	0
Atrazine	0.02	0.03	0.02	0.03	0.05	0.02
Simazine	0	0.04	0	0.00	0.05	0
Fluroxypyr	0.03	0	0	0.03	0	0
Dicamba	0	0	0	0	0	0
Triclopyr	0	0.04	0.01	0	0.07	0.01
Chlorsulfuron	0	0	0	0	0	0
Sulfometuron-methyl	0	0	0	0	0	0
Metsulfuron-methyl	0	0	0	0	0	0
Triasulfuron	0	0	0	0	0	0

*Calculated by multiplying mass concentration (mg/kg) detected by area and average bulk density (derived from www.soilquality.org) for each soil layer

How do soil functions respond to herbicide residues?

A literature review of more than 300 published studies identified common themes with respect to herbicide impacts on soil function. Most papers reported negligible impacts of herbicides on beneficial soil functions when applied at recommended rates. Even in the cases where negative effects were observed, they were usually minor and only lasted for periods of less than one month.

However, some exceptions were apparent, especially regarding the effects of repeated herbicide application. For example, there is evidence the accumulation of some SU herbicides after repeat application can reduce plant-available nitrogen, by slowing down the processes involved in nitrogen cycling. Persistence of SU herbicides in soil has also been linked with increased incidence of Rhizoctonia diseases in cereals and legumes. These effects are more likely to occur in alkaline soils, where SU herbicides are significantly more persistent.

There are also cases in which other herbicides (e.g. glyphosate) can increase the incidence of disease, but these interactions appear to be site-specific and often occur under stressful growing conditions.

Based on this information and the herbicide residues detected in the soil survey, it is unlikely SU residues are having ongoing negative impacts to soil functions in the paddocks surveyed. However, the high residue loads of glyphosate, its metabolite AMPA and trifluralin may be altering some soil functions or plant-pathogen interactions. The localised nature of interactions with glyphosate, and the lack of specific data on trifluralin, means firm conclusions cannot yet be made with respect to the residues detected.

How do crops respond to herbicide residues?

Because the potential for each herbicide to damage crops varies according to soil, agroclimate and crop, comprehensive damage thresholds (given as soil residue concentrations) for assessing plant-back risk are not readily available. Here we focus only on the potential for glyphosate (+AMPA) or trifluralin residues to cause seedling damage, given their high frequency of application and detection in the residue survey.

It is generally accepted glyphosate is deactivated when it reaches the soil and poses little risk to crops. However, recent research has shown under certain circumstances glyphosate can be remobilised and become plant bioavailable, including:

1. in the event of phosphorus (P) fertiliser application, which can compete with glyphosate for binding sites on soil and remobilise bound glyphosate residues
2. in the event of glyphosate applied to a high density of weeds soon before sowing, such that dying weeds translocate glyphosate into the soil and act as a more soluble pool of glyphosate to the germinating crop.

In a pot experiment a sandy, low OM soil from Wongan Hills, WA, was used to construct dose-response curves for wheat and lupins encountering residues from glyphosate applied one month before sowing. To demonstrate the interaction between glyphosate and phosphorus fertiliser, half the test pots received a one-off application of 20kg P/ha fertiliser (as soluble potassium phosphate) at sowing.

As can be seen in Figure 2, in soil not receiving phosphorus fertiliser, wheat was not affected by an application of 27kg/ha of glyphosate in soil, while lupin biomass was significantly decreased at rates above 12kg/ha (when upper 95% confidence level falls below 100% biomass).

When phosphorus fertiliser was added at 20kg P/ha, both wheat and lupins showed signs of damage at lower glyphosate concentrations. For lupins this occurred at levels of glyphosate >3.5kg/ha and for wheat >12.5kg/ha (Figure 2). Previous research has shown that increasing the level of phosphorus fertiliser application will continue to lower the toxicity threshold at which plants will show damage from glyphosate/AMPA residues in soil.

The soil samples from this experiment are currently being analysed to determine the residue level of both glyphosate and AMPA in soil. This will provide a more accurate understanding of whether the residues found in the field survey are likely to cause crop growth impacts following phosphorus fertilisation.

With respect to trifluralin, plant-back damage thresholds for oats vary from 0.1–0.2mg/kg and wheat vary from 0.2–0.4mg/kg depending on the soil type. Table 2 shows the number of paddocks in which the topsoil trifluralin residue concentration exceeds the lower threshold for oats and wheat, respectively. Again, it must be stressed the residues detected in this field survey constitute 'aged' residues, which are likely to be less bioavailable and hence less of a threat to crop growth. Nevertheless, considering some of these paddocks will receive a pre-emergent application of trifluralin during 2016, the risk of some plant-back damage is tangible.

Summary and future work

Growers need to be aware that glyphosate, trifluralin and diflufenican residues, plus the glyphosate metabolite AMPA, can accumulate to agronomically significant levels in certain soils. Although the risk to soil biological



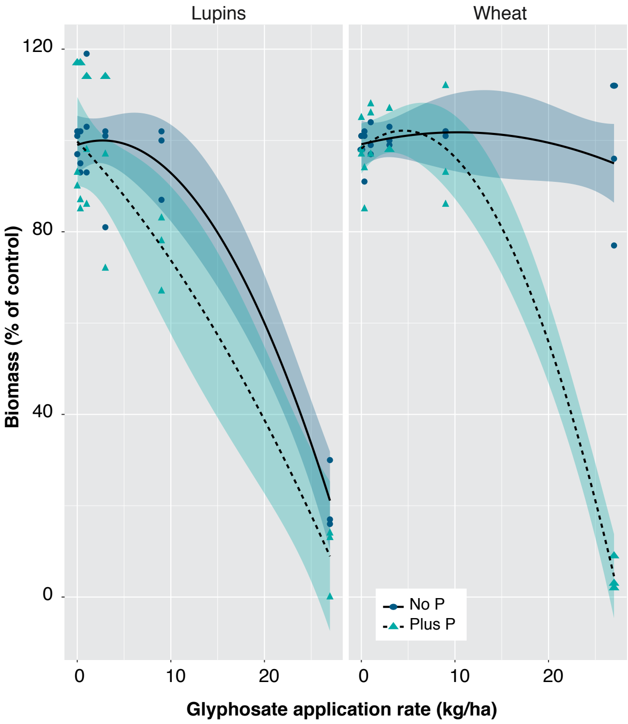

FIGURE 2 Growth response of wheat and lupins to glyphosate applied to soil one month before sowing. Phosphorus fertiliser (20kg/ha) was added at sowing to half the pots

processes is generally minor when herbicides are used at label rates and given sufficient time to dissipate before re-application, our findings suggest there is plant-back risk of damage to crops, mainly in sites with lower rainfall and sandy soils with low organic matter.

Ideally, growers and advisers would have tools available for rapid diagnosis of herbicide residues in soil, together with information of the biological relevance of these residues. Our current work is testing rapid in-field dipstick technology that can give a semi-quantitative indication of herbicide residue levels in soil within 30 minutes. We are

TABLE 2 The number of paddocks exceeding the trifluralin lower phytotoxicity thresholds for oats (0.1mg/kg) and wheat (0.2mg/kg) in topsoil (0–10 cm)

Region	Trifluralin > 0.1 mg/kg	Trifluralin > 0.2 mg/kg	Number of paddocks surveyed
WA	10	5	12
SA	2	0	15
NSW and Qld	0	0	13

also formulating improved models that can account for the effects of weather and soil type on herbicide persistence, to give growers and advisers the ability to estimate soil residue concentrations in a given paddock at a certain time after herbicide application. Output from current and future glasshouse dose-response experiments on herbicide impacts to soil functions and plant growth will be linked to model output in a handheld, 'App' format for quick reference.

Sponsors

The research undertaken as part of this project is made possible by the support of the Grains Research and Development Corporation (GRDC). We would like to acknowledge the generosity of all farmers participating in this survey for support, access and information regarding on-farm herbicide use. Thanks also to our collaborators from Farmlink, NSW; SANTFA, SA; Liebe Group, WA; Facey Group, WA; and NSW DPI, for invaluable assistance with soil sampling and liaison. Ken Lisha and Scott Petty, NSW DPI, provided excellent support in processing soil samples.

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Canola seed trial — size matters

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Key points

- Selecting for larger canola seed has production and profitability benefits.
- The extra value from larger canola seed is independent of sowing date.

Background

For a number of years growers have shown increasing interest in quantifying the potential benefits of seed size on canola production and profitability.

As a response to this interest, a number of seed size treatments were included in replicated trials at Baker Seeds, Rutherglen, to measure the benefits of grading grower-retained open-pollinated triazine-tolerant (TT) canola seed for size.

Aim

The aim of this trial was to quantify the benefits of selecting larger canola seed from grower-retained stocks and determine the profitability of doing so.

Method

Canola seed was graded to ensure clean and undamaged seed was used for the trial. Three different canola size grades were identified and segregated:

- small (1.35–1.75mm diameter)
- medium (1.75–2mm diameter)
- large (>2mm diameter).

Trials were carried out during 2014 and 2015 as part of a larger seed treatment trial. The 2014 trial used Gem TT canola, sown on a single sowing date, while the 2015 trials used Bonito TT canola sown on two sowing dates. Both the Gem TT and Bonito TT canola had been grown at Rutherglen by Lilliput Ag.

Seed was treated with Jockey® and Gaucho® during 2014 trial, and Jockey and Poncho Plus® during 2015.

Seed was counted and sown to achieve the same target plant numbers (45 plants/m^2).

The trial was established in a randomised block design, with a plot size of 1.4m x 10m. Each treatment was replicated three times. Agronomic management and fertiliser application across the trial site was uniform. Results were statistically analysed, with least significant differences (LSD) calculated.

Results

Results from the two years of trials are shown in Figure 1. The 2014 trial, sown on 30 April, showed a significant increase in yield of 200kg/ha at the largest seed size compared with both the small and medium-sized seed.

The 2015 canola sown on 16 April did not show any significant differences, due to high variability within the trial. However, the medium and large-seeded canola sown on 29 April yielded significantly more than the small seed. The yield increase with large-sized canola over the small-seeded canola was 310kg/ha.

The results on vigour have also been consistent and remarkable in the trials, with visual differences evident (Figure 2).

Economics

Seed sizing and sowing large grower-retained seed from open-pollinated TT varieties resulted in returns between medium and large-sized seed ranging from $67.50/ha to $94.50/ha (Table 1).

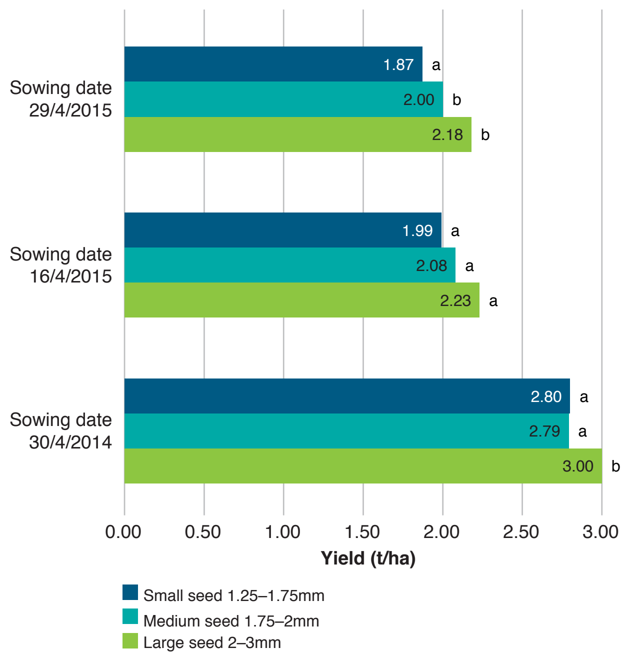

FIGURE 1 Effect of seed size on canola yield, when sown on 30 April 2014, 16 April 2015 and 29 April 2015
Letters denote significant difference in yield within each sowing date.

FIGURE 2 Visual differences in vigour were evident between treatments sown with small, medium and large canola seed (left to right). These photos were taken on 22 May 2014, 23 days after sowing

TABLE 1 Economic return from seed sizing and sowing of grower-retained open-pollinated TT varieties sown on 30 April 2014, and 16 and 29 April, 2015

	Sowing date 30 April 2014		Sowing date 16 April 2015		Sowing date 29 April 2015	
	Yield (t/ha)	Income ($/ha)	Yield (t/ha)	Income ($/ha)	Yield (t/ha)	Income ($/ha)
Small seed	2.80[a]	1260.00	1.99[a]	895.50	1.87[a]	841.50
Medium seed	2.79[a]	1255.50	2.08[a]	936.00	2.00[b]	900.00
Large seed	3.00[b]	1350.00	2.23[a]	1003.50	2.18[b]	981.00
LSD P=0.05	0.172		0.284		0.185	
CV	3.630		8.090		5.730	

Figures followed by different letters are regarded as statistically significant.
*Based on a farm gate canola price of $450/t

There was also a correlation of yield improvement between each size grade, highlighting that the bigger the seed the better the yield outcome. The exception to this was during the 2014 trial where the small seed tended to perform better slightly better than that of the medium-sized seed.

Conclusions

Commercial seed sizing and grading is achievable, with the cost of seed sizing and grading currently at $2.00/kg (over 2.2–2.4t) based on clean bare seed, and when 10% of a bulk seed line is retained from high-quality seed. This could be considered an affordable investment for the return achieved with increased early vigour and potential yield.

Acknowledgements

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Effect of drought alone, and combined with cold stress, on wheat varieties

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Key points

- Crops experience more than one stress during the growing season and wheat varieties differ in their genetic potential to tolerate one or multiple stresses.
- Better understanding the ability of particular varieties to tolerate stress allows growers to make the best varietal choice at the start of the cropping season.

Background

Wheat is severely influenced by different abiotic (physical external) stresses, such as drought and cold stress, and on occasion a combination of both. Consequently, crop yields suffer when crops are exposed to such stresses during critical stages of growth. To sustain production it is important to understand the differences in the genetic potential of existing varieties to withstand the impact of drought and cold stress alone and in combination.

Aim

The aim of this study was to investigate the impacts of drought stress alone and combined with low temperature during flowering on different wheat varieties and also to better understand how varieties differ in their genetic potential to withstand one or the other kind of stress.

Method

This experiment was designed to explore plant physiological and agronomic traits to ascertain the genetic variation of wheat varieties for drought alone and combined (drought and cold) stress. Four popular varieties were selected for the experiment: Gregory, Gauntlet, Gladius and Lincoln. The trial was established in a completely-randomised block design, with three replications, in a glasshouse and coldroom facility at Parkville Campus, The University of Melbourne.

These wheat varieties were tested during flowering and exposed to three different treatments in each replication: control, drought stress and combined stress of drought and cold. Wheat varieties were raised in 25cm diameter pots (10 plants per pot), filled with standard potting mix and subsequently fertilised based on current recommendations for optimal growth. The crop was grown during winter season 2014.

Drought stress alone was induced by withholding water supply to the plants before flowering for a period of 15 days starting from the 18th day after sowing and during flowering for a period of 15 days.

For combined stress, plants were simultaneously exposed to drought and cold stress, which was simulated by exposing plants to a temperature as low as 5°C (night hours) for a period of 12 days during flowering in a coldroom.

During the experiment, a set of physiological (relative water content) and morphological (plant height, grain yield, biomass and harvest index) traits were measured to determine the ability of the plants to tolerate drought and cold stress. Analysis of variance (ANOVA) was undertaken using Minitab.

Results

All four varieties varied significantly between the treatments for the different traits considered.

Gregory and Gauntlet were found to be sensitive to both drought and combined stress treatments, while Gladius and Lincoln appeared to tolerate both stresses and had relatively similar yields when compared with control plants.

Two wheat varieties (Gauntlet and Gregory) had significantly reduced plant height when exposed to drought and combined stress (Figure 1).

All four varieties exhibited marginal variation for relative water content (RWC) across different treatments. Relative water content is measured using the following formula (where FW, DW and TW are leaf fresh weight, dry weight and turgor weight respectively):

$$RWC = (FW - DW) \div (TW - DW) \times 100$$

This variation for RWC increased marginally when plants were exposed to combined stress. However, Gauntlet, Gladius and Lincoln recorded higher RWC under control conditions compared with stress conditions (Figure 2).

Grain yield per pot for Gregory and Gauntlet were significantly different across the three treatments. In



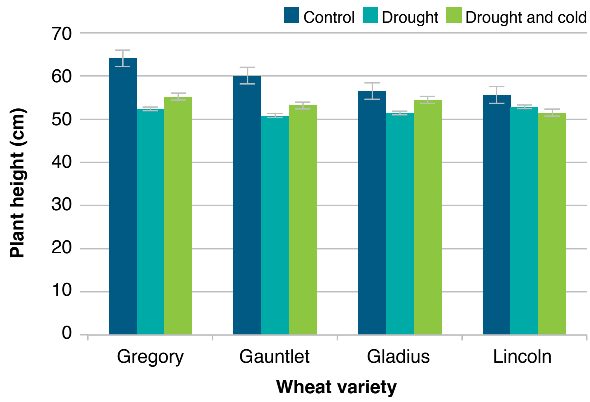

FIGURE 1 Plant height of four wheat varieties in response to drought and cold stress

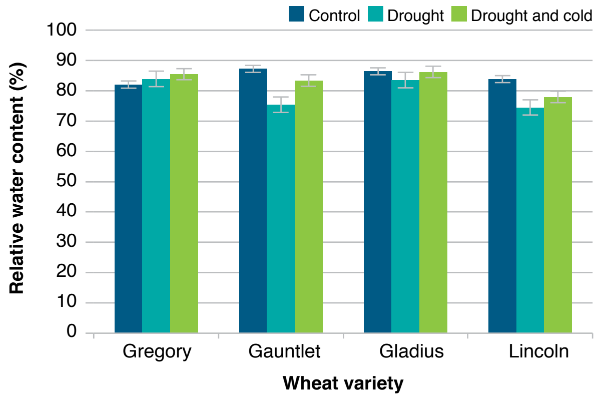

FIGURE 2 Effect of drought and cold stress on relative water content of four wheat varieties

general, grain yield was heavily reduced under combined stress compared with drought alone. Conversely, Gladius and Lincoln performed well under combined stress conditions compared with drought alone. However, Gladius had the highest grain yield under combined stress. Gregory had the highest grain yield under control and drought alone (Figure 3).

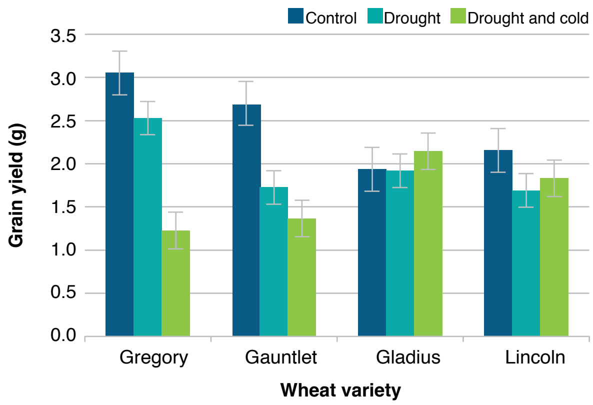

FIGURE 3 Grain yield of four wheat varieties in response to drought and cold

Similar to grain yield, Gregory and Gauntlet varied greatly for biomass (dry matter) across the three treatments. Biomass was highest in the control treatment for Gregory, Gauntlet and Lincoln, followed by drought alone and then the combined stress treatment (Figure 4).

Finally, all four varieties recorded a high harvest index (HI) under control conditions. However, the combined stress resulted in Gregory and Gauntlet having the lowest HI, while the impact of drought alone resulted in the lowest HI values in Gladius and Lincoln. Across the three treatments, Gladius produced statistically significant higher HI compared with the other three wheat varieties (Figure 5).

Observation and comments

This work evaluated the ability of four wheat varieties to tolerate drought alone and combined stress conditions. Surprisingly, an immediate cold stress exposure of plants after drought stress substantially increased the RWC of all four varieties, which might be attributed to reduced water movement in plant caused by a dip in temperatures.

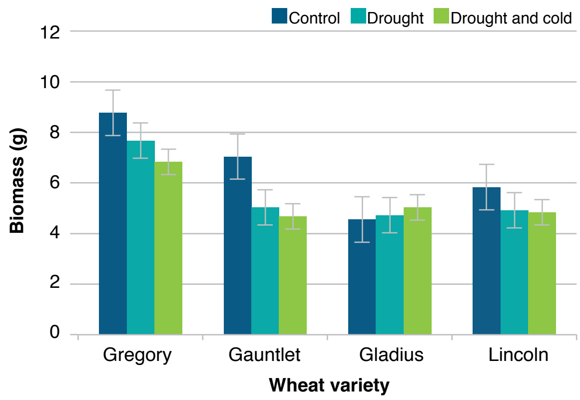

FIGURE 4 Effect of drought and cold on biomass of four wheat varieties

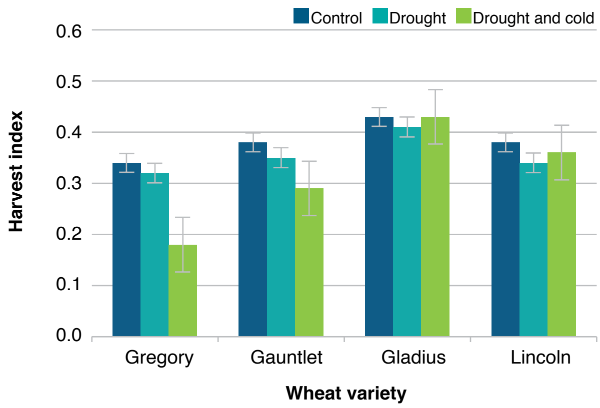

FIGURE 5 Harvest index of four wheat varieties under drought and cold

Drought stress and cold stress impacts DM production largely through inhibited leaf expansion and development, leading to hampered grain filling and smaller and fewer grains. Similarly, varieties Gregory, Gauntlet and Lincoln had reduced grain yield, biomass and subsequent HI due to drought and combined stress at flowering. Nevertheless, Gladius tolerated stress conditions and produced heavier grain, higher biomass and subsequently higher HI.

The results obtained in this study illustrate that drought alone, and combined with low temperature stress, had a negative effect on wheat growth and yield. The results suggested Gladius has inherent ability to tolerate drought stress. Future studies should concentrate on evaluating more wheat varieties to better understand their genetic potential for individual and combined abiotic stresses and the mechanisms underlying tolerance to combined stresses.

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The effect of lignite-treated and non-treated animal manure on wheat

Dorin Gupta, Muhammad Jamal Khan, Rama Harinath Dadu, Tom Irwin, Deli Chen
The University of Melbourne

Key points

- Animal manure can meet the same nitrogen (N) requirement of wheat crops as the recommended urea application.
- Treatment of animal manure with lignite (brown coal) slows the release of nitrogen from manure, to be efficiently utilised throughout the growing season.

Aim

The aim of this project was to examine the residual effect of nitrogen from animal manure applied to a summer sorghum crop, on a subsequent wheat crop.

The objective was to record any differences in crop growth rate and grain yield from organic nitrogen sources, including lignite (brown coal) treatments, compared with the use of inorganic nitrogen fertiliser. It may be that applying such treatments is a useful strategy for adding organic nitrogen as a long-term sustainable way to minimise the use of inorganic nitrogen fertilisers.

Method

The trial site was established on the University of Melbourne, Dookie Campus farm, which had been sown to a summer sorghum crop during late 2014 and was sown to wheat during 2015. Five manure treatments were applied to the sorghum crop during 2014.

- N = Control — nil manure nitrogen, urea applied at 150kg urea/ha
- OC = Old cow manure non-lignite treated
- OT = Old cow manure lignite-treated
- NC = New cow manure non-lignite treated
- NT = New cow manure lignite-treated

Old cow manure had been stockpiled for three months and new manure had been stockpiled for less than a month. Treatment details are shown in Table 1.

The experiment was laid out in a randomised complete block design with four replications. Each plot size was 2m × 2m.

TABLE 1 Urea and manure treatments applied to experimental plots University of Melbourne, Dookie Campus farm

Treatment	Application rate (kg/plot)	Details
N	0.77	Urea
OC	55.8	Old manure control, light brown colour
OT	35.3	Old manure lignite, dark brown colour
NC	29.7	New manure control, light brown colour
NT	29.2	New manure lignite, dark brown colour

Sorghum was harvested during February 2015 and wheat was subsequently established during autumn 2015 across the field site in order to determine if there was any residual nitrogen benefit from the organic materials applied before the sorghum crop. Only the 'N' treatment was re-applied, with urea added at 150kg/ha at the three-leaf stage (GS13), to meet the nitrogen demand of the wheat crop.

Wheat (Corack) was treated with Vibrance® fungicide (1.8L/100kg of seed) and sown into moisture at a rate of 85kg/ha on 25 May 2015. Starter fertiliser (MAP @ 90kg/ha) was applied at sowing to meet initial crop requirements.

Above-ground plant biomass was manually harvested on 12 December, 2015 by using the 0.5m^2 quadrat from each experimental unit. Biomass was kept in an oven at 65°C for 24 hours and grains were manually threshed for yield estimation.

Analysis of variance (ANOVA) was undertaken using MATLAB and least significant difference (LSD) test was used to compare the treatment averages at the 5% level of significance.

The harvest index (HI) was calculated by using the following equation:

$$HI = \frac{\text{Grain yield}}{\text{Dry matter yield}} \times 100$$

Results

Dry matter (DM) yield was statistically non-significant among three manure treatments — old cow manure non-lignite treated (OC), new cow manure lignite treated (NT)

and new cow manure non-lignite treated (NC) and the control (N). However, old cow manure lignite treated (OT) had significantly low DM compared with remaining manure treatments and the control (Figure 1).

High DM did not translate into high grain yield for the treatments: OC, NC and NT. Only NT exhibited significantly high grain yield among all the treatments, including control (Figure 2). The NC, OT, OC and control had non-significant grain yield differences.

Similar to DM, HI was significantly high only in OT (Figure 3). The remaining three treatments (NT and NC and OC) had non-significant differences for HI when compared with the control.

Observations and comments

This experiment was carried out to observe the effect of remaining nitrogen from lignite-treated and non-treated manures applied before the previous sorghum crop and to compare it with a recommended urea application. No nitrogen adjustments were made before sowing the wheat crop.

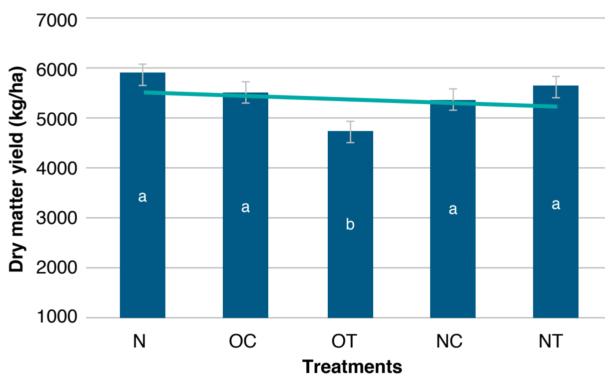

FIGURE 1 Effect of various manure treatments and urea treatment on wheat dry matter yield

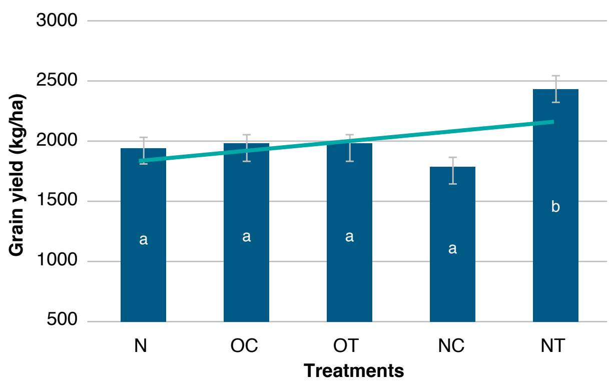

FIGURE 2 Effect of various manure treatments and urea treatment on wheat grain yield

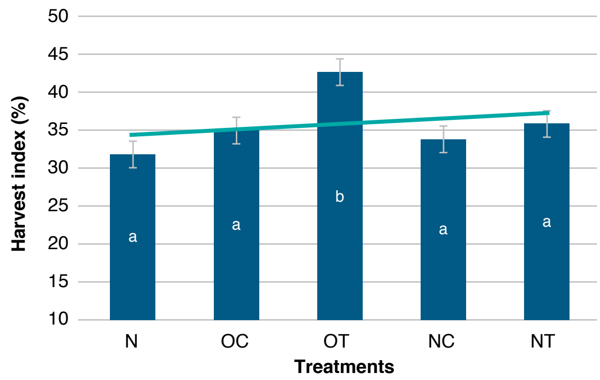

FIGURE 3 Effect of various manure treatments and urea treatment on wheat harvest index

Non-significant differences in grain yield, DM and HI for most of the manure treatments and control indicates the future potential of exploring manure as a slow-release source of nitrogen, and to act as a substitute for some sources of inorganic nitrogen used to supply crop requirements.

The most important observation from this experiment was that the manure applied before the summer sorghum crop left enough nitrogen in the soil for the following wheat crop to produce a grain yield statistically similar to that produced by applying the recommended rate of urea.

Other traits recorded included plant height, spike length, and number of tillers per square metre, which exhibited non-significant differences among most of the treatments and the recommended urea application.

This was a preliminary trial to understand the effect of residual lignite-treated and non-treated manure on wheat crop production compared with recommended urea application. Significant DM and grain yield results indicate the potential to include manure in inorganic fertiliser trials, given its ability to slowly release nitrogen.

Analysis of soil samples collected before sowing the wheat crop and soil and plant samples taken at two different growth stages during the trial will give additional insight into the utilisation of available nitrogen and translation of this into grain yield.

Acknowledgement

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Getting the most out of your irrigation system

Dennis Watson
Department of Economic Development, Jobs, Transport and Resources (DEDJTR), Rutherglen

Key points

- An efficient spray irrigation system maximises crop and pasture production while keeping power and water costs down.
- Irrigation uniformity is important to ensure consistent moisture availability across the paddock maximising yield potential throughout the crop.
- Irrigation scheduling (applying the right amount of water at the right time) is important to maximise yields.
- Irrigation pump efficiency impacts on the overall cost of irrigation — poor efficiency increases the amount of energy required to deliver water from the source to the crop.

Background

Efficient irrigation systems maximise crop and pasture production while keeping power and water costs to a minimum. For an irrigation system to work efficiently:

- water must be applied uniformly across the irrigated area
- irrigation scheduling (timing and amount of water) must meet crop needs
- pump pressure must be minimised by ensuring friction loss in the delivery pipe is low by having correct diameter pipes and ensuring the pressure at the sprinkler is not too high
- the motor and pump must be working effectively and matched correctly to the flow rate and pressure at the pump
- crop or pasture agronomy also needs to be adequate to make the most of the water applied (agronomic considerations vary with crop and pasture type and use and so are beyond the scope of this article).

Irrigation uniformity

Irrigation uniformity is a measure of how evenly the water is applied across the area being irrigated. Absolute uniformity is never obtained under paddock conditions and is impacted by a range of factors including sprinkler spacing, type and age, system pressure and wind.

For example, an average application across the paddock might be 15mm but some areas of the paddock may receive 7mm while others receive 23mm. The result of poor irrigation uniformity is uneven moisture availability across the crop or pasture, which is often expressed in distinct patterns. When compared with a more uniform application system, a poor system will use more water to adequately irrigate any given area

The uniformity of irrigation is typically measured in two different ways: the coefficient uniformity (CU) and the distribution uniformity (DU). The CU is considered a more accurate way to measure variation, while the DU is better used for adjusting irrigation application rates. Both are expressed as a percentage uniformity around the average. The lower the percentage, the larger the deviation from the average.

The CU is often preferred for describing the performance of overhead pressurised systems, such as centre pivots and linear move irrigators. For a centre pivot more emphasis is placed on the extremities of the pivot as this irrigates a larger area than the centre of the pivot. The DU is a measure of how uniformly water is applied to the area being watered.

The industry standard for centre pivots and linear move irrigation systems is a CU above 90% and a DU above 80%.

Irrigation uniformity is measured by placing ‘catch cans’ every 2.5m to 5m in front of, and along the length of, the irrigator (centre pivot or linear move), running the irrigator over the top, and then measuring and comparing the depth of water in each catch can.

An example of the results of a ‘catch-can test’ can be seen in Figure 1. This centre pivot had an application rate of 8.1mm with a CU of 91% and a DU of 86% averaged across both tests, which would be considered acceptable.

The DU is used when factoring in the effective application rate. Using the above example, with an average application rate of 8.1mm and a DU of 86% (0.86), to ensure most of the area under the centre pivot is getting enough water the actual effective application rate is calculated as:



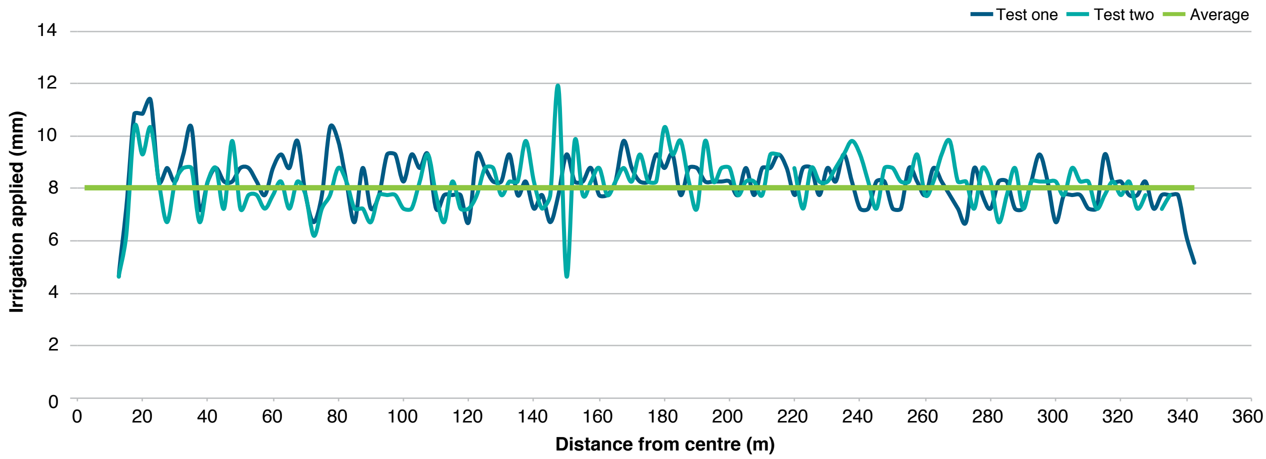

FIGURE 1 The results of a 'catch-can test' of a 350m (38ha) centre pivot showing an average application rate of 8.1mm

Effective application rate = application rate x distribution uniformity

= 8.1 x 0.86

= 7.1mm

If the centre pivot results above revealed a DU of 75% instead of 86%, and looking at the whole irrigation season, typically with a crop demand of 8ML/ha the extra water required would be 1.4 ML/ha to cover for the low application areas and avoid a yield loss.

Water required above crop demand at 86%DU = (crop demand ÷ DU – crop demand)

= (8 ÷ 0.86) – 8

= 1.3ML/ha

Water required above crop demand at 75%DU = (crop demand ÷ DU – crop demand)

= (8 ÷ 0.75) – 8

= 2.7ML/ha

Difference between 75%DU and 86%DU = 2.7 – 1.3

= 1.4ML/ha

For this 38ha centre pivot, a DU of 75% compared with 86% would require an extra 53ML of water and, depending on the depth water is drawn from, friction losses, requiring upwards of an extra 1600L of diesel ($1920 @ $1.2/L diesel) or 6000kW.hrs ($1200 @ $0.2/kW.hrs), which shows the value of improving the uniformity of water distribution.

Irrigation scheduling

Applying the right amount of water at the right time is important to maximise yields. Stretching out irrigation intervals or applying lower than required application rates to save water and pumping costs are generally not economical, and result in lower yields per megalitre of water applied.

There are several ways to adequately schedule irrigation: using soil moisture probes, using evapotranspiration data, or with a shovel and hand texturing along with some gut feeling. While the third option may not be ideal, never discount the value of experience built up over time.

There are a large number of soil moisture monitoring set-ups available, ranging in their detail and complexity. While there are numerous approaches to recording, collecting and displaying the data, the probes generally are split into two categories: soil tension (pressure) and capacitance probes.

Those that measure in pressure (kPa) provide a guide as to how hard it is for the plants to extract moisture from the soil. This reading can be compared across sites as it is independent of soil type. This probe is often referred to as a gypsum block, which eventually breaks down, needing to be replaced after several years.

Capacitance probes measure soil water percentage, the meaning of the value varies with soil type. For example, heavy clays can hold a greater percentage of soil water, with only a small proportion of this water available to plants. Unless damaged these probes do not need to be replaced.

Data from both types of probes can help growers keep track of water movement through the soil profile and at what depths the crop is extracting moisture. With experience, this can indicate when irrigation should occur. Figure 2 provides an image where the soil moisture at four depths was measured in kPa for lucerne. The higher the value the drier the soil. The dark blue line represents 15cm, the

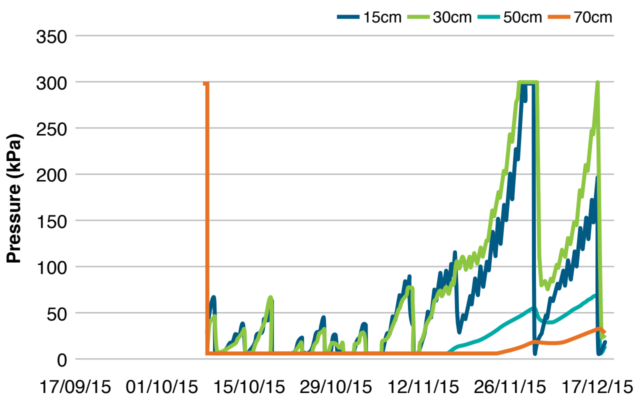

FIGURE 2 Graph displaying results of four soil moisture probes at 15, 30, 50 and 70cm below the soil surface

green line represents 30cm soil depth, the light blue line represents 50cm and the orange line represents 70cm. Plants generally extract moisture from the shallowest depth until that dries out to a point where it is easier to get water deeper. This is demonstrated where moisture is extracted first from the 15cm depth, closely followed by the 30cm depth. With a few rainfall events, it is not until mid November that moisture is starting to be used from the 50cm deep probe, as the two shallower probes reach a level of 100kPa. A small rainfall event occurred close to 20 November 2015, but this was only enough to affect the 15cm deep probe.

While this information can be invaluable it is important to realise these probes only measure a small amount of soil around the probe and care needs to be taken when extrapolating this information across a whole paddock, especially when soil types and irrigation uniformity vary. The use of an electromagnetic (EM) survey could help with correct probe placement.

With this in mind, using evapotranspiration rates can provide an overarching estimate of theoretical plant use. Evapotranspiration rates in conjunction with a crop coefficient can provide a guide to how much water the crop is using and hence indicate how much needs to be replaced. The crop coefficient relates specifically to different crop types and crop stages of growth. A healthy lucerne crop has a crop coefficient of around 1.0, whereas a newly-planted crop with little ground cover could have a crop coefficient of only 0.4. A healthy maize crop in full swing may have a crop coefficient of 1.2.

To calculate the amount of water used by the crop, the evapotranspiration rate is multiplied by the crop coefficient.

While evapotranspiration rates vary from day to day and year to year Figure 3 shows the long-term average throughout the year for the Yarrawonga area.

This means typically in the middle of an average January a healthy lucerne crop will be using around 8.8mm/day, or 62mm in a week.

It is important to remember this is how much the lucerne is using, not what should be applied. To determine the amount of water to apply consider the DU, using the formula below. Using the centre pivot in the example provided earlier, with a DU of 86%, 10.2mm/day or 71mm/week should be applied assuming no rainfall.

Water to be applied = potential evapotranspiration x crop coefficient ÷ distribution uniformity

= 8.8 x 1 ÷ 0.86

=10.2mm/day

or

=10.2 x 7

=71mm/week

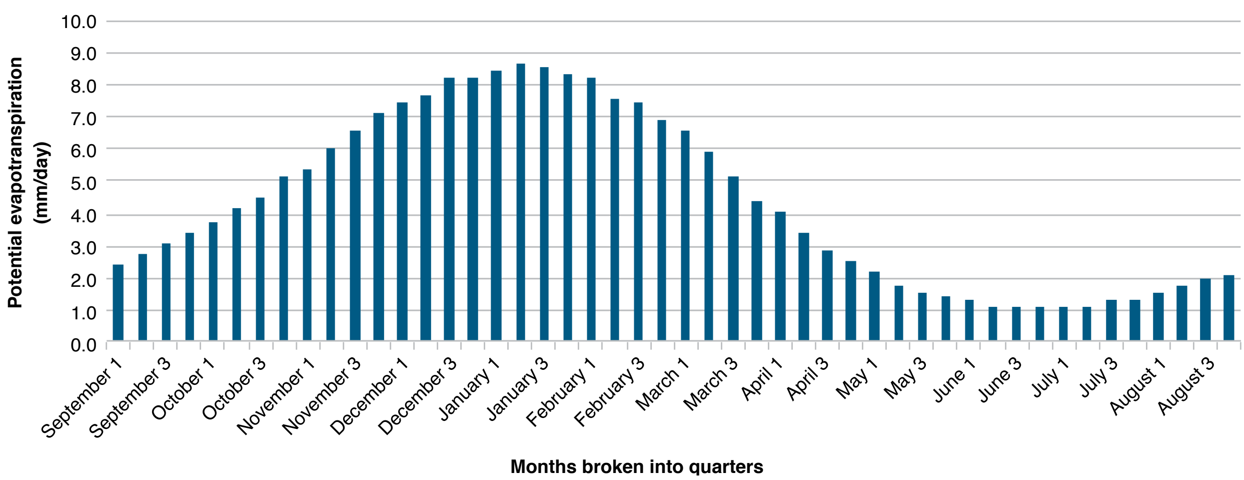

FIGURE 3 Average daily evapotranspiration rates for Yarrawonga*

*Each month is broken into quarters — the first and third quarters are labelled on the graph

  

Note, these evapotranspiration figures are averages and can be higher or lower on any given day. Rain should be included as water applied.

A combination of soil moisture monitoring and the use of evapotranspiration rates is the best way to ensure adequate water is applied throughout the growing season.

Pump pressures and energy cost

While efficient pumping can directly affect the economics of irrigation, it only affects water use efficiency (WUE) if irrigators start to apply less water in an effort to reduce the pumping cost.

The higher the pressure at which the pump is working, the higher the energy use (usually diesel or electricity) per megalitre pumped. A rough guide is that for every increase by one psi at the pump the amount of diesel used goes up by 0.7L/ML pumped and the amount of electricity used goes up by 2.6kW.hrs per megalitre pumped. This assumes a 70% efficiency for a diesel pump and 80% for the electric pump.

The pressure placed on a pump is made up of the:

- height water has to be lifted
- the residual pressure (the pressure at the sprinkler/ nozzles)
- the friction loss in the pipes and suction line
- the velocity head, which is generally negligible in irrigation systems.

Little can be done to change the height water is pumped or lifted. For example if you are pumping using a diesel pump from a bore with water 10m deep it will take 10L of diesel to lift each megalitre before any of the other pressures are considered.

Similarly, little can be done to change the pressure the spray nozzles are designed to operate at. Most centre pivot and linear move systems have pressure-compensated nozzles generally at 15psi. It is recommended the pressure above these be 5–10psi higher to ensure they work correctly. An increase in pressure above that required will increase pumping costs.

The pressure created from the friction loss in the pipes delivering water should be low if the system has been designed with the aim to minimise pumping costs rather than set-up costs. Friction loss can be calculated from the flow rate, the pipe diameter and type, the distance water has to be pumped and extras, such as foot valves, filters, elbows etc. Irrigation systems are not always designed to minimise pumping costs, particularly if the seller is trying to provide the cheapest quote possible. In some cases it is economical to dig up and replace pipes to decrease pumping costs.

Pump efficiency

In the example above of diesel and electricity used to pump water it has been assumed the efficiency of the diesel pump was 70% and the electric pump was 80%. This is not always the case, it can be better or worse. Diesel for instance performs comparatively poorly at higher temperatures — for every 10°C above 25°C, there is a 5% loss of efficiency.

While pumps may be capable of operating at a 90% efficiency level this will only be the case if the pump is operating at its best efficiency point. An increase or decrease in pressure resulting in a change in flow rate can shift the pump's duty point to one of a lower efficiency.

Changing the impeller size or the revolution of the pump (such as variable speeds) can also change the efficiency at which a pump is operating for the better or worse.

Sometimes the pump being used can work efficiently, but does not correctly match the irrigation system it is attached to, forcing the pump to operate inefficiently

Conclusion

All of the components of irrigation discussed above have the potential to reduce the profitability of the irrigation enterprise, whether this is through higher-than-necessary water use, reduced yield or increased pumping cost.

For more information or to gain access to evapotranspiration data, help to measure the uniformity or pressures of your system or to establish if your pumping cost can be reduced, please contact the author.

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Impacts of grazing management and recovery period on lucerne productivity and persistence

Meredith Mitchell[1] and Steve Clark[2]

[1] DEDJTR, Rutherglen

[2] DEDJTR, Hamilton

Key points

- Understanding the effects of defoliation (e.g. grazing or cutting for hay or silage) on lucerne productivity and persistence enables growers to better manage lucerne for agricultural production.
- A lucerne pasture requires a recovery period after a defoliation event and the length of the recovery period is more important than the level of defoliation.
- Repeated grazing of the lucerne stand, with inadequate recovery periods, leads to loss of production and reduced stand life (i.e. persistence).
- A comparison of four treatments examining the effect of four currently-recommended grazing regimes indicated a simple 42-day recovery period is at least as robust as any of the other systems investigated.

Background

It is well understood that lucerne requires a recovery period after grazing or cutting, and the length of recovery is more important than the level of defoliation. Repeated defoliation with inadequate recovery leads to loss of production and reduced stand life (i.e. persistence).

New 'grazing-tolerant' lucerne cultivars are more tolerant of frequent defoliation, but the general principle of recovery still holds. While a range of recommendations exist around recovery periods after defoliation, evaluation of various recovery regimes in different environments is limited.

Popular extension material from Australia and New Zealand favours the onset of grazing when new lucerne shoots reach 2cm and grazing for 7–8 days before removing stock.

Lucerne plants accumulate carbon (C) and nitrogen (N) in their roots during summer and early autumn if there is adequate soil moisture, and will mobilise carbon and nitrogen reserves from their roots immediately after grazing, with general mobilisation also occurring during spring. The grazing management imposed will affect this pattern and it is desirable to understand the compromises made and their consequent effects on production, herbage nutritive value and persistence of the stand. Recommendations include resting lucerne during late summer–early autumn until approximately 50% flowering to allow root reserves to be restored before winter.

The following article reports on initial results of a two-year DEDJTR-funded project — *Lucerne for lamb: increasing lucerne pasture persistence and growth for lamb production* — examining the effect of four currently-recommended grazing regimes at two contrasting sites in Victoria, to test the hypothesis that short defoliation intervals will reduce productivity and persistence.

Aim

The aim of this project is to increase lucerne pasture quantity and persistence by using appropriate management practices, with a flow-on effect for lamb production.

Method

During November 2014 the research team established a replicated experiment in existing lucerne stands of SARDI 7 lucerne at two sites in Victoria — one at Rutherglen and one at Hamilton (Figure 1). Four defoliation treatments were applied and treatments were replicated four times, with each plot 10m x 5.5m. Two permanent 1m x 1m quadrats (each with 100 cells) were established in each plot and the basal frequency (percentage of live lucerne plant bases) in each cell was recorded at the start and throughout the project. All results were statistically analysed using analysis of variance (ANOVA), with means separated using the unrestricted least significant difference (LSD) procedure.

Defoliation was achieved by mowing plots to a height of 5cm.

The four treatments included:

A. *Short recovery (SR):* The SR cycle consisted of a 21-day rest after defoliation and represents half the traditional rest period (42 days). The SR period is less than most historical recommendations for grazing lucerne stands with livestock.

B. *Long recovery (LR):* A LR cycle consisted of a 42-day rest after defoliation and represents the historical recommendation of fixed-recovery periods

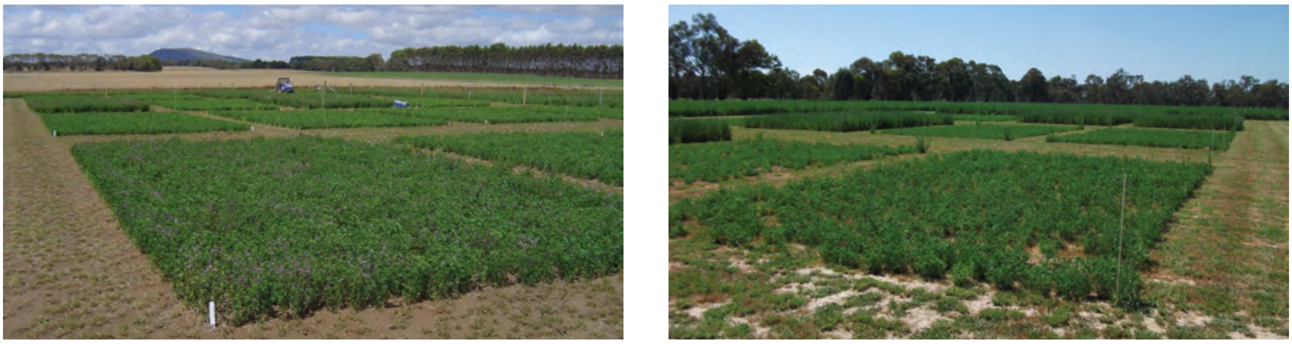

FIGURE 1 Hamilton (left) and Rutherglen (right) lucerne sites

expected to maintain maximum lucerne productivity and persistence.

C. *New shoots (NS):* The NS treatment involved defoliating the lucerne plant when new shoots reached >2cm long. Plots were monitored leading up to a defoliation event and were mown if an average of seven out of 10 randomly-selected plants per plot had new shoots exceeding 2cm. This represents a contemporary recommendation to encourage new growth.

D. *New shoots flowering (NSF):* The defoliation/recovery period followed the same guidelines as for NS with the exception of early autumn, when this treatment was allowed to reach late flowering (phenology stage 6–7) before defoliation. Plots were monitored and mown when an average of 7 out of 10 randomly-selected plants per plot had new shoots exceeding 2cm. This represents a combination of the contemporary recommendation to encourage new growth and a prolonged recovery period for the lucerne stand post-summer.

Measurements started during November 2014 in Hamilton and January 2015 in Rutherglen, with the experiments set to run for at least 18 months. Basal frequency was assessed in each plot before the first defoliation (20 November 2014 at Hamilton and 16 December 2014 at Rutherglen). The basal frequency of lucerne was 58% for Hamilton and 44% for Rutherglen. Differences between the two sites reflect management history before the commencement of this experiment, soil type and weather conditions.

Results

No significant differences in basal frequency were found between treatments from July–December 2015 (Figure 2), reflecting negligible impact on persistence of the various defoilation and recovery treatments.

Each treatment was harvested (defoliated) between eight and 21 times from November 2014 to January 2016 and dry matter (DM) production was calculated for each treatment.

The LR treatment produced the most herbage DM at each site (9400kg DM/ha at Rutherglen and 12,000kg DM/ha at Hamilton) (Figure 3), with the SR treatment producing significantly less DM than the other treatments at Rutherglen (6700kg DM/ha).

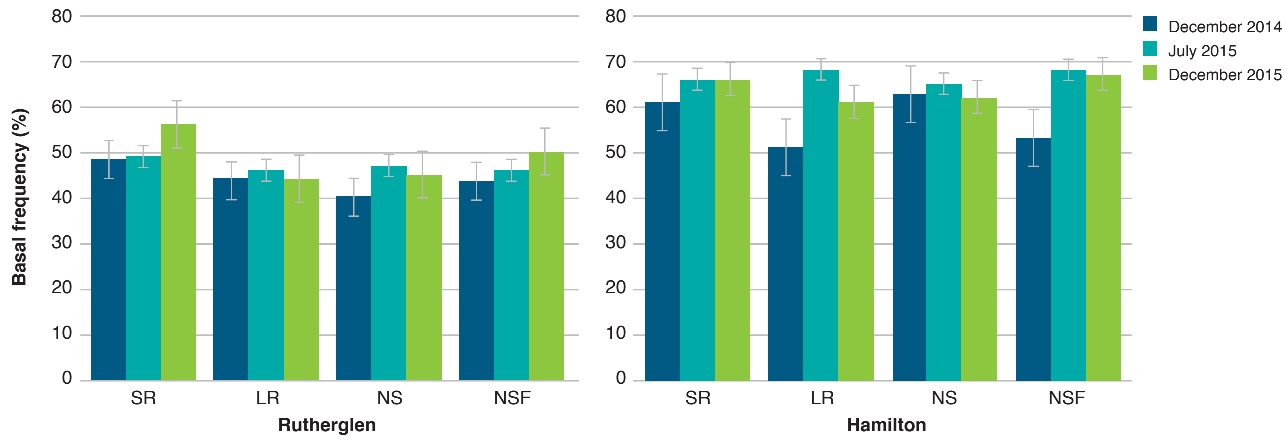

FIGURE 2 Basal frequency for short recovery (SR), long recovery (LR), new shoots (NS) and new shoot flowering (NSF) treatments at Rutherglen and Hamilton in December 2014, July 2015 and December 2015

Error bars are the standard error for comparison within date.

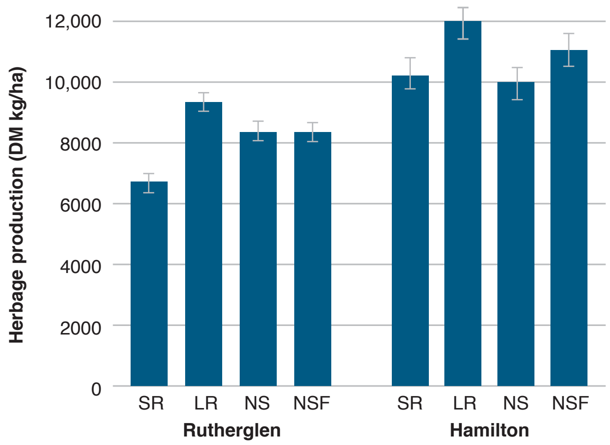

FIGURE 3 Total dry matter production from lucerne treatments at Rutherglen and Hamilton (December 2014 to November 2015)

Error bars are standard error of the difference (SED)

Observations and comments

Lucerne is a reliable perennial, capable of producing green feed in most seasons, subject to soil moisture and temperature and often when other pastures are dormant (e.g. during summer). It can respond to rain in any season, so the risk of extended feed shortages is greatly reduced and the opportunity for out-of-season production is increased.

Strategic rotational grazing is essential to ensure lucerne is both productive and persistent. Adequate recovery time is the most important element of a successful lucerne grazing management strategy. Our results indicate that the simple 42-day recovery period, which reflects the historical recommendation of fixed-recovery periods expected to maintain maximum lucerne productivity and persistence, is at least as robust as any of the other systems investigated. In terms of practical on-farm application, this approach also removes the subjective assessment of new shoots, which is not always easy to determine.

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North east Victoria National Variety Testing Trials 2015

Trials conducted by Agrisearch and NSW Agriculture

Data collated by Katherine Hollaway (formerly DEDJTR Horsham), Julia Severi, Darcy Warren and Dale Grey (DEDJTR Bendigo) from data provided by the NVT website.

TABLE 1 Long-term predicted wheat yield (main-season) in north east Victoria for 2011–15

Variety	Predicted yield (t/ha)	% of EGA Gregory	Site years
Beckom	4.76	109	10
Cobalt	4.72	108	4
LRPB Trojan	4.68	107	13
Scepter	4.68	107	4
Cutlass	4.63	106	4
LRPB Cobra	4.63	106	13
Hydra	4.59	105	3
LRPB Viking	4.59	105	7
Corack	4.55	104	16
Cosmick	4.55	104	9
Suntop	4.55	104	16
Condo	4.50	103	13
Flanker	4.50	103	5
LRPB Scout	4.50	103	16
Espada	4.46	102	9
Mace	4.46	102	10
Correll	4.42	101	14
Impala	4.42	101	15
LRPB Phantom	4.42	101	15
Magenta	4.42	101	15
QAL2000	4.42	101	11
Sunmate	4.42	101	10
Buchanan	4.37	100	4
EGA Gregory	4.37	100	15
Gascoigne	4.37	100	15
Clearfield Stl	4.33	99	6
Elmore CL Plus	4.33	99	15
Orion	4.33	99	9
Wallup	4.33	99	16
Chara	4.29	98	11
DS Darwin	4.29	98	13
Emu Rock	4.29	98	14
Estoc	4.29	98	14
Harper	4.29	98	14
Kord CL Plus	4.29	98	11
Peake	4.29	98	4
Sentinel	4.29	98	6
Axe	4.24	97	14
Bolac	4.24	97	7
GBA Ruby	4.24	97	4
Gladius	4.24	97	15
Justica CL Plus	4.24	97	14
LRPB Gauntlet	4.24	97	15
LRPB Lincoln	4.24	97	14
Sabel CL Plus	4.24	97	3
Shield	4.24	97	4
Ventura	4.24	97	4
Derrimut	4.20	96	16
Kennedy	4.20	96	3
Livingston	4.20	96	8
Sunguard	4.20	96	3
Yitpi	4.20	96	11
Young	4.20	96	4
Barham	4.16	95	14
DS Pascal	4.16	95	10
Gazelle	4.16	95	10
Hatchet CL Plus	4.16	95	3
LRPB Dart	4.16	95	9
Clearfield JNZ	4.11	94	6
DS Newton	4.11	94	10
Grenade CL Plus	4.11	94	14
LRPB Merlin	4.11	94	14
Forrest	4.07	93	4
Frame	4.07	93	4
LRPB Lancer	4.07	93	9
SF Ovalo	3.77	86	3



TABLE 2 Long-term predicted wheat yield (long-season) in north east Victoria for 2011–15

Variety	Predicted yield (t/ha)	% of Preston	Site years
Beaufort	6.19	101	3
SQP Revenue	6.14	100	4
Preston	6.13	100	4
Kiora	6.03	98	3
QAL2000	6.01	98	4
Orion	5.82	95	3
Gazelle	5.81	95	4
Viking	5.74	94	3
Elmore CL Plus	5.72	93	3
Sentinel	5.69	93	3
Bolac	5.67	93	4
EGA Gregory	5.60	91	4
Chara	5.56	91	4
Forrest	5.52	90	3
EGA Wedgetail	5.50	90	4
Estoc	5.44	89	3
Kellalac	5.42	88	4
Gascoigne	5.41	88	3
DS Darwin	5.36	87	3
Gauntlet	5.36	87	3
Lancer	5.34	87	4
Mansfield	5.11	83	4

TABLE 3 Yield and quality of wheat varieties (main-season) at Dookie for 2015

Variety	Yield (t/ha)	Test weight (kg/hL)	Protein (%)	Screenings <2.0mm (%)	Seed size (g/1000 seeds)	Height (cm)	Heading year day*
Beckom	3.34	77	14.6	19.5	23	80	267
Scepter	3.17	78	14.7	17.9	26	84	269
Cobalt	3.00	78	15.4	10.7	27	93	258
Mace	2.97	-	-	-	-	87	266
Gascoigne	2.94	78	15.0	16.7	28	88	278
Corack	2.93	77	14.6	13.5	31	79	269
Cutlass	2.92	76	15.8	15.5	23	83	275
LRPB Trojan	2.87	79	15.9	21.2	25	87	266
Suntop	2.85	79	14.9	14.9	28	90	264
LRPB Phantom	2.84	78	15.4	12.7	28	81	269
LRPB Cobra	2.83	76	15.4	15.3	25	85	266
Derrimut	2.81	78	15.0	14.3	25	77	275
Gladius	2.81	77	14.7	9.6	29	81	274
Harper	2.78	78	15.9	20.2	24	83	266
LRPB Scout	2.78	79	15.7	18.7	26	83	269
Condo	2.73	79	15.0	11.2	32	95	269
Cosmick	2.73	60	15.3	25.0	24	93	261
Estoc	2.73	79	17.1	29.3	24	78	266
Steel	2.73	75	14.6	14.8	26	95	269
DS Darwin	2.71	-	-	-	-	82	269
LRPB Gauntlet	2.71	80	15.1	9.7	26	80	272
Kord CL Plus	2.71	76	16.2	14.5	27	77	266
Axe	2.69	-	-	-	-	77	266
DS Newton	2.68	73	15.5	8.3	26	71	273
Wallup	2.66	78	16.3	20.7	25	91	258
Sunmate	2.65	73	15.1	20.7	24	81	266
Emu Rock	2.61	77	16.1	15.9	32	79	269
LRPB Merlin	2.56	78	16.5	23.3	26	81	261
QAL2000	2.55	76	14.6	18.2	25	76	278
Grenade CL Plus	2.54	75	15.7	22.7	24	86	269
LRPB Spitfire	2.53	77	16.5	24.3	27	83	269
EGA Gregory	2.50	79	15.5	12.2	26	99	280
Yitpi	2.50	-	-	-	-	84	270
Magenta	2.49	75	17.0	18.0	26	82	273
LRPB Lincoln	2.47	69	15.4	18.8	26	91	273
Correll	2.46	76	16.3	13.3	28	80	278
Justica CL Plus	2.45	74	16.3	20.9	24	69	275
Elmore CL Plus	2.44	76	16.8	21.0	22	83	278
Impala	2.43	76	16.1	20.8	21	103	268
LRPB Viking	2.40	76	16.9	22.1	23	90	268
LRPB Lancer	2.39	-	-	-	-	81	275
LRPB Flanker	2.36	-	-	-	-	93	278
Buchanan	2.35	-	-	-	-	93	271
Barham	2.28	-	-	-	-	85	273
DS Pascal	2.23	-	-	-	-	87	272
Sown	13 May 2014		**F prob**	<0.001			
Harvested	10 December 2014		**LSD (t/ha)**	0.29			
Site mean (t/ha)	2.69		**pH ($CaCl_2$)**	5.6			
CV (%)	6.00		**GSR (Apr–Oct)**	233mm			

* Heading year day is the calendar day of the year on which the crop heads emerged.

TABLE 4 Yield and quality of wheat varieties (main-season) at Wunghnu for 2015

Variety	Yield (t/ha)	Test weight (kg/hL)	Protein (%)	Screenings <2.0mm (%)	Seed size (g/1000 seeds)	Height (cm)	Heading year day*
Beckom	2.62	80.8	11.6	9	27	68	258
Cosmick	2.56	79.8	11	10.9	26	74	264
Cobalt	2.45	81.6	11.6	8.8	27	81	258
Cutlass	2.45	70.4	12.2	4.3	30	75	268
Elmore CL Plus	2.45	82.2	12.2	7.9	28	76	271
Corack	2.41	79.2	11.6	6.6	30	74	264
Mace	2.39	80.0	11.5	9.9	29	80	261
Estoc	2.37	81.2	12.9	12.3	27	73	268
LRPB Trojan	2.32	81.8	12.4	8	29	78	271
LRPB Scout	2.30	81.4	11.9	7.4	27	73	264
LRPB Phantom	2.28	80.4	12.3	9.6	31	77	271
Axe	2.24	80	11.7	5.4	29	70	258
Buchanan	2.21	79.4	13.2	12.4	25	71	271
Kord CL Plus	2.21	79.8	11.9	6.4	25	76	264
Magenta	2.21	79.8	12.5	7.2	31	69	271
Derrimut	2.17	54	12.3	7.1	27	71	275
Condo	2.15	78.4	12.0	8.1	29	93	255
EGA Gregory	2.15	2.16	12.3	4.8	29	82	275
Impala	2.15	80.8	11.8	12.0	23	88	268
Scepter	2.15	81.0	11.0	6.4	29	72	268
LRPB Flanker	2.13	78.2	12.3	4.5	28	87	271
Wallup	2.13	81.4	12.4	7.7	26	73	264
Correll	2.11	78.2	12.6	9.2	27	76	271
LRPB Cobra	2.06	78.8	12.7	7.0	27	68	261
DS Pascal	2.06	-	-	-	-	62	278
Grenade CL Plus	2.06	80.6	11.8	6.3	29	83	251
LRPB Spitfire	2.06	79.4	13.1	11.6	28	76	261
LRPB Viking	2.06	82.4	13.1	8.7	25	82	271
Yitpi	2.06	79.6	12.4	7.5	30	75	268
Sunmate	2.04	78.8	12.3	11.2	25	76	261
LRPB Merlin	2.02	79.8	12.6	12.5	29	80	264
Gladius	1.98	79.4	12.3	5.9	30	76	264
Justica CL Plus	1.98	78.2	13.0	6.6	27	68	271
Barham	1.96	76.2	12.0	10.5	25	78	268
DS Darwin	1.96	-	-	-	-	63	264
DS Newton	1.96	78.8	12.9	7.7	25	61	268
Suntop	1.96	80.8	13.1	11.8	28	80	264
Harper	1.91	80.2	13.0	12.5	27	74	261
Steel	1.91	79.2	13.1	6.0	28	83	258
Emu Rock	1.85	78.2	12.4	11.3	30	62	255
Gascoigne	1.83	79.0	12.5	9.5	28	71	271
LRPB Lancer	1.83	81.4	13.2	6.0	30	58	275
LRPB Lincoln	1.81	79.8	12.5	14.1	28	87	261
LRPB Gauntlet	1.74	83.6	12.7	3.4	29	65	268
Sown	12 May 2015		**F prob**	<0.001			
Harvested	4 December 2015		**LSD (t/ha)**	0.40			
Site mean (t/ha)	2.15		**pH ($CaCl_2$)**	4.6			
CV (%)	11.20		**GSR (Apr–Oct)**	195mm			

* Heading year day is the calendar day of the year on which the crop heads emerged.

TABLE 5 Yield and quality of irrigated wheat varieties (main-season) at Numurkah for 2015

Variety	Yield (t/ha)	Test weight (kg/hL)	Protein (%)	Screenings <2.0mm (%)	Seed size (g/1000 seeds)
DS Newton	8.66	83.9	12.2	1.4	39.0
Manning	8.38	73.5	11.6	5.4	36.3
Beaufort	8.16	79.8	11.8	2.6	39.3
Adagio	8.02	75.0	11.9	4.0	36.0
Cutlass	7.95	84.8	11.4	1.8	40.7
DS Pascal	7.88	83.9	11.0	0.9	38.0
Steel	7.80	81.8	12.5	1.8	46.3
Buchanan	7.73	85.2	11.2	2.2	42.0
Cosmick	7.59	84.2	11.8	2.6	37.7
Kiora	7.59	83.4	11.8	2.7	38.0
LRPB Cobra	7.59	81.1	12.2	3.8	34.0
Scepter	7.59	80.6	11.9	3.0	40.3
LRPB Scout	7.52	86.0	11.3	1.8	41.0
Beckom	7.45	81.2	12.1	7.2	30.3
Gascoigne	7.45	86.7	12.8	0.9	48.3
LRPB Viking	7.45	85.6	11.7	2.5	40.7
Cobalt	7.37	82.2	12.7	2.1	43.3
Corack	7.37	87.0	12.1	0.4	51.3
Mitch	7.30	82.3	10.9	1.8	42.3
Gazelle	7.23	81.0	9.7	1.6	37.3
Wedin	7.23	81.2	10.9	2.4	40.0
AGT Katana	7.16	88.0	12.7	0.9	46.0
EGA Wedgetail	7.16	81.0	11.4	1.0	38.7
Mace	7.16	85.6	12.0	1.6	43.0
DS Darwin	7.09	84.4	11.9	0.8	47.3
SQP Revenue	7.02	73.5	11.6	7.6	33.0
Condo	6.95	87.2	12.6	1.3	50.3
Derrimut	6.95	84.4	12.0	2.4	38.0
LRPB Trojan	6.87	84.2	11.8	1.5	44.7
Einstein	6.80	70.4	11.3	5.0	31.3
Scenario	6.80	72.3	11.8	5.4	30.3
Chara	6.73	83.6	11.9	4.2	34.7
Elmore CL Plus	6.66	86.3	11.9	1.0	37.3
LRPB Gauntlet	6.66	84.4	12.5	1.6	44.0
Sunmate	6.59	83.7	11.3	2.4	44.0
Wallup	6.59	84.9	12.0	1.6	40.3
Impala	6.52	85.0	12.2	2.2	34.0
Forrest	6.44	79.7	12.7	7.0	39.0
QAL2000	6.37	80.0	10.1	2.4	44.3
Suntop	6.30	83.1	11.8	4.0	39.7
Sunvale	5.73	85.1	13.3	2.8	38.3
Merinda	5.58	85.2	12.0	2.2	33.7
Livingston	5.23	83.2	13.8	3.2	36.7
EGA Gregory	4.94	83.8	12.5	3.0	39.3
Sown	01 May 2015		**F prob**	<0.001	
Harvested	08 December 2015		**LSD (t/ha)**	0.73	
Site mean (t/ha)	7.16		**pH ($CaCl_2$)**	6.4	
CV (%)	6.00		**GSR (Apr–Oct)**	170.1mm	
This trial was sprayed with fungicide during September					



TABLE 6 Yield and quality of wheat varieties (main-season) at Yarrawonga for 2015

Variety	Yield (t/ha)	Test weight (kg/hL)	Protein (%)	Screenings <2.0mm (%)	Seed size (g/1000 seeds)	Height (cm)	Heading year day*
Beckom	3.31	78.0	12.1	21.8	24	77	268
Scepter	3.25	79.0	11.1	16.3	29	82	273
Suntop	3.25	79.8	13.2	11.4	30	87	275
Mace	3.19	79.4	11.6	15.7	28	84	271
Emu Rock	3.16	78.2	12.3	14.9	30	75	264
Corack	3.10	78.4	11.3	13.0	29	77	268
LRPB Cobra	3.10	77.0	12.3	16.0	24	81	261
Sunmate	3.10	78.4	12.8	14.1	21	79	268
Cobalt	3.07	79.6	12.3	11.0	28	88	271
Condo	3.07	79.0	12.0	15.9	28	95	264
Gascoigne	3.07	78.2	12.3	11.0	30	86	271
LRPB Gauntlet	3.07	81.6	12.4	7.5	28	78	273
LRPB Trojan	3.05	79.8	12.6	11.2	27	85	268
Cutlass	2.99	78.8	12.3	11.5	26	80	273
Axe	2.96	78.6	12.8	11.8	27	78	264
LRPB Merlin	2.96	79.6	12.8	15.8	27	80	268
Steel	2.96	78.8	13.1	10.5	28	93	264
Kord CL Plus	2.93	78.6	12.3	15.1	28	78	273
Buchanan	2.90	77.8	13.5	10.8	26	91	271
Elmore CL Plus	2.90	80.6	12.1	11.7	25	80	275
Estoc	2.90	79.6	12.2	13.9	27	77	274
Cosmick	2.87	77.0	12.2	22.8	25	87	273
Gladius	2.87	78.2	12.4	10.1	30	79	271
LRPB Flanker	2.87	79.4	11.7	11.3	28	91	278
Impala	2.84	79.8	11.8	11.9	22	102	268
LRPB Spitfire	2.84	80.6	12.8	12.7	29	81	268
DS Darwin	2.81	79.8	11.8	10.5	25	72	273
EGA Gregory	2.81	79.2	11.6	9.7	31	96	278
Grenade CL Plus	2.81	78.0	12.1	14.5	31	86	268
Wallup	2.78	80.4	12.1	10.2	27	88	268
Derrimut	2.76	78.6	12.2	17.0	25	76	273
LRPB Phantom	2.73	78.8	12.2	12.4	27	80	273
LRPB Scout	2.73	78.6	12.5	17.0	27	79	273
QAL2000	2.73	76.2	12.5	16.7	28	72	278
Harper	2.70	78.8	11.9	18.2	27	84	271
LRPB Viking	2.67	80.0	12.8	12.8	26	88	275
Correll	2.64	77.6	12.2	15.7	29	82	273
Yitpi	2.64	79.0	12.4	14.3	27	81	275
LRPB Lancer	2.58	79.2	12.6	9.2	28	73	281
Magenta	2.58	76.4	13.0	14.4	29	81	275
Justica CL Plus	2.55	75.0	13.1	14.5	25	69	278
LRPB Lincoln	2.55	79.0	11.6	12.3	26	88	264
DS Newton	2.52	78.4	12.8	7.3	27	69	275
Barham	2.49	73.8	12.7	15.4	23	85	271
DS Pascal	2.32	77.2	13.2	14.3	24	72	275

Sown	11 May 2015	**F prob**	<0.001
Harvested	01 December 2015	**LSD (t/ha)**	0.19
Site Mean (t/ha)	2.90	**pH ($CaCl_2$)**	4.9
CV (%)	3.70	**GSR (Apr–Oct)**	264mm

* Heading year day is the calendar day of the year on which the crop heads emerged.

TABLE 7 Yield and quality of wheat varieties (main-season) at Rutherglen for 2015

Variety	Yield (t/ha)	Protein (%)	Screenings <2.0mm (%)	Height (cm)	Heading year day*
Adagio	6.75	9.7	14.3	96	285
Beckom	6.07	9.6	12.0	81	253
Bolac	5.94	10.3	13.1	108	268
Chara	6.31	9.4	11.7	105	257
Cutlass	5.94	9.7	15.4	109	257
DS Darwin	5.63	-	-	94	257
DS Newton	6.25	-	-	90	253
DS Pascal	6.62	-	-	101	268
EGA Gregory	4.70	9.5	13.7	114	278
EGA Wedgetail	6.31	9.6	11.9	123	264
Elmore CL Plus	5.76	10.4	12.9	107	257
Forrest	6.38	9.7	12.9	123	264
Gascoigne	6.07	10.3	14.2	115	253
Gazelle	6.38	9.4	9.6	116	264
Kellalac	6.31	9.8	10.9	105	278
Kiora	6.31	10.4	10.6	110	261
LRPB Flanker	5.51	9.1	11.6	118	261
LRPB Gauntlet	5.76	10.2	27.1	97	257
LRPB Lancer	5.94	10.2	10.9	105	270
LRPB Phantom	5.63	9.6	16.5	113	257
LRPB Trojan	6.69	9.7	22.4	103	261
LRPB Viking	5.20	9.6	14.8	118	264
Manning	5.57	9.2	16.0	93	289
Mansfield	5.01	10.6	14.4	82	289
Preston	7.30	9.9	13.4	102	257
QAL2000	6.38	8.9	14.7	120	261
Scenario	5.94	9.8	16.2	98	285
SF Ovalo	6.44	9.9	20.5	106	289
SQP Revenue	6.44	9.1	18.6	100	285
Sunlamb	5.88	10.5	15.5	122	285
Suntop	6.38	10.2	11.3	116	253

Sown	22 April 2015	**F prob**	<0.001
Harvested	18 December 2015	**LSD (t/ha)**	0.80
Site mean (t/ha)	6.19	**pH ($CaCl_2$)**	6.1
CV (%)	7.90	**GSR (Apr–Oct)**	460mm

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



TABLE 8 Long-term predicted triticale yields in north east Victoria for 2008–15

Variety	Predicted yield (t/ha)	% of Jaywick	Site years
Astute	4.56	112	6
Bison	4.52	111	6
Fusion	4.52	111	12
Bogong	4.24	104	16
Hawkeye	4.20	103	16
Berkshire	4.16	102	16
Canobolas	4.16	102	16
Jaywick	4.08	100	16
Chopper	4.04	99	16
Tobruk	3.96	97	4
Goanna	3.92	96	10
Crackerjack	3.88	95	4
Rufus	3.88	95	16
Tahara	3.84	94	16
Yowie	3.84	94	12
Tuckerbox	3.48	85	14
Speedee	3.28	80	4

TABLE 9 Yield of triticale varieties at Rutherglen for 2015

Variety	Yield (t/ha)	Test weight (kg/hL)	Protein (%)	Screenings <2.0mm (%)	Seed size (g/1000 seeds)	Height (cm)	Heading year day*
Bogong	6.39	73.4	9.5	13.1	39	137	270
Berkshire	6.28	75.4	9.9	11.0	41	137	264
Bison	6.21	71.4	9.3	9.5	43	131	261
Hawkeye	6.18	72.2	9.5	10.2	43	131	264
Goanna	5.96	74.6	9.7	6.6	37	132	264
Yowie	5.88	73.2	9.5	8.4	40	135	268
Fusion	5.86	71.2	9.4	14.7	41	138	264
Jaywick	5.72	73.8	9.1	9.4	40	133	268
Canobolas	5.68	73.6	9.6	11.8	40	138	264
Endeavour	5.55	71.2	10.0	10.0	24	137	285
Astute	5.44	-	-	-	-	127	268
Tahara	5.35	70.8	10.1	9.7	38	124	270
Chopper	5.34	70.8	9.9	12.0	34	105	264
Rufus	5.25	70.2	10.0	11.3	38	141	264
Tuckerbox	4.95	71.4	9.8	10.7	34	130	274

Sown	13 May 2015	**F prob**	<0.001
Harvested	18 December 2015	**LSD (t/ha)**	0.70
Site mean (t/ha)	5.86	**pH ($CaCl_2$)**	6.10
CV (%)	7.30	**GSR (Apr–Oct)**	460mm

* Heading year day is the calendar day of the year on which the crop heads emerged.

TABLE 10 Yield of triticale varieties at Yarrawonga for 2015

Variety	Yield (t/ha)	Test weight (kg/hL)	Protein (%)	Screenings <2.0mm (%)	Seed size (g/1000 seeds)	Height (cm)	Heading year day*
Bison	2.55	64.8	13.4	14.3	27	97	254
Canobolas	2.47	69.4	14.4	19.6	28	123	266
Bogong	2.42	69.8	13.2	19.1	31	124	269
Astute	2.41	69.2	12.5	14.8	30	96	269
Fusion	2.39	67.0	13.6	22.7	27	107	269
Chopper	2.34	64.4	12.7	20.1	27	93	261
Berkshire	2.29	71.2	14.4	16.0	30	109	266
Jaywick	2.22	65.8	13.6	21.8	29	108	261
Goanna	2.14	69.4	13.4	22.8	25	117	269
Endeavour	2.06	68.0	13.7	14.1	29	98	278
Hawkeye	2.05	67.6	13.6	20.2	28	97	266
Rufus	2.04	67.6	14.4	20.8	28	110	261
Yowie	2.01	67.2	13.5	32.7	27	101	269
Tuckerbox	1.94	68.4	12.9	31.4	26	104	269
Tahara	1.93	65.6	14.0	26.5	27	108	269
Sown	11 May 2015		**F prob**	<0.001			
Harvested	01 December 2015		**LSD (t/ha)**	0.29			
Site mean (t/ha)	2.3		**pH ($CaCl_2$)**	4.9			
CV (%)	7.8		**GSR (Apr–Oct)**	264			

* Heading year day is the calendar day of the year on which the crop heads emerged.



TABLE 11 Long-term predicted barley yield in north east Victoria for 2009–15

Variety	Predicted yield (t/ha)	% of Gairdner	Site years
Malting barley			
Charger	4.07	116	5
La Trobe	3.86	110	4
Granger	3.82	109	5
Commander	3.71	106	6
Wimmera	3.71	106	4
Fairview	3.68	105	6
Flinders	3.64	104	5
Buloke	3.61	103	6
Scope	3.61	103	6
Westminster	3.61	103	6
Macquarie	3.57	102	6
Bass	3.53	101	5
Gairdner	3.50	100	6
Flagship	3.43	98	6
Baudin	3.25	93	6
Navigator	3.14	90	5
Schooner	3.11	89	6
Feed barley			
Fathom	3.82	109	5
Oxford	3.82	109	6
Alestar	3.78	108	3
Fleet	3.78	108	3
Hindmarsh	3.78	108	6
Maltstar	3.75	107	3
Capstan	3.71	106	3
Skipper	3.71	106	4
Barley under malt evaluation			
Compass	4.18	119	3
SY Rattler	3.64	104	6

TABLE 12 Yield of barley varieties at Wunghnu for 2015

Variety	Yield (t/ha)	Test weight (kg/hL)	Protein (%)	Screenings <2.0mm (%)	Seed size (g/1000 seeds)	Height (cm)	Flowering year day*
Rosalind	3.22	59.6	11.7	43.9	30	75	250
Compass	3.12	58.2	10.7	27.6	32	84	250
Fathom	3.06	57.8	11.8	49.7	32	89	254
Hindmarsh	2.89	60.8	11.4	51.1	25	74	247
La Trobe	2.87	59.8	11.8	66.0	25	78	247
Charger	2.85	56.8	12.2	66.6	27	81	254
Spartacus CL	2.82	61.2	11.9	41.8	24	71	250
Scope	2.55	60.8	12.3	50.0	30	94	258
SY Rattler	2.53	56.6	12.6	79.5	25	81	254
Buloke	2.45	59.2	12.5	68.3	29	85	261
Flagship	2.37	59.4	12.1	68.3	29	86	254
Schooner	2.37	60.4	13.6	54.9	28	85	250
Alestar	2.36	56.2	12.8	65.8	26	71	261
Flinders	2.36	60.0	13.1	50.2	25	60	261
Bass	2.35	59.4	13.6	55.6	27	66	261
Gairdner	2.25	57.0	13.6	74.7	34	78	261
Granger	2.22	58.6	13.1	69.2	27	78	250
Westminster	2.15	59.2	13.9	53.9	26	74	265
Commander	2.14	57.2	12.5	58.4	26	66	261
Maltstar	2.12	55.0	12.0	85.8	23	60	261
Oxford	2.03	60.8	13.5	63.1	24	61	271
Macquarie	1.97	58.2	11.7	67.2	26	77	261
Baudin	1.95	56.6	13.5	75.5	25	60	265
Fairview	1.9	58.0	13.9	83.4	24	71	261
Navigator	1.88	60.6	14.2	34.9	26	54	271

Sown	13 May 2015	**F prob**	<0.001
Harvested	10 November 2015	**LSD (t/ha)**	0.3
Site mean (t/ha)	2.42	**pH ($CaCl_2$)**	4.6
CV (%)	7.2	**GSR (Apr–Oct)**	195mm

* Flowering year day is the calendar day of the year on which the crop flowered.



TABLE 13 Long-term predicted oat yield in north east Victoria for 2011–15

Variety	Predicted yield (t/ha)	% of Mitika	Site years	Type
Williams	3.75	124	13	Milling
Bannister	3.58	118	13	Milling
Potoroo	3.52	116	4	Feed
Kojonup	3.40	112	3	Feed
Quoll	3.40	112	6	Feed/ hay
Wombat	3.37	111	13	Milling
Dunnart	3.28	108	13	Milling
Echidna	3.25	107	6	Feed
Euro	3.19	105	4	Milling
Possum	3.07	101	13	Milling
Carrolup	3.04	100	3	Milling
Mitika	3.04	100	13	Milling
Yallara	3.01	99	13	Milling
Numbat	2.44	80	5	Hull-less

TABLE 14 Yield of oat varieties at Yarrawonga for 2015

Variety	Yield (t/ha)	Test weight (kg/hL)	Protein (%)	Screenings 2.0mm (%)	Seed size (g/1000 seeds)	Height (cm)	Heading year day*
Possum	2.83	55.6	14.0	45.5	2.6	91	285
Mitika	2.63	53.4	13.6	31.3	2.9	71	272
Yallara	2.31	55.8	13.0	33.2	2.7	96	278
Bannister	2.27	50.0	12.8	42.9	2.2	87	277
Wombat	2.25	52.8	14.0	86.4	2.5	79	288
Potoroo	2.17	48.8	13.8	62.6	2.3	74	281
Williams	2.17	46.6	14.5	53.1	2.1	92	271
Echidna	1.71	50.6	14.1	43.4	2.5	59	285
Dunnart	1.55	53.0	13.8	43.1	2.5	83	282
Sown	11 May 2015		**F prob**	<0.001			
Harvested	01 Dec 2015		**LSD (t/ha)**	0.38			
Site mean (t/ha)	2.27		**pH ($CaCl_2$)**	4.9			
CV (%)	10.4		**GSR (Apr–Oct)**	264			

* Heading year day is the calendar day of the year on which the crop heads emerged.

TABLE 15 Yield of oat varieties at Dookie for 2015

Variety	Yield (t/ha)	Test weight (kg/hL)	Protein (%)	Screenings <2.0mm (%)	Seed size (g/1000 seeds)	Heading year day*
Mitika	3.06	47.0	13.5	23.8	29	271
Possum	2.74	47.4	13.7	33.3	29	270
Williams	2.73	42.0	13.4	49.1	22	273
Potoroo	2.57	44.0	13.5	36.4	26	277
Wombat	2.54	46.6	13.8	46.8	32	282
Echidna	2.46	43.0	13.1	42.3	32	275
Bannister	2.44	46.0	12.4	36.5	26	275
Dunnart	2.18	43.6	12.6	30.3	28	276
Yallara	2.03	47.2	12.8	36.4	28	274
Sown	08 May 2015		**F prob**	<0.001		
Harvested	07 December 2015		**LSD (t/ha)**	0.32		
Site mean (t/ha)	2.53		**pH ($CaCl_2$)**	5.6		
CV (%)	7.90		**GSR (Apr–Oct)**	233mm		

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

TABLE 16 Long-term predicted conventional canola yield varieties in north east Victoria for 2011–15

Variety	Predicted yield (t/ha)	% of Garnet	Site years
AV Garnet	1.99	100	5
AV Zircon	1.97	99	5
CB Agamax	2.01	101	3
CB Tango C	1.95	98	3
Hyola 50	2.15	108	4
Nuseed Diamond	2.25	113	4
Victory V3002	2.09	105	3
Victory V3003	1.93	97	2

TABLE 17 Yield of conventional canola varieties (mid-season) at Wunghnu for 2015

Variety	Yield (t/ha)	Oil (%)	Seed protein (%)	Seed size (g/1000 seeds)	Height (cm)	50% flowering year day*
Nuseed Diamond	1.78	37.8	24.9	28	132	215
Victory V3002	1.34	40.5	23.5	28	139	224
AV Garnet	1.22	39.2	24.3	35	143	230
AV Zircon	1.22	39.2	23.2	30	136	236
Sown	30 April 2015		**F prob**	<0.001		
Harvested	12 Nov 2015		**LSD (t/ha)**	0.2		
Site mean (t/ha)	1.47		**pH ($CaCl_2$)**	4.5		
CV (%)	6.40		**GSR (Apr–Oct)**	195mm		

* 50% flowering year day is the calendar day of the year on which 50% of the crop flowered.



TABLE 18 Long-term predicted yield of imidazolinone-tolerant (IMI) canola varieties (mid-season) in north east Victoria for 2009–15

Variety	Predicted yield (t/ha)	% of Hyola 474CL	Site years
Banker CL	2.43	110	3
Pioneer 44Y89 (CL)	2.32	105	4
Pioneer 45Y88 (CL)	2.32	105	8
Archer	2.30	104	8
Pioneer 45Y86 (CL)	2.30	104	10
Rimfire CL	2.28	103	5
Pioneer 44Y87 (CL)	2.25	102	6
Hyola 577CL	2.23	101	6
Pioneer 45Y82 (CL)	2.23	101	4
Carbine	2.21	100	6
Hyola 474CL	2.21	100	10
Hyola 575CL	2.21	100	10
Pioneer 44Y84 (CL)	2.21	100	6
Pioneer 46Y83 (CL)	2.19	99	2

TABLE 19 Yield and quality of imidazolinone-tolerant (IMI) canola varieties (mid-season) at Yarrawonga for 2015

Variety	Yield (t/ha)	Oil (%)	Seed size (g/1000 seeds)	Seed protein (%)	Height (cm)	50% flowering year day*
Banker CL	2.58	39.2	4.8	24.2	166	248
Pioneer 44Y89 (CL)	2.42	39.7	5.3	22.0	162	215
Rimfire CL	2.31	38.7	4.8	24.2	182	248
Pioneer 45Y88 (CL)	2.29	38.9	5.3	24.1	157	243
Archer	2.25	38.9	4.9	23.5	184	253
Hyola 474CL	2.23	42.4	4.9	24.1	161	223
Hyola 577CL	2.23	42.9	5.1	24.9	168	248
Pioneer 45Y86 (CL)	2.23	38.9	5.1	23.2	174	237
Pioneer 44Y87 (CL)	2.19	38.5	4.8	22.6	167	229
Hyola 575CL	2.17	42.0	5.2	24.2	162	229
Sown	29 Apr 2015		**F prob**	<0.001		
Harvested	18 November 2015		**LSD (t/ha)**	0.14		
Site mean (t/ha)	2.34		**pH ($CaCl_2$)**	5.4		
CV (%)	3.7		**GSR (Apr–Oct)**	264mm		

* 50% flowering year day is the calendar day of the year on which 50% of the crop flowered.

TABLE 20 Yield and quality of imidazolinone-tolerant (IMI) canola varieties (mid-season) at Wunghnu for 2015

Variety	Yield (t/ha)	Oil (%)	Seed size (g/1000 seeds)	Seed protein (%)	Height (cm)	50% flowering year day*
Pioneer 44Y89 (CL)	1.41	36.5	29	23.1	145	224
Banker CL	1.19	36.6	32	25.5	142	236
Pioneer 45Y86 (CL)	1.13	35.4	31	25.7	142	236
Pioneer 44Y87 (CL)	1.11	35.4	35	25.4	138	224
Pioneer 45Y88 (CL)	1.11	35.3	34	26.2	132	236
Rimfire CL	1.1	37.4	29	25.5	143	221
Hyola 474CL	1.08	35.6	31	26.6	133	230
Hyola 575CL	0.96	35.8	34	26.9	136	240
Archer	0.95	37.3	30	25.1	150	246
Hyola 577CL	0.83	37	35	27.2	133	236
Sown	30 Apr 2015		**F prob**	<0.001		
Harvested	12 Nov 2015		**LSD (t/ha)**	0.15		
Site mean (t/ha)	1.13		**pH ($CaCl_2$)**	4.5		
CV (%)	8.2		**GSR (Apr–Oct)**	195mm		

* 50% flowering year day is the calendar day of the year on which 50% of the crop flowered.

TABLE 21 Long-term predicted yield of triazine tolerant (TT) canola varieties (mid season) in north east Victoria for 2011–15

Varieties	Predicted yield (t/ha)	% of Hyola 444TT	Site years
Hyola 559TT	2.32	114	8
SF Turbine TT	2.32	114	2
DG 560TT	2.30	113	2
Hyola 555TT	2.28	112	6
Hyola 650TT	2.28	112	5
Hyola 751TT	2.28	112	2
Hyola 656TT	2.25	111	4
ATR Mako	2.23	110	4
Crusher TT	2.23	110	6
Pioneer 45T01TT	2.23	110	5
Pioneer Atomic TT	2.23	110	6
ATR Bonito	2.21	109	8
CB Henty HT	2.21	109	6
Hyola 725RT	2.21	109	3
ATR Wahoo	2.19	108	8
Hyola 450TT	2.19	108	4
ATR Gem	2.17	107	9
CB Nitro HT	2.17	107	4
Hyola 525RT	2.17	107	6
Jackpot TT	2.14	106	2
ATR Stingray	2.10	103	6
CB Jardee HT	2.10	103	6
Monola 416TT	2.08	102	4
Pioneer Sturt TT	2.06	101	4
Hyola 444TT	2.03	100	2
Thumper TT	2.03	100	6
ATR Snapper	1.99	98	4
CB Junee HT	1.99	98	4
Monola 314TT	1.99	98	6
Tawriffic TT	1.99	98	2
Monola 515TT	1.97	97	4
Monola 413TT	1.94	96	4
Monola 77TT	1.92	95	2
CB Mallee HT	1.90	94	2
Monola 506TT	1.88	93	4
Monola 605TT	1.88	93	5
Monola 76TT	1.83	90	2
ATR Cobbler	1.81	89	4
Bonanza TT	1.81	89	4
CB Scaddan	1.77	87	2
Monola 707TT	1.77	87	2



TABLE 22 Yield and quality of triazine tolerant (TT) canola varieties (mid-season) at Yarrawonga for 2015

Variety	Yield (t/ha)	Oil (%)	Seed size (g/1000 seeds)	Seed protein (%)	Height (cm)	50% flowering year day*
SF Turbine TT	2.37	37.0	3.1	25.3	158	229
ATR Mako	2.27	38.6	2.9	23.0	162	237
Hyola 559TT	2.24	41.3	3.0	24.4	162	237
Pioneer 45T01TT	2.20	42.0	3.1	25.4	172	243
ATR Wahoo	2.17	41.5	3.3	24.7	150	253
DG 560TT	2.17	37.7	2.4	25.2	153	233
Hyola 650TT	2.12	40.7	3.1	24.5	150	248
Monola 416TT	2.04	41.2	3.0	22.8	146	243
ATR Bonito	2.03	39.6	3.0	25.6	143	237
Hyola 525RT	2.01	41.8	3.5	23.9	154	215
Hyola 725RT	2.01	42.8	3.3	24.8	183	257
ATR Gem	1.99	40.5	3.2	23.3	161	237
Monola 314TT	1.91	37.5	2.8	22.9	145	223
Monola 515TT	1.82	40.4	3.0	23.0	148	253

Sown	29 April 2015	**F prob**	<0.001
Harvested	18 November 2015	**LSD (t/ha)**	0.14
Site mean (t/ha)	2.08	**pH ($CaCl_2$)**	5.4
CV (%)	4.10	**GSR (Apr–Oct)**	264mm

* 50% flowering year day is the calendar day of the year on which 50% of the crop flowered.

TABLE 23 Yield and quality of triazine tolerant (TT) canola varieties (mid-season) at Wunghnu for in 2015

Variety	Yield (t/ha)	Oil (%)	Seed size (g/1000 seeds)	Seed protein (%)	Height (cm)	50% flowering year day*
SF Turbine TT	1.27	35.7	27	28.1	118	230
DG 560TT	1.19	35.1	28	27.3	128	236
ATR Bonito	1.09	37.0	27	27.8	114	230
Hyola 559TT	1.08	37.1	32	27.2	135	233
Monola 314TT	1.08	35.0	24	26.4	123	224
Pioneer 45T01TT	1.05	36.5	31	28.0	145	230
ATR Mako	1.03	37.0	30	25.0	140	236
Hyola 650TT	1.01	37.4	33	27.0	122	236
Hyola 525RT	0.98	36.2	33	27.3	121	230
ATR Gem	0.96	37.5	28	26.6	98	236
Monola 416TT	0.96	36.5	24	26.2	117	224
ATR Wahoo	0.94	38.1	29	26.6	107	240
Hyola 725RT	0.80	36.2	33	27.7	142	236
Monola 515TT	0.78	36.2	29	24.0	115	247

Sown	30 April 2015	**F prob**	<0.001
Harvested	12 November 2015	**LSD (t/ha)**	0.15
Site mean (t/ha)	1.02	**pH ($CaCl_2$)**	4.50
CV (%)	9.10	**GSR (Apr–Oct)**	195mm

* 50% flowering year day is the calendar day of the year on which 50% of the crop flowered.

TABLE 24 Long-term predicted yield of Roundup Ready (RR) canola varieties in north east Victoria for 2011–15

Variety	Predicted yield (t/ha)	% of GT Cobra	Site years
Pioneer 45Y25 (RR)	2.50	122	7
Pioneer 43Y23 (RR)	2.45	119	4
Nuseed GT-50	2.43	118	10
Pioneer 44Y24 (RR)	2.43	118	10
Hyola 600RR	2.39	116	4
Hyola 404RR	2.36	115	10
Pioneer 44Y26 (RR)	2.36	115	4
DG 460RR	2.34	114	2
Hyola 504RR	2.34	114	4
Monola G11	2.34	114	5
Pioneer 45Y22 (RR)	2.34	114	6
Hyola 500RR	2.32	113	4
IH52 RR	2.32	113	5
Victory V5002RR	2.32	113	9
Hyola 400RR	2.30	112	4
Hyola 505RR	2.30	112	5
IH30 RR	2.30	112	2
IH51 RR	2.28	111	4
CB Frontier RR	2.25	110	6
DG 550RR	2.25	110	5
IH50 RR	2.25	110	8
Nuseed GT-41	2.25	110	4
GT Cobra	2.19	106	6
Monola 513GT	2.17	105	8
Pioneer 46Y20 (RR)	2.17	105	2
CB Eclipse RR	2.14	104	4
Victory V5001RR	2.14	104	2
GT Cougar	2.06	100	2
GT Mustang	2.06	100	2
GT Viper	1.99	97	6
CB Status RR	1.94	95	2
GT Scorpion	1.88	91	2
GT Taipan	1.81	88	2

TABLE 25 Yield of Roundup Ready (RR) canola varieties at Yarrawonga for 2015

Variety	Predicted yield (t/ha)	Oil (%)	Seed size (g/1000 seeds)	Seed protein (%)	Height (cm)	50% flowering year day*
Nuseed GT-50	2.57	39.4	3.0	22.6	169	243
Pioneer 44Y24 (RR)	2.52	39.3	3.1	22.6	169	230
Pioneer 45Y25 (RR)	2.43	41.0	3.8	24.2	166	257
IH51 RR	2.37	38.3	2.6	22.5	175	245
Victory V5002RR	2.31	43.8	3.4	21.8	173	248
DG 460RR	2.29	43.4	3.8	22.6	173	243
Hyola 600RR	2.29	42.9	3.6	24.3	195	251
VICTORY V5003RR	2.26	42.6	3.3	22.3	173	248
Hyola 504RR	2.21	41.6	3.7	22.6	161	243
IH52 RR	2.20	40.3	3.0	21.9	157	243
Hyola 404RR	2.19	43.1	3.3	21.9	165	218
Pioneer 44Y26 (RR)	2.19	41.2	2.9	22.3	173	243
Monola G11	2.18	43.8	2.9	22.0	172	223
Monola 513GT	2.10	44.6	2.9	22.1	175	237
DG 550RR	2.04	41.6	3.3	23.3	162	232
Sown	29 April 2015		**F prob**	<0.001		
Harvested	18 November 2015		**LSD (t/ha)**	0.14		
Site mean (t/ha)	2.32		**pH ($CaCl_2$)**	5.4		
CV (%)	3.6		**GSR (Apr–Oct)**	264mm		

* 50% flowering year day is the calendar day of the year on which 50% of the crop flowered.

TABLE 26 Yield of Roundup Ready (RR) canola varieties at Wunghnu for 2015

Variety	Predicted yield (t/ha)	Oil (%)	Seed size (g/1000 seeds)	Seed protein (%)	Height (cm)	50% flowering year day*
Hyola 404RR	1.47	41.5	34	22.3	140	236
IH30 RR	1.46	39.5	33	24.2	125	221
IH52 RR	1.46	38.4	29	23.1	136	230
Monola G11	1.42	40.4	32	23.3	147	224
VICTORY V5003RR	1.4	41.1	32	23.4	155	236
Nuseed GT-50	1.38	39.4	32	23.5	147	227
Pioneer 44Y24 (RR)	1.32	37.6	30	24.2	140	230
Pioneer 45Y25 (RR)	1.32	39.8	33	24.2	135	230
IH51 RR	1.20	36.7	30	24.6	139	230
Monola 513GT	1.18	40.6	30	24.5	131	236
DG 460RR	1.13	40.9	33	23.1	151	236
Pioneer 44Y26 (RR)	1.13	39.0	29	24.1	147	233
DG 550RR	1.08	39.2	32	24.8	134	236
Hyola 600RR	1.04	39.0	36	23.5	135	230
Hyola 504RR	1.03	37.9	36	25.1	145	230
Victory V5002RR	1.02	40.1	33	23.6	145	227
Sown	30 April 2015		**F prob**	<0.001		
Harvest	12 November 2015		**LSD (t/ha)**	0.16		
Site mean (t/ha)	1.28		**pH ($CaCl_2$)**	4.5		
CV (%)	7.4		**GSR (Apr–Oct)**	195mm		

* 50% flowering year day is the calendar day of the year on which 50% of the crop flowered.

TABLE 27 Long-term predicted yield of faba bean varieties in north east Victoria for 2008–15

Variety	Predicted yield (t/ha)	Site years
PBA Zahra	2.87	4
PBA Samira	2.80	4
Fiesta VF	2.65	8
Farah	2.62	8
Nura	2.61	8
PBA Rana	2.55	8
Doza	2.25	3

TABLE 28 Yield and quality of faba bean varieties at Dookie for 2015

Variety	Yield (t/ha)	50% flowering year day*
PBA Zahra	1.73	229
Nura	1.66	236
Fiesta VF	1.62	229
PBA Samira	1.52	233
Farah	1.47	229
PBA Rana	1.38	223
Sown	27 April 2015	
Harvested	04 December 2015	
Site mean (t/ha)	1.6	
CV (%)	9	
F prob	0.0142	
LSD (t/ha)	0.23	
pH ($CaCl_2$)	5.1	
GSR (Apr–Oct)	233mm	

* 50% flowering year day is the calendar day of the year on which 50% of the crop flowered.

TABLE 29 Long-term predicted yield of lupin varieties in north central Victoria for 2009–15

Variety	Predicted yield (t/ha)	% of Mandelup	Site years
PBA Jurien	2.18	101	4
Mandelup	2.16	100	6
PBA Gunyidi	2.12	98	5
Jenabillup	2.10	97	6
PBA Barlock	2.06	95	5
Coromup	2.02	93	6
Wonga	1.81	83	6

Note: The 2015 Diggora (near Elmore) lupin variety trial has data too variable and low yielding to publish.

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