RiverinePlains

Research for the Riverine Plains 2017

A selection of research relevant to agriculture in the Riverine Plains

Farmers inspiring farmers

riverineplains.com.au



Research for the
Riverine Plains 2017

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.

Compiled by Michelle Pardy
Technical editing by Cassandra Schefe
Sub-editing by Hot Tin Roof Communications
Design and layout by Redtail Graphic Design

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CONTRIBUTORS

Advanced Ag	**Elders Yarrawonga**	**Market Check**
Advanta Seeds	**Farmanco**	**NAB Agribusiness**
AdvantAgri Australia	**Hunter Rural**	**Nufarm**
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Department of Economic Development, Jobs, Transport and Resources

Welcome to Research for the Riverine Plains, 2017

During 2016, Riverine Plains Inc was involved in a number of significant and diverse research projects. As a result, the 2017 edition of *Research for the Riverine Plains* largely consists of articles written by Riverine Plains Inc, or by one of our project partners. This is particularly exciting for Riverine Plains Inc as a group, as it reflects our efforts in bringing high-quality, farmer-driven local research to the region. Having access to local research is vitally important to the productivity and sustainability of farmers across the Riverine Plains and we hope you find this collection of articles both interesting and relevant.

FAR Australia is our project partner for the *Maintaining Profitable Farming Systems with Retained Stubble in the Riverine Plains Region* project and has again contributed several articles to this year's publication. These include results from the large-scale trials as well as small plot trials looking at row spacing, yellow leaf spot, plant growth regulators and nitrogen sensing. We sincerely thank Nick Poole, Michael Straight and Tracey Wylie for their valuable contributions.

Riverine Plains Inc has produced a number of articles describing the results from our project, work on frost, soil moisture and harvest weed seed control, as well as our own local work on nitrogen. We sincerely thank each of our project funders, project partners and host farmers for their financial and in-kind contributions.

To provide further information and context to some of the other regional agronomic issues we face, we have again included results from research carried out by other organisations and industry bodies. We trust these articles complement the range of research outcomes presented in this edition.

On behalf of Riverine Plains Inc, I would like to formally thank all authors for sharing their results with our members.

We also 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 thank you to the Riverine Plains Inc staff and committee for their contribution to this publication and to Michelle Pardy, Riverine Plains Inc Communications Officer for managing the editing and publication process. Thanks also to sub-editor Catriona Nicholls and graphic designer Josephine Eynaud for their work in producing a professional and easy-to-read publication.

We hope you enjoy reading your copy of *Research for the Riverine Plains 2017* and wish you all the best for the 2017 cropping season.

Dr Cassandra Schefe
Research and Extension Officer, Riverine Plains Inc.

RiverinePlains

4/97–103 Melbourne Street
Mulwala NSW 2647

PO Box 214 Mulwala NSW 2647

T: (03) 5744 1713
E: info@riverineplains.org.au
W: www.riverineplains.org.au



Contents

Area covered by
Riverine Plains Inc
Membership area



2017 Riverine Plains Inc Committee, support and staff

Committee			
Chairman	Ian Trevethan	Howlong	0428 265 015
Deputy Chair	Adrian Clancy	Splitters Creek	0417 690 117
Immediate Past Chair	John Bruce	Barooga	0428 315 814
Treasurer	Barry Membrey	Wodonga	0400 872 799
Research Subcommittee Chair	Peter Campbell	Henty	0427 293 715
Extensions Subcommittee Chair	Adrian Clancy	Splitters Creek	0417 690 117
Public Officer	John Bruce	Barooga	0428 315 814
Committee Members	Lisa Castleman	Wagga Wagga	0427 201 963
	Paul Gontier	Shepparton	0429 388 563
	Adam Inchbold	Yarrawonga	0418 442 910
	Fiona Marshall	Rennie	0427 324 123
	Eric Nankivell	Albury	0428 914 263
	Clare Robinson	Thurgoona	0428 339 821
	Andrew Russell	Browns Plains	0417 401 004
	Curt Severin	Brocklesby	0427 294 261
	Jo Slattery	Chiltern	0427 261 640
	Brad Stillard	Barooga	0427 733 052

Executive Support			
DEDJTR Victoria	Dale Grey	Bendigo	0409 213 335

Staff			
Executive Officer	Fiona Hart	Mulwala	(03) 5744 1713
Finance Officer	Kate Coffey	Mulwala	(03) 5744 1713
Research & Extension Officer	Cassie Schefe	Mulwala	(03) 5744 1713
Communications Officer	Michelle Pardy	Mulwala	(03) 5744 1713

Units of measurement

Row spacings

Some trials carried out during 2016 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

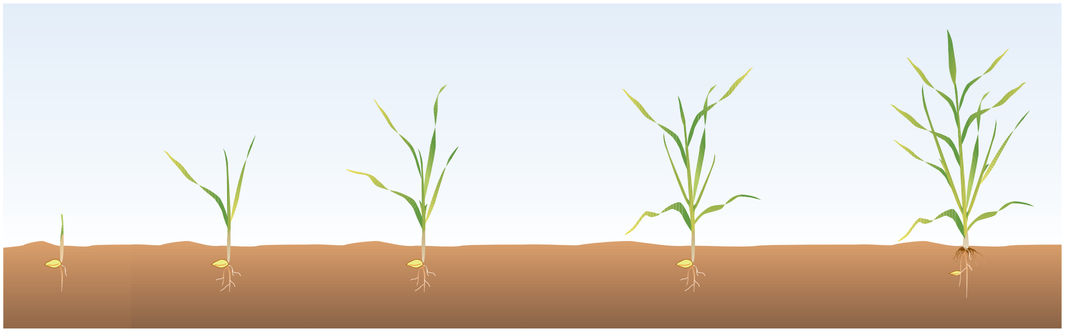
The most commonly used growth stage key for cereals is the:

- 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)

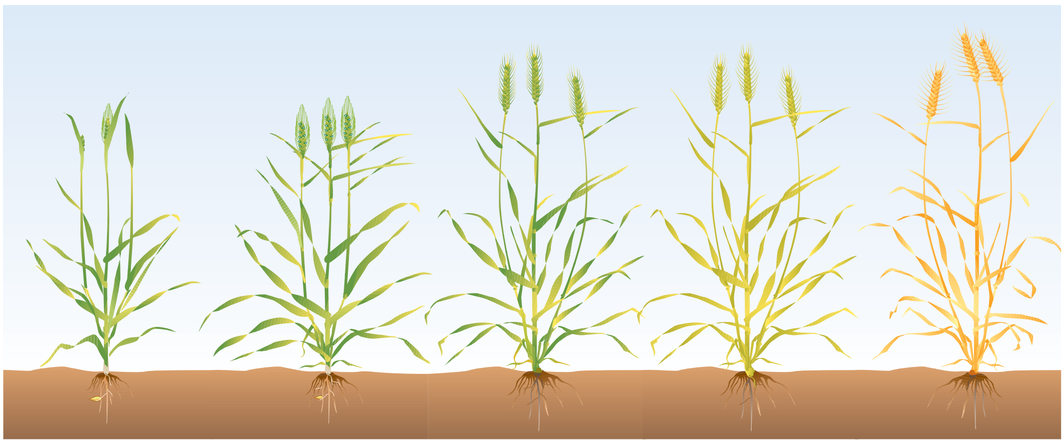
Within each of the 10 development phases there are 10 individual growth stages, for example, in the seedling stage:

- 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 (past) Chairman

John Bruce

Chairman February 2014 to October 2016

Welcome to the 2017 edition of *Research for the Riverine Plains*.

The 2016–17 season was one we won't forget quickly. After a reasonably non-eventful start to the cropping season, the wet really set in over winter and spring, and many crops suffered the effects of waterlogging. With September rainfall ranging from decile 10 to highest on record, trafficability became an issue, with weed management, nutrition and disease management challenges all causing flow-on effects into the 2017 season and probably beyond. In terms of harvest, it was certainly a case of the haves and the have nots — with record-breaking yields in free-draining country and next to nothing in waterlogged ground.

Dealing with challenges like those we faced last year can be financially and emotionally overwhelming. However, groups like Riverine Plains Inc can offer support and direction in difficult times by providing forums for discussions and access to ideas and quality information. 'Farmers inspiring farmers' is what Riverine Plains Inc is all about and sometimes all it takes is being part of a discussion, or hearing about new research or an alternative farming method to get us thinking about ways to improve our farming businesses. With that in mind, I'd like to encourage members to make the most of all that Riverine Plains Inc can offer, by getting along to events and field days or using our publications to stay informed.

Riverine Plains Inc had an exceptionally busy 2016–17; we hosted or co-hosted 25 separate events, with a combined attendance of more than 1000 people. Given these events included both small workshops and large field days, this was a terrific result and is testament to the relevance of these days.

Rutherglen Soil Pit Day: The 2016–17 extension program started with a soil pit day at Rutherglen on 19 January 2016, attended by about 15 farmers. The soil pits at Lilliput and Browns Plains helped illustrate how soil structure and clay content influence water movement, root penetration and nutrient movement. Results from nearby deep nitrogen sampling and moisture probes were also used to discuss nitrogen decision-making. This event was supported by the North East Catchment Management Authority (NECMA) through the *Soil Moisture Probe Network Project*, and Sustainable Agriculture Victoria: Fast-Tracking Ag Innovation initiative made possible with the support of the Foundation for Rural and Regional Renewal (FRRR) together with the William Buckland Foundation.

Sykesy's Buraja Day: The Buraja Recreation Reserve Hall was host to 100 farmers and agribusiness representatives on 4 February 2016 for *Sykesy's Buraja Day*. This annual event continues a tradition started by the late John Sykes 'Sykesy' in providing a forum to discuss the season that was, and hear about varieties and agronomic information relevant to the year ahead.

Sprayer Training Workshop: More than 100 people attended a sprayer training workshop at Rennie on 5 February 2016, which was held as part of the project *Maintaining Profitable Farming Systems with Retained Stubble in the Riverine Plains Region* (the *Stubble Project*), funded by GRDC. Craig Day from Spray Safe and Save conducted the half-day workshop delivering training on optimising boomspray set-up for effective herbicide delivery, with an emphasis on achieving even spray coverage in stubble. A range of spray rigs and equipment was also available for inspection.

GRDC Update: More than 120 growers and industry representatives attended the Grains Research and Development Corporation (GRDC) *Grains Research Update* at Corowa on 18 February 2016. Riverine Plains Inc hosted the event which presented the latest in grain industry research and extension to help growers prepare for the season ahead.

Dookie Soil Pit Day: On 3 March 2016, six growers attended a soil pit day in the Dookie district. Soil pits were dug at Boxwood and Bungeet and provided an opportunity to look at different soil types within the Dookie region. The day focused on identifying the key constraints to plant growth and rooting depth and was held as part of the *GRDC Stubble Project*.

Being a Better Boss Workshops: Riverine Plains Inc supported Partners in Grain (Victoria) in hosting two workshops at Tungamah around legal obligations and managing people on 8 and 15 March 2016 respectively. These workshops provided the 24 participants with training and support across a complex area of farm business management.

Farmers inspiring farmers

Seeder Day: About 60 people attended the Riverine Plains Inc *Seeder Day* events at Barooga and Dookie on 22 March 2016. A number of farmer-owned machines were used and growers saw first-hand how each machine handled medium–high stubble loads. A number of machinery dealers were also present.

Fertiliser Spreader Calibration Day: A 'drop-in' fertiliser spreader calibration day was held at Rutherglen on 2 June 2016. The event featured Russell Nichol, a Fertcare registered calibration specialist, who calibrated three spreaders in front of the 40 growers who attended during the course of the day. The day was run as part of the *GRDC Stubble Project*, which has a component looking at improving the nitrogen (N) use efficiency of crops sown in stubble-retained systems.

GRDC Farm Business Update: On 24 June 2016 Riverine Plains Inc hosted a *GRDC Farm Business Update* held in Yarrawonga/Mulwala. An audience of 80 heard about employing and retaining quality staff, investing in agricultural land, principles of selling grain, communication tools and multi-peril crop insurance.

Farmer Focus Groups: The five-year *GRDC Stubble Project* is investigating ways to improve and maintain profit and sustainability in stubble-retained cropping systems across the region. The project has established four focus farms at Corowa, Henty, Yarrawonga and Dookie, with large, commercial-scale trials at each focus farm. The trials are evaluating a range of stubble management options, with supporting small-scale trials focusing on specific issues, such as row spacing and cultivar selection, nitrogen timing and disease management.

Paddock walks were held at each site during July and October 2016. The July paddock walks saw a total of 50 growers and agribusiness representatives visit the four sites. Nick Poole led the October paddock with a total of 70 participants attending across the four sites.

Drone Technology Workshop: On 14 July 2016 Riverine Plains Inc and Southern Growers hosted a workshop showing local growers the latest in drone technology and demonstrating how drones can be useful agricultural tools. The workshop was held in Berrigan and was attended by 85 people.

In-season Update: A total of 70 growers and agribusiness representatives attended the Riverine Plains Inc *In-season Update* held at Mulwala on 11 August 2016. The update provided information on the seasonal outlook, crop nutrition, pest management, canola agronomy and disease management, as well as precision agriculture. An update of the research projects being conducted by Riverine Plains Inc was also presented.

GRDC Making More Profit from Crop Nutrition Workshop: Following the *In-season Update* on August 11, Riverine Plains Inc partnered with GRDC and Birchip Cropping Group (BCG) to deliver a *Making More Profit from Crop Nutrition* workshop. The workshop was attended by 50 people, who heard about phosphorus (P) management, critical soil nutrient levels, chasing micronutrient responses, and nitrogen management.

Precision Agriculture Workshop: Riverine Plains Inc hosted a *Making Big Data Pay* workshop for growers looking to do more with precision agriculture at Mulwala on 16 August 2016. About 20 attendees heard about making the most of sensor technology, moisture probes and EM38, normalised difference vegetation index (NDVI) and elevation mapping. Applications for variable rate technology (VRT) were also discussed. The workshop was made possible with the support of Murray Local Land Services with funding from the Australian Government's National Landcare Programme.

Social Media for Agriculture Workshop: On 8 September 2016, six people attended a practical skills session to explore social media and mobile technology use in agriculture. The workshop was held at Mulwala and was facilitated by Charles Sturt University (CSU), in partnership with the Graham Centre for Agricultural Innovation.

International Study Tour: Between 28 August – 12 September 2016, 20 Riverine Plains Inc members visited Argentina, Uruguay and Brazil. This was the group's second international agricultural study tour and incorporated visits to a wide range of farms, leading research facilities, no-till specialists and agricultural commodity businesses, with a focus on no-till cropping systems. The tour was supported by the GRDC's *Grower and Advisor Development Program*.

Spring Field Day: The inaugural *Spring Field Day* was held on 13 September 2016 at the Riverine Research Centre (RRC), which is a collaboration between Riverine Plains Inc and FAR Australia. Around 90 farmers, sponsors, advisors and industry representatives heard about the research being carried out at the RRC, as well as nitrogen management and wet-season agronomy.

The Evan Moll Gerogery Field Day: The *Evan Moll Gerogery Field Day* was held on 3 November 2016, and was attended by about 70 people. Attendees were shown through the wheat and canola *GRDC National Variety Trials* where they heard about options for direct heading and wet-season dessication, grain marketing, summer crop options and other agronomic issues. Two soil pits were used to illustrate how root growth can be affected

Attendees at the launch of the Riverine Research Centre, September 2016.

by the wet conditions and other subsoil constraints. The field day was supported by Murray LLS through funding from the Australian Government's National Landcare Programme.

Committee

The Riverine Plains Inc Annual General Meeting was held during October 2016, at which Ian Trevethan of Howlong was elected the new Chairman. Ian was the previous Research Sub-Committee chair (2014–16) and his familiarity with the group, his expertise in farming and his interest in farming systems research will ensure Riverine Plains Inc continues to deliver the highest possible quality farming systems research and extension outcomes.

As I step down from the role as Chairman, I would like to thank the Executive and General Committee members for all of their support and assistance during the past two and a half years. I would also like to thank staff members Fiona Hart, Cassandra Schefe, Kate Coffey and Michelle Pardy for their support. In my time as Chairman, I have also had the opportunity to meet many members and sponsor representatives and I am appreciative of the support and encouragement shown to me by everyone involved in the Riverine Plains Inc community.

The Riverine Plains Committee plays a vital role in the ongoing success of the group. Our committee and various sub-committees provide direction for the research and extension programs, oversee all governance and financial management while also ensuring the needs and expectations of our members, sponsors and funders continue to be met. This is a significant task and I would like to thank the Riverine Plains Inc volunteer committee for their time, dedication and expertise. I have enjoyed my time in the chair and have valued the opportunities for personal development that have come about as a result of my involvement. As such, I would encourage interested members to consider nominating for a position on the committee in the coming months.

I wish you all the best and look forward to catching up at an event or in the paddock somewhere soon.

John Bruce
Chairman

A word from the (new) Chairman

Ian Trevethan

Riverine Plains Inc Chairman

Outgoing Chair John Bruce hands over to Ian Trevethan at the 2016 Riverine Plains Inc Annual General Meeting.

Firstly, on behalf of the Riverine Plains Inc Committee, members, sponsors and friends, I would like to sincerely thank John Bruce who stepped down from the Chairman's role in October, 2016. John has been a stabilising influence for the group over his two and a half years in the Chair and his common-sense approach has been highly valued. John has worked tirelessly behind the scenes to build and maintain relationships during a time of rapid change in the field of grower-driven research and extension and his efforts have been greatly appreciated. John also played an integral role in the development and launch of the Riverine Research Centre, the collaboration between Riverine Plains Inc and FAR Australia. He presided over many changes within Riverine Plains Inc, including the updating of the constitution and the development of our three-year strategic plan in 2015. We wish John all the best and look forward to his continued input on the Committee.

Extension summary

As John described, 2016 was an incredibly busy, but successful, year for Riverine Plains Inc. Putting together such a large program of events would not be possible without the dedicated efforts of the Extension sub-committee (now chaired by Adrian Clancy), as well as our staff. Thank you to all those who help plan, organise and run these events, as well as those who attend and contribute to discussions on the day — your input helps ensure members get the most possible value out of each event.

Research summary

Quality grower-driven research is a fundamental part of Riverine Plains Inc's mission and the Research sub-committee works exceptionally hard to manage our existing projects and develop new project ideas. There is a considerable amount of work involved in each project, and I'd like to acknowledge the efforts of the Riverine Plains Inc Research sub-committee (now chaired by Peter Campbell), our staff (including Research and Extension Officer Dr Cassandra Schefe) and all our farmer hosts for their ongoing work and support in this area.

Our research program for 2017 includes the continuation of work with the GRDC-funded *Stubble Project*, the Department of Agriculture and Water Resources-funded *Nitrous Oxide Project* (led by FAR Australia, which concluded in June 2017), as well as the GRDC-funded *Harvest Weed Seed Project* (led by Southern Farming Systems). We also continue with the Sustainable Agriculture Victoria: Fast-tracking Ag Innovation initiative made possible with the support of the Foundation for Rural and Regional Renewal (FRRR) together with the William Buckland Foundation.

I am pleased to announce we have been successful in securing funding from the GRDC to run a 12-month project *Optimising crop nutrition in canola in the southern region of NSW*, which is looking at sulphur and nitrogen interactions in canola during the 2017 growing season.

In 2017 we also start two short-term projects: *Improving fertiliser and chemical use through local real-time weather and soil information for farmers of the productive plains* and *Refining deep soil nitrogen testing to reduce environmental losses*. These projects are both supported by the Goulburn Broken Catchment Management Authority (CMA) through funding from the Australian Government's National Landcare Programme.

Further, we also begin the *Connecting fertiliser requirements with soil water storage and soil type in cropping systems* project funded through the North East Catchment Management Authority (NECMA), as well as the *Linking nutrient movement to soil water at weather stations in the Murray and Riverina region* weather station extension projects, funded by Murray and Riverina Local Land Services through funding from the Australian Government's National Landcare Programme.

In 2016 we formally completed the *Weather Stations on Farms* project, which was funded by Riverina and Murray LLS through the Australian Government's National Landcare Programme. The LLS weather stations are located at Barooga, Berrigan, Culcairn, Lockhart, Pleasant Hills, Rand and Henty and the data from these stations is available on our website riverineplains.org.au. Thank you to our farmer co-operators for their financial and in-kind contributions to the project.

We also wish to acknowledge the financial contribution provided by Murray LLS through funding from the Australian Government's National Landcare Programme to support the publication of this research compendium.

Print and other media

Riverine Plains produces a significant volume of written material for local and state media. We have again been very well supported by a number of local print, radio and television outlets, who regularly feature our stories or come along and report on our events. These organisations play a significant role in ensuring the wider community is aware of our activities and we greatly appreciate their involvement.

In 2017 we launched our new website riverineplains.org.au. The new website has streamlined the way we deliver information to our members and has made it easier for staff to communicate the group's activities and project information. We would like to thank Mel Wilke at WMedia (Albury) for her role in developing and hosting the website.

Our bi-monthly newsletter and in-season *Grower Bulletin* are published to help inform our members of the latest industry happenings. We wish to thank our network of sponsors, researchers, agronomists, committee members and staff who contribute material to these publications, thus ensuring they continue to be timely, useful and relevant.

During May 2017 we released a new publication *Soil Carbon in Cropping Systems*. The report summarises the key findings from the Riverine Plains Inc managed project *Increased soil carbon by accelerated humus formation from crop residues* (2012–15), which specifically aimed to evaluate the potential for soil carbon to be increased by adding stubble residues and nutrients to soils during the summer fallow period.

Soil Carbon in Cropping Systems was funded by the Sustainable Agriculture Victoria: Fast-Tracking Ag Innovation initiative, made possible with the support of the Foundation for Rural and Regional Renewal (FRRR) together with the William Buckland Foundation and was mailed to all members during May 2017. Its publication was a major undertaking and I would like to acknowledge Dr Cassandra Schefe for her role in collating the data and words for this book.

Funding partners

Riverine Plains Inc is supported by a range of organisations that fund local research and extension programs across the region. We gratefully acknowledge the support of the GRDC, the Australian Government's Department of Agriculture and Water Resources, the FRRR together with the William Buckland Foundation, NSW DPI, the Australian Government's National Landcare Programme and their partner organisations: Murray LLS, Riverina LLS, North East CMA and Goulburn Broken CMA.

Sponsors

Through their financial support, the businesses that sponsor Riverine Plains Inc play an important role in allowing us to deliver services to members. Our sponsors and their representatives are also tremendous supporters of our field days, seminars and other events and we sincerely value their presence and contributions at each event. Many of our sponsors have been with us for a long time and I'd like to encourage our members to support the businesses that support the region's farmers. We have recently welcomed several new sponsors and look forward to growing these relationships into the future.

Staff

On behalf of the committee and our members I would like to thank all our staff for the work they do on behalf of Riverine Plains Inc. Our Executive Officer Fiona Hart, Finance Officer Kate Coffey, Research & Extension Officer Dr Cassandra Schefe and Communications Officer Michelle Pardy all do a terrific job in their respective fields and during the past few years have relieved the committee of a significant workload; this has a allowed the committee to focus on more strategic issues and has led to a much more efficient organisation.

Community

This year, the Riverine Plains Inc community sadly farewelled two former Committee Members: Paul I'Anson (January 2017) and Ben Bailey (April 2017).

Paul I'Anson was an inaugural Riverine Plains Inc Committee Member. Paul served on the Committee for nine years and was instrumental in the early precision agriculture research undertaken by the group. Through his work, Paul remained closely involved with the group and was a great supporter of innovation and technology.

Farmers inspiring farmers

Ben Bailey spent three years (2010–13) on the committee of Riverine Plains Inc and was known for his enthusiasm and passion for farming. He first served on the extension subcommittee before moving across to the research subcommittee. In 2011, Ben spoke at the *In-season Update*, describing how he and Georgina managed a low-capital-based farming operation.

We extend our deepest sympathies to the I'Anson and Bailey families.

Research for the Riverine Plains

This book is our flagship publication, and an enormous amount of effort goes into bringing you this work. Riverine Plains Inc is currently involved in a significant number of projects and the 2017 edition of *Research for the Riverine Plains* is mostly comprised of articles written by Riverine Plains Inc, or by our project partners. This highlights the significant amount of local research being conducted in our region by our group, with the results set to benefit local farmers for many years to come.

Several other organisations have also provided articles for the trial book and we would like thank each of the contributors for their involvement. I particularly thank Dr Cassandra Schefe for her roles in collating and technical editing, as well as to Michelle Pardy and Fiona Hart their roles in editing and preparing the publication for print.

Many of the 2016 research trials were affected by the wet conditions, with some data collection having to be abandoned, while other data was too variable to publish. However variability is part and parcel of farming and by reflecting on what we learnt during 2016, we can better prepare ourselves to meet these challenges head on next time.

We trust you will enjoy the read and find value in the reports contained within. All the best for the 2017 season.

Ian Trevethan
Riverine Plains Inc Chairman



2016 — the year in review

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

The cropping season of 2016 was a year of contrasting weather conditions. The region experienced its warmest autumn on record, then progressed into the second wettest winter on record. The growing season rainfall (April–October) varied across the Murray region, with Urana receiving 501mm (55% higher than the long-term average — LTA), Henty receiving 617mm (61% higher than the LTA), Corowa receiving 566mm (62% higher than the LTA) and Albury receiving 604mm (68% higher than the LTA). This resulted in widespread waterlogging. The wet spring resulted in concerns around waterlogging, lodging and disease. Crop yields were another contrast of the season. The above-average rainfall contributed to high yields on well-drained paddocks and poor yields across waterlogged areas.

Warm autumn to cool spring

The 2016 cropping season may be remembered for the rainfall totals, but temperature played a crucial role in crop performance and yield. The warmest autumn on record was due to above-average maximum and minimum temperatures from March to May. The region received substantial opening rains at the start of May, which combined with warm soil temperatures, resulted in even and high crop germination.

The above-average minimum temperature continued through the winter months (Figure 1). Thermal time (the relationship between time and temperature, governing plant growth and development) was accumulated more rapidly and many crops developed quickly, reaching stem elongation and flowering up to 10–14 days earlier than during 2015.

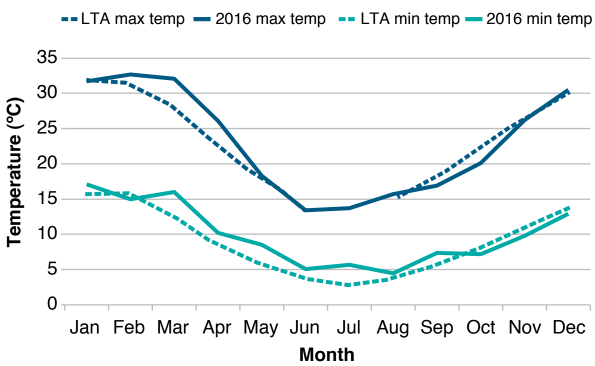


FIGURE 1 Minimum and maximum temperatures for 2016, compared with the long-term average (LTA) at Corowa Airport (BOM No: 74034)

The warmer minimum temperatures and persistent cloud cover resulted in an 80% reduction in the number of potential frost incidents from May–July; however an average number of frosts were experienced during August. The rush to flowering meant early-sown crops, particularly those at early ear emergence, were exposed to the August frost episodes resulting in yield penalties and reduced grain quality.

The cooler-than-average spring maximum temperature was in contrast to the warm autumn. The cool, wet conditions were ideal for most canola crops, allowing grain fill during a low stress period, which resulted in high oil contents. However, for cereal crops, the spring conditions resulted in the production of secondary tillers, which delayed harvest in some areas.

How much rain did you get?

January storms produced some substantial rainfall totals for most of the region with the exception of Corowa Airport. This rainfall had little impact on stored soil moisture but was enough for summer weeds to germinate. The warmer and drier-than-average February to April contributed to extremely dry topsoil moisture at the end of April (Figure 2).

The region received breaking rainfall at the start of May and the follow-up rainfall a week later saw the season turn around quickly. The dry-sown crops responded and with the warmer temperatures established quickly.

May–July rainfall was well above average, filling up the soil profile (Figure 3). The constant rainfall throughout winter shortened the residual effectiveness of pre-emergent herbicides and the wet conditions restricted trafficability for post-emergent spraying. The effects of waterlogging also reduced crop competition. The combination of all these factors enabled weeds to proliferate, even in paddocks previously considered 'clean'.

September experienced the highest monthly rainfall totals on record across the region. This resulted in widespread flooding of tributaries and low-lying areas. Soils with clay subsoils experienced substantial waterlogging and many were severely impacted, reducing yield considerably. Barley crops lodged

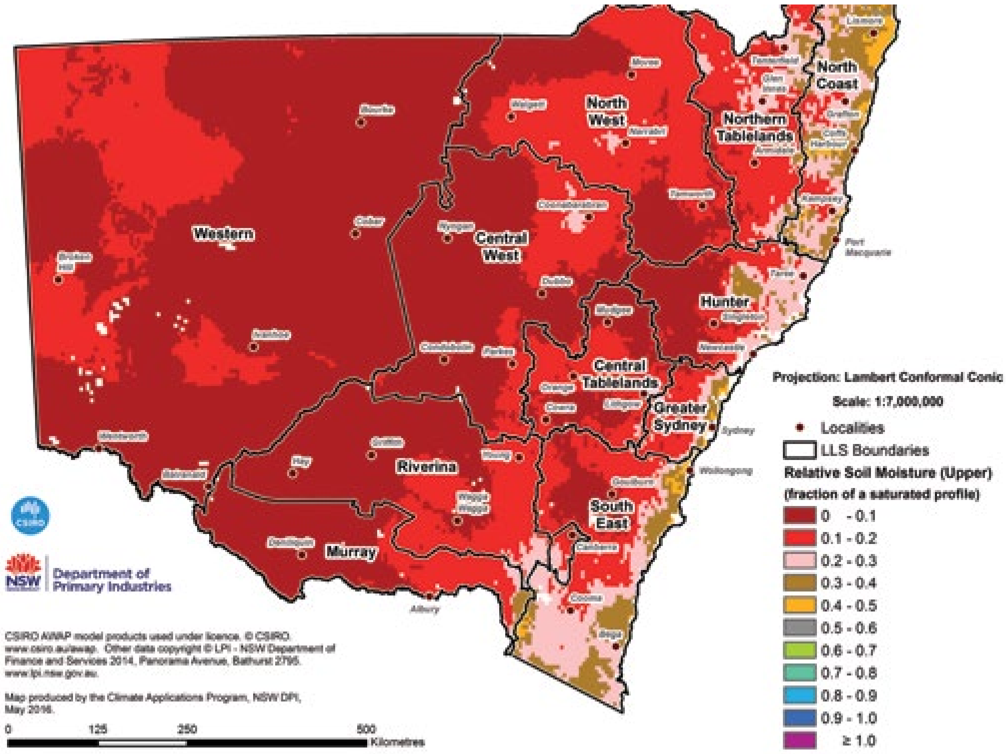


FIGURE 2 April topsoil moisture

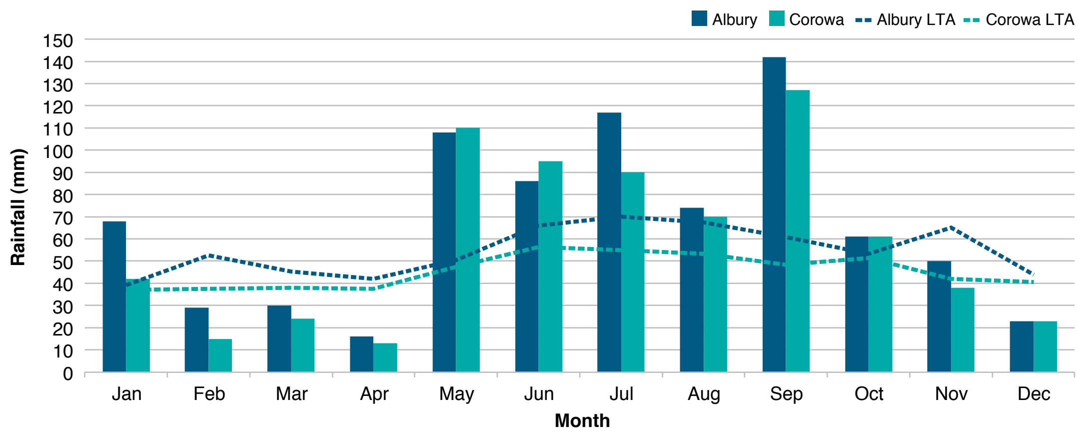


FIGURE 3 Monthly rainfall for 2016, compared with the long-term average (LTA) at Albury Airport (No. 72160) and Corowa Airport (No. 74034)

during September, which occurred much earlier in the season than usual, causing reshooting and mixed maturity, which posed a challenge at harvest.

Cool conditions and isolated showers during November caused some harvest delays. The season ended with variable crop yields from complete failure to above-average yields.

Disease and pest incursions during 2016

The winter and spring growing season conditions were highly conducive for the development of sclerotinia stem rot. Prolonged wet weather during winter was ideal for the germination and development of apothecia, the fruiting structures of the sclerotinia fungus. The first warning signs appeared during early July. The continued wet weather throughout August and September provided ideal conditions for extended leaf wetness and outbreaks of the disease were widespread, even in districts that rarely experience the disease.

Blackleg was common in canola crops across the region, as the main risk factors, such as annual rainfall greater than 600mm and 100mm rainfall received between March and May, occurred in all areas of the Murray



Rainfall deciles and how they are determined

Deciles indicate whether the rainfall is above average, average or below average. Rainfall deciles are calculated by taking the record of measured rainfall over time, and sorting the rainfall amounts into 10 equal parts. Decile one relates to lowest rainfall on record and decile 10 is the highest rainfall on record.

Overall the 2016 season was wetter than average with Albury, Henty, Corowa and Urana receiving rainfall above the decile eight value. The growing season rainfall (GSR) was also wetter than average, with the GSR at Henty and Urana being decile ten and nine respectively (Figure 4).

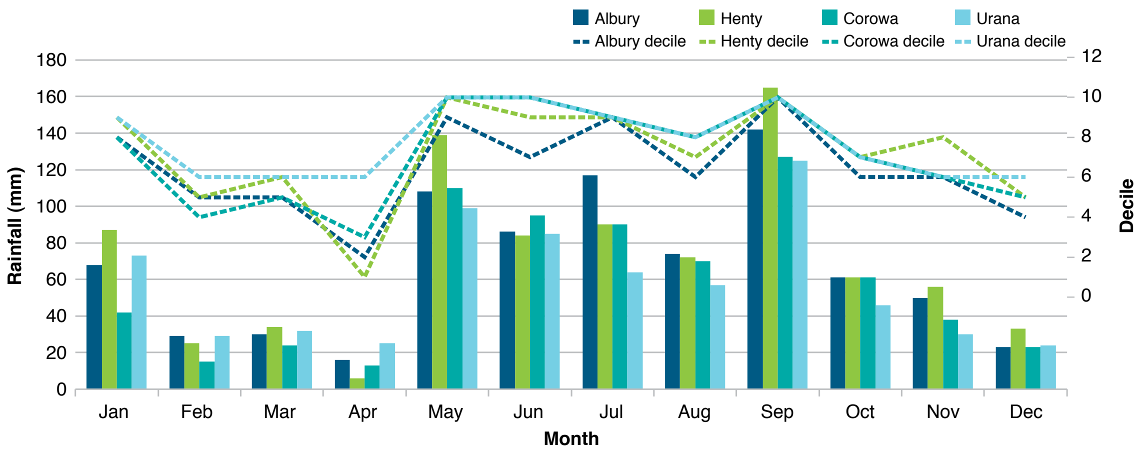


FIGURE 4 Monthly rainfall and decile for 2016, Albury, Henty, Corowa and Urana

region. Early-flowering canola crops were at greater risk of pod infection due to the prolonged exposure to the blackleg spores.

During August NSW DPI confirmed Russian wheat aphid in the Barham area. It was also identified in another two locations across the Murray region. Heavy and continual rainfall and associated flooding reduced the Russian wheat aphid population and slowed its spread.

In October lupin anthracnose was detected for the first time in the Riverine region of NSW, resulting in a lupin anthracnose biosecurity zone in the three Local Government Areas of Cootamundra/Gundagai, Junee and Coolamon.

This report was compiled from weather data sourced from Bureau of Meteorology (BoM), NSW Department of Primary Industries (NSW DPI) seasonal condition summaries and the Grains Research and Development Corporation (GRDC).

Contact

Sue Briggs Murray LLS

T: (02) 6051 2210
M: 0438 018 749
E: sue.briggs@lls.nsw.gov.au

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

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 high-rainfall environments;
- build on findings from the previous Riverine Plains Inc (RPI) *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 NTSR 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 in 2015 was that a site near Corowa was used rather than Coreen/Redlands, in order to maintain the same rotation position, moving back to Coreen in 2016.

As a key component of this project is identifying the long-term impact of a one-off change in management, the sites used in 2014 were returned to the farmer for commercial cropping, with new sites (in the same rotation position) established in 2015 and 2016. These are referred to as 'time replicate 1 (2014 sites)' 'time replicate 2 (2015 sites)' and 'time replicate 3 (2016 sites)'.

As 2016 is the third year of the project, the trial reports include both the experimental results from the 2016 trials, with selected yields also measured on the 2015 and 2014 sites, to understand if the change in stubble management has influenced the performance of the following commercial crop.

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

FIGURE 1 Locations of large block (focus farm) trials

A series of small plot trials has been established to address specific aspects of management in a 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 2016 were:

1. early sowing and the interaction with row spacing and variety in first wheat under full stubble retention (Barooga, Yarrawonga), page 40;
2. interaction between fungicide program and in-crop nitrogen timing for the control of yellow leaf spot (YLS) in early-sown wheat (Coreen), page 46.
3. the interaction between plant growth regulator (PGR) and nitrogen application in early-sown first wheat (Yarrawonga), page 54; and
4. monitoring the performance of nitrogen application to wheat under full stubble retention (Dookie, Corowa), page 58.

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.

Contact

Dr Cassandra Schefe Riverine Plains Inc
T: (03) 5744 1713
E: cassandra@riverineplains.org.au

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

Nick Poole, Tracey Wylie and Michael Straight
FAR Australia

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 page 10.

Method

Different methods of stubble management were trialled in four large (farm-scale) replicated trials during 2014, 2015 and 2016. 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
- 2016 trial site: time replicate 3.

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 1, Table 2 and Table 3. At some sites 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, 2016 (time replicate 3)

	Trial 1	Trial 2	Trial 3	Trial 4
Trial details	**Coreen#**	**Yarrawonga**	**Dookie**	**Henty**
Treatments				
NTSR* (control)	✓	✓	✓	✓
NTSR + 40kg N/ha 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	×	36cm	34cm	×
NTSR — short stubble	×	15cm	15cm	×
NTSR — straw mown and removed	×	✓	✓	×
NTSR — stubble mulched and retained	×	×	×	✓
NTSR — stubble mulched + 40kg extra nitrogen at sowing	×	×	×	✓
NTSR — lupins sown for forage	✓	×	×	×
NTSR — lupins sown for grain	✓	×	×	×
Trial plot dimensions (m)	40 x 15	40 x 18	40 x 18	40 x 15
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)	7.0	4.7	7.9	6.6
Stubble height (cm)	26	36	15	47
Soil type description	Loam over clay	Self-mulching red loam over grey clay	Red loam over clay	Yellow brown earth
Row spacing (cm)	30	32	33.3	19
Crop and rotation position	Second cereal (barley)	Second wheat	Second wheat	Canola following wheat

The site was relocated to a paddock near Daysdale in 2014, near Corowa in 2015 and near Coreen in 2016 in order to maintain the required rotation position.
* No-till stubble retention (NTSR)



TABLE 2 Site details for 2016 crops sown onto 2015 stubble management trial sites (time replicate 2)

Trial details	Trial 1 Corowa[#]	Trial 2 Yarrawonga	Trial 3 Dookie	Trial 4 Henty
Treatments				
Crop type/variety	Wheat/Trojan	Canola/45Y25	Canola/Bonito	Wheat/Gregory
Paddock burnt	✓	✓	✓	×
Farmer harvested	×	✓	✓	✓
Plot harvester	✓	×	×	×
Trial plot dimensions (m)	40 x 15	40 x 18	40 x 15	40 x 15
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)	5.8	4.3	5.6	3.2
*Stubble height (cm)**	5	3	3	20
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	Third wheat	Canola following wheat	Canola following wheat	Wheat following canola

[#] The site was relocated to a paddock near Daysdale in 2014, near Corowa in 2015 and near Coreen in 2016 in order to maintain the required rotation position.
* Stubble height was measured post burn at sowing time.

TABLE 3 Site details for 2016 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	Canola/Bonito	Canola/Bonito	Wheat/Corack	Wheat/Wedgetail
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)	7.0	5.9	3.0	5.8
*Stubble height (cm)**	26	4	8	35
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	Canola following wheat	Canola following barley	Wheat following canola	Grazing wheat following oats

[#] The site was relocated to a paddock near Daysdale in 2014, near Corowa in 2015 and near Coreen 2016 in order to maintain the required rotation position.
[^] The Henty site was affected by waterlogging and was grazed off and left (not harvested).
* Stubble height was measured post burn at sowing time.

Trial 1: Coreen, NSW

Sowing date: 4 May 2016

Rotation: Second cereal (barley)

Variety: Barley cv Hindmarsh, lupins cv Mandelup

Stubble: Wheat (various treatments applied)

Stubble load at sowing: 7.0t/ha

Rainfall:

GSR: 567mm (April–October)

Summer rainfall: 80mm

Soil nitrogen at sowing: 111kg N/ha NTSR (control) and 103kg N/ha multidisc (0–60cm)

Key points

- There were significant increases in dry matter (DM) accumulation, nitrogen (N) uptake and crop canopy greenness where barley was established following cultivation with one pass of the multidisc, which was most evident where additional nitrogen was added at sowing.
- Although there was a trend for cultivated stubble with additional sowing nitrogen to yield more than burning, there were no significant yield differences in the trial.
- Growing a faba bean crop instead of a second wheat crop increased the yield of the following wheat by 0.34–0.47t/ha in 2016 compared with a 2t/ha advantage in the following wheat crop in 2015.
- Adequate nitrogen availability in the third wheat crop, combined with higher yield potential, and poor nodulation in the faba beans, appears to be partly the reason for the smaller yield benefit in 2016.
- Across three years of field trials, none of the different stubble management treatments have been superior to the no-till stubble retention (NTSR) control, despite differences in DM production.

Results

i) Establishment and crop structure

With sufficient moisture levels at sowing there were no differences in crop establishment five weeks after sowing (Table 4). Tiller numbers were relatively high and differed between the treatments. Tiller numbers varied from 3.9 tillers per plant in burnt plots to 5.3 tillers per plant in cultivated plots, when assessed at the second node stage (GS32). However, there were no differences in head numbers between treatments, with an average of just more than 400 heads/m^2.

TABLE 4 Plant counts 9 June 2016, three-leaf stage (GS13); tiller counts 28 July 2016, second-node stage (GS32) and head counts 19 November 2016, harvest (GS99)

	Crop growth stage		
	GS13	GS32	GS99
Treatment	Plants/m^2	Tillers/m^2	Heads/m^2
NTSR (control)	97^{a}	483^{ab}	406^{a}
Cultivated (one pass)	108^{a}	568^{a}	429^{a}
Cultivated (one pass) + 40kg N/ha	107^{a}	497^{ab}	440^{a}
Burnt	103^{a}	406^{b}	387^{a}
Mean	**103**	**488**	**415**
LSD	17	116	121

Figures followed by different letters are regarded as statistically significant.

ii) Dry matter production and nitrogen uptake

Plots that had been cultivated with additional nitrogen at sowing produced significantly more DM at first node (GS31), compared with both the NTSR (control) and burnt treatment. The cultivated treatments also produced significantly more DM at flowering (GS69) compared with the NTSR plots (Table 5). By harvest there were no significant differences in DM production between any of the treatments.

Similar trends were apparent in the nitrogen uptake figures at first node (GS31), with more nitrogen present in the cultivated and cultivated plus 40kg N/ha compared with the burnt treatment and the control plots. At later assessments there were no significant differences in nitrogen content between the different stubble treatments (Table 6).

iii) Green leaf retention differences

The NTSR plots were not as green at key assessment growth stages as the burnt and cultivated plots; observations confirmed by normalised difference vegetation index (NDVI) readings (Figure 1). The presence of stubble (brown vegetation) in the NTSR plots may have partly influenced earlier NDVI readings, compared with the burnt treatment readings. Crops

TABLE 5 Dry matter 15 July 2016, first node (GS31); 18 August 2016, flag leaf fully emerged (GS39); 26 September 2016, end of flowering (GS69) and 21 November 2016, at physiological maturity (GS95–99)

	Dry matter (t/ha)			
Treatment	GS31	GS39	GS69	GS95–99
NTSR (control)	1.17^{bc}	2.97^{a}	7.30^{b}	9.37^{a}
Cultivated (one pass)	1.49^{ab}	3.40^{a}	8.92^{a}	9.27^{a}
Cultivated (one pass) + 40kg N/ha	1.56^{a}	3.37^{a}	8.44^{a}	9.22^{a}
Burnt	1.06^{c}	2.89^{a}	8.42^{ab}	8.41^{a}
Mean	**1.32**	**3.15**	**8.27**	**9.07**
LSD	0.36	0.98	1.12	2.17

Figures followed by different letters are regarded as statistically significant.



TABLE 6 Nitrogen uptake in crop 15 July 2016, first node (GS31); 18 August 2016, flag leaf fully emerged (GS39); 26 September 2016, end of flowering (GS69) and 21 November 2016, at physiological maturity (GS95–99)

Treatment	Nitrogen uptake in dry matter (kg N/ha)			
	GS31	GS39	GS69	GS95–99
NTSR (control)	55[ab]	64[a]	102[a]	51[a]
Cultivated (one pass)	69[a]	64[a]	132[a]	51[a]
Cultivated (one pass) + 40kg N/ha	62[a]	85[a]	122[a]	58[a]
Burnt	42[b]	77[a]	118[a]	46[a]
Mean	**57**	**73**	**118**	**52**
LSD	16	22	59	14

Figures followed by different letters are regarded as statistically significant.

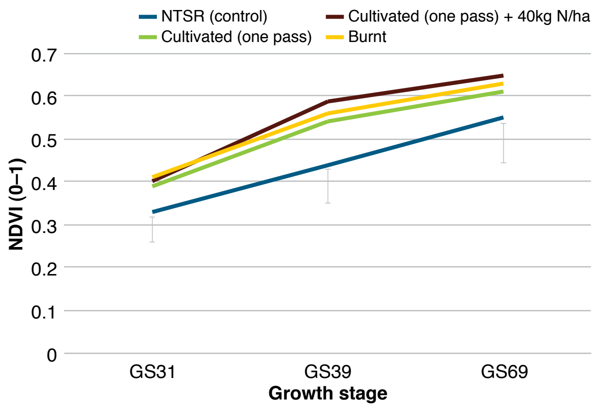


FIGURE 1 Influence of stubble management on barley crop canopy NDVI assessed July 15 2016 first node (GS31); 18 August 2016, flag leaf fully emerged (GS39) and 26 September 2016, end of flowering (GS69)

Error bars presented as a measure of LSD

established following cultivation had higher NDVI values, which appear to be correlated to higher DM and nitrogen content up to the end of flowering (GS69).

iv) Yield and grain quality

The trial was harvested on 9 December 2016. While the cultivated plus 40kg N/ha treatment recorded the highest yield, and the burnt treatment recorded the lowest, these yields were not significantly different. Therefore, there were no significant yield advantages of any stubble treatments over the NTSR (control) for barley at this site (Table 7); a result consistent with previous years of field trials in second wheat in this region. The only significant difference in grain quality was a lower protein level in cultivated plots that did not receive nitrogen at sowing.

v) Three-year results (time replicates 1, 2 and 3) — yield data 2014–16

For the past three years a replicated large block stubble management trial has been established in a different paddock on the Coreen focus farm. The trial set-up in 2014 (year one of the experiment) is referred to as the time replicate 1 in the trial series, the trial set-up in year two is time replicate 2 and in the third year it is time replicate 3. After each trial has been completed the trial area reverts to being a commercial farm crop undergoing uniform management. The stubble management for all subsequent years has therefore been uniform across all trial plots and dictated by commercial farm operations. In each subsequent year the trial area has then been revisited in order to assess any carryover yield effects of the stubble management treatments set up in year one on yields of the farm crop in the following years.

The results from this focus farm during the past three years show the rank order of stubble management treatments has been similar, with significant differences in yield only recorded during 2015 when the cultivated plus 40kg N/ha treatment significantly outyielded the burnt treatment (Figure 2). While similar trends were observed during 2016, the yield differences were not significant. Despite benefits of earlier DM production and disease control (yellow leaf spot) from burning, no yield advantage has been observed due to burning over NTSR (control) at this trial site during the past three seasons of stubble management trials.

vi) 2015 stubble management treatments — influence on 2016 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 also to assess

TABLE 7 Wheat yield, protein, test weight, screenings and thousand seed weight (TSW) 9 December 2016, at harvest (GS99)

Treatment	Yield and quality				
	Yield (t/ha)	Protein (%)	Test weight (kg/hL)	Screenings (%)	TSW (g)
NTSR (control)	5.24[a]	9.5[a]	63.9[a]	4.2[a]	38.0[a]
Cultivated (one pass)	4.82[a]	8.5[b]	59.8[a]	4.3[a]	35.4[a]
Cultivated (one pass) + 40kg N/ha	5.54[a]	9.7[a]	61.9[a]	4.6[a]	37.9[a]
Burnt	4.81[a]	9.5[a]	63.7[a]	4.5[a]	37.0[a]
Mean	**5.11**	**9.3**	**62.4**	**4.4**	**37.1**
LSD	1.15	0.7	7.4	1.9	4.1

Figures followed by different letters are regarded as statistically significant.

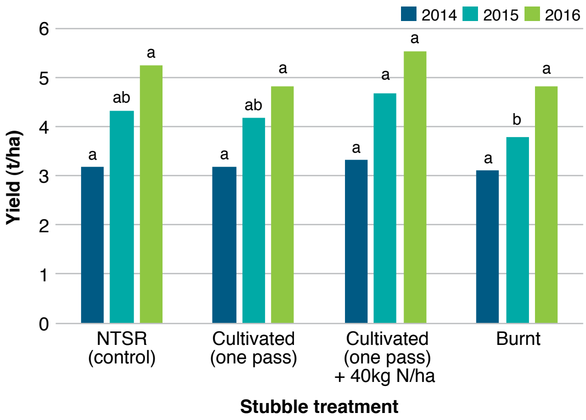


FIGURE 2 Yield data from time replicate trials 1, 2 and 3 — the Daysdale (red brown earth), Corowa (heavy grey clay) and Coreen (loam over clay) trials for 2014, 2015 and 2016 — cv Whistler (wheat) in 2014, cv Mace (wheat) in 2015, cv Hindmarsh (barley) in 2016

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

Note: The three trials were carried out on the same farm but not on the same trial site. During 2014 the cultivation treatments were established with two passes of a multidisc, while in 2015 and 2016 a single pass was used.

whether there are any rotational effects on following crops. For example, does burning or cultivating between the first and second wheat crop impact yield performance the year after the second wheat? Table 8 shows the performance of a commercial wheat crop (cv Trojan) sown during 2016 into the large block 2015 stubble management trial. As the faba bean crops sown in 2015 suffered from poor nodulation they do not represent an effective legume break crop.

The stubble management treatments carried out during the 2015 trial (time replicate 2) did not significantly influence the following third wheat crop (cv Trojan), although there was a trend for crops established by cultivation or NTSR to yield more than crops following

TABLE 8 Wheat yield, protein, test weight and screenings at Corowa, 2016

2015 stubble treatments	2016 yield and quality			
	Yield (t/ha)	Protein (%)	Test weight (kg/hL)	Screenings (%)
NTSR (control)	6.72[ab]	8.8[a]	79.9[ab]	2.4[a]
Cultivated (one pass)	6.53[ab]	8.8[a]	78.6[b]	2.5[a]
Cultivated (one pass) + 40kg N/ha	6.66[ab]	9.1[a]	80.5[ab]	2.2[a]
Burnt	5.90[b]	8.7[a]	80.4[ab]	1.6[a]
Faba beans (green manure)	7.03[a]	8.9[a]	81.0[a]	2.1[a]
Faba beans (grain)	6.96[a]	9.3[a]	80.2[ab]	1.7[a]
Mean	**6.63**	**8.9**	**80.1**	**4.4**
LSD	0.82	0.8	2.3	1.9

Figures followed by different letters are regarded as statistically significant.

burning during 2016. Wheat yields following faba beans, which nodulated poorly, were 0.34–0.47t/ha higher yielding than a third continuous wheat crop, as compared with a 2t/ha advantage in the 2014 (time replicate 1) trial. Although wheat yields were higher following faba beans, there was no difference in protein levels between treatments. This indicates a greater nitrogen offtake, although the extra nitrogen offtake is relatively small and statistically insignificant in the 2015–16 trial sequence. The nitrogen offtake in grain following faba beans equated to 112kg N/ha (average of forage and grain faba bean treatments) versus 104kg N/ha in the third wheat established with NTSR (control). The difference in the previous year's research (2015 commercial crop sown over 2014 trial site) was 111kg N/ha offtake following faba beans versus 57kg N/ha following wheat, however in 2016 the host farmer applied 108kg N/ha across his wheat crop compared with 53kg N/ha during 2015.

Faba beans sown alongside second wheat stubble management treatments in July and then September in 2015.

Trial 2: Yarrawonga, Victoria

Sowing date: 28 April 2016

Rotation: Second wheat

Variety: Corack

Stubble: Wheat (various treatments applied)

Stubble load at sowing: Long stubble 4.7t/ha, short stubble 4.3t/ha

Rainfall:

GSR: 604mm (April–October)

Summer rainfall: 125mm

Soil nitrogen at sowing: 64kg N/ha NTSR (control) and 60kg N/ha multidisc (0–60cm)

Key points

- Despite differences in DM production early in the season, there were no differences in yield or grain protein due to stubble management treatments (burning, removing straw, cultivating or NTSR).
- There was a non-significant trend for burning to produce small yield gains (4–5%) over NTSR, a result seemingly linked to higher DM production.
- With a higher yield potential for 2016, applying nitrogen at sowing significantly increased grain yield and protein when stubble was cultivated. However this may be due to optimal nitrogen management rather than stubble management.
- In all three seasons of trials (2014–16), there was more DM accumulation earlier in the season and small non-significant yield gains (3–5%) when stubbles were burnt; however with a sharp finish to the 2015 season, burning significantly reduced yield compared with NTSR (12.5% yield decrease).
- Stubble management options that support high DM production earlier in the season (i.e. stubble removal) can be beneficial when yield potential is higher (2014 and 2016) and either neutral or disadvantageous in seasons when yield potential is lower (2015).

Results

i) Establishment and crop structure

The NTSR — short stubble treatment significantly reduced plant establishment compared with treatments where stubble (straw) was removed or burnt. As the short stubble was prepared by cutting the long stubble after harvest (late March/early April), the cut straw on the ground may have created a mulching effect, which may have impeded plant emergence. Other treatments, such as the NTSR — long stubble and cultivation treatments, were not significantly different from the straw removed or burnt plots (Table 9). By second node (GS32) the long stubble treatments had significantly reduced tiller numbers relative to the other treatments, which followed through to a significant reduction in head number in the long stubble plus nitrogen treatment.

ii) Dry matter production

The lower tiller number recorded with NTSR — long stubble (control) at second node (GS32) correlated to less DM accumulation compared with the other treatments. The burnt treatment produced significantly more DM throughout the season (Table 10). Up until grain fill there was a lag in DM production in the NTSR — long stubble treatment compared with NSTR — short stubble treatment, which was not apparent at the harvest assessment; indicating later compensation in these treatments.

The reduction in DM accumulation with NTSR — long stubble (control) correlated to decreased nitrogen uptake in the crop canopy at GS32 compared with the burnt or cultivated treatments (Table 11). The difference in nitrogen uptake between long and short stubble treatments was not significantly different despite there being significantly more DM following short stubble when assessed at the same growth stage.

At early grain fill (GS71) all the NTSR treatments had significantly lower crop canopy nitrogen contents compared with the other stubble treatments, although this was offset in the NTSR — long stubble + 40kg N/ha treatment. The additional nitrogen at sowing generated a small increase in nitrogen offtake compared with the

TABLE 9 Plant counts and vigour 10 June 2016, one tiller (GS21); tiller counts 2 August 2016, second node (GS32) and head counts 6 December 2016, harvest (GS99)

	Crop growth stage		
	Plants/m^2	Tillers/m^2	Heads/m^2
Treatment	GS11	GS32	GS99
NTSR — long stubble (control)	151^{ab}	248^{b}	266^{bc}
NTSR — long stubble + 40kg N/ha	153^{ab}	271^{b}	225^{c}
NTSR — short stubble	140^{b}	334^{a}	304^{ab}
Straw removed	159^{a}	371^{a}	300^{ab}
Cultivated (one pass)	146^{ab}	335^{a}	304^{ab}
Cultivate (one pass) + 40kg N/ha	152^{ab}	354^{a}	327^{a}
Burnt	158^{a}	373^{a}	325^{ab}
Mean	**151**	**327**	**293**
LSD	16	62	60

Figures followed by different letters are regarded as statistically significant.

TABLE 10 Dry matter 2 August 2016, second node (GS32); 5 September 2016, mid-booting (GS45); 12 October 2016, watery ripe grain (GS71) and 6 December, harvest (GS99)

Treatment	Dry matter (t/ha)			
	GS32	GS45	GS71	GS99
NTSR — long stubble (control)	1.57^{b}	5.13^{b}	8.82^{d}	11.83^{bc}
NTSR — long stubble + 40kg N/ha	1.53^{b}	5.74^{ab}	9.65^{cd}	10.85^{c}
NTSR — short stubble	1.91^{a}	5.45^{ab}	10.57^{bc}	11.89^{bc}
Straw removed	2.10^{a}	6.72^{a}	10.55^{bc}	11.68^{bc}
Cultivated (one pass)	2.02^{a}	5.63^{ab}	11.10^{b}	11.94^{bc}
Cultivate (one pass) + 40kg N/ha	2.12^{a}	6.49^{ab}	12.31^{a}	12.93^{ab}
Burnt	2.13^{a}	6.69^{a}	12.22^{a}	14.41^{a}
Mean	**1.91**	**5.98**	**10.75**	**12.22**
LSD	0.22	1.41	1.08	1.96

Figures followed by different letters are regarded as statistically significant.

TABLE 11 Nitrogen uptake in biomass 2 August 2016, second node (GS32); 5 September 2016, mid-booting (GS45); 12 October 2016, watery ripe grain (GS71) and 6 December, harvest (GS99)

Treatment	Nitrogen uptake in biomass (kg N/ha)			
	GS32	GS45	GS71	GS99
NTSR — long stubble (control)	49^{c}	72^{a}	79^{b}	93^{b}
NTSR — long stubble + 40kg N/ha	51^{c}	75^{a}	87^{ab}	95^{b}
NTSR — short stubble	54^{bc}	63^{a}	72^{b}	98^{b}
Straw removed	55^{bc}	84^{a}	105^{a}	105^{b}
Cultivated (one pass)	61^{ab}	66^{a}	105^{a}	124^{a}
Cultivate (one pass) + 40kg N/ha	65^{a}	86^{a}	101^{a}	122^{a}
Burnt	60^{ab}	71^{a}	108^{a}	100^{b}
Mean	**56**	**74**	**94**	**105**
LSD	8	24	22	15

Figures followed by different letters are regarded as statistically significant.

NTSR (control), but where the stubble was cultivated there was no increase in nitrogen offtake at harvest due to extra nitrogen at sowing compared with the cultivation only treatment.

iii) Photosynthetically active radiation (PAR)

During the past three seasons (2014–16) one of the most consistent effects of the stubble management treatments in NTSR systems has been the influence of stubble length on DM production. There is a consistent reduction in tillering and DM production in longer stubble. In part this appears to be linked with nitrogen availability and temperature, but as these factors could not completely explain this effect, in 2016 for the first time the research team looked at differences in light interception by the growing crop canopy; more accurately described as photosynthetically active radiation (PAR). During the winter months (June and July 2016) the influence of the different stubble management treatments on PAR was assessed.

The results revealed reductions in PAR of more than 50% compared with short stubble NTSR (Figure 3). Burnt plots captured the most PAR, but this was only slightly more than the cultivation and NTSR — short stubble treatments. Although the PAR will be influenced by the Sun's zenith (high point in the sky) the results clearly show the ability to capture available sunlight is a key difference between long and short stubble treatments and could be the major factor in why there is reduced tillers and a lag in DM production with long stubble.

iv) Green leaf retention at the stem elongation and early grain-fill stages

At second node (GS32) and booting (GS45) the burnt and cultivated treatments resulted in higher NDVI crop canopy scores (Figure 4). This increased greenness of the canopy was evident in the NDVI assessments (conducted with the Greenseeker®) at GS32 and GS45. All NDVI scores declined at early grain fill (GS71) but cultivation with extra nitrogen and burnt stubble plots still gave higher NDVI readings than NTSR — short stubble and NTSR — long stubble treatments.

v) Disease levels

There were no appreciable levels of disease in the trial, a result that is linked to the better resistance of Corack to yellow leaf spot (YLS) compared with Young, a variety used in previous years.

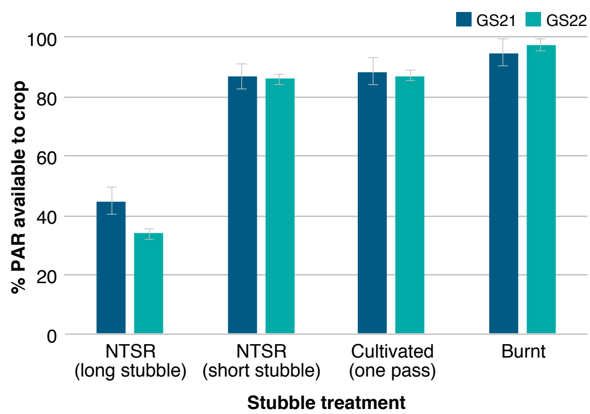


FIGURE 3 Influence of stubble treatment on availability of photosynthetically active radiation (PAR) on 10 June 2016 (GS21) and 15 June 2016 (GS21/22) at the Yarrawonga trial site

*The error bars are a measure of LSD

Note: 10 June readings were taken at 1pm with the average above-canopy PAR measuring $866 \mu mol/m^2/s$, in the 400–700nm waveband

15 June readings were taken at 10am with the average above canopy PAR measuring $733 \mu mol/m^2/s^1$, in the 400–700nm waveband

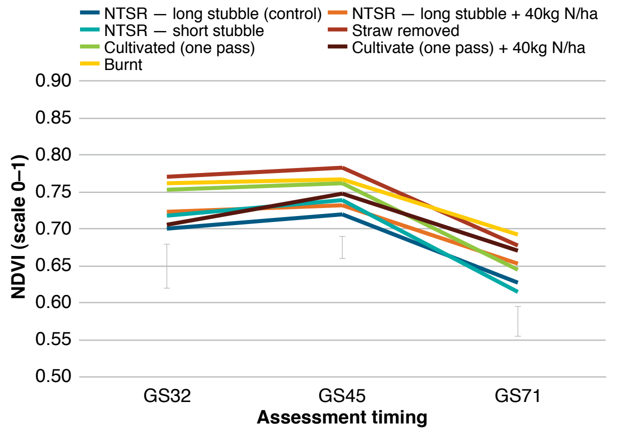


FIGURE 4 Influence of stubble management on resultant crop canopy NDVI (0–1 scale) assessed at stem elongation (GS32), booting (GS45) and early grain fill (GS71)

*The error bars are a measure of LSD

vi) Grain yield and quality

The trial was harvested on 12 December 2016. There were statistical differences in grain yield and quality as a result of stubble management. Despite a lag in DM accumulation at stem elongation (GS32) with the NTSR — long stubble treatment there was no difference in yield between long and short stubble treatments (Table 12). There was also no yield advantage associated with straw removal. Burning the previous wheat crop residues gave a small, non-significant yield increase (4–5%) over all NTSR treatments,— a result similar to that observed during 2014. Cultivation produced no yield benefits over the NTSR — long stubble (control) treatment.

The high in-season rainfall and high yield potential meant crops responded to extra nitrogen applied at sowing, which is evident in both the NTSR and cultivated plots. In both cases applying 40kg N/ha at sowing resulted in significantly higher grain protein and significantly more yield with cultivation (0.79t/ha). Where no extra nitrogen was applied at sowing the effect of the different stubble management treatments (burnt, cultivated, straw removed and NTSR) had no impact on grain quality.

vii) Three-year results (time replicates 1, 2 and 3) — yield data 2014–16

The stubble management trial has been established in the same crop rotation position on different paddocks during the past three years. There have been only a few significant yield effects associated with stubble management over the three years of trials. In 2016 there were significant yield increases when additional nitrogen was applied at sowing, however removing the influence of treatments with additional nitrogen, there were no significant differences in yield between burning, cultivating and straw removal, compared with NTSR (Figure 5).

Although burning has increased DM production in all three years it has not generated any statistical yield advantages, with only a small, non-significant trend suggesting a 3–5% yield benefit. With the harder finish during 2015, the burnt treatment had significantly less grain yield compared with NTSR — short stubble, with the greater biomass of the burnt treatment possibly being a disadvantage in such a season.

viii) 2015 stubble management treatments — influence on 2016 canola yields

Different stubble management treatments established pre-sowing during 2015 resulted in significant differences in wheat yields during 2015, with the NTSR — short stubble treatment significantly increasing wheat yields compared with straw removal and burning. However, these treatment effects did not follow through to have any effect on the yield of a commercial crop of canola sown across the 2015 site during 2016 (Table 13).

TABLE 12 Wheat yield, test weight, protein, screenings, harvest index (HI) and thousand seed weight (TSW) 12 December 2016, at harvest (GS99)

Treatment	Yield (t/ha)	Protein (%)	Test weight (kg/hL)	Screenings (%)	HI (%)	TSW (g)
NTSR — long stubble (control)	5.86^{bc}	8.5^{c}	79.9^{a}	2.9^{a}	50.3^{abc}	46.6^{c}
NTSR — long stubble + 40kg N/ha	6.19^{ab}	9.7^{ab}	80.1^{a}	2.5^{ab}	57.1^{a}	47.3^{bc}
NTSR — short stubble	5.81^{bc}	8.9^{c}	79.9^{a}	2.1^{b}	49.3^{abc}	48.7^{ab}
Straw removed	5.6^{c}	8.6^{c}	79.8^{a}	2.5^{ab}	48.3^{bc}	49.0^{a}
Cultivated (one pass)	5.9^{bc}	9.1^{bc}	80.4^{a}	2.2^{b}	49.7^{abc}	49.3^{a}
Cultivate (one pass) + 40kg N/ha	6.69^{a}	10.0^{a}	80.4^{a}	2.5^{ab}	52.0^{ab}	49.9^{a}
Burnt	6.12^{abc}	8.9^{c}	80.3^{a}	2.2^{b}	42.8^{c}	50.0^{a}
Mean	**6.03**	**9.1**	**80.1**	**2.4**	**49.9**	**48.7**
LSD	0.58	0.7	0.9	0.6	8.6	1.4

Figures followed by different letters are regarded as statistically significant.

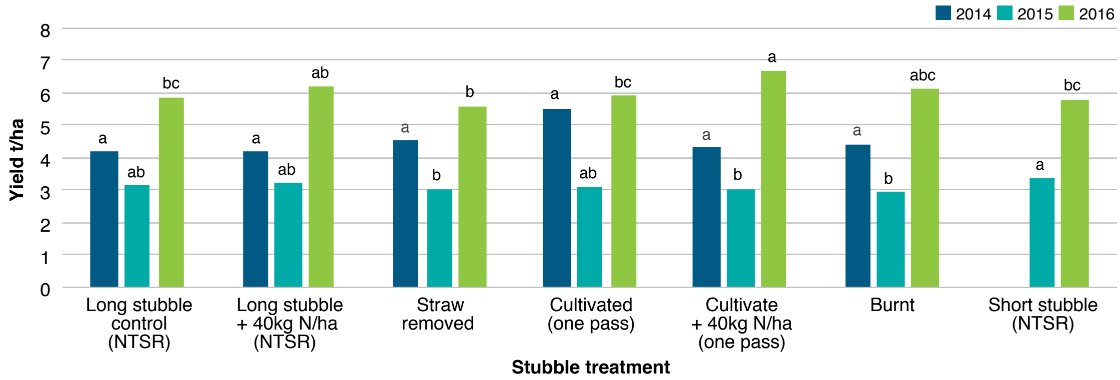


FIGURE 5 Yield data from the three Yarrawonga trials for 2014, 2015 (cv Young) and 2016 (cv Corack).

Note: The NTSR — short stubble was not part of the 2014 list of treatments.

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

TABLE 13 Canola yield in the 2016 commercial crop following different stubble management treatments set up in the 2015 stubble management site and the 2015 wheat yield

2015 stubble management treatments (all blocks were burnt before the 2016 crop)	2015 second wheat yield (t/ha)	2016 canola yield (t/ha)
NTSR — long stubble (control)	3.13[ab]	2.76[a]
NTSR — long stubble + 40kg N/ha	3.20[ab]	2.73[a]
NTSR — short stubble	3.35[a]	2.84[a]
Straw removed	3.03[b]	2.72[a]
Cultivated (one pass)	3.10[ab]	2.75[a]
Cultivate (one pass) + 40kg N/ha	3.05[b]	2.69[a]
Burnt	2.93[b]	2.73[a]
Mean	**3.11**	**2.74**
LSD	0.29	0.42

Figures followed by different letters are regarded as statistically significant.

Influence of stubble height on sunlight interception in the NTSR — long stubble (left) and NTSR — short stubble (right) at the Yarrawonga site, 20 May, 2016.



Trial 3: Dookie, Victoria

Sowing date: 12 May 2016

Rotation: Second wheat

Variety: Corack

Stubble: Wheat (various treatments applied)

Stubble load at sowing: 7.9 t/ha

Rainfall:

GSR: 509mm (April–October)

Summer rainfall: 130mm

Soil nitrogen: 110kg N/ha control NTSR, 102kg N/ha multidisc (0–60cm)

Key points

- A growing season rainfall of 509mm resulted in average yields of 5.8t/ha compared with 2.4t/ha in 2015 and 5.5t/ha in 2014 for the equivalent trial in a second wheat rotation position.
- Transient waterlogging influenced the results of the trial and gave variable yield effects resulting in a high LSD of 1.02t/ha.
- As a consequence, there were no yield differences during 2016 due to stubble management, with all treatments achieving 5–6t/ha yields, screenings less than 1% and grain protein levels above 10.5%.
- Though there was a trend for the burnt and straw removed treatments to increase plant establishment and early DM production compared with NTSR — long stubble (control), the trend for these treatments to be higher yielding (3–7%) was not statistically significant.
- Across the three years of the trial, NTSR — long stubble has reduced early DM production in all years, however it has only significantly reduced yield compared with other stubble treatments during 2014 (0.7t/ha decrease).
- The significant yield reduction in 2014, due to long stubble, resulted in a significant increase in canola yields during 2015.
- However, the influence of stubble management treatments set up in 2014 had no effect on the yield of wheat in 2016, following canola.

Results

i) Establishment and crop structure

Burning the straw resulted in a significantly higher plant population than all NTSR and cultivation treatments, however the differences were relatively small (less than 20 plants/m²). At first node (GS31), the NTSR — long stubble treatment had significantly fewer tillers compared with the short stubble and other treatments (Table 14). Burning stubble produced the highest tiller number (445 tillers/m²), however the advantage over the NTSR — short stubble treatment was not significant. At maturity there were no significant differences in head numbers between the different treatments and the large range in tiller number (approximately 150 tillers/m²) was narrowed with only an approximate range of 50 heads/m² between treatments.

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

The NTSR long stubble treatment produced significantly less DM at first node (GS31), a result that correlates to observations on tiller numbers (Table 14 and 15). At early grain fill (GS71) the burnt treatment still maintained an increase in DM over NTSR — long stubble. Although the short stubble treatment tended to produce more DM than long stubble during ear emergence (GS55) and at early grain fill (GS71), these differences were not statistically significant, with no difference between the two treatments at physiological maturity (GS95–99); a result noted in previous years.

The lower DM production under the NTSR — long stubble treatment compared with other treatments also equated to lower nitrogen uptake in the canopy at first node (GS31), however there were no differences in nitrogen uptake at later assessment times (Table 16).

iii) Disease levels

Assessments for disease revealed only trace levels of yellow leaf spot (YLS), a result similar to that seen at the Yarrawonga site. Again, this is thought to be linked to greater resistance rating of Corack to this disease. There

TABLE 14 Plant counts and vigour 8 June 2016, two leaf (GS12); tiller counts 2 August 2016, first node (GS31) and head counts 30 November 2016, physiological maturity (GS95–99)

	Crop growth stage		
	Plants/m²	Tillers/m²	Heads/m²
Treatment	GS12	GS31	GS99
NTSR — long stubble	135^{b}	296^{c}	356^{a}
NTSR — short stubble	133^{b}	389^{ab}	383^{a}
Cultivated (one pass)	136^{b}	363^{bc}	391^{a}
Straw removed	141^{ab}	378^{ab}	343^{a}
Burnt	152^{a}	445^{a}	378^{a}
Mean	**139**	**374**	**370**
LSD	14	77	52

Figures followed by different letters are regarded as statistically significant.

TABLE 15 Dry matter 2 August 2016, first node (GS31); 19 September 2014, head half emerged (GS55); 17 October, watery ripe grain (GS71) and 30 November, physiological maturity (GS95–99)

Treatment	Dry matter (t/ha)			
	GS31	GS55	GS71	GS95–99
NTSR — long stubble	0.76[b]	6.6[a]	10.3[b]	14.1[a]
NTSR — short stubble	1.12[a]	7.3[a]	11.2[ab]	14.0[a]
Cultivated (one pass)	1.04[a]	6.6[a]	11.1[ab]	12.5[a]
Straw removed	1.10[a]	6.6[a]	10.5[ab]	12.9[a]
Burnt	1.17[a]	7.1[a]	11.5[a]	12.6[a]
Mean	**0.86**	**6.8**	**10.9**	**13.2**
LSD	0.22	1.3	1.2	1.7

Figures followed by different letters are regarded as statistically significant.

TABLE 16 Nitrogen uptake in dry matter 2 August 2016, first node (GS31); 19 September 2014, head half emerged (GS55); 17 October, watery ripe grain (GS71) and 30 November, physiological maturity (GS95–99)

Treatment	Nitrogen uptake (kg N/ha)			
	GS31	GS55	GS71	GS95–99
NTSR — long stubble	32[b]	139[a]	116[ab]	71[a]
NTSR — short stubble	49[a]	138[a]	142[a]	80[a]
Cultivated (one pass)	45[a]	116[a]	106[b]	73[a]
Straw removed	52[a]	124[a]	124[ab]	52[a]
Burnt	50[s]	149[a]	112[b]	79[a]
Mean	**46**	**133**	**120**	**71**
LSD	10	45	30	31

Figures followed by different letters are regarded as statistically significant.

were traces of leaf rust at the end of the season, but no observable differences in disease between treatments.

iv) Green leaf retention

The soft finish to the season produced conditions suitable for an extended grain fill period, unlike the heat stress of 2015, although it was evident that transient waterlogging in parts of the trial precluded this from happening to the extent that might be suggested by available water and temperatures. Assessments of the crop canopy, using NDVI, revealed initial differences at first node (GS31), however these differences were not measured later in the season, at half head emerged (GS55) and early grain fill (GS71) (Figure 6). Long and short stubble NTSR recorded lower crop canopy greenness compared with the burnt plots at first node (GS31), but not when assessed later.

v) Yield and grain quality

The trial was harvested on 13 December 2016. The yield results at this site were highly variable as parts of the trial site were subject to waterlogging during the growing season. As a result, there were no significant differences between the different stubble management treatments (Table 17). Yield results and grain quality were based on three replicates as the fourth replicate was badly affected by waterlogging. The yield range in the trial was 5.37–6.23t/ha, which is similar to results achieved in 2014 at this site. There were no statistical differences in grain quality (Table 17).

vi) Three-year results (time replicate 1, 2 and 3) — yield data 2014–16

For the past three years a replicated large block stubble management trial has been established in a different

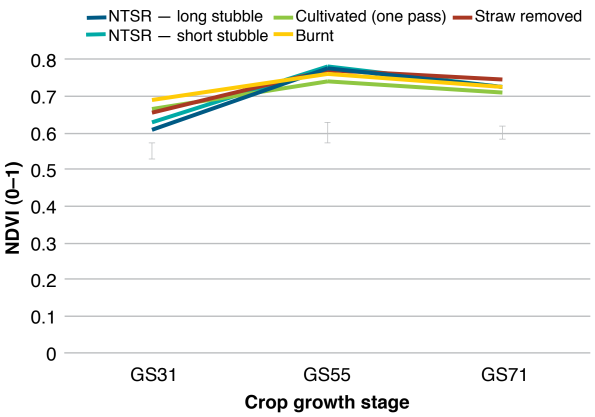


FIGURE 6 Influence of stubble management on crop canopy NDVI (0–1 scale)*

*The error bars are a measure of LSD

TABLE 17 Wheat yield, protein, test weight, screenings and thousand seed weight (TSW) 13 December 2016, at harvest (GS99)

Treatment	Yield and quality				
	Yield (t/ha)	Protein (%)	Test weight (kg/hL)	Screenings (%)	TSW (g)
NTSR — long stubble	5.80[a]	10.7[a]	76.5[a]	0.7[a]	53.9[a]
NTSR — short stubble	5.37[a]	10.7[a]	79.4[a]	0.6[a]	54.4[a]
Cultivated (one pass)	5.60[a]	11.3[a]	79.4[a]	0.7[a]	53.2[a]
Straw removed	6.00[a]	10.5[a]	80.5[a]	0.7[a]	52.5[a]
Burnt	6.23[a]	11.1[a]	79.7[a]	0.6[a]	52.8[a]
Mean	**5.80**	**10.9**	**79.1**	**0.7**	**53.3**
LSD	1.02	1.6	5.0	0.2	4.6

Figures followed by different letters are regarded as statistically significant.

Dookie site on 8 June 2016 (GS12)

paddock on the Dookie focus farm. The trial set-up in 2014 (year one of the experiment) is referred to as time replicate 1 in the trial series, the trial set up in year two is time replicate 2 and in the third year it is time replicate 3.

After each trial has been completed the trial area reverts to being a commercial farm crop undergoing uniform management. The stubble management for all subsequent years has been uniform across the trial area and dictated by commercial farm operations. In each subsequent year the trial area has then been remarked in order to assess any yield effects of stubble management set-up in year one on yields in the year two and three farm crop.

The yield results from each time replicate trial at the Dookie focus farm have shown only one significant yield difference due to stubble management over the three years the trial has run. In 2014 the NTSR — long stubble (45cm) treatment significantly reduced yield by approximately 0.7t/ha, compared with other treatments, including NTSR — short stubble treatment. This equates to a yield reduction of 0.25t/ha for every 10cm increase in stubble height above 15cm, assuming it is a linear response between yield and stubble height (Figure 7).

Although a significant yield reduction associated with long stubble was only observed in 2014, there has been evidence in all three years that long stubble has significantly decreased DM production, resulting in less tillering and reduced crop canopy greenness. In some seasons, this reduction in crop canopy greenness has been reversed later in the season, with NTSR treatments being greener at grain fill. This was most pronounced during 2015, and was also associated with slower phenological development of the crop. In a stressed season with yields of 2.5t/ha these greenness/ phenological differences did not influence yield.

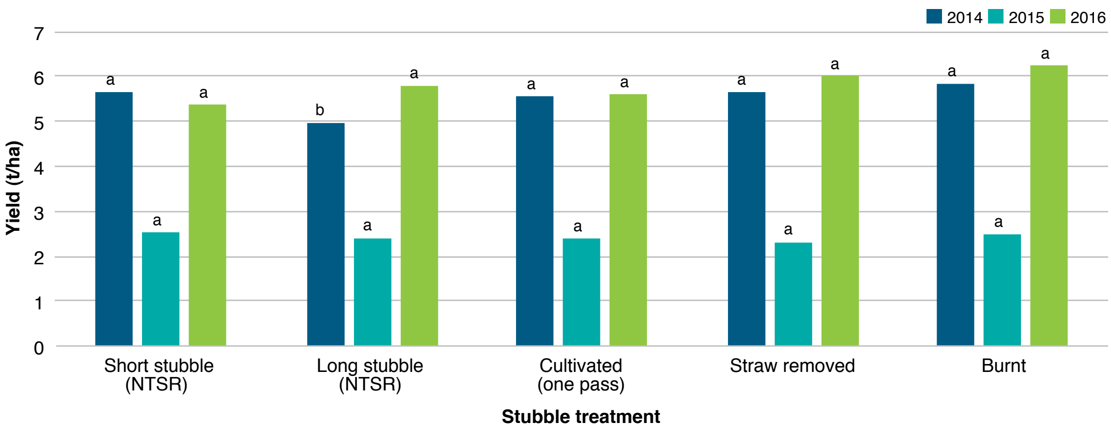


FIGURE 7 Yield data from 2014, 2015 and 2016 stubble management trials conducted in the wheat-on-wheat rotation position (time replicate 1, 2 and 3), cv Corack (2014), cv Mace (2015) and cv Corack (2016)

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

vii) Time replicate 1 — yield data 2014–16

Looking at crop productivity on the same trial site over three years revealed that stubble management treatments during 2014 significantly influenced canola yields in 2015 but had no effect on wheat yields in 2016. The significant reduction in yield caused by NTSR — long stubble in 2014 significantly increased commercial canola yields during 2015, even though the site was burnt following the 2014 trial, before sowing the canola. The higher canola yields in 2015 are likely due to greater stored water or unused nitrogen retained in the lower-yielding NTSR — long stubble plots. There were no flow-on effects from stubble management in 2014 on 2016 wheat yields (Table 18).

viii) 2015 trial treatments — 2016 canola yield data

The 2015 stubble management trial at the Dookie focus farm was sown to a commercial crop of canola during 2016. The 2015 second wheat trial stubbles were burnt in preparation for the commercial canola crop. Despite large visual differences in crop appearance in 2015 with NTSR — long stubble plots being greener (*Research for the Riverine Plains 2016*, p22) and slightly less developed, there were no yield differences due to stubble management treatments in either the 2015 trial, sown to wheat or the following canola crop, when sown over the 2015 stubble treatments with a yield range of 0.2t/ha across the site in both seasons (Table 19).

TABLE 18 2015 canola yields and 2016 wheat yields, on the site of the 2014 stubble management trial, which was sown to second wheat (time replicate 1)

2014 stubble management (2015 all trial blocks burnt prior to canola)	2014 trial results, second wheat yield	2015 canola yield	2016 wheat yield
NTSR — long stubble	5.0[b]	1.4[a]	7.1[a]
NTSR — short stubble	5.7[a]	1.3[ab]	7.1[a]
Cultivated (one pass)	5.6[a]	1.4[ab]	7.2[a]
Straw removed	5.7[a]	1.3[ab]	6.9[a]
Burnt	5.9[a]	1.2[b]	7.1[a]
Mean	**5.5**	**1.3**	**7.1**
LSD	0.5	0.2	0.7

TABLE 19 2016 canola yields, on the site of the 2015 stubble management trial, which was sown to second wheat (time replicate 2)

2015 stubble management (2016 all trial blocks burnt prior to canola)	2015 trial results, second wheat yield	2016 canola yield
NTSR — long stubble	2.41[a]	2.6[a]
NTSR — short stubble	2.52[a]	2.6[a]
Cultivated (one pass)	2.39[a]	2.7[a]
Straw removed	2.32[a]	2.6[a]
Burn	2.49[a]	2.5[a]
Mean	**2.42**	**2.6**
LSD	0.22	0.2

Figures followed by different letters are regarded as statistically significant.

NTSR — long stubble 2 August 2016 (GS31)

Burnt stubble 2 August 2016 (GS31)



Trial 4: Henty, NSW

Sowing date: 10 April 2016
Rotation: Wheat stubble
Variety: Canola 650 TT
Stubble: Wheat (various treatments applied)
Stubble load at sowing: 6.6t/ha
Rainfall:
GSR: 619mm (April–October)
Summer rainfall: 145mm
Soil nitrogen at sowing: 106kg N/ha NTSR (control), 101kg N/ha multidisc (0–60cm)

Key points

- Trial results were highly variable, with no significant differences in canola yield although there was a trend for the cultivation treatments to be higher yielding.
- Canola 650TT showed higher DM accumulation at flowering where the seedbed had been cultivated (multidisc) compared with the NTSR control, although adding nitrogen to the NTSR treatment negated this effect.
- The 2016 results were similar to 2014 when cultivation before sowing significantly increased canola yields.

Results

i) Establishment and crop structure

There were no significant differences in crop establishment in terms of crop and weed plant populations, however plant establishment was significantly more vigorous where the seedbed had been cultivated (Table 20).

TABLE 20 Plant and weed counts 3 May 2016, three leaves unfolded (GS13) and vigour score 17 July 2016, green bud stage (GS51)

Treatment	Canopy composition		
	GS13		GS51
	plants/m^2	weeds/m^2	Vigour
NTSR (control)	31^{a}	0.4^{a}	4.3^{bc}
NTSR + 40kg N/ha	35^{a}	0.6^{a}	5.4^{ab}
Mulched	31^{a}	0.4^{a}	4.9^{abc}
Mulched + 40kg N/ha	25^{a}	0.4^{a}	3.8^{c}
Cultivate (one pass)	34^{a}	0.0^{a}	6.0^{a}
Cultivate (one pass) + 40kg N/ha	28^{a}	1.0^{a}	5.1^{abc}
Mean	**31**	**0.5**	**4.9**
LSD	14	1.2	1.6

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

While the results were highly variable, the NTSR (control) and mulched treatments generally produced less DM than the cultivated treatment, up to the mid-flower assessment (Table 21). Early DM production was increased by either cultivation and/or adding nitrogen to the NTSR (control), but by harvest there were no significant differences in DM between treatments (Table 21). Similar trends are observed in the nitrogen uptake data (Table 22).

iii) Yield

There were no significant yield differences due to stubble management, with variable yield results due to transient waterlogging across the trial site. There was a non-significant trend for crops in the cultivated treatment to yield more, a result that was significant in 2014 when cultivated crops significantly out-yielded the NTSR (control) blocks (Table 23).

TABLE 21 Dry matter 11 July 2016, green bud (GS51); 9 August 2016, mid-flower (GS65); 26 September 2016, 50% pods reached final size (GS75) and 11 November, harvest (GS99)

Treatment	Dry matter (t/ha)			
	GS51	GS65	GS75	GS99
NTSR (control)	1.64^{b}	3.70^{c}	6.90^{b}	9.76^{a}
NTSR + 40kg N/ha	2.15^{a}	4.51^{abc}	6.09^{b}	7.98^{a}
Mulched	1.69^{b}	3.91^{bc}	7.58^{ab}	8.31^{a}
Mulched + 40kg N/ha	1.58^{b}	4.19^{abc}	9.11^{a}	9.59^{a}
Cultivate (one pass)	1.84^{ab}	5.17^{a}	6.64^{b}	8.33^{a}
Cultivate (one pass) + 40kg N/ha	1.75^{ab}	5.12^{ab}	7.49^{ab}	8.87^{a}
Mean	**1.78**	**4.43**	**7.30**	**8.81**
LSD	0.46	1.23	1.78	2.99

TABLE 22 Nitrogen uptake in dry matter 11 July 2016, green bud (GS51); 9 August 2016, mid-flower (GS65); 26 September 2016, 50% pods reached final size (GS75) and 11 November, harvest (GS99)

Treatment	Nitrogen uptake (kg N/ha)			
	GS51	GS65	GS75	GS99
NTSR (control)	86^{bc}	117^{bc}	141^{b}	151^{a}
NTSR + 40kg N/ha	112^{a}	130^{bc}	114^{b}	153^{a}
Mulched	96^{abc}	94^{c}	161^{b}	91^{b}
Mulched + 40kg N/ha	82^{c}	167^{ab}	227^{a}	130^{ab}
Cultivate (one pass)	111^{ab}	132^{bc}	132^{b}	98^{b}
Cultivate (one pass) + 40kg N/ha	94^{abc}	201^{a}	164^{b}	165^{a}
Mean	**97**	**140**	**157**	**131**
LSD	26	61	51	52

NTSR (control) treatment, 3 June 2016, 4–6 leaves

Cultivated treatment, 3 June 2016, 4–6 leaves

TABLE 23 Canola yield and % of trial site mean 6 December 2016, at harvest (GS99)

Treatment	Yield (t/ha)
NTSR (control)	2.40[a]
NTSR + 40kg N/ha	2.26[a]
Mulched	2.48[a]
Mulched + 40kg N/ha	2.53[a]
Cultivate (one pass)	2.80[a]
Cultivate (one pass) + 40kg N/ha	2.72[a]
Mean	**2.53**
LSD	0.72

iv) Three-year results (time replicates 1, 2 and 3) — yield data 2014–16

The yield results from year one of each trial run at the Henty focus farm (time replicates 1, 2 and 3) have shown variable results, but similar trends (Figure 8). This trend has been for canola crops to yield more following cultivation compared with the NTSR (control) treatment, though it was only in 2014 that the yield advantage of cultivation (by multidisc) was statistically significant. In all three years the trial site has been subjected to variable amounts of waterlogging, which was particularly problematic in early spring across all three years.

Acknowledgements

Thanks to the farmer co-operators at each of these sites:

- Corowa/Coreen: Tomlinson Ag
- Yarrawonga: Telewonga Pty Ltd
- Dookie: Ludeman Brothers
- Henty: Peter Campbell

This work 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).

Contact

Michael Straight Foundation for Arable Research, Australia

E: michael.straight@far.org.nz

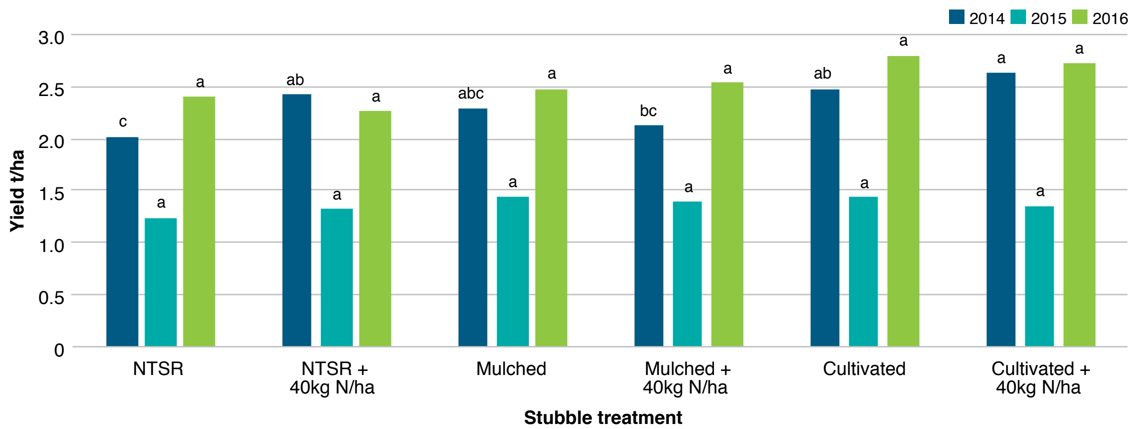


FIGURE 8 Yield data from 2014, 2015 and 2016 stubble management trials carried out in canola following wheat (time replicates 1, 2 and 3), cv GT50 RR (2014), cv 314 TT Monola (2015) and cv Hyola 650 TT (2016)

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

Darcy Warren[1], Dr Cassandra Schefe[2], Michael Straight[3], Nick Poole[3] and Dale Grey[1]

[1] Department of Economic Development, Jobs, Transport and Resources (DEDJTR)

[2] Riverine Plains Inc

[3] FAR Australia

Key points

- Stubble management can influence in-canopy temperatures.
- The in-canopy temperature of long stubble was colder than short stubble.
- All trial sites experienced fewer temperature extremes during 2016 than in previous years of this trial.
- There were no measured frosts during flowering in 2016. Further research is needed to determine the physiological significance of the observed temperature differences.

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. After much interest and feedback from growers in the region, understanding the influence of frost on retained stubble systems became a priority. While there has been a perception that full stubble retention may increase the risk and severity of frosts, there has also been a lack of research directly relevant to the Riverine Plains region, as much of the frost-related research has been carried out in Western Australia, where yields and stubble loads are normally lower.

Additional 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 across three large plot trials at Corowa/Coreen, Yarrawonga and Dookie from 2015 – 2017. This funding links the project into the GRDC *National Frost Initiative*, with all data generated being submitted for review and statistical analysis in conjunction with other *National Frost Initiative* projects.

The 2015 results showed that the no-till stubble retention (NTSR) — long stubble treatment measured the lowest minimum temperatures and stayed colder the longest. However, no difference in physiological frost damage was seen between the different treatments.

Aim

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

Method

The 2016 sites at Coreen, New South Wales, and Yarrawonga and Dookie, Victoria were chosen for this trial as they were on a second-cereal rotation in areas that were flat, relatively uniform and therefore had a higher frost risk. Site, crop and treatment details are listed in the previous report (*Active stubble management to enhance residue breakdown and subsequent crop management — focus farm trials,* page 12). Treatments specific to each site are outlined in Table 1, along with the placement of temperature loggers in each trial (installed during May and removed before harvest).

Each site had four replicates of each treatment, with temperature loggers installed in every plot at two different heights.

The temperature loggers used were Tinytags, which are battery-powered temperature sensors, which recorded the temperature every 15 minutes for the length of the growing season (Figure 1). The Tinytag loggers faced north and were not shielded from direct sunlight. As a result, they recorded higher daytime temperatures compared with the temperatures recorded in a Stevenson screen at a weather station.

There was also a weather station, with a one-metre-deep soil moisture probe, located at each site to measure local climatic conditions to support the temperature data.

The temperature data was statistically analysed using Genstat. Measures of least significant difference (LSD) were used to determine which, if any, treatments were significantly different.

Results

The following results are from the temperature loggers installed at a height of 300mm, which were moved up to 600mm at the dates listed in Table 1 (unless otherwise stated).

TABLE 1 Sites, selected treatments and temperature monitoring carried out during 2016

Site	Treatments	Measurements
Coreen, NSW	• Stubble retained (NTSR) • Stubble burnt • Stubble incorporated (disc)	• Loggers (300mm height and moved to 600mm on 25 August) • Loggers at 50mm height
Yarrawonga, Victoria	• NTSR — long stubble (300mm) • NTSR — short stubble (150mm) • Stubble burnt • Stubble incorporated (disc)	• Loggers (300mm height and moved to 600mm on 25 August) • Loggers at 50mm height
Dookie, Victoria	• NTSR — long stubble (330mm) • NTSR — short stubble (150mm) • Stubble burnt • Stubble incorporated (disc)	• Loggers (300mm height and moved to 600mm on 26 August) • Loggers at 50mm height • Loggers buried 50mm below the soil surface

FIGURE 1 Tinytag temperature loggers installed in the burnt treatment at Yarrawonga 26 May 2016

Note: The yellow 50mm and 300mm loggers are attached to the PVC tube.

Site 1. Coreen, NSW

The temperature profile of the Coreen site is displayed in Figure 2. This graph shows the range and extremes of temperatures reached within the crop canopy. It is important to note the Tinytags were not shaded when they recorded daytime temperature data. This is in contrast to the ambient temperature measured in the weather station's Stevenson screen. Therefore, temperatures as high as 53.4°C were recorded by the loggers, while the highest daily maximum recorded by the weather station at the site was 42.3°C.

The Tinytags also demonstrated the differences between the minimum temperatures reached within the crop canopy and those measured by the weather stations, which measure the temperature at a height above-ground level of 1.2m. The lowest temperatures recorded in the crop canopy for the burnt, incorporated and standing stubble treatments were -3.7°C, -3.6°C and -4.0°C respectively. At the same time the temperature recorded by the weather station was 4.75°C (7:30am, 26 August 2016).

Frost risk is determined by the amount of time a crop experiences sub-zero temperatures and the minimum

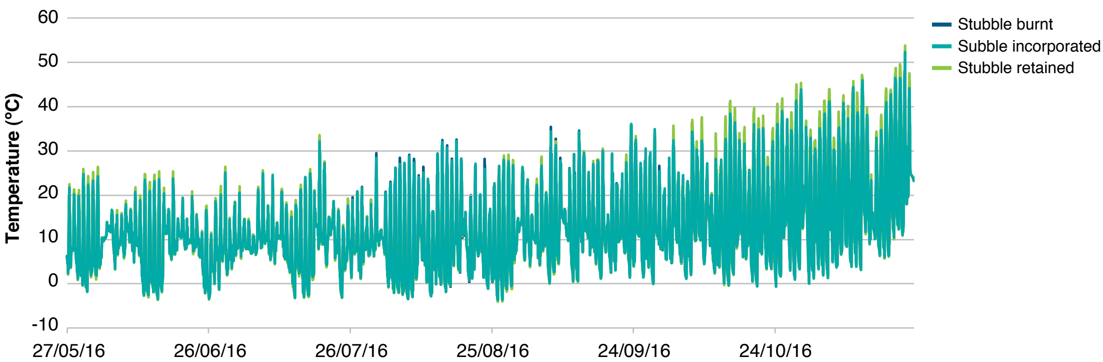


FIGURE 2 In-canopy temperatures measured at the Coreen site from 27 May – 21 November 2016

Flowering at this site occurred on 19 September 2016.

temperatures reached. In Figure 3, these indicators were used to determine if the different stubble treatments influenced the amount of time the crop experienced temperatures below 0°C (time threshold). While there was a trend for the standing stubble to be colder at the Coreen site, there were no significant difference between each of the three treatments (Figure 3).

There were three distinct frost events during the first two weeks of temperature recording (29, 30, and 31 May) when the wheat was at the seedling growth and early tillering stages (Figure 4). During this time of development wheat plants can withstand sub-zero temperatures, with frost events serving to 'harden' the crops, helping them withstand subsequent frost events (Agriculture Victoria, 2009).

The 50mm high loggers are particularly useful in capturing the conditions under the retained-stubble treatment. The frost event that occurred on the 29 May (Figure 4) demonstrated a significant difference between the minimum temperature reached between the burnt stubble and the standing stubble, with the standing stubble being the colder of the two. There was no statistical difference between the incorporated (disc) treatment and the burnt or standing treatments.

In these early vegetative stages, the Coreen site spent far less time below 0°C. In the first two weeks the stubble retained treatment spent around 12 hours (cumulatively) below 0°C, compared to 26 hours and 47 hours at Yarrawonga and Dookie respectively (Figures 4, 7 and 10).

Site 2. Yarrawonga, Victoria

The coldest temperature recorded by a Tinytag at the Yarrawonga site was -4.29°C, recorded on 27 July 2016 in the NTSR — long stubble treatment (Figure 5).

The temperature threshold results showed no significant differences between the NTSR — short stubble and NTSR — long stubble treatments, unlike the previous year where the NTSR — long stubble treatment spent more time below 0°C than the NTSR — short stubble treatment (Figure 6).

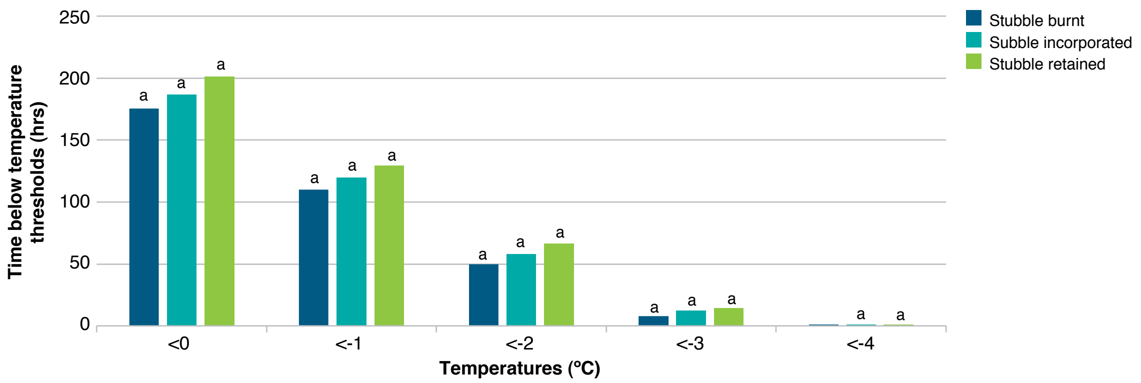


FIGURE 3 The effect of stubble treatment on the duration of in-canopy temperatures at zero and each degree below, at the Coreen site

Letters denote statistical significant between treatments at each temperature.

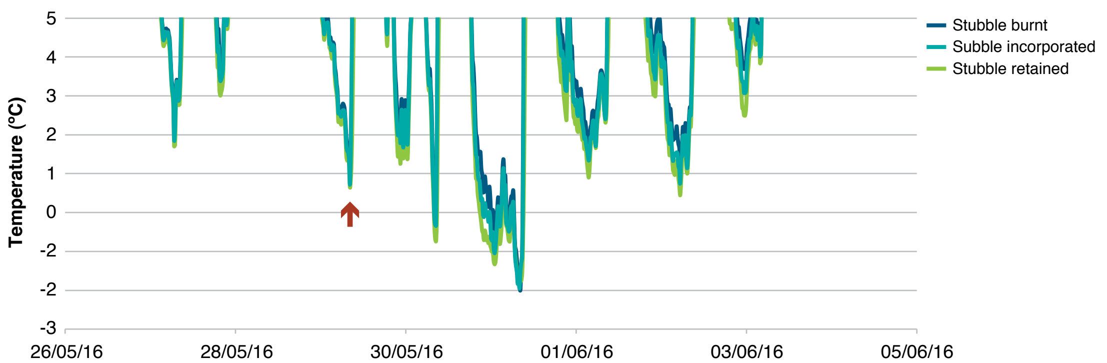


FIGURE 4 In-canopy temperatures measured at 50mm above the soil surface for the first 10 days of the Coreen site trial (arrow represents the time when there was a significant difference between treatments)

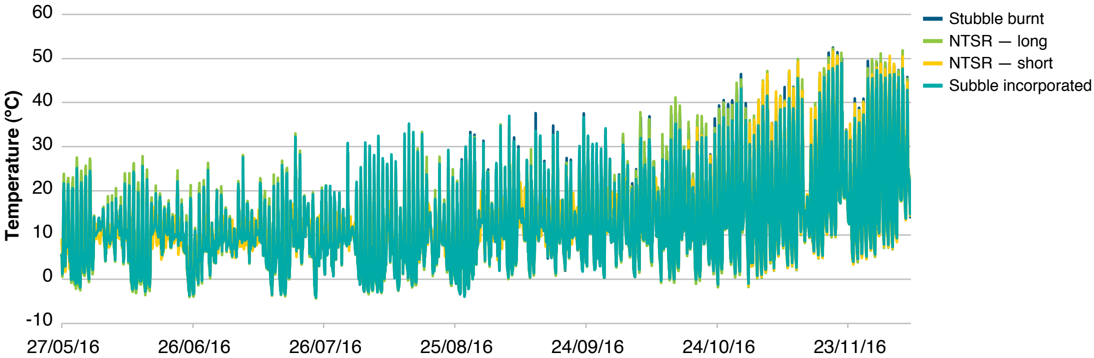


FIGURE 5 In-canopy temperatures measured at the Yarrawonga site from 27 May – 7 December 2016

Flowering at this site occurred on 26 September 2016.

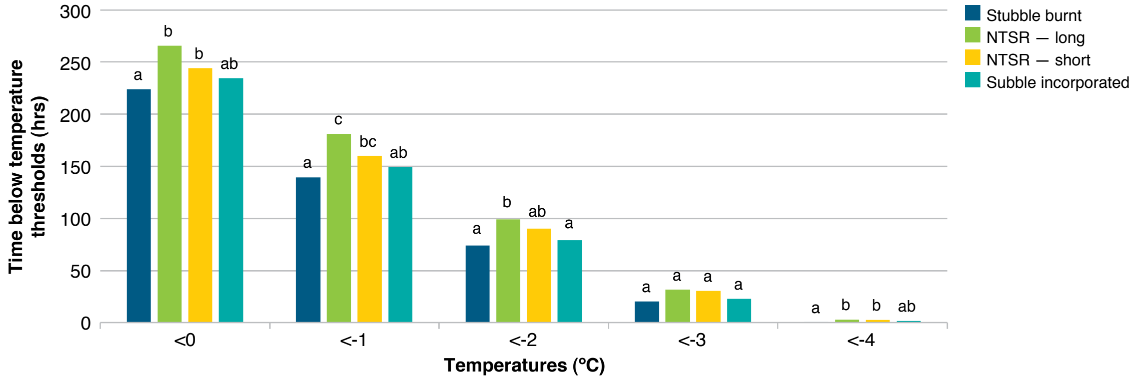


FIGURE 6 The effect of stubble treatment on the duration of in-canopy temperatures at zero and each degree below, at the Yarrawonga site

Letters denote statistical significance between treatments at each temperature.

Moreover, during the first two weeks of temperature recording the NTSR — short stubble plots were found to be reaching colder temperatures and maintaining this lower temperature for longer periods (Figure 7). This occurred during four frost events which were recorded between the 28 and 31 May. Rather than being due to a stubble height effect, the colder temperatures in the NTSR — short stubble treatment may have been due to chopped stubble straw lying on the ground, which can stop warm air moving from the soil into the canopy overnight. This insulating effect was caused by cutting the tall stubble to create the short stubble treatments.

Despite this, the NTSR — short stubble treatment was not significantly different to the burnt and incorporated treatments when comparing time spent at 0°C and -2°C, while the NTSR — long stubble treatment spent significantly more time between 0 and -2°C compared with the incorporated and burnt treatments (Figure 6).

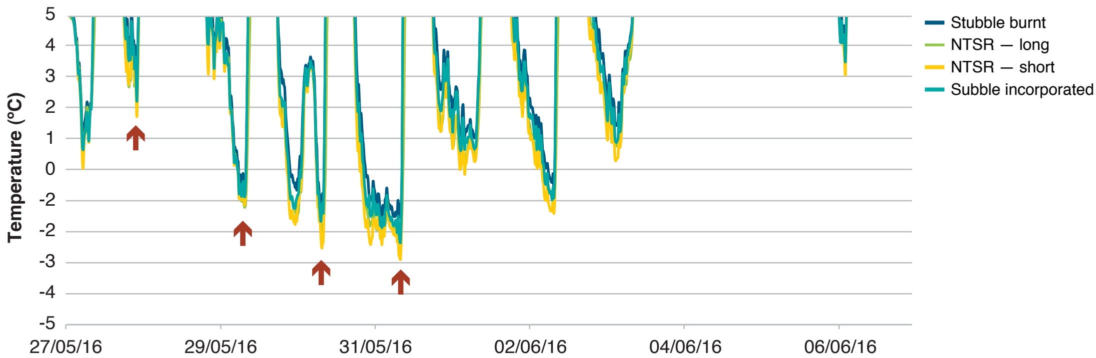


FIGURE 7 In-canopy temperatures measured at 50mm above the soil surface for the first 10 days (27 May to 6 June) of the Yarrawonga site trial (arrows represent periods of significant differences between treatments)

All treatments reached temperatures below -4°C, however the duration of time at these temperatures was much less than during 2015, which also saw temperatures fall below -5°C and -6°C. This year at the Yarrawonga site, the time spent below -4°C ranged from 0.25 hours in the burnt treatment to 3.56 hours in the NTSR — long treatment compared with a range of 17.6 hours and 25.1 hours in the burnt and cultivated treatments in the 2015 season.

Despite minimum temperatures being less severe during 2016, similar trends can be observed between treatments from 2015. The main difference in these trends is the significant difference between the NTSR — long treatment and cultivated treatments in the -1°C and -2°C thresholds in the 2016 season (Figure 6).

Site 3. Dookie, Victoria

The results shown in Figure 8 demonstrate a similar pattern of temperatures as those experienced at the Coreen and Yarrawonga sites. The coldest temperature reached at this site during 2016 was -4.35°C in the NTSR — long stubble treatment on 24 July at 7:15am.

Following trends similar to those from 2015, the burnt treatments spent significantly less time below each temperature threshold compared with the NTSR — long treatment except below the -1°C and -3°C thresholds. There was no significant difference between the burnt, incorporated and NTSR — short treatment below the 0°C, -1°C and -4°C thresholds. Both NTSR treatments spent significantly more time below the -2°C threshold when compared to the other treatments, but below -3°C no statistical difference was seen between any treatments (Figure 9).

During the first two weeks of temperature recording at the Dookie site, treatments can be seen to have dropped below 0°C on six occasions. As marked on Figure 10, the NTSR — long treatment was significantly colder on the 11 June when compared with both the burnt and incorporated treatments and significantly different to all treatments on 12 June. Furthermore, the NTSR — short treatments were significantly colder than the burnt treatment on the 11 June frost event. Throughout the entire year, there were four more frost events in which

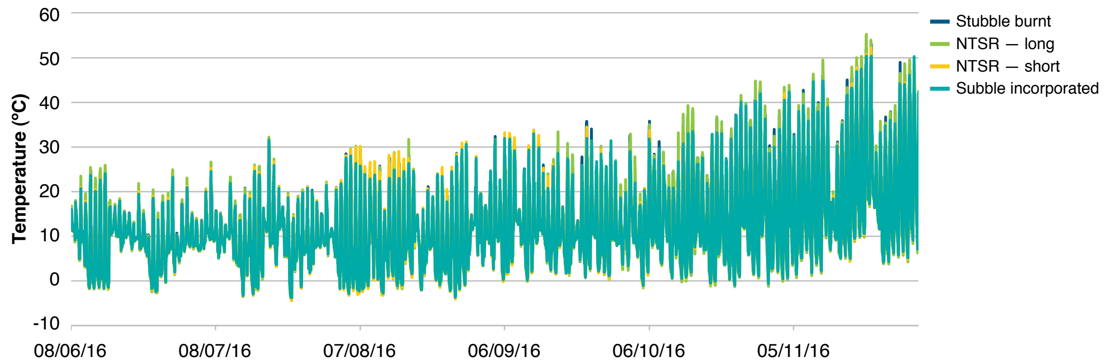


FIGURE 8 In-canopy temperatures measured at the Dookie site during 8 June – 1 December
Flowering at this site occurred on 10 October 2016.

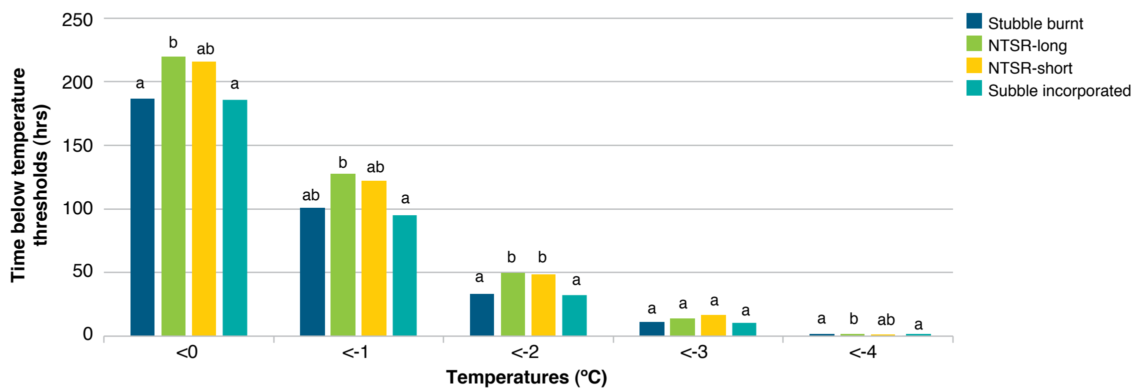


FIGURE 9 The effect of stubble treatment on the duration of in-canopy temperatures at zero and each degree below, at the Dookie site
Letters denote statistical significance between treatments at each temperature.

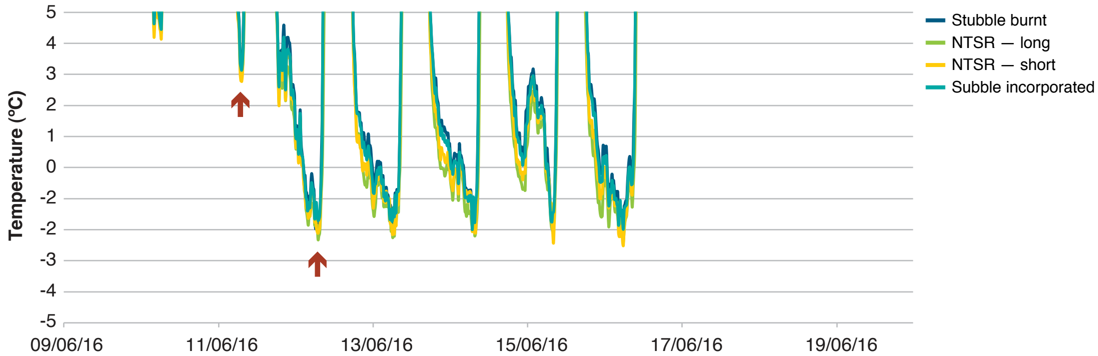


FIGURE 10 In-canopy temperatures measured at 50mm above the soil surface for the first 10 days of the Dookie site trial (arrows represent periods of significant differences between treatments)

the NTSR — long treatment was significantly colder than both burnt and incorporated treatments (24 June, 25 June, 27 June and 19 October).

Comparison of temperatures recorded at different positions at Dookie

As noted in Table 1, the Dookie site was instrumented with Tinytag temperature loggers 50mm below the soil surface in addition to the 50mm and 300mm above-surface in-canopy loggers. The two above-ground loggers showed more fluctuation in recorded temperature than the logger positioned below the soil surface (Figure 11). The NTSR — short stubble treatment has been used as an example to show how the temperatures recorded by the 50mm and 300mm were similar during the early part of the season.

As the plant canopy increased in height above the 50mm logger, the temperature differences between it and the 300mm logger became more significant. As the 300mm loggers remained exposed at the top of the canopy, they tended to record more extreme temperatures when compared with the 50mm loggers.

Compared to the above-ground loggers, the sub-surface logger recorded less fluctuation in temperature. While the 300mm loggers measured a minimum temperature of -4.25°C on 24 July, 5:30am, the in-soil logger only dropped to 5.32°C at the same time (Figure 11).

Observations and comments

The 2016 season had less extreme temperatures than those measured during 2015, with all of the sites and treatments recording average minimum temperatures only to the -4°C threshold or warmer. During 2015 the Corowa and Yarrawonga sites recorded minimum temperatures down to the -6°C threshold, with -7°C measured at the Dookie site.

The mildness of the 2016 season was due to the high amount of in-season rainfall (decile 10 in Yarrawonga and Dookie, decile 9 in Corowa) and associated high cloud cover. These clouds had an insulating effect, which prevented temperatures from plummeting overnight. Victoria experienced its fifth warmest year on record, which was partly the result of mean minimum

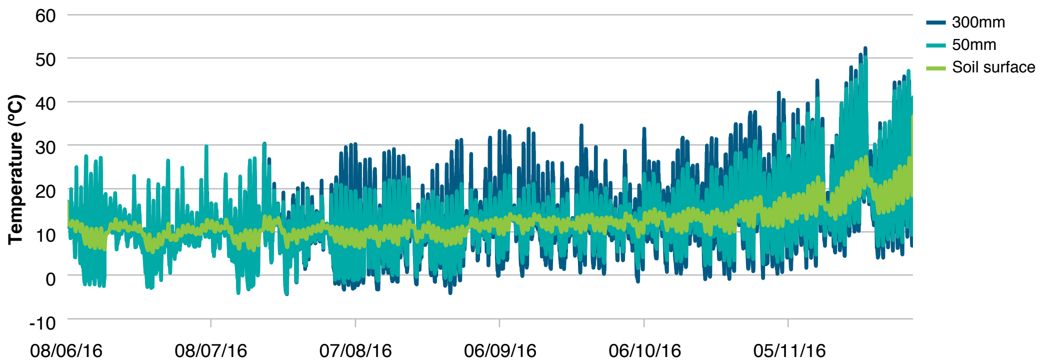


FIGURE 11 Temperatures measured at 300mm, 50mm and soil surface for NTSR — short stubble at the Dookie site between 8 June and 1 December 2016

temperatures being 1.06 degrees warmer (and mean maximum temperatures 0.74 degrees above average). However, October and November temperatures were cooler than average due to a number of cold fronts, which spared crops from heat events such as those seen during early October in 2015 (Bureau of Meteorology, 2017).

Despite the mild temperatures of the 2016 season, there were still clear trends in temperature difference between the stubble treatments. In general, the NTSR — short stubble treatment appears to be a viable option to reduce the risk of frost by maintaining a warmer canopy than the NTSR — long stubble treatment, while still retaining stubble. As well as reducing the risk of frost, the NTSR — short stubble treatment has the same benefits as full stubble retention while increasing the ease of sowing operations.

Although the effect of stubble treatments on in-canopy temperature has been shown to be statistically different, most notably between NTSR — long stubble and burnt treatments, the physiological importance of these differences on plant development and the potential to reduce frost damage during flowering, is still unknown. Due to the lack of frosts during flowering, the importance of the differences in temperature between each treatment requires further study, with monitoring continuing through the 2017 season.

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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Contact

Dr Cassandra Schefe Riverine Plains Inc

T: (03) 5744 1713

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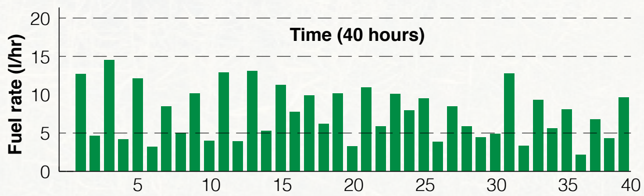

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The impact of stubble treatment on soil nitrogen supply to crops

Dr Cassandra Schefe
Riverine Plains Inc.

Key points

- Soil mineral nitrogen (N) values were low across all sites, which was indicative of the wet seasonal conditions and high nitrogen losses.
- There were no significant differences in mineral nitrogen values between the stubble treatments due to high variability (likely due to transient waterlogging across the sites).
- The project has been extended to enable the research to be repeated during 2017.

Aims

The aim of this work was to determine if differences in early crop growth and development of crops under different stubble management strategies was due to differences in early-season nitrogen (N) supply.

Background

Within the GRDC-funded project *Maintaining Profitable Farming Systems with Retained Stubble in the Riverine Plains Region (2013–18)* (described on page 10), large-scale replicated trials were established from 2014–16. These trials have consistently shown that no-till stubble retention (NTSR) treatments show a biomass lag, with slower early growth and dry matter (DM) production compared with treatments where stubble was removed.

As early crop establishment and growth is largely driven by nutrient supply, light and temperature, it is likely this biomass lag was due to differences in these parameters. While differences in light interception and temperature were quantified within the GRDC-funded *Stubble Project* (for light interception results see page 18 and in-canopy temperature see page 28), detailed nitrogen sampling throughout the season was outside the scope of this project.

In order to understand if the measured biomass lag of NTSR crops was due to differences in nitrogen supply between stubble treatments, during 2016 detailed nitrogen sampling was carried out at each of the Focus Farm trial sites established as part of the GRDC funded Stubble project. This sampling effort was carried out under the Sustainable Agriculture Victoria: Fast-Tracking Innovation initiative, which has been made possible with the support of the Foundation for Rural and Regional Renewal (FRRR) together with the William Buckland Foundation.

Stubble impact

The presence or absence of stubble may impact nitrogen availability to the crop. When stubble is retained from the previous crop, it continues to be broken down by microbes and converted into soil organic matter (OM) throughout the following cropping season. As cereal stubbles are high in carbon compared with nitrogen (carbon:nitrogen ratio of 100:1), soil microbes need to ‘borrow’ nitrogen from the soil in order to balance their nutrient requirements while they break down the cereal stubble. This in turn can lead to nitrogen *immobilisation*, or *tie-up*, which reduces the total amount of soil nitrogen available to the growing crop.

This *tie-up* effect is most evident early during the season when microbial activity accelerates with increased soil moisture following the autumn break.

As soil microbes break down the stubble during the growing season, they gradually release, or *mineralise*, nitrogen back into the soil.

In comparison, if the stubble is burnt, microbes do not require soil nitrogen to support the stubble decomposition process and, as a result, more soil nitrogen is readily available to the early crop. While this may aid crop establishment and early growth, on the other hand there is no slow release of nitrogen throughout the season.

While the processes of nitrogen immobilisation and mineralisation under NTSR systems are significant, it is unknown if they result in measurable differences in nitrogen supply to crops when nitrogen fertiliser is applied through the season. This project aimed to quantify the impacts.

Methods

The soil sampling was carried out on selected treatments at the Coreen, Henty, Yarrawonga and Dookie Focus Farm sites, established as part of the GRDC Stubble Project (Table 1).



TABLE 1 Selected treatments from each Focus Farm, from which soil samples were collected on specified dates during July, August and September 2016

Coreen	Henty	Yarrawonga	Dookie
Treatment			
NTSR — control	NTSR — control	NTSR — short stubble	NTSR — short stubble
Cultivate (one pass)	NTSR + 40kg N/ha	NTSR — long stubble	NTSR — long stubble
Burnt	Mulched	Cultivate (one pass)	Cultivate (one pass)
	Cultivate (one pass)	Burnt	Burnt
Soil sampling: July: 27/7/16 Sept: 6/9/16	Soil sampling: July: 20/7/16 Aug: 29/8/16	Soil sampling: July: 15/7/16 Sept: 7/9/16	Soil sampling: July: 18/7/16 Sept: 1/9/16

After the initial stubble treatments were established, sites were managed by the host farmer for the remainder of the season. The rates and timing of fertiliser applications at each site during 2016 are shown in Table 2.

The wet conditions of 2016 limited the access to the sites and soil sampling was difficult. As a result, soil sampling was only completed to 0–10cm depth during July, and to 0–10, 10–20, 30–40cm increments during September 2016 in each of the four replicates of each treatment. A set of 10 sub-samples was collected from each plot, and combined into one composite sample per replicate.

When soil sampling was completed, soils were analysed for mineral nitrogen (nitrate + ammonium), with results analysed using analysis of variance (ANOVA) with the Minitab statistical software.

Results

i) July sampling

The mineral nitrogen levels varied at each site, with the Yarrawonga site measuring the lowest range of nitrogen values for the July sampling of the 0–10cm depth (Figure 1). While there appeared to be differences in mineral nitrogen values between some treatments (i.e. the Henty cultivated treatment), these were not statistically significant due to the high variation within each treatment (Figure 1). The high variability was likely exacerbated by the wet conditions, with nitrogen losses related to transient waterlogging and associated leaching and denitrification.

ii) September sampling

The September sampling was carried out to a depth of 40cm and revealed the low nitrogen values present in the profile last year (Figure 1). At the time of sampling, about 100kg/N ha had been applied to all crops. While crops would have taken up some nitrogen, it is likely there were high losses through leaching and denitrification. While there are trends for differences in measured nitrogen at 0–10cm between treatments at some sites, the high variability negated any significant differences.

Observations and comments

The measured nitrogen values correspond well with other soil sampling conducted across the Riverine Plains region during winter 2016. Low surface mineral nitrogen values were common, with high nitrogen losses occurring as a result of leaching through the profile (measured by increased nitrogen at 60cm, and which was also observed in the *Seasonal soil moisture and nitrogen availability* project, page 86) and through denitrification due to the saturated conditions.

While the aim of this work was to determine if differences in plant growth and development under different

TABLE 2 Rates and timing of nitrogen fertiliser applications at each of the Stubble Project Focus Farms

Location	Sowing (kg N/ha)	May 2016 (kg N/ha)	June 2016 (kg N/ha)	July 2016 (kg N/ha)	August 2016 (kg N/ha)	Total nitrogen (kg/ha)
Coreen	22.9		46 (15/6/16)	36.8 (21/7/16)		105.7
Henty	8	34.5 (19/5/17)		36.8 (8/7/17)		79.3
Yarrawonga	7.5		50.6 (29/6/16)	-	41.4 (10/8/16)	99.5
Dookie	8		23.1* 36.8* (16/6/16) (29/6/16)		41.4 (9/8/16)	109.3

* Split application by farmer

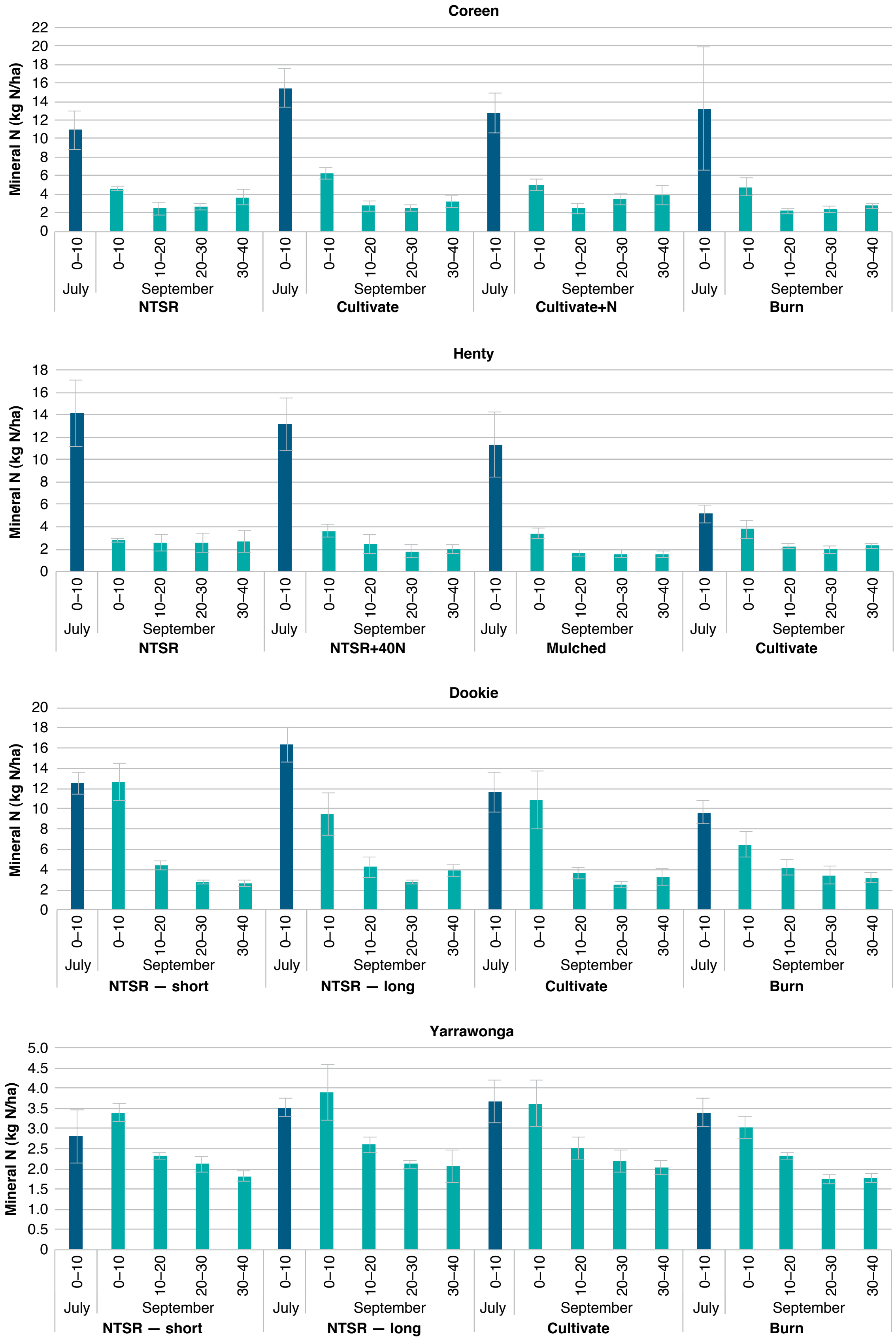


FIGURE 1 Soil nitrogen sampling at each trial site, to a depth of 0–10cm (July 2016) and 0–10, 10–20, 20–30, 30–40cm (September 2016)

Bars are measures of standard error.



stubble management regimes was due to differences in nitrogen supply through the season, the excessively wet conditions confounded the data through high movement and losses of nitrogen. Therefore, it is unclear whether the results presented truly represent treatment effects (i.e. there are no significant treatment effects), or if the results are not representative of a 'normal' year where the soil is not saturated for extended periods of time.

In order to generate more confidence around these results, this work will be repeated during the 2017 season.

Acknowledgements

This nitrogen sampling work was funded through The Sustainable Agriculture Victoria: Fast-Tracking Ag Innovation initiative, which has been made possible with the support of the Foundation for Rural and Regional Renewal (FRRR) together with the William Buckland Foundation.

Thank you to our farmer co-operators at each of the GRDC funded *Maintaining Profitable Farming Systems with Retained Stubble in the Riverine Plains Region* Focus Farm sites:

- *Corowa/Coreen:* Tomlinson Ag
- *Dookie:* Ludeman Brothers
- *Henty:* Peter Campbell
- *Yarrawonga:* Telewonga Pty Ltd.

Contact

Dr Cassandra Schefe Riverine Plains Inc

T: (03) 5744 1713

E: cassandra@riverineplains.org.au

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

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

Key points

- Four wheat trials sown during mid-April 2014 and 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/Kiora, Lancer, Trojan and EGA Wedgetail).
- The 2016 trial sown during mid-April again showed no difference in yield between 22.5cm and 30cm row spacings, however yields were significantly less with the widest row spacing (37.5cm).
- Trial yields in 2016 were 1.5t/ha higher than 2014 and 2015 (3–4.25t/ha), with the higher yield potential likely to be a key factor in the poor performance of the widest row spacing (37.5cm).
- The Riverine Plains *Water Use Efficiency (WUE)* project (2009–13) showed that when crops were sown in the traditional sowing window, the 22.5cm spacing was more successful than the 30cm spacing, except in drier years with lower yield potential (2.5–3.0t/ha).
- In the three years (2014–16) of trialling row spacing on early-sown crops, crops grown on a 22.5cm row spacing produced more dry matter (DM) than crops grown on wider rows. However, the 2016 trial was the first to show a yield disadvantage to the widest row spacing (37.5cm) when sown early.
- As a result of lower yields, the 37.5cm row spacing gave significantly poorer water use efficiency (WUE) than 30cm row spacing, with a greater proportion of calculated water losses (soil evaporation, drainage or unused water).
- A barley row spacing trial, sown at the same time alongside the wheat, provided some useful comparative observations during 2016, with La Trobe barley producing higher DM and yields than wheat with a harvest index (HI) of approximately 50% compared with wheat at 40%.

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 when sown in wider rows (30–37.5cm). Trials sown for the WUE project were established during the mid-May–early June sowing window, prompting research questions as to whether wider row spacing would be more successful if crops were sown earlier.

During the past two years results have shown no difference in grain yield or quality as a result of row spacing (from 22.5–37.5cm) when wheat crops were sown during mid-April, despite lower DM production with wider rows.

Method

To complete a third and final year of research, two trials were established in 2016 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 carried out in the same locations as in 2015, one in Barooga, New South Wales and the other in Yarrawonga, Victoria.

Four varieties, EGA 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 14 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 per unit area across the trials for the remainder of the season.

During 2016, a barley observation trial was added alongside the main wheat trial. While plot assessments were replicated, restrictions on the ability to spatially replicate these plots means these results are therefore presented as observation results.

Trial 1: Barooga, NSW

This trial suffered prolonged waterlogging over winter and had to be abandoned since large parts of the trial did not recover.

Trial 2: Yarrawonga, Victoria

Sowing date: 14 April 2016

Rotation: First wheat after canola

Variety: Kiora, Lancer, Trojan, EGA Wedgetail and La Trobe (barley)

Stubble: Canola unburnt

Rainfall:

GSR: 604mm (April – October)

Summer rainfall: 125mm

Soil mineral nitrogen: 50kg N/ha (0–60cm)

Results

i) Establishment and crop structure

Row spacing produced no difference in plant establishment but resulted in significant differences in tiller and head number when the widest rows (37.5cm) were compared with the 22.5cm and 30cm row spacings (Table 1 and Figure 1). The widest row spacing had significantly fewer tillers and heads per unit area than the narrower row spacings.

Lancer produced significantly fewer plants than Kiora and Trojan, and significantly fewer tillers and head numbers than the other three cultivars. The winter wheat EGA Wedgetail was slower to develop and produced significantly higher head numbers at harvest than the spring wheat varieties tested. The faster development of Trojan lead to the lowest head number per plant (2.58 heads/plant), a feature noted in the 2015 trials. In contrast, the head number per plant of the winter wheat EGA Wedgetail was 3.52 heads/plant.

TABLE 1 Plant counts 13 May 2016, three leaves unfolded (GS13), tiller counts 28 July 2016, targeted first node* (GS30–32) and head counts 5 December 2016, harvest (GS99)

Row spacing (cm)	Crop structure		
	Plants/m²	Tillers/m²	Heads/m²
22.5	127^{a}	456^{a}	408^{a}
30	133^{a}	469^{a}	400^{ab}
37.5	128^{a}	416^{b}	342^{b}
Mean	**129**	**447**	**383**
LSD	23	34	60
Variety			
Wedgetail	129^{ab}	549^{a}	454^{a}
Kiora	132^{a}	435^{b}	385^{b}
Lancer	112^{b}	373^{c}	323^{c}
Trojan	144^{a}	431^{b}	372^{b}
LSD	18	47	48

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

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 harvest (GS99) (Table 2). Wedgetail and Trojan produced more DM at harvest than Lancer.

The wider row spacing (37.5cm) did not have any effect on nitrogen uptake at the assessment targeting first node (GS31), however at the start of grain fill there was evidence of greater nitrogen uptake in the canopy of the narrowest row spacing (22.5cm). The reduced establishment and tillering with Lancer correlated with reduced nitrogen uptake compared with the other three cultivars when assessed throughout the season (Table 3).

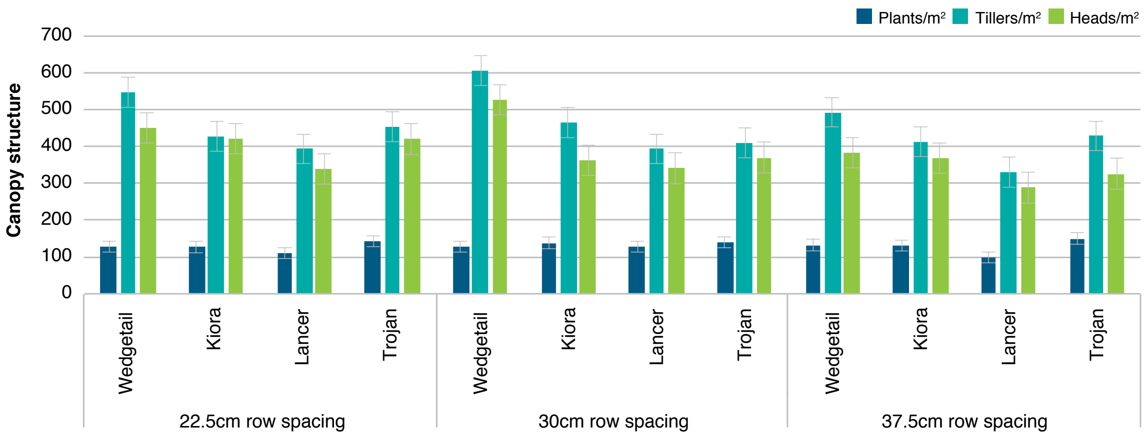


FIGURE 1 Plant counts 13 May 2016, three leaves unfolded (GS13), tiller counts 28 July 2016, targeted first node* (GS30–32) and head counts 5 December 2016, harvest (GS99)

*Actual growth stages at tiller assessment to account for varietal differences; Kiora GS31, Wedgetail GS30, Trojan GS32, Lancer GS31. Error bars presented as a measure of LSD.

TABLE 2 Dry matter production 28 July 2016 (GS30-32)*; 25 October 2015, grain watery ripe^ (GS71–75) and 5 December 2016, harvest (GS99)

Row spacing (cm)	Dry matter (t/ha)		
	GS31	GS71	GS99
22.5	1.74^{a}	12.33^{a}	12.19^{a}
30	1.67^{a}	11.50^{a}	12.06^{ab}
37.5	1.52^{a}	10.31^{b}	11.21^{b}
Mean	**1.64**	**11.37**	**11.82**
LSD	0.29	1.15	0.90
Variety			
Wedgetail	1.66^{a}	10.94^{ab}	12.89^{a}
Kiora	1.78^{a}	11.96^{a}	11.78^{ab}
Lancer	1.36^{b}	10.33^{b}	10.16^{b}
Trojan	1.79^{a}	12.28^{a}	12.44^{a}
LSD	0.22	1.47	1.81

*Actual growth stages at first node assessment to account for varietal differences; Kiora GS31, Wedgetail GS30, Trojan GS32, Lancer GS31.
^Actual growth stages GS71 assessment Trojan GS75 Kiora GS73 Lancer GS73 Wedgetail GS71.

TABLE 3 Nitrogen uptake in dry matter 28 July 2016, (GS30–32)*; 25 October 2015, grain watery ripe^ (GS71–75) and 5 December 2016, harvest (GS99)

Row spacing (cm)	Nitrogen uptake in biomass (kg N/ha)		
	GS31	GS71	GS99
22.5	64^{a}	112^{a}	93^{a}
30	62^{a}	89^{ab}	101^{a}
37.5	54^{a}	81^{b}	107^{a}
Mean	**60**	**94**	**100**
LSD	10	20	19
Variety			
Wedgetail	60^{a}	108^{a}	113^{a}
Kiora	64^{a}	78^{c}	101^{a}
Lancer	56^{b}	91^{bc}	66^{b}
Trojan	62^{a}	99^{ab}	122^{a}
LSD	10	13	23

*Actual growth stages at tiller assessment to account for varietal differences; Kiora GS31, Wedgetail GS30, Trojan GS32, Lancer GS31.
^Actual growth stages GS71 assessment Trojan GS75 Kiora GS73 Lancer GS73 Wedgetail GS71.

iii) Grain yield and quality

The 22.5cm and 30cm row spacings had similar impacts on grain yield when averaged across the four varieties, however the lower DM observed with the widest row spacing (37.5cm) resulted in significantly less grain than the 30cm row spacing (Table 4). There were also no significant effects of row spacing on grain quality.

There were no significant varietal differences in yield, however Kiora had significantly lower protein than Trojan and EGA Wedgetail.

iv) Water use efficiency (WUE) calculations

The overall levels of WUE were generally low, since calculations showed that much of the water falling this spring was either lost or left unused (Table 5). Despite a softer finish, the overall harvest index (HI) was only 40% (40% of the final biomass was grain) compared with ideal, non-limited high-yielding longer-season scenarios of up to 50% in wheat.

There were significant differences in WUE when the 30cm row spacing was compared with the 37.5cm spacing; the 30cm offered superior WUE and showed a similar efficiency to the 22.5cm row spacing. There was no difference in WUE between the 22.5cm and 30cm spacings. By virtue of lower DM accumulation, the widest row spacing lost less water through the plant during the course of the season, but was calculated to have either lost or left unused more water than the narrower row spacing, which produced significantly more DM.

v) Results from three years of trials at Yarrawonga

The early-sown row spacing trial (mid-April) at Yarrawonga has now run for three years in different paddocks in the same rotation position after canola. In both 2014 and 2015 the narrow-row-spaced crops produced more DM, however 2016 was the only season where there were differences in grain yields (Figure 2). Higher yields in 2016 resulted in the widest row spacing (37.5cm) producing yields 0.34–0.43t/ha less than the 22.5cm and 30cm row spacing.

In previous work carried out by Riverine Plains Inc and FAR Australia, the influence of row spacing on grain yields has been shown to be affected by the overall yield potential of the season, with comparable yields across row spacings under lower-yielding scenarios. At a yield potential of 3.0–6.0t/ha there has been no difference in yield between 22.5cm and 30cm row spacings when wheat crops have been sown in mid-April. Wheat crops sown on a 37.5cm row spacing at the same time show no yield disadvantage provided grain yields are less than 3.5t/ha; this was observed with the harder finish in 2015. In a harder finish a higher HI helps to compensate, so relatively more grain is produced from the final DM. Under higher yield scenarios, the loss of final harvest DM at the widest row spacing cannot be compensated for with other factors such as HI.

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 the 22.5cm spacing produced more DM than the 30cm spacing, and which led to more yield. In this study, the results demonstrate that the actual row spacing: either 22.5cm

TABLE 4 Yield, protein, test weight and screenings at harvest (GS99), 11 December 2016

Row spacing (cm)	Yield and quality			
	Yield (t/ha)	Protein (%)	Test weight (kg/hL)	Screenings (%)
22.5	5.60^{ab}	9.1^{a}	80.1^{a}	2.2^{a}
30	5.69^{a}	9.2^{a}	80.0^{a}	2.6^{a}
37.5	5.26^{b}	9.2^{a}	79.8^{a}	2.4^{a}
Mean	**5.52**	**9.2**	**80.0**	**2.4**
LSD	0.36	0.3	1.1	0.6
Variety				
Wedgetail	5.45^{a}	9.4^{a}	79.5^{a}	2.6^{a}
Kiora	5.80^{a}	8.5^{b}	80.2^{a}	2.6^{a}
Lancer	5.33^{a}	9.2^{ab}	80.0^{a}	2.4^{a}
Trojan	5.49^{a}	9.6^{a}	80.0^{a}	2.1^{a}
LSD	0.76	0.78	1.36	1.0

TABLE 5 Average biomass at harvest, yield (expressed at 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	12.19^{a}	5.04^{ab}	41.6^{a}	7.6^{ab}	206.4^{a}	456.6^{a}	22.9^{a}
30.0	12.06^{ab}	5.12^{a}	41.6^{a}	7.7^{a}	206.2^{a}	456.8^{a}	22.9^{a}
37.5	11.21^{b}	4.74^{b}	40.0^{a}	7.1^{b}	193.3^{a}	469.7^{a}	22.0^{a}
Mean	**11.82**	**4.97**	**41.1**	**7.5**	**202.0**	**461.0**	**22.6**
LSD	0.90	0.32	10.9	0.5	39.7	39.7	6.0

GSR (April – October) 604mm plus calculated soil water available on 1 April 2016 59mm — total 663mm

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 by the water transpired through the plant.

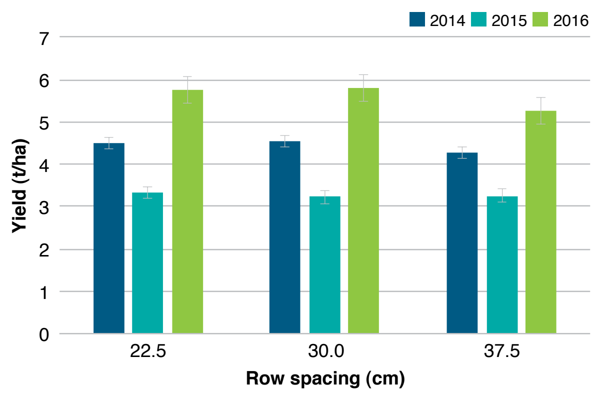


FIGURE 2 Influence of row spacing on grain yield in early-sown first wheat (average of four varieties) in 2014, 2015 and 2016, Yarrawonga, Victoria

Error bars presented as a measure of LSD.

or 30cm, is less important in determining wheat yield when crops are sown early (mid-April in this research project) compared with crops sown later.

vi) Barley observation trial

Adjacent to the wheat row spacing trial, La Trobe barley was sown on the same day and at the same row spacing as the wheat trial. Various measurements were taken throughout the season, similar to the wheat row spacing trial. As these plots were replicated, but not spatially randomised, the figures have not been statistically analysed.

In all plots, 100% of the crop was brackled by harvest, with a severity of 5 (scale 1–5 where 5 is completely brackled).

Note: Brackling occurs when crop stems break or bend part way up the stem, letting the head hang down — this is different to lodging where the stem bends or breaks at the base, or the roots lose anchorage. Brackling in barley is often associated with head loss at harvest, while wheat rarely, if ever, brackles.

Row spacing had no effect on brackling severity at harvest. There appeared to be few differences in crop structure measurements with tiller numbers per plant exceeding wheat with 620–690 tillers/m² from 115–130 plants/m² (Figure 3).

As was the case in wheat, the narrower row spacing in barley produced more DM per unit area than the wider rows, with similar harvest DM accumulation to the wheat (Figure 4).

A comparison of the mean yield of the wheat (average of four cultivars) and barley row spacing trial (La Trobe) revealed that barley, for the same early sowing (14 April), was higher yielding than wheat (Figure 5). While trials are not statistically comparable, the scale of the yield increase of barley would suggest merit in further investigating early-sown barley after canola (depending on potential profitability and farming system fit) (Table 6). The harvest indices for barley show it was more efficient than wheat at turning final harvest biomass (measured on 5 December) into grain.

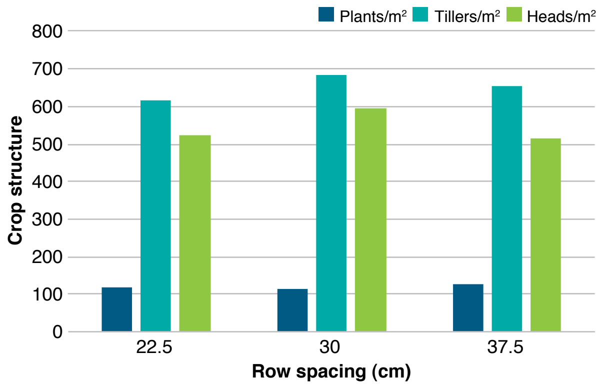


FIGURE 3 Plant counts 13 May 2016 for La Trobe barley, three leaves unfolded (GS13); tiller counts 17 August 2016; flag leaf visible (GS37) and head counts 5 December 2016, harvest (GS99)

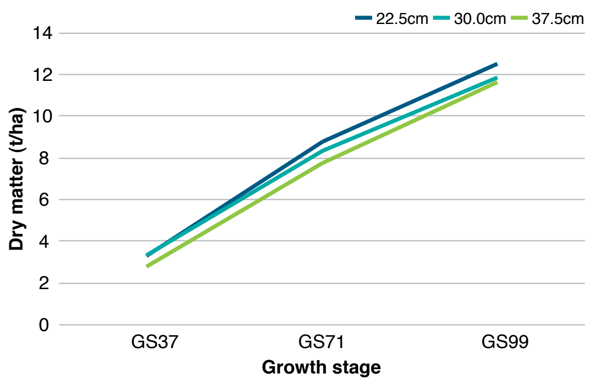


FIGURE 4 Dry matter production for the barley observation trial, 28 July 2016, third node (GS33); 25 October 2016, late milk stage (GS77) and 5 December 2016, harvest (GS99)

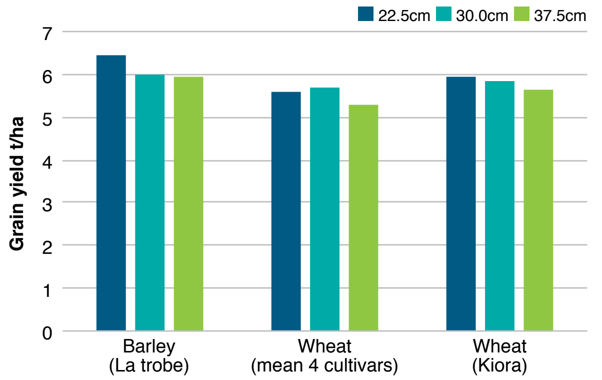


FIGURE 5 Comparative yield of barley, wheat (mean of four cultivars) and wheat (Kiora) at 11 December 2016, harvest (GS99)

TABLE 6 Yield, protein, test weight and screenings of La Trobe barley at 11 December 2016, harvest (GS99)

	Yield and quality			
Row spacing (cm)	Yield (t/ha)	Protein (%)	Test weight (kg/hL)	Screenings (%)
22.5	6.46	10.2	65.0	10.3
30.0	5.99	9.9	64.3	11.5
37.5	5.95	10.0	64.3	13.9

No means or LSD values are presented as this was designed as a demonstration trial, without randomisation of treatments.

Implications for commercial practice

Wheat crops sown early in the Riverine Plains region during mid-April (emerging 20–30 April) have shown no difference in grain yield between a 22.5cm and 30cm row spacing over three years of research. However, as sowing dates move later (mid-May–June) the advantage of the narrower 22.5cm row spacing becomes more apparent (see the Riverine Plains *Between the Rows* publication).

Row spacings wider than 30cm were successful with wheat, provided crop yield potential did not exceed 4t/ha and crops were sown in mid-April. For later sowing and for regions or seasons with higher yield potential, a row spacing of 37.5cm significantly reduced DM production and resultant grain yield.

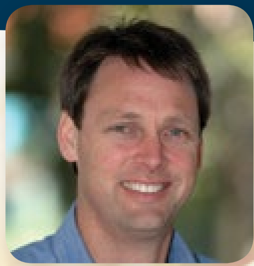
Acknowledgements

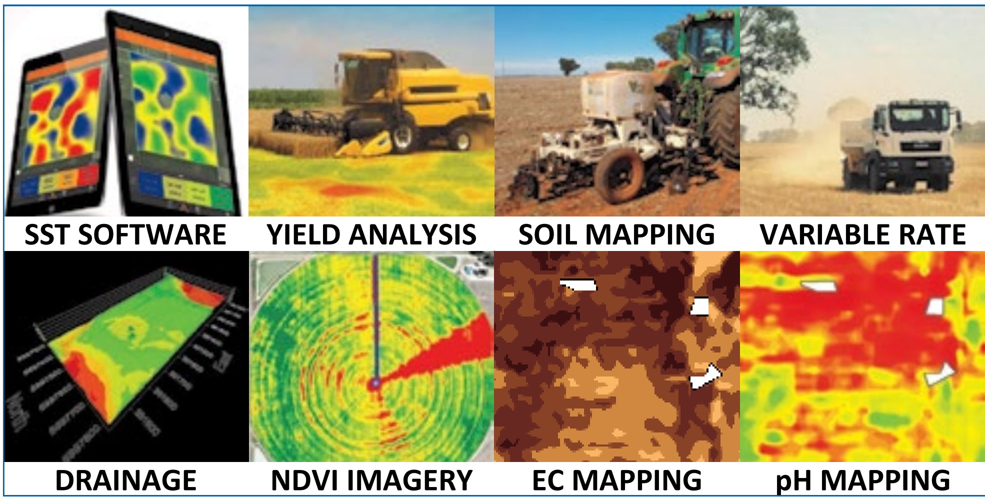
This trial was carried out as part of the Riverine Plains Inc GRDC funded project *Maintaining Profitable Farming Systems with Retained Stubble in the Riverine Plains Region (2013–18)*. Thank you to our farmer co-operators, J and S Bruce Barooga, NSW and Telewonga Pty Ltd, Yarrawonga, Victoria. ✓

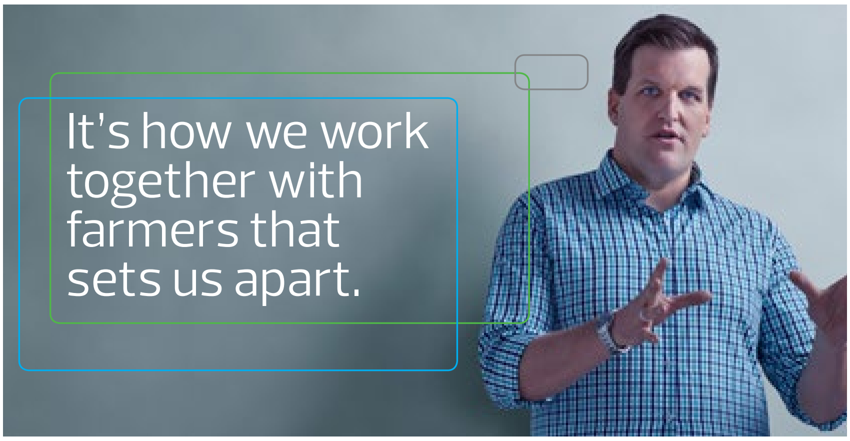
Contact

Michael Straight Foundation for Arable Research, Australia

E: michael.straight@far.org.nz




SST SOFTWARE
YIELD ANALYSIS
SOIL MAPPING
VARIABLE RATE
DRAINAGE
NDVI IMAGERY
EC MAPPING
pH MAPPING


It's how we work together with farmers that sets us apart.

Interaction between fungicide program and in-crop nitrogen timing for the control of yellow leaf spot (YLS) in mid-May 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 either first node (GS31) or third node (GS33) in a susceptible wheat-on-wheat situation (cv EGA Gregory) was between 25–50% in most assessments.
- This relatively poor level of disease control has been consistent across the four years of research.
- There was no significant yield response to fungicide application during 2016, but there was a trend for small yield gains where fungicide was applied at first node (GS31), or third node (GS33) or applied twice at first node (GS31) and third node (GS33).
- These small (0.15–0.25t/ha) yield increases have been common across the four years of trials, either from a single later spray at third node (GS33) or from two sprays where a third node (GS33) application was preceded with a tillering (GS23) or first node (GS31) spray.
- A single YLS fungicide application at tillering (GS23), carried out as part of a weed control spray, did not generally prove to be economical.
- Nitrogen (N) applied at tillering (GS23) or first node (GS31) has not produced statistical yield differences, but delaying the main nitrogen dose until third node (GS33) reduced yield by and average of 0.5t/ha compared with the first node (GS31) timing during 2016.
- There were no significant differences in YLS severity due to fungicide product — Tilt® (propiconazole) and Prosaro® (prothioconazole and tebuconazole) — or nitrogen timing.

Location: Coreen, NSW
Sowing date: 12 May 2016
Rotation: Second wheat
Variety: EGA Gregory
Stubble: EGA Gregory unburnt
Rainfall:
GSR: 567mm (April – October)
Summer rainfall: 80mm

Method

The trial examined the influence of two nitrogen timings: 40kg N/ha applied at first node (GS31) or third node (GS33) (Table 1) and four fungicide strategies (untreated, fungicide at first node — 12 August, third node — 5 September and fungicide at both timings) on levels of yellow leaf spot (YLS — *Pyrenophora tritici repentis*) 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), fungicide timing as the sub plot and fungicide product as the sub-sub plot, replicated four times. During spring 2016 the trial was badly affected by waterlogging, making yield data more variable.

For each of the nitrogen 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.

TABLE 1 Nitrogen application rates and timings

	12 May 2015 (sowing)	12 August 2016 (GS31)	6 September 2016 (GS33)	Total nitrogen applied
	(kg N/ha)			
Tillering timing	6	40	Nil	46
First node timing	6	Nil	40	46

There were no restrictions on the uptake of nitrogen, although several transient waterlogging events are likely to have resulted in nitrogen being lost as nitrous oxide (N_2O).



TABLE 2 Treatment list

Treatment		Active ingredient (g/ha ai)	Fungicide timing (mL/ha)		Nitrogen timing (kg N/ha)	
			GS31 12 Aug	GS33 6 Sep	GS31 12 Aug	GS33 6 Sep
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).

As outlined, the commercially-sown crop of EGA Gregory was badly affected by waterlogging, particularly through September, which reduced both the plant and tiller population to 75 plants/m^2 and 153 tillers/m^2 when assessed at the two-leaf stage (GS12) 31 May and at the first node stage (GS31) on 12 August, respectively.

Results

i) Disease assessment data

At the first fungicide application timing at first node (GS31) there was a high level of disease incidence on the top two newly-emerged leaves (flag-5 and flag-6) with the newest emerging leaf (flag-4) showing no infection (Table 3).

When assessed at third node (GS33), before the second fungicide application timing, there was little evidence of earlier treatment effects except on flag-4, which was the newest emerged leaf at the first node (GS31) application (Table 4). On this leaf, YLS severity was reduced from about 60% to 47%, which is equivalent to less than 25% control.

TABLE 3 Yellow leaf spot severity and incidence assessed 12 August 2016, first node (GS31), on the newest fully-emerged infected leaves (flag-5 and flag-6)

GS31	YLS (%)	
	Flag-5	Flag-6
Disease severity	1.9	31.1
Disease incidence	66.7	100

There was no difference in fungicide performance applied at first node (GS31).

At 50% ear emergence, the impact of the first node (GS31) spray and later spray at third node (GS33) was evident in the YLS infection levels recorded on the flag leaf and flag-1 however, spraying gave less than 50% control (Figure 1).

The double-spray approach was significantly better than the single first node (GS31) spray on flag-1, but control was still short of 50% and severity differences were small (Table 5).

Fungicide application significantly improved green leaf retention (GLR) with the later spray and double sprays giving about 60% GLR compared with 36% in the untreated control.

The first node (GS31) spray improved GLR, but the improvement was not statistically significant (Table 5). No differences in product performance were recorded at this assessment. There also was no evidence the two different fungicides interacted with application timings differently, with the later spray and double-spray programs giving the best results, irrespective of product tested.

Disease assessments at flowering (GS61) showed significant effects from fungicides, which were similar to those recorded two weeks earlier. There were no effects of fungicide product or nitrogen timing on YLS or GLR (Table 6 and Figure 2).

TABLE 4 Yellow leaf spot severity (% leaf area infected) and incidence (% of leaves infected) assessed 6 September 2016, third node (GS33), on the second newest fully-emerged leaf (flag-2, flag-3 and flag-4)

	YLS (%)					
	Flag-2		Flag-3		Flag-4	
Nitrogen timing	Severity	Incidence	Severity	Incidence	Severity	Incidence
GS31	1.8[a]	95.0[a]	10.2[a]	100[a]	48.9[a]	100[a]
GS33	2.0[a]	92.4[a]	12.0[a]	100[a]	53.9[a]	100[a]
Mean	**1.9**	**93.7**	**11.1**	**100**	**51.4**	**100**
LSD	0.3	4.8	2.6	–	6.4	–
Fungicide timing						
Untreated control	2.0[a]	94.2[a]	12.2[a]	100[a]	60.6[a]	100[a]
GS31	2.0[a]	94.8[a]	11.9[a]	100[a]	46.9[b]	100[a]
LSD	0.4	6.8	3.7	–	9.1	–
Product						
Prosaro	1.9[a]	92.8[a]	11.0[a]	100[a]	52.8[a]	100[a]
Tilt	2.0[a]	94.6[a]	11.2[a]	100[a]	50.1[a]	100[a]
LSD	0.3	4.8	2.6	–	6.4	–

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

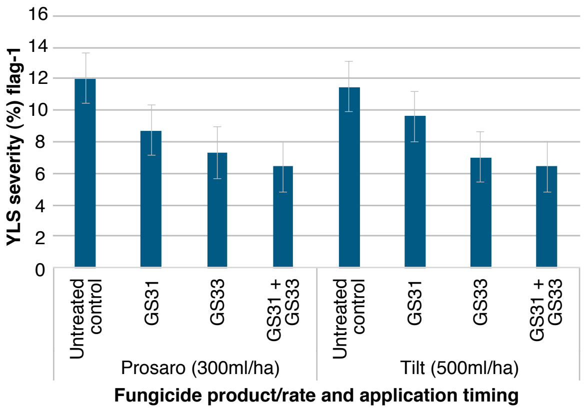


FIGURE 1 Interaction between fungicide application timing* and product on YLS severity (flag-1), assessed 50% head emergence (GS55), 29 September 2016

*Mean of two nitrogen application timings

The error bars are a measure of LSD 3.2%. The interaction was not significant.

The best disease control from fungicide strategies on the flag leaf were in the range of 30–40% and on flag-1 it was approximately 50%.

On flag-1 the disease control achieved with the later spray and double-spray programs was superior to the earlier first node (GS31) spray (mean of both nitrogen timings). There was no difference between the double-spray program and the single application at third node (GS33) on either disease severity or GLR.

Despite differences in YLS severity, and high levels of disease in the canopy, levels of the disease on the flag leaf were only moderate and there were no differences in crop canopy greenness (measured as crop reflectance with the Greenseeker®) in this trial at any of the three assessment timings (Table 7).

Yellow leaf spot damage in the canopy at the start of flowering (GS61)

TABLE 5 Yellow leaf spot severity and incidence assessed 29 September 2016, 50% ear emergence (GS55), on the flag leaf and flag-1, and green leaf retention (GLR) on flag-2

GS55	YLS (%)				GLR (%)
	Flag		Flag-1		Flag-2
Nitrogen timing	**Severity**	**Incidence**	**Severity**	**Incidence**	**GLR**
GS31	1.7^{a}	82.9^{a}	9.6^{a}	100.0^{a}	49.0^{a}
GS33	1.2^{b}	76.7^{a}	7.6^{b}	99.6^{a}	50.4^{a}
Mean	**1.4**	**79.8**	**8.6**	**99.8**	**49.7**
LSD	0.3	7.1	1.6	0.9	6.9
Fungicide timing					
Untreated control	1.9^{a}	89.2^{a}	11.8^{a}	100.0^{a}	36.4^{b}
GS31	1.4^{b}	84.2^{ab}	9.1^{b}	100.0^{a}	43.8^{b}
GS33	1.2^{b}	77.5^{bc}	7.1^{bc}	100.0^{a}	57.4^{a}
GS31 and 33	1.2^{b}	68.3^{c}	6.4^{c}	99.2^{a}	61.2^{a}
LSD	0.4	10.1	2.3	1.2	9.8
Product					
Prosaro	1.4^{a}	77.9^{a}	8.6^{a}	99.6^{a}	51.2^{a}
Tilt	1.5^{a}	81.7^{a}	8.6^{a}	100.0^{a}	48.2^{a}
LSD	0.3	7.1	1.6	0.9	6.9

Figures followed by different letters are regarded as statistically significant.

TABLE 6 Yellow leaf spot severity and incidence assessed 14 October 2016, start of flowering (GS61), on the flag leaf and flag-1 and green leaf retention (GLR) on flag-1

Treatment	YLS (%)				GLR (%)
	Flag		Flag-1		Flag-1
Nitrogen timing	**Severity**	**Incidence**	**Severity**	**Incidence**	**GLR**
GS31	7.2^{a}	100^{a}	40.2^{a}	100^{a}	59.8^{a}
GS33	7.4^{a}	100^{a}	41.3^{a}	100^{a}	55.6^{a}
Mean	**7.3**	**100**	**40.7**	**100**	**57.7**
LSD	0.9	–	2	–	10.1
Fungicide timing					
Untreated control	9.9^{a}	100^{a}	62.6^{a}	100^{a}	37.4^{b}
GS31	7.1^{b}	100^{a}	42^{b}	100^{a}	58.1^{a}
GS33	5.9^{b}	100^{a}	29.7^{c}	100^{a}	64.2^{a}
GS31+33	6.2^{b}	100^{a}	28.7^{c}	100^{a}	71.3^{a}
LSD	1.3	–	10.1	–	14.3
Product					
Prosaro	7.5^{a}	100^{a}	42.4^{a}	100^{a}	54.5^{a}
Tilt	7.1^{a}	100^{a}	39.1^{a}	100^{a}	60.9^{a}
LSD	0.9	–	7.12	–	10.1

Figures followed by different letters are regarded as statistically significant.

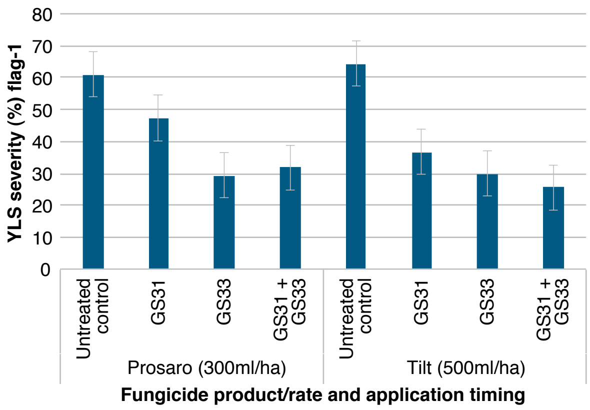


FIGURE 2 Interaction between fungicide application timing* and product on YLS severity (flag-1), assessed start of flowering (GS61), 14 October 2016

*Mean of two nitrogen application timings

The error bars are a measure of LSD 14.2%

ii) Yield and quality results

Influence of nitrogen timing

The earlier timing of applying nitrogen at first node (GS31) resulted in significantly more yield than with the later nitrogen timing at third node (GS33) (Table 8). The 0.52t/ha yield increase when nitrogen was applied at first node (GS31) reduced grain protein by 0.5%, but there was no difference between the two nitrogen timings in terms of test weight or screenings.

TABLE 7 Normalised difference vegetation index (NDVI) 6 September 2016, third node (GS33), 29 September 2016, 50% head emergence (GS55) and 14 October 2016 start of flowering (GS61)

Treatment	NDVI		
Nitrogen timing	**GS33**	**GS55**	**GS65**
GS22	0.69[a]	0.65[a]	0.57[a]
GS31	0.68[a]	0.64[a]	0.57[a]
Mean	**0.68**	**0.65**	**0.57**
LSD	0.03	0.03	0.03
Fungicide timing			
Untreated control	0.69[a]	0.65[ab]	0.59[a]
GS23	0.66[a]	0.62[b]	0.56[a]
GS33	0.68[a]	0.65[ab]	0.57[a]
GS23+33	0.70[a]	0.66[b]	0.59[a]
LSD	0.04	0.04	0.04
Product			
Prosaro	0.69[a]	0.65[a]	0.58[a]
Tilt	0.68[a]	0.64[a]	0.57[a]
LSD	0.03	0.03	0.03

Figures followed by different letters are regarded as statistically significant.

Influence of fungicide timing and product

Waterlogging resulted in a thin crop, which was low yielding, and there were no significant differences in yield as a result of fungicide treatment, although in common with previous years there was a trend for yield effects to be positive (0.1–0.17t/ha). Fungicide application did give small improvements in test weight, which was statistically significant when applied at first node (GS31).

There were no yield or quality differences measured between Tilt and Prosaro (Figure 3). In this trial both products partially controlled YLS, rarely giving more than 50% control, a result similar to 2014 and 2015.

Commercial implications

This research trial has been run for four years using susceptible and moderately susceptible wheat cultivars. In a wheat-on-wheat situation, YLS has been the principal disease causing infection. The most severe infection was noted during 2016.

The influence of fungicide treatment against this disease has been consistent over the four years of work. Using either Prosaro (tebuconazole/prothioconazole) or Tilt (propiconazole) disease control has rarely exceeded 50% and has more typically been in the range of 25–50%. This level of disease control is poor relative to traditional control levels observed with fungicides against other diseases. Despite this there were small, but consistent, positive yield effects across the four years (maximum response to fungicide during 2013 was 0.25t/ha, during 2014 was 0.21t/ha, during 2015 was 0.4t/ha and during 2016 was 0.17t/ha). These small yield effects were seen in response to two applications of fungicide and later spray timings during stem elongation, or third node (GS33).

Foliar fungicides applied at tillering (GS23) during 2014–16 gave poor disease control and were rarely, if ever, economic. In all years, although the rotation and cultivar have favoured the disease, the yields of the trials have still been in the 2–4t/ha range. The early control of YLS up to the start of stem elongation (GS30) has been greater with stubble management practices such as burning than that observed with foliar fungicides. It was also noticeable that in the large block stubble management trials a switch to the more resistant cultivar Corack has controlled YLS such that differences in YLS control as a result of stubble management treatment have not been observed.

TABLE 8 Yield, protein, test weight and screenings at harvest (GS99), 9 December 2016

Treatment	Grain yield and quality			
Nitrogen timing	**Yield (t/ha)**	**Protein (%)**	**Test weight (kg/hL)**	**Screenings (%)**
GS31	3.78[a]	8.8[b]	82.3[a]	2.5[a]
GS33	3.26[b]	9.3[a]	81.9[a]	2.4[a]
Mean	**3.52**	**9.0**	**82.1**	**2.5**
LSD	0.18	0.2	0.5	0.3
Fungicide timing				
Untreated control	3.42[a]	9.2[a]	81.6[b]	2.4[a]
GS31	3.52[a]	9.0[a]	82.4[a]	2.6[a]
GS33	3.55[a]	9.0[a]	82.2[ab]	2.4[a]
GS31+33	3.59[a]	8.9[a]	82.2[ab]	2.4[a]
LSD	0.25	0.3	0.7	0.4
Product				
Prosaro	3.54[a]	9.1[a]	82.1[a]	2.4[a]
Tilt	3.50[a]	9.0[a]	82.1[a]	2.5[a]
LSD	0.18	0.2	0.5	0.3

Figures followed by different letters are regarded as statistically significant.

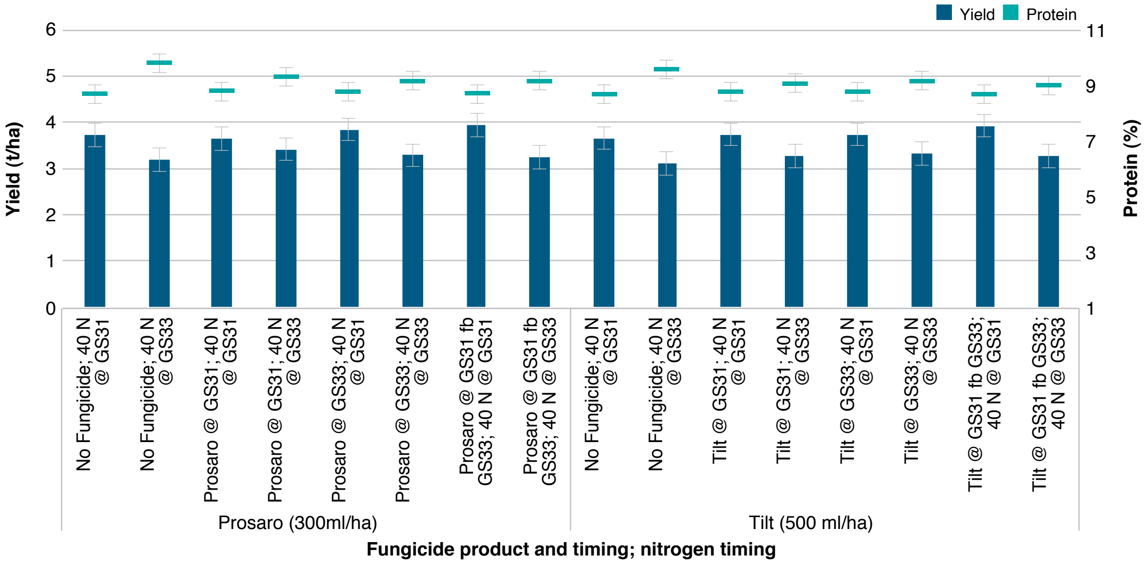


FIGURE 3 Influence of nitrogen timing and fungicide strategy on yield and protein, 9 December 2016

*The error bars are a measure of LSD – yield 0.5 t/ha and 0.7% protein.

Application details:

T1 Application 12 August 2016

Application description		Application equipment	
Application date	12 August 2016	**Nozzle brand**	Air mix
Actual growth stage at application	GS31	**Nozzle type**	Air induction
Crop height (cm)	18	**Nozzle size**	11001
Method/equipment used	FAR hand boom	**Nozzle spacing (cm)**	50
Soil moisture	Moist	**Boom height above crop (cm)**	50
Air temperature (°C)	9.7	**Operating pressure (kPa)**	200
Cloud cover (%)	100	**Ground speed (km/h)**	4.32
Relative humidity (%)	80.2	**Spray volume (L/ha)**	100
Wind velocity (km/h) (start/finish)	3.2–5.8		
Wind direction (start/ finish)	N		
Dew presence (Y/N)	N		
Crop cover (%)	50		

T2 Application 6 September 2016

Application description		Application equipment	
Application date	6 September 2016	**Nozzle brand**	Air mix
Actual growth stage at application	GS33	**Nozzle type**	Air induction
Crop height (cm)	40	**Nozzle size**	11001
Method/equipment used	FAR hand boom	**Nozzle spacing (cm)**	50
Soil moisture	Damp	**Boom height above crop (cm)**	50
Air temperature (°C)	15	**Operating pressure (kPa)**	300
Cloud cover (%)	50	**Ground speed (km/h)**	4.8
Relative humidity (%)	85	**Spray volume (L/ha)**	100
Wind velocity (km/h) (start/finish)	2.5–2.7		
Wind direction (start/ finish)	SW		
Dew presence (Y/N)	SW		
Crop cover (%)	85		

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).

Contact

Nick Poole Foundation for Arable Research, Australia
E: Nick.Poole@far.org.nz

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

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

Key points

- For a wheat crop with an average yield of 4.5–5t/ha, increasing the rate of nitrogen (N) applied (40 and 80 extra kilograms of nitrogen per hectare above the farm standard) significantly increased dry matter (DM) accumulation, crop height and final yield of first wheat following canola.
- Applying a plant growth regulator (PGR) (Moddus + chlormequat) reduced crop height by 3cm and significantly decreased DM production.
- A small, non-significant yield reduction was measured with PGR application, which was similar to that observed during 2014, when yields were in the 5–6t/ha range. Conversely, during 2015, there was a positive yield effect of 0.1t/ha, when average crop yield was approximately 3t/ha.
- Although differences were small, the PGR application significantly increased screenings and decreased test weight, results that are not in line with the effects observed during 2015.
- After three years of trials there is no evidence to suggest PGR application has delivered any positive yield effects or consistent quality effects.
- In all three years of trials, PGR application showed a trend to reduce DM, which was significant in 2016.

Location: Yarrawonga, Victoria
Sowing date: 17 May 2016
Rotation: First wheat after canola
Variety: Beckom
Stubble management: Canola unburnt
Rainfall:
GSR: 604mm (April–October)
Summer rainfall: 125mm
Soil mineral nitrogen: 50kg N/ha (0–60cm)

Method

A commercial crop of wheat, cv Beckom, sown 17 May 2016, was fertilised with three different rates of nitrogen (104, 144 and 184kg 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 (Moddus + chlormequat) at the third-node stage (GS33) as outlined in Table 2.

Results

i) Dry matter accumulation

Increasing nitrogen application from 104kg N/ha to 184kg N/ha significantly increased DM production when assessed at flowering (GS61) and harvest (GS99). Applying the PGR significantly reduced DM when all levels of nitrogen were averaged at harvest (Table 3). There was no significant interaction of the two factors (nitrogen and PGR) on DM at harvest, indicating that PGR application did not influence DM based on nitrogen rate. There was a significant reduction in DM with PGR application when 104kg N/ha was applied, compared with 184kg N/ha, however the reduction without PGR was not significant (Figure 1).

ii) Crop reflectance using normalised difference vegetation index (NDVI)

The additional nitrogen applied above the farm standard significantly increased the NDVI recorded with the Greenseeker® after the third node (GS33) assessment (Table 4). The PGR application resulted in a slight decrease in NDVI as was seen during 2014 and 2015, but in 2016 this decrease was not significant when all nitrogen levels were averaged (Figure 2).

iii) Crop height

Under a standard nitrogen application, the addition of PGR reduced crop height by 3cm at harvest. However when a PGR was applied with an extra 80kg/ha of nitrogen, there was no reduction in crop height compared with the control (Figure 2). Additional nitrogen significantly increased crop height (by more than 4cm at the highest nitrogen level).

iv) Yield and quality

Nitrogen effect

Despite the 2016 trial being sown later than previous seasons (a factor that would traditionally decrease yield potential and with it the need for nitrogen), additional nitrogen significantly increased yield and resulted in a response of more than 1t/ha to an additional 80kg N/ha and a 0.5t/ha response from an extra 40kg N/ha when plus and minus PGR results were averaged (Table 5).



TABLE 1 Nitrogen application rates and timings Yarrawonga, Victoria

Nitrogen treatment	17 May 2016 (sowing) (kg N/ha)	25 July 2016 (kg N/ha)	28 July 2016 (GS30) (kg N/ha)	15 August 2016 (kg N/ha)	Total nitrogen applied (kg N/ha)
Standard nitrogen applied	7	58	Nil	39	**104**
Standard + 40kg N/ha	7	58	40	39	**144**
Standard + 80kg N/ha	7	58	80	39	**184**

TABLE 2 PGR application details

Application description		Application equipment	
Date	29 August 2016	**Nozzle brand**	Agrotop
Crop growth stage	GS33	**Nozzle type**	Air inducted flat fan
Crop height (cm)	50	**Nozzle size**	AirMix 11001
Equipment	Petrol driven backpack sprayer with hand boom	**Nozzle spacing (cm)**	50
Soil moisture	Moist	**Boom height above crop (cm)**	50
Air temperature (°C)	16.8	**Operating pressure (kPa)**	300
Cloud cover (%)	50	**Ground speed (km/h)**	4.82
Relative humidity (%)	70.8	**Spray volume (L/ha)**	100
Droplet size	Medium		
Wind velocity (km/h)	5.5		
Wind direction	NEE		

TABLE 3 Dry matter 9 September 2016, flag leaf fully emerged (GS39); 5 October 2016, start of flowering (GS61) and 7 December 2016, harvest (GS99)

Nitrogen treatment	DM (t/ha)		
	GS39	GS61	GS99
Standard (104kg N/ha)	3.97[a]	6.29[b]	10.37[b]
Standard + 40kg N/ha	4.10[a]	6.02[b]	11.14[b]
Standard + 80kg N/ha	4.15[a]	7.03[a]	12.23[a]
Mean	**4.07**	**6.45**	**11.25**
LSD	0.29	0.68	1.05
PGR treatment			
Untreated control	4.13[a]	6.46[a]	11.83[a]
Moddus + chlormequat	4.02[a]	6.44[a]	10.67[b]
LSD	**0.30**	**0.31**	**0.98**

Figures followed by different letters are regarded as statistically significant.

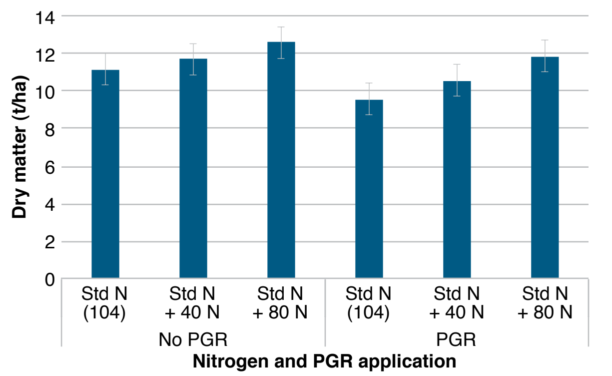


FIGURE 1 Interaction between nitrogen rate and PGR application on dry matter production 7 December, harvest (GS99)

The error bars are a measure of LSD 1.69 t/ha — *interaction not significant*

Despite a significant reduction in harvest DM with PGR application there was no significant difference in yield when all nitrogen levels were averaged. Additional nitrogen significantly increased grain protein, indicating applied nitrogen rates may have been sub-optimal as grain protein levels did not exceed 9%.

PGR effect

Although differences were small, PGR application resulted in significantly lower test weight and higher screenings (less than 1.0% difference), but yield was not affected.

Nitrogen x PGR interaction

There were no significant interactions between additional nitrogen and PGR application in terms of yield or grain quality (Figures 3 and 4). Differences in harvest DM with PGR addition did not correspond to any differences in the harvest index (% DM harvested as grain) as shown in Table 5.

Although there is no significant difference in yield plus and minus PGR at the lowest nitrogen level, it is noticeable that PGR looks to have been more detrimental at the lowest nitrogen level tested.

TABLE 4 NDVI readings measured 24 August, second node (GS32); 29 August, third node (GS33); 16 September, flag leaf fully emerged (GS39) and 6 October, start of flowering (GS61)

Nitrogen treatment	NVDI reading (scale 0–1)			
	GS32	GS33	GS39	GS61
Standard (104kg N/ha)	0.640[a]	0.694[a]	0.774[c]	0.694[c]
Standard + 40kg N/ha	0.620[a]	0.708[a]	0.815[b]	0.747[b]
Standard + 80kg N/ha	0.632[a]	0.748[a]	0.836[a]	0.777[a]
Mean	**0.631**	**0.717**	**0.808**	**0.739**
LSD	0.034	0.056	0.011	0.021
PGR treatment				
Untreated control	0.628[a]	0.704[a]	0.813[a]	0.750[a]
Moddus + chlormequat	0.633[a]	0.730[a]	0.804[a]	0.728[a]
LSD	0.027	0.030	0.019	0.022

Figures followed by different letters are regarded as statistically significant.

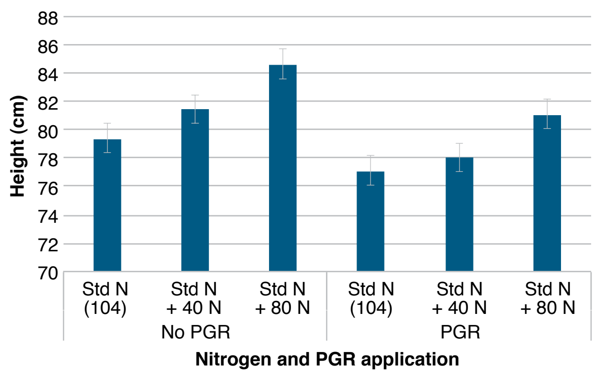


FIGURE 2 Interaction between nitrogen rate and PGR application on crop height at harvest, 7 December 2016

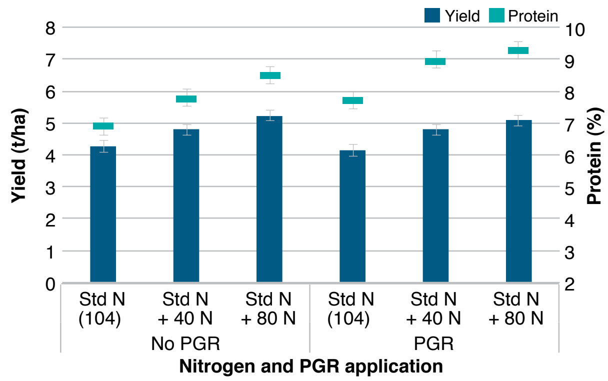


FIGURE 3 Influence of nitrogen application and PGR application on yield and protein

The error bars are a measure of LSD Yield (0.35 t/ha), Protein (0.54%) — interactions are not significant.

TABLE 5 Yield, protein, test weight, screenings, and harvest index (HI) at harvest (GS99), 11 December 2016

Nitrogen treatment	Yield and quality				
	Yield (t/ha)	Protein (%)	Test weight (kg/hL)	Screenings (%)	HI (%)
Standard (104kg N/ha)	4.21[b]	7.3[b]	79.4[a]	2.0[a]	40.3[a]
Standard + 40kg N/ha	4.79[a]	8.4[a]	80.3[a]	1.6[a]	42.5[a]
Standard + 80kg N/ha	5.15[a]	8.9[a]	79.6[a]	2.1[a]	41.5[a]
Mean	**4.72**	**8.2**	**79.8**	**1.9**	**41.4**
LSD	0.37	1.0	1.9	0.7	6.0
PGR treatment					
Untreated control	4.77[a]	7.7[b]	80.7[a]	1.5[b]	39.8[a]
Moddus + chlormequat	4.67[a]	8.6[a]	78.8[b]	2.3[a]	43.1[a]
LSD	0.20	0.3	1.3	0.5	4.1

Figures followed by different letters are regarded as statistically significant.

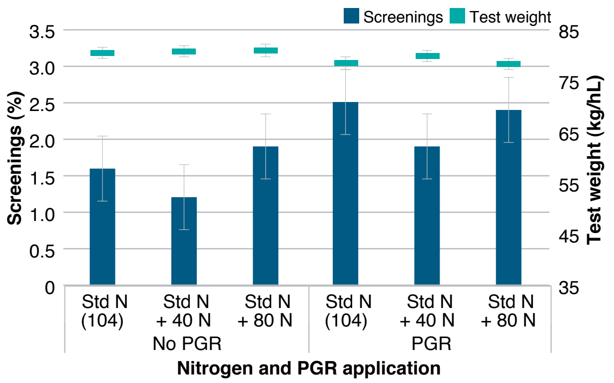


FIGURE 4 Influence of nitrogen and PGR application on screenings and test weight

The error bars are a measure of LSD Screenings (0.9%), Test weight (2.3kg/hl) – no interactions are significant.

Conclusions

For the third year in succession there have been no significant yield benefits to the application of PGR (Moddus + chlormequat) irrespective of the different nitrogen levels applied. There has been a trend in all three years (which was significant in 2016) to show that PGR application reduces final harvest DM. The influence of PGR application on grain quality has been minimal, with some small positive trends in 2015 and small negative effects recorded in 2016. With a range of soft finish (2014, 2016) and hard finish seasons (2015), the work has given variable results to increasing nitrogen rate (above 80–100kg N/ha) in first wheat after canola. In 2014 (5t/ha yields) and 2015 (3t/ha yields) there was no yield response to extra nitrogen due to high background nitrogen levels, while in 2016 there was up to a 1t/ha yield response to an extra 80kg N/ha when the trial was moved to a site with lower starting nitrogen levels.

Acknowledgements

This 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*.

This trial was run at the Riverine Research Centre (RRC), an independent and dedicated crop research site located near Yarrawonga, Victoria. The RRC is a partnership between Riverine Plains Inc and FAR Australia and is supported by RRC hosts, the Cummins family.

Contact

Michael Straight Foundation for Arable Research, Australia

E: michael.straight@far.org.nz

Monitoring the performance of nitrogen applied to wheat

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

Key points

- At both Corowa, NSW and Dookie, Victoria, there were significant yield responses to applied nitrogen (N), with maximum yields of 6.25t/ha at Corowa and 6.21t/ha at Dookie.
- Both sites gave identical unfertilised yields, averaging 4.67t/ha.
- Yield responses were associated with significantly higher dry matter (DM) production and greater nitrogen offtake when 120kg N/ha was applied at both sites.
- The maximum nitrogen offtake in the unfertilised crops at both sites equated to about 70–80kg N/ha, which was similar to the 95kg N/ha available to the crop at the start of the season at Corowa and the 65kg N/ha available at the start of the season at Dookie.
- The normalised difference vegetation index (NDVI) response index (NDVI of fertilised:NDVI of unfertilised plots equal to 1.17) was measured at third node stage (GS33) and equated to maximum measured yield responses of 1.5–1.6t/ha to applied nitrogen.
- Applying an extra 60kg N/ha on top of the initial 60kg N/ha at Corowa (total 120kg N/ha) produced an average yield increase of 0.17t/ha (maximum 0.25t/ha), which was not cost effective (data not shown).
- At Dookie in 2016 applying 120kg N/ha gave greater returns and was economically worthwhile based on an extra 0.64t/ha for the additional 60kg N/ha applied (data not shown).

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 Corowa, NSW and Dookie, Victoria. They were set up in an established wheat crop, sown 2 May 2016 at Corowa and 20 May 2016 at Dookie. The trials were run according to host farmer standard paddock practice, except for nitrogen application.

Nitrogen as urea 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 tillering (GS24) and 50% at the start of stem elongation (GS30–31). The second strategy was based on timings where 50% of the nitrogen rate was applied at the start of stem elongation (GS30–31) and 50% was applied at third-node (GS33).

Although both sites received some blanket-applied nitrogen at sowing as MAP, this was before the plots were established and it is not considered in the treatment list. Therefore those plots that only received nitrogen at sowing are still referred to as the 'unfertilised' plots.

Trials were established as a split plot design with nitrogen rate as the main plot and nitrogen timing the sub plot, replicated four times. To maintain trial balance, the trial included included two untreated treatments. Data has been statistically analysed using analysis of variance (ANOVA), with means separated using unrestricted least significant difference (LSD) procedure.

Trial 1: Corowa, NSW

Sowing date: 2 May 2016
Rotation: Third wheat
Variety: Trojan
Stubble: Burnt stubble
Rainfall:
GSR: 567mm (April–October)
Summer rainfall: 80mm
Soil mineral nitrogen: 95kg N/ha (0–60cm)

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 treatment most affected by dry conditions following application.

i) Establishment and crop structure

Crops receiving either a total of 60kg and 120kg N/ha post-sowing produced significantly higher tiller numbers compared with the unfertilised crop, with the 120kg N/ha

TABLE 1 Nitrogen application rates and timings at Corowa, NSW, 2016

Treatment	2 May 2016 (GS00) (kg N/ha)	1 July 2016 (GS24) (kg N/ha)	29 July 2016 (GS31) (kg N/ha)	23 August 2016 (GS33) (kg N/ha)	Total nitrogen applied (kg N/ha)
1	23	–	–	–	23
2	23	–	–	–	23
3	23	30	30	–	83
4	23	–	30	30	83
5	23	60	60	–	143
6	23	–	60	60	143

Note: To maintain trial balance the trial included two untreated treatments where 23kg N/ha was applied as part of the sowing fertiliser regime. Sowing nitrogen was 5kg N/ha as MAP plus 18kg N/ha as urea.

TABLE 2 Rainfall measured for five days following each nitrogen application

	Five-day rainfall following nitrogen application (mm)					Date of rainfall >5mm after application
Application 1: 1 July	1 July	2 July	3 July	4 July	5 July	
	13	0.4	0.8	0	0.4	1 July (0 days)
Application 2: 29 July	29 July	30 July	31 July	1 August	2 August	
	0	1.4	1.6	4	30	2 August (4 days)
Application 3: 23 August	23 August	24 August	25 August	26 August	27 August	
	0	0	0	0	0	31 August (8 days)

rate producing significantly more tillers than the 60kg N/ha rate. However, at harvest (GS99) there were no differences in the final head numbers or crop height due to the rate of nitrogen applied (Table 3).

There was no difference in tiller numbers between the two timing strategies when assessed prior to the nitrogen application at third node (GS33). This indicates little additional response to the tillering (GS24) nitrogen application over the later nitrogen application at early stem elongation (GS31).

TABLE 3 Tiller counts 18 August third node (GS33), head counts and crop height 28 November harvest (GS99)

Nitrogen rate (kg N/ha)	Crop structure		
	GS33	GS99	
	Tillers (m²)	Heads (m²)	Height (cm)
0	327[c]	311[a]	89[b]
60	463[b]	334[a]	92[a]
120	498[a]	312[a]	90[ab]
Mean	**429**	**315**	**90**
LSD	29	36	2
Nitrogen timing			
GS24 and GS31	429[a]	322[a]	90[a]
GS31 and GS33*	430[a]	309[a]	90[a]
LSD	32	29	2

Figures followed by different letters are regarded as statistically significant.
N.B. 23kg N/ha was added to the different fertiliser treatments as a component of the basal fertiliser.
* Comparison of tiller numbers made prior to GS33 application.

ii) Dry matter production and nitrogen uptake

There were no significant differences in dry matter (DM) production between the different nitrogen treatments and the unfertilised control plots (Table 4), although there was evidence of increased nitrogen uptake in the DM analysis (Table 5).

The sharp decline in nitrogen content of the crop canopy between flowering and harvest cannot be explained and appears to be an assessment anomaly, although at this assessment, both nitrogen rates showed significantly higher nitrogen uptake into the canopy.

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 for canopy greenness reading) between the two different nitrogen application timings when measured at stem elongation (GS31), flag leaf and third node (GS33) (Table 6). The early split timing (GS24 and GS31) was significantly greener (higher NDVI reading) at both stem elongation (GS31) and third node (GS33), due to more nitrogen being applied at that stage. By flowering there was no disadvantage of the later nitrogen strategy in terms of NDVI. There was a trend for the higher nitrogen rate to stay greener for longer, but this was not statistically significant (Figure 1).

TABLE 4 Dry matter 1 July, mid-tiller (GS24); 29 July, first node (GS31); 27 August, third node (GS33); 26 September start of flowering (GS61) and 28 November, harvest (GS99)

Nitrogen rate (kg N/ha)	Dry matter (t/ha)				
	GS24	GS31	GS33	GS61	GS99
0	0.8	1.6	3.8^{a}	10.2^{a}	12.5^{a}
60		1.7	3.9^{a}	10.6^{a}	14.2^{a}
120		1.8	3.8^{a}	10.3^{a}	12.6^{a}
Mean	**0.8**	**1.7**	**3.9**	**10.4**	**13.1**
LSD			0.5	0.8	2.2
Nitrogen timing					
GS24 and GS31	0.8	1.7	3.9^{a}	10.4^{a}	13.4^{a}
GS31 and GS33			3.7^{a}	10.3^{a}	12.8^{a}
LSD			0.3	0.9	0.9

Figures followed by different letters are regarded as statistically significant.
Note. No LSD values are presented for GS24 and GS31 as no nitrogen had been applied at the time of application.

TABLE 5 Nitrogen uptake 1 July, mid-tiller (GS24); 29 July, first node (GS31); 27 August, third node (GS33); 26 September start of flowering (GS61) and 28 November, harvest (GS99)

Nitrogen rate (kg N/ha)	Nitrogen uptake (kg N/ha)				
	GS24	GS31	GS33	GS61	GS99*
0	45	55	69^{c}	127^{b}	65^{b}
60		60	88^{b}	120^{b}	98^{a}
120		73	103^{a}	149^{a}	92^{a}
Mean	**45**	**63**	**87**	**132**	**85**
LSD			10	12	13
Nitrogen timing					
GS00 and GS30	45	63	97^{a}	133^{a}	78^{b}
GS30 and GS33			76^{b}	131^{a}	92^{a}
LSD			6	10	6

Figures followed by different letters are regarded as statistically significant.
Note. No LSD values are presented for GS24 and GS31 as no nitrogen had been applied at the time of application.

TABLE 6 NDVI (scale 0–1), 1 July, mid-tiller (GS24); 29 July, first node (GS31); 27 August, third node (GS33); 10 October mid-end of flowering (GS65–69) and 7 November, early dough stage (GS83)

Nitrogen rate (kg N/ha)	NDVI				
	GS24	GS31	GS33	GS65–69	GS80
0	0.47^{a}	0.56^{a}	0.64^{b}	0.60^{b}	0.26^{c}
60	0.48^{a}	0.58^{a}	0.74^{a}	0.70^{a}	0.33^{b}
120	0.48^{a}	0.59^{a}	0.75^{a}	0.75^{a}	0.38^{a}
Mean	**0.48**	**0.58**	**0.71**	**0.68**	**0.32**
LSD	0.03	0.06	0.06	0.06	0.04
Nitrogen timing					
GS24 and GS31	0.48^{a}	0.60^{a}	0.72^{a}	0.69^{a}	0.33^{a}
GS31 and GS33	0.48^{a}	0.56^{b}	0.70^{b}	0.68^{a}	0.32^{a}
LSD	0.01	0.02	0.02	0.03	0.03

Figures followed by different letters are regarded as statistically significant.

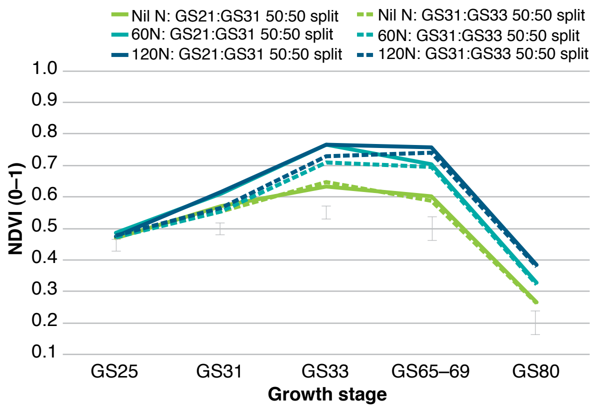


FIGURE 1 Influence of applied nitrogen timing and rate on NDVI assessments (scale 0–1)*

*The error bars are a measure of LSD

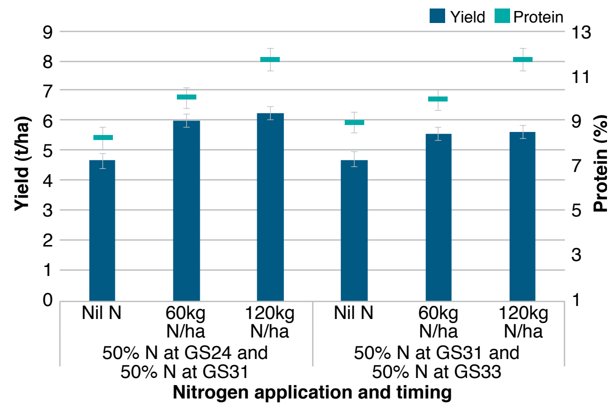


FIGURE 2 Grain yield and protein results, 10 December Corowa, NSW

The error bars for yield and protein are a measure of LSD.

iv) Yield and grain quality

Despite no significant increase in DM with additional nitrogen, the two nitrogen strategies significantly increased both yield and protein compared with the unfertilised plots, although the only difference between the 120kg N/ha treatment over the 60kg N/ha treatment was increased grain protein, with no yield advantage (11.7% protein for 120kg N/ha compared with 10% for 60kg N/ha) (Table 7, Figure 2).

There was a significant yield advantage (average of 0.34t/ha) with the earlier nitrogen timing over the later timing, despite the canopies being similar at flowering and harvest in terms of NDVI, DM and head number. There was no significant interaction between nitrogen rate and timing, as both timings showed that high levels of nitrogen increased yield and protein.

Nitrogen offtake was significantly greater at higher nitrogen rates. If 25% of the nitrogen at harvest was assumed to be present in the straw and chaff, and taking account of the 23kg N/ha applied at sowing, the offtake of nitrogen in the 60kg N/ha treatment was greater than that applied, with the unfertilised crop removing about 75kg N/ha (Table 7).

Trial 2: Dookie, Victoria

Sowing date: 20 May 2016

Rotation: First wheat after canola

Variety: Corack

Stubble: Canola unburnt

Rainfall:

GSR: 509mm (April-October)

Summer rainfall: 130mm

Soil mineral nitrogen: 65kg N/ha (0–60cm)

TABLE 7 Yield, protein, test weight, screenings and nitrogen offtake in grain at harvest (GS99), 10 December 2016

Nitrogen rate (kg N/ha)	Yield and quality				
	Yield (t/ha)	Protein (%)	Test weight (kg/hL)	Screenings (%)	Nitrogen offtake in grain (kg N/ha)
0	4.67b	8.6c	81.6a	1.7a	70c
60	5.77a	10.0b	80.4a	2.3a	101b
120	5.94a	11.7a	80.2a	1.9a	122a
Mean	**5.46**	**10.1**	**80.7**	**2.0**	**98**
LSD	0.67	0.6	1.8	0.9	12
Nitrogen timing					
GS24 and GS31	5.63a	10.0a	80.8a	2.0a	100a
GS31 and GS33	5.29b	10.2a	80.6a	2.0a	95a
LSD	0.27	0.56	0.87	0.51	8

Figures followed by different letters are regarded as statistically significant.

The application rates and timings of nitrogen applied to the Dookie trial are presented in Table 8 with the rainfall surrounding application outlined in Table 9.

i) Establishment and crop structure

The application of 60kg N/ha and 120kg N/ha significantly increased tiller production relative to the unfertilised plots, while only the 120kg N/ha treatment significantly increased final head number (Table 10). There was no difference in tiller or head number due to nitrogen timing. The height of the crop canopy at harvest (GS99) was increased by 2cm with additional nitrogen.

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 60kg and 120kg N/ha producing significantly more DM at head emergence (GS51) and harvest (GS99) (Table 11, Figure 3).

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

Nitrogen uptake followed similar trends to DM production, with DM increased by applying both 60kg and 120kg N/ha, although by grain fill (GS71) only the 120kg N/ha nitrogen rate significantly increased nitrogen uptake in the plant (Table 12). The later timing strategy, at GS30 and GS33, saw lower uptake of nitrogen at harvest.

TABLE 10 Tiller counts 26 August, third node (GS33), head counts and crop height 29 November harvest (GS99)

	Crop structure		
	GS33	GS99	
Nitrogen rate (kg N/ha)	Tillers (m^2)	Heads (m^2)	Height (cm)
0	334[c]	277[b]	89[b]
60	359[b]	320[ab]	91[a]
120	381[a]	338[a]	91[a]
Mean	**358**	**312**	**90**
LSD	21	48	2
Nitrogen timing			
GS13 and GS30	354[a]	302[a]	91[a]
GS30 and GS33	361[a]	322[a]	90[a]
LSD	19	34	1

Figures followed by different letters are regarded as statistically significant.

iii) Normalised difference vegetation index (NDVI)

The greenness of the crop canopy at third node (GS33) and early grain fill (GS71) (measured with a GreenSeeker®) was significantly greater where nitrogen had been applied at 120kg N/ha than where the crop was left unfertilised (Table 13). The crop treated with 120kg N/ha was the greenest throughout the assessment period.

TABLE 8 Nitrogen application rates and timings at Dookie, Victoria, 2016

Treatment	20 May (sowing) (kg N/ha)	27 June (GS13) (kg N/ha)	2 August (GS30) (kg N/ha)	26 August (GS33) (kg N/ha)	Total nitrogen applied (kg N/ha)
1	7.5	-	-	-	7.5
2	7.5	-	-	-	7.5
3	7.5	30	30	-	67.5
4	7.5	-	30	30	67.5
5	7.5	60	60	-	127.5
6	7.5	-	60	60	127.5

Note: To maintain trial balance the trial included two untreated treatments. Starting nitrogen was applied as MAP.

TABLE 9 Rainfall measured for five days following each nitrogen application

Application	Five-day rainfall following nitrogen application (mm)					Date of rainfall >5mm after application
1: 27 June	27 June	28 June	29 June	30 June	1 July	
	0	0	0	0	11	1 July (5 days)
2: 2 August	2 August	3 August	4 August	5 August	6 August	
	27.5	0	0	0	0	2 August (1 day)
3: 26 August	26 August	27 August	28 August	29 August	30 August	
	0	0	0	0	0	31 August (6 days)



TABLE 11 Dry matter 2 August, stem elongation (GS30); 26 August, third node (GS33); 19 September, start of head emergence (GS51); 17 October, grain fill (GS71) and 29 November, harvest (GS99)

Nitrogen rate (kg N/ha)	Dry matter (t/ha)				
	GS30	GS33	GS51	GS71	GS99
0	0.4	1.9[b]	4.7[b]	9.1[a]	11.5[b]
60	0.6	2.1[ab]	5.3[a]	9.4[a]	14.1[a]
120	0.6	2.3[a]	5.2[a]	9.9[a]	15.3[a]
Mean	**0.5**	**2.1**	**5.1**	**9.4**	**13.6**
LSD		0.3	0.2	1.1	1.2
Nitrogen timing					
GS13 and GS30	0.5	2.1[a]	5.0[a]	9.5[a]	13.6[a]
GS30 and GS33		2.0[a]	5.1[a]	9.4[a]	13.7[a]
LSD		0.3	0.5	0.9	1.5

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 GS30.

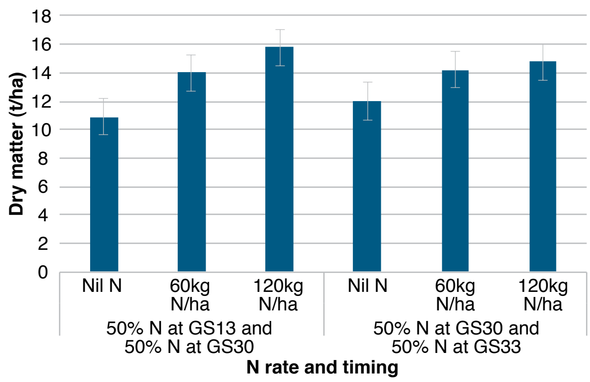


FIGURE 3 The effect of nitrogen application rate and timing on dry matter at harvest (GS99) at Dookie, 2016

TABLE 13 NDVI (scale 0–1), 2 August, stem elongation (GS30); 26 August, third node (GS33): 19 September, start of head emergence (GS51) and 17 October, start of grain fill (GS71)

Nitrogen rate (kg N/ha)	NDVI			
	GS30	GS33	GS51	GS71
0	0.44[a]	0.54[b]	0.72[a]	0.66[b]
60	0.48[a]	0.61[ab]	0.74[a]	0.70[ab]
120	0.46[a]	0.63[a]	0.76[a]	0.72[a]
Mean	**0.46**	**0.59**	**0.74**	**0.69**
LSD	0.06	0.08	0.04	0.06
Nitrogen timing				
GS13 and GS30	0.47[a]	0.61[a]	0.74[a]	0.70[a]
GS30 and GS33	0.45[a]	0.57[a]	0.74[a]	0.68[a]
LSD	0.04	0.06	0.02	0.04

Figures followed by different letters are regarded as statistically significant.

TABLE 12 Nitrogen uptake 2 August, stem elongation (GS30); 26 August, third node (GS33); 19 September, start of head emergence (GS51); 17 October, grain fill (GS71) and 29 November, harvest (GS99)

Nitrogen rate (kg N/ha)	Nitrogen uptake (kg N/ha)				
	GS30	GS33	GS51	GS71	GS99
0	21	57[b]	81[b]	91[b]	60[b]
60	32	80[a]	115[a]	91[b]	54[b]
120	37	92[a]	125[a]	116[a]	85[a]
Mean	**30**	**76**	**107**	**99**	**66**
LSD		16	16	14	10
Nitrogen timing					
GS13 and GS30	30	79[a]	105[a]	90[a]	71[a]
GS30 and GS33		73[a]	110[a]	109[a]	61[b]
LSD		13	13	22	6

Figures followed by different letters are regarded as statistically significant.
Note. Since not all the nitrogen was applied at GS30 no LSD values are presented for this.

The early split of nitrogen (GS13 and GS30) gave similar NDVI readings to the later-timed nitrogen strategy (GS30 and GS33) (Figure 4), whereas in 2015 lower NDVI readings were measured with later-applied nitrogen due to limitations on crop nitrogen uptake.

At the start of stem elongation (GS30) the difference in NDVI readings between crops fertilised with nitrogen at GS13 and the untreated crops was not significant. When all nitrogen had been applied at GS33 the NDVI readings showed greater crop canopy greenness where nitrogen was applied.

The differences in NDVI between the fertilised and unfertilised crops can be used as a guide to the background fertility of the trial site. The greater the difference in NDVI readings, the less fertile the site. This is referred to as the response index (RI). For example, at the third-node stage (GS33) applying 120kg N/ha produced an NDVI score of 0.63 compared with 0.54 for the untreated crop (Figure 4). In this case the RI at Dookie was 1.17 (0.63/0.54 = 1.17), with the same RI at Corowa (0.75/0.64 = 1.17). These calculations indicate the yield response to nitrogen at Dookie was likely to be similar to that at Corowa, but at a lower level of background fertility.

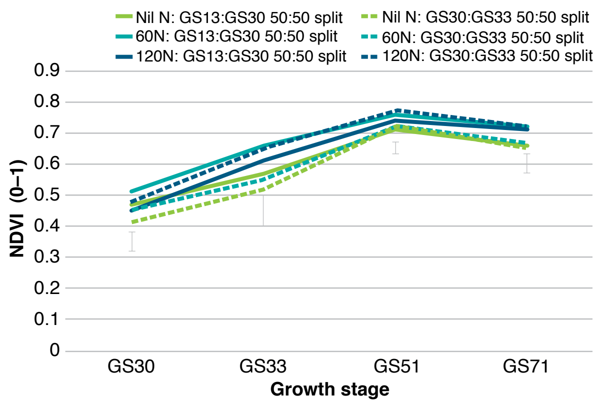


FIGURE 4 Influence of applied nitrogen timing and rate on NDVI (scale 0–1)*

*The error bars are a measure of LSD.

iv) Yield and grain quality

Applying the highest rate of nitrogen (120kg N/ha) significantly increased yield, with a 1.29t/ha yield advantage compared with the unfertilised treatment and a 0.64t/ha advantage over the 60kg N/ha treatments (Table 14, Figure 5).

There was no significant interaction between nitrogen rate and timing strategies, as both timings gave similar responses to increasing nitrogen rate. The later nitrogen timing, split at GS30 and GS33, was 0.27t/ha higher yielding than where nitrogen was split between GS13 and GS30.

Grain protein was significantly greater in the nitrogen fertilised crops compared with those where no nitrogen was applied.

Crops receiving 120kg N/ha also produced significantly higher test weights than the untreated crops, but differences were small.

There were no differences in screenings between the treatments.

The nitrogen offtake in the unfertilised plots was about 90kg N/h if we assume 25% of the nitrogen is in the crop canopy at harvest (Table 14). Where 60kg N/ha was applied, nitrogen offtake exceeded nitrogen application by about 50kg N/ha while the application of 120kg N/ha resulted in similar nitrogen offtakes to the nitrogen application rate.

TABLE 14 Yield, protein, test weight and screenings 13 December 2016, harvest (GS99)

Treatment	Grain yield and quality				
Nitrogen rate (kg N/ha)	Yield (t/ha)	Protein (%)	Test weight (kg/hL)	Screenings (%)	Nitrogen offtake in grain (kg N/ha)
0	4.67[c]	9.7[b]	80.5[b]	0.6[a]	80[c]
60	5.32[b]	10.3[a]	81.0[ab]	0.6[a]	96[b]
120	5.96[a]	10.4[a]	81.2[a]	0.7[a]	108[a]
Mean	**5.32**	**10.2**	**80.9**	**0.7**	**95**
LSD	0.41	0.3	0.7	0.1	7
Nitrogen timing					
GS00 and GS30	5.18[b]	10.2[a]	80.9[a]	0.6[a]	93[a]
GS30 and GS33	5.45[a]	10.1[a]	80.9[a]	0.7[a]	97[a]
LSD	0.28	0.4	0.4	0.1	4

Figures followed by different letters are regarded as statistically significant.



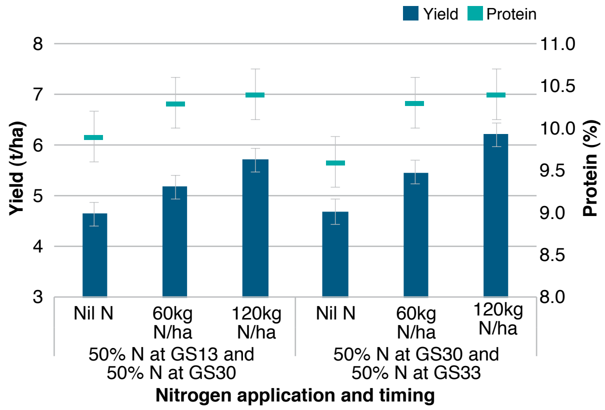


FIGURE 5 Grain yield and protein 13 December 2016, harvest (GS99)*

*The errors bars are a measure of LSD

Conclusions

At both the Corowa and Dookie sites the NDVI scores (a measurement of crop reflectance) indicated additional nitrogen would be required to maximise yield based on scores taken during early stem elongation (GS33).

There were significant DM growth responses with nitrogen application that resulted in significant yield increases at both sites (maximum nitrogen response of 1.52t/ha at Dookie and 1.6t/ha at Corowa).

In comparison, despite a higher NDVI response index in 2015, hot conditions between ear emergence (GS59) and the end of flowering (GS69) resulted in no yield advantage from additional nitrogen, with average yields about 4t/ha.

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*.

Thank you the farmer co-operators, Mark Harmer, Dookie, Victoria and Denis Tomlinson, Corowa, NSW.

Contact

Nick Poole Foundation for Arable Research, Australia

E: Nick.Poole@far.org.nz

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

The following article is taken from the final report of a Department of Agriculture and Water Resources project, Management Strategies for Improved Productivity and Reduced Nitrous Oxide Emissions, *run in the Riverine Plains region and in the mid North of South Australia at the Hart Field Site during the past three years.*

Dr Sarah Noack[1], Peter Hooper[1], Nick Poole[2], Michael Straight[2], Tracey Wylie[2], Dr Clemens Scheer[3], Dr Cassandra Schefe[4], Sam Trengove[5] and Stuart Sherriff[5]

[1] Hart Field-Site Group
[2] Foundation for Arable Research
[3] Queensland University of Technology
[4] Riverine Plains Inc
[5] Precision Agriculture Association

Summary

Nitrous oxide emissions (N_2O) from Australian grain cropping systems are highly variable due to the large variations in soil, climate and management practices. Overall this research confirms that N_2O emissions from dryland cropping systems in the Riverine Plains is at the low end of the range for temperate climatic zones in eastern Australia.

In the current study, N_2O emissions and crop productivity were assessed under a range of nitrogen (N) management strategies. Six nitrogen treatments were assessed, including combinations of nitrogen rate (0, 40 or 80 kg/ha), application timing (incorporated by sowing (IBS) or first node (GS31) of wheat), a nitrification inhibitor (DMPP) and real time crop nitrogen prediction using a Greenseeker®. These six nitrogen strategies were applied to wheat sown after canola or a legume.

In general, across the three seasons (2014–16), N_2O emissions from fertiliser applications were slightly elevated compared with the control. In some seasons however, N_2O emissions were increased above background levels and cumulative values were at the higher end of those reported from dryland farming (>2kg or 2000g N_2O-N/ha/season). High emissions were measured from both IBS and first node (GS31) application timings, depending on the seasonal conditions. Seasons dominated by early heavy rainfall favoured in-season nitrogen application for reduced N_2O emissions. However, these treatments often did not result in the highest grain yield or quality. It is important to note that cumulative emissions were only assessed over the growing season to look at in-season fertiliser nitrogen management. Annual values may have been higher if summer fallow emissions were also assessed prior to sowing.

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 through denitrification processes, and is increased in the presence of nitrogen fertilisers, high levels of organic residues and livestock waste, especially when the soil conditions are anaerobic (void of oxygen) such as occurs with waterlogging. Recent research has shown there is a range of reduction strategies that may benefit growers both environmentally and economically. The objective of this research was to measure and demonstrate on-farm strategies to reduce N_2O emissions from cropping soil.

Soils also release dinitrogen (N_2) gas through denitrification, however this is difficult to measure as dinitrogen is naturally occurring in the Earth's atmosphere at relatively high concentrations. In comparison, as N_2O concentrations in the atmosphere are much lower, it is easier to detect changes in N_2O emissions due to denitrification under different management strategies. In general, the release of N_2 from soil can be 20–30 times greater than nitrogen lost through N_2O, though the exact relationship between the two gases depends on the water content of the soil. This means the total amount of nitrogen lost from soil through gas release could be 20–30 times greater than that measured through N_2O emissions.

As the field trials for this project were completed during 2016, this report presents a summary of results from three years of field trials.

Aim

The aim of the *Management Strategies for Improved Productivity and Reduced Nitrous Oxide Emissions* project, funded by the Department of Agriculture and Water Resources, Action on the Ground program, was to

measure and demonstrate on-farm strategies to reduce N_2O emissions and improve nitrogen use efficiency.

Method

This project measured the N_2O emissions and crop productivity under a range of nitrogen management strategies in wheat crops from 2014–16.

Trials were carried out at Yarrawonga, Victoria and Hart, South Australia for three seasons. The actual location of the trial site was relocated each year, as each year required a wheat crop to be sown into canola or a legume. In order for this to be done, in the season prior to the trials being established, a paddock at each location (Yarrawonga and Hart) was split in half. One half of the paddock was sown to canola, the other to a legume (peas at Yarrawonga). The following year, this paddock was all sown to wheat, with the different nitrogen treatments applied.

Due to the logistics of such a trial, the preceding canola and legume could not be sown within an integrated statistically robust design. Rather, the wheat trials following canola or legume were established side-by-side. This means a direct statistical comparison of the nitrogen treatments in wheat following canola or legume could not be done. Therefore, the results from each rotation are presented separately.

Six nitrogen treatments were assessed including combinations of nitrogen rates (0, 40 or 80 kg/ha), which were either incorporated by sowing (IBS) or applied at first node (GS31). Urea coated with a nitrification inhibitor was also evaluated, which is marketed as Entec® (DMPP; 3, 4 dimethylpyrazole phosphate), with a final treatment where the rate and timing of nitrogen application was determined by in-crop normalised difference vegetative index (NDVI) measurements, using a Greenseeker® (Table 1).

While trials were carried out at both Yarrawonga and Hart, only the Yarrawonga results are presented in this report as both sites displayed similar trends, with the Yarrawonga results being most relevant to this region.

Results

Nitrous oxide emissions

The trials showed that nitrogen fertiliser applications sometimes resulted in increased N_2O emissions compared to the control (nil nitrogen plots), however this was very seasonally dependent (Table 2; Figure 1).

In 2014 heavy rainfall early in the season, shortly after sowing, resulted in transient waterlogging at the Yarrawonga site (Figure 2). This corresponded to high

TABLE 1 Nitrogen rates and application timing for wheat trials located at Yarrawonga, from 2014–16

Treatment No.	Nitrogen rate and application timing
1	Nil nitrogen applied (control)
2	#80kg N/ha as urea incorporated by sowing (IBS)
3	#40kg N/ha applied as urea at first node (GS31) of the wheat crop
4	#80kg N/ha applied as urea at first node (GS31) of the wheat crop
5	#80kg N/ha applied urea + DMPP* at first node (GS31) of the wheat crop — urea coated with nitrification inhibitor, commercially available as Entec
6	**Real time tactical (RTT) — post-emergent nitrogen application determined using a Greenseeker to measure crop NDVI. Applied as one or two split nitrogen applications post start of stem elongation (GS30) **Wheat following canola** (applied as single or two split applications in-season): 2014 – 59kg N/ha 2015 – 35kg N/ha 2016 – 44kg N/ha. **Wheat following legume** (applied as single or two split applications in-season): 2014 – 53kg N/ha 2015 – 24kg N/ha 2016 – 15kg N/ha.

Due to wet conditions at Yarrawonga during 2014, all 80kg N/ha applications were increased to 100kg N/ha and 40kg N/ha applications were increased to 50kg N/ha at the GS31 application time.

* DMPP = 3, 4 dimethylpyrazole phosphate.

** Greenseeker® NDVI measures the combined effects of chlorophyll concentration and total biomass of the crop. Nitrogen application rate was calculated using a NDVI response index (RI) and yield potential estimates.

TABLE 2 Cumulative N_2O emissions for nil, 80kg N/ha applied IBS or first node (GS31) for wheat following peas or canola at Yarrawonga in 2014–16

Previous crop	Treatment	Yarrawonga 2014	2015	2016
		g N_2O-N/ha/season		
Canola	Nil	212[b]	109[c]	1779[a]
	80kg/ha IBS	1922[a]	301[a]	2443[a]
	80kg/ha @ GS31	340[b]	197[b]	2556[a]
	80kg @ GS31 + DMPP	-	-	1872[a]
	Mean	**82**	**202**	**2163**
	LSD (P≤0.05)	1339	50	1189
Legume	Nil	287[a]	78[b]	809[b]
	80kg/ha IBS	1686[a]	198[a]	2738[a]
	80kg/ha@ GS31	390[a]	151[ab]	2052[ab]
	80kg @ GS31 + DMPP	-	-	1135[b]
	Mean	**785**	**142**	**2378**
	LSD (P≤0.05)	1505	73	1262

Figures followed by different letters are regarded as statistically significant.

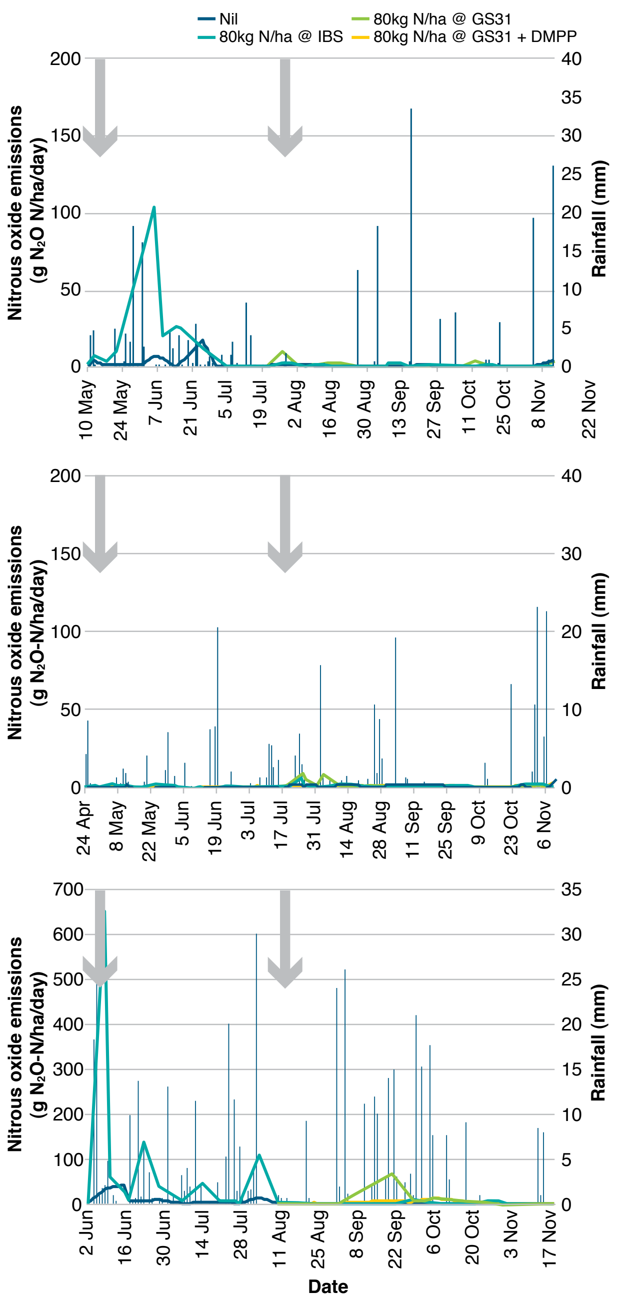


FIGURE 1 Nitrous oxide emissions for nil, IBS and GS31 nitrogen applications for wheat sown after a legume in 2014 (top), 2015 (mid) and 2016 (bottom) at Yarrawonga*

* The GS31 + DMPP emissions were also measured in 2016. The grey arrows indicate the date of nitrogen fertiliser application. Please note the change in scale for N_2O emissions in 2016.

daily N_2O emissions, with the highest measurements observed where fertiliser nitrogen was applied IBS (Figure 1). However the yields from the IBS nitrogen were significantly higher than other treatments, despite N_2O emissions that were five times greater than nitrogen applied at first node (GS31) (Table 3). This shows that nitrogen management for grain yield, and for reduced N_2O emissions, cannot always be achieved.

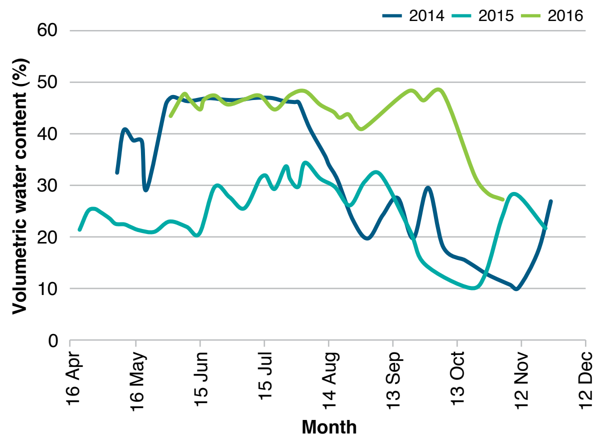


FIGURE 2 Volumetric water content to a depth of 12cm for the growing season at Yarrawonga from 2014–16

Similarly, the wet 2016 season saw cumulative N_2O emissions at the high end of the range reported for dryland cropping systems (>2000g N_2O-N/ha/season). Total N_2O emissions ranged from 809–2738g N_2O-N/ha/season for the nil and 80kg N/ha applied treatments (Table 2). Immediately after sowing, N_2O emissions were highest at 60 g N_2O-N/ha/day (Figure 1). This was followed by another four 'peak' emission periods, which occurred during late June through to mid-September 2016. These high emission periods corresponded to high rainfall and waterlogged soil conditions (Figure 3).

The volumetric water content was consistently high at 40–50% with twice the number of days of waterlogging in 2016 compared with 2014, measured from May through to mid-October (Figure 2). Adding to this issue, the low nitrogen demand from the patchy and poorly-established wheat crop (counts ranged from 0–70 plants/m^2 at two leaf stage (GS12)) would have increased the amount of fertiliser nitrogen available for loss. In general, N_2O emissions were high regardless if nitrogen was applied IBS or at first node (GS31) in the 2016 season. When compared with crop performance, the most economic nitrogen strategy in 2016 was for growers to apply no nitrogen in terms of both crop yield and N_2O emissions.

In contrast, volumetric water content during 2015 never rose above 30% (Figure 2) and emissions were minimal, although there was a significant increase associated with upfront nitrogen following both canola and peas.

There was evidence the nitrification inhibitor Entec reduced N_2O emissions. When used at first node (GS31) during 2016 it produced significantly less N_2O than the IBS applied nitrogen, although this reduction in

TABLE 3 Grain yield and protein levels for nitrogen treatments applied to wheat following canola or a legume at Yarrawonga from 2014–16

Previous crop	Nitrogen rate	2014 Yield (t/ha)	2014 Protein (%)	2015 Yield (t/ha)	2015 Protein (%)	2016 Yield (t/ha)	2016 Protein %
Canola	Nil	5.45^{b}	8.6^{c}	4.04^{b}	8.5^{d}	1.35^{b}	8.6
	*80kg @ IBS	6.75^{a}	11.0^{ab}	4.31^{a}	11.3^{bc}	2.11^{a}	9.6
	40kg @ GS31	5.92^{b}	10.1^{b}	4.24^{ab}	10.3^{cd}	1.88^{ab}	9.2
	*80kg @ GS31	5.68^{b}	11.7^{a}	4.11^{ab}	13.4^{a}	2.13^{a}	10.3
	*80kg @ GS31 + DMPP	5.48^{b}	11.1^{ab}	4.24^{ab}	12.1^{ab}	2.13^{a}	10.0
	Tactical nitrogen	5.90^{b}	11.2^{ab}	4.28^{ab}	9.9^{cd}	1.92^{ab}	8.7
	Mean	**5.86**	**10.6**	**4.20**	**10.9**	**1.90**	**9.3**
	LSD (P≤0.05)	0.60	1.4	0.27	1.8	0.68	n/a
Legume	Nil	5.28^{b}	8.2^{c}	4.42^{ab}	10.6^{d}	1.93^{a}	8.2
	*80kg @ IBS	6.74^{a}	11.1^{a}	4.36^{ab}	13.7^{ab}	2.32^{a}	9.6
	40kg @ GS31	5.84^{b}	10.3^{ab}	4.29^{ab}	12.3^{c}	1.52^{a}	9.3
	*80kg @ GS31	6.03^{ab}	11.2^{a}	4.04^{b}	14.5^{a}	2.43^{a}	10.3
	*80kg @ GS31 + DMPP	5.70^{b}	10.5^{ab}	4.47^{a}	12.9^{bc}	2.00^{a}	10.3
	Tactical nitrogen	5.58^{b}	10.0^{b}	4.49^{a}	12.5^{bc}	1.91^{a}	8.6
	Mean	**5.86**	**10.2**	**4.35**	**12.8**	**2.02**	**9.4**
	LSD (P≤0.05)	0.77	1.1	0.41	1.2	1.07	n/a

* In 2014 only the 40 and 80kg N/ha treatments were increased to 50 and 100kg N/ha, respectively at GS31.
# Total nitrogen rate applied for 2014, 2015, and 2016 as one or two split applications in-season.
n/a = not statistically analysed due to the combination of replicate samples for protein assessment.

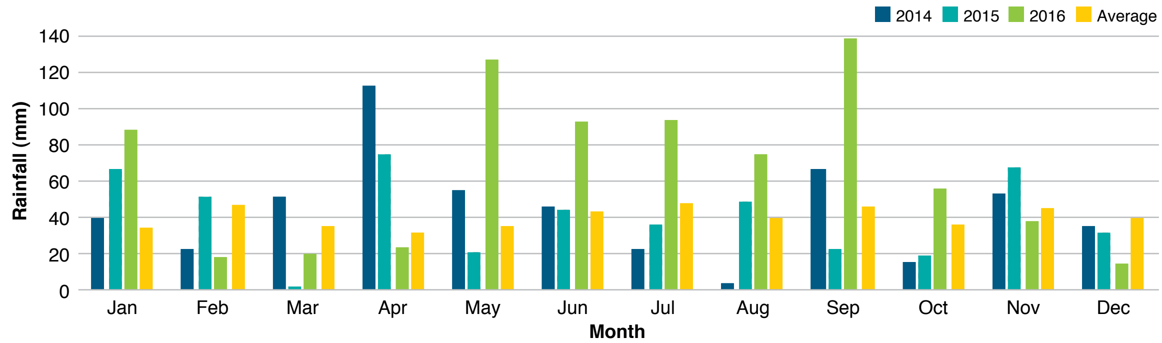


FIGURE 3 Annual rainfall for Yarrawonga from 2014–16 including historic long-term average rainfall (based on 100 years of records)

emissions was not always significantly lower than urea when applied at the same growth stage (GS31).

Though emissions were not measured in the tactical nitrogen treatment there was evidence that using crop sensor technology allowed nitrogen levels to be reduced without affecting crop yield. The use of the Greenseeker crop sensor allowed better quantification of the nitrogen available in the soil during spring and for nitrogen rates to better match crop demand.

As similar trends in emissions were measured when wheat was sown after canola, those results are not displayed in Figure 1.

How the results affect our overall approach with nitrogen

This study highlighted that growers can try to synchronise nitrogen supply with peak crop nitrogen demand to encourage greater fertiliser uptake and potentially reduce N_2O losses. However, while this strategy was beneficial for grain yield and quality, in some seasons it was not optimal for reducing N_2O emissions due to waterlogged conditions. There was evidence that RTT nitrogen prediction, using Greenseeker technology allowed the residual nitrogen from the previous crop to be better identified. The RTT treatment using the Greenseeker allows the crop itself to be the indicator of nitrogen uptake rather than depending on a soil test taken earlier in the season. NDVI measurements taken at the start of stem elongation (GS30) showed that more soil nitrogen was available to satisfy crop yield potential than was originally thought at sowing, and this allowed reduced fertiliser application without compromising grain yield.

There are some general strategies to assist growers with nitrogen management decisions to maximise crop uptake and reduce the potential for N_2O emissions. If the forecast is for a dry to average season the results suggest minimising up-front nitrogen additions, which was of benefit during 2015.

In the project, delaying nitrogen applications maintained grain yield, while protein was increased compared with IBS only applications (Table 3). The strategy of delaying nitrogen applications allows growers to make fertiliser decisions as the season progresses with more accurate forecasting and when crop demand for nitrogen is higher (e.g. stem elongation phases). If the forecast is for a wet season, there will be higher potential for nitrogen losses. In this scenario applying more nitrogen upfront to get the crop through 'wet' periods may be the best strategy in terms of grain yield and quality, when there are limited opportunities to spread fertiliser in season, but may result in elevated N_2O losses.

Acknowledgments

The authors acknowledge the Department of Agriculture and Water Resources for funding this research as part of the Action on The Ground (AOTGRR2-0015) program.

The authors would also like to acknowledge the collaboration of Queensland University of Technology, Riverine Plains Inc, the Hart Farming Group and SPAA — The Australian Precision Agriculture Association, in this project.

Thanks go to the Inchbold family, Yarrawonga, Victoria and John and Sarah Bruce, Boomanoomana, NSW.

Contact

Nick Poole Foundation for Arable Research, Australia

E: Nick.Poole@far.org.nz



Building an understanding of normalised difference vegetation index (NDVI), through the comparison of nitrogen products, nitrogen application timing and rate in wheat and barley

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

[1] Riverine Plains Inc
[2] FAR Australia

Key points

- A wet winter and spring during 2016 meant that nitrogen (N) applied at sowing was inefficient in meeting crop requirements during the season, due to high losses through leaching and denitrification.
- Application of nitrogen at first node (GS31) and third node (GS33) improved crop uptake, and was reflected as increased 'greenness' in wheat towards the end of the season, as measured by normalised difference vegetation index (NDVI).
- Using the Greenseeker® to measure NDVI in-crop was useful to determine crop responses to fertiliser treatments, and aligned well with final yield results.
- Determining crop nitrogen requirements based on in-crop NDVI readings improved the efficiency of nitrogen supply, as nitrogen was only added as needed, reducing input costs
- For both wheat and barley there was no difference between urea and Easy N® in terms of tiller and head numbers, dry matter (DM) production, yield or grain quality parameters when comparable nitrogen application rates and timings were used.

Background

In order to improve the efficiency and cost-effectiveness of nitrogen applications, there are three key aspects that can be manipulated: product type (solid urea vs liquid nitrogen), application timing and application rate.

While any differences in these parameters can influence final yield, being able to measure in-crop performance allows greater flexibility in modifying the in-season fertiliser strategy, while appreciating how seasonal conditions have influenced the crop response to fertiliser product, timing and rate.

The use of normalised difference vegetation index (NDVI) to measure and monitor crop 'greenness' and better understand variance in crop vigour and biomass (dry matter — DM) production is becoming more generally accepted. Growers and advisors can measure NDVI using either satellite imagery, or via a hand-held sensor, such as a Greenseeker. A hand-held Greenseeker was used in this trial to evaluate the extent and rate with which the crop responded to the different fertiliser treatments, and additionally, if the form in which the nitrogen was applied (solid vs liquid) resulted in a different rate or intensity of crop response.

The intent of this trial was to understand if wheat and barley would respond to the applied nitrogen treatments differently and if the responses would result in comparable changes in NDVI values.

Riverine Plains Inc funded this trial through member and sponsor support and the trial was located at the *Riverine Research Centre*: a partnership between Riverine Plains Inc and FAR Australia.

Aims

The specific aims of this trial were to:

- understand if the crop responded differently to urea compared with Easy N (liquid nitrogen)
- define the sensitivity with which the NDVI method can detect differences in timing and rate of nitrogen application
- determine if wheat and barley respond comparatively to nitrogen type (product), timing and rate, as measured by NDVI
- quantify how the use of different nitrogen types, timing and rates influence grain yield and quality.

Trial site: Riverine Research Centre, Yarrawonga, Victoria

Location: Telewonga Pty Ltd
Sowing date: 17 May 2016
Rotation: First wheat and barley after canola
Variety: Wheat: Trojan, Barley: Latrobe
Stubble: Canola unburnt, one pass with a Kelly chain
Rainfall:
GSR: 604mm (April–October)
Summer rainfall: 125mm
Soil mineral nitrogen: 50kg N/ha (0–60cm)

Method

A range of nitrogen treatments was applied in a randomised complete block design across replicated small plots of wheat or barley.

Two products were used: granular urea (42% N w/w) and liquid Easy N (50% urea, 25% ammonium, 25% nitrate — total 42.5% N w/v). While the maximum nitrogen application rate with urea was 150kg N/ha, there was a fluid application limit of 100kg N/ha with Easy N due to concentration restrictions.

Statistical analysis was carried out using analysis of variance (ANOVA), with statistical significance determined at 5% variance. Measures of least significant difference (LSD) were used to determine which, if any, treatments were significantly different.

Due to the large number of treatments across both wheat and barley, the results will be discussed separately for each crop type.

Wheat results

The range of nitrogen treatments applied to wheat is shown in Table 1.

The nitrogen application rates for the NDVI treatments (treatment 8: NDVI1 – 171kg N/ha and treatment 9: NDVI2 – 133kgN/ha)) were based on the NDVI 'response index' from representative plots. The method was based on a rate of change of NDVI during early stem elongation (GS30–33), which determined the amount of nitrogen required for the crop to reach either full yield potential or three-quarters of the yield potential. In order to respond to that change, a later nitrogen application was required at third node (GS33).

i) Establishment and crop structure

Plant establishment

The key differences in wheat establishment and development are shown in Table 2.

At the three-leaf to one-tiller stages there was no clear nitrogen response on plant numbers, with the control (nil N applied) having comparable plant numbers to Treatment 4 (50kg N/ha applied at sowing) (data not shown).

In addition, there was no benefit of using Easy N (Treatment 2) in terms of early plant establishment compared with urea (Treatment 4), when applied at comparable rates and timings.

Tiller numbers

As tiller numbers were assessed immediately *prior* to the third node (GS33) nitrogen applications, the final nitrogen applications for Treatments 6, 8, 9 and 10 had not yet been applied. This means the results shown in Table 2 for Treatment 4 (50kg N/ha @ sowing, 50kg N/ha @ GS31) and Treatment 6 (50kg N/ha @ sowing, 50kg N/ha @ GS31, 50kg N/ha @ GS33) are both comparable to those for Treatment 2 (Easy N 50kg N/ha @ sowing, 50kg N/ha @GS31).

TABLE 1 Nitrogen treatments applied to wheat, Riverine Research Centre, 2016

Treatment	Total N applied (kg N/ha)	Sowing (GS00) (kg N/ha)	First node (GS31) (kg N/ha)	Third node (GS33) (kg Nha)
1 Control	Nil nitrogen			
2 Easy N	100	50	50	
3 Urea	100	100		
4 Urea	100	50	50	
5 Urea	100		100	
6 Urea	150	50	50	50
7 Urea	150	50	100	
8 Urea: NDVI 1	171	50	115	6
9 Urea: NDVI 2	133	50	79	4
10 Urea: N budget	204	50	100	54

TABLE 2 Plant counts 16 May 2016, three leaf–one tiller (GS13–21); tiller counts 25 August 2016, third node (GS33) and head counts 1 December 2016, harvest (GS99)

Treatment	Nitrogen treatments				Plant counts		
	Total N applied (kg N/ha)	Sowing (GS00)	First node (GS31)	Third node (GS33)	Plants/m^2 (GS13–21)	Tillers/m^2 (GS33)	Heads/m^2 (GS99)
1 Control	Nil nitrogen				157^{ab}	320^{c}	198^{c}
2 Easy N	100	50	50		144^{b}	350^{bc}	272^{ab}
3 Urea	100	100			143^{b}	372^{b}	203^{c}
4 Urea	100	50	50		163^{a}	362^{bc}	263^{abc}
5 Urea	100		100			352^{bc}	277^{ab}
6 Urea	150	50	50	50		444^{a}	289^{ab}
7 Urea	150	50	100			384^{b}	253^{bc}
8 Urea: NDVI 1	171	50	115	6		379^{b}	322^{a}
9 Urea: NDVI 2	133	50	79	4		379^{b}	270^{ab}
10 Urea: N budget	204	50	100	54		368^{bc}	294^{ab}
Mean					**152**	**371**	**264**
LSD					15	50	65

Figures followed by different letters are regarded as statistically significant.

While some significant differences in tiller numbers were measured between treatments, there are no clear messages, as comparable treatments behaved differently. For example, while the control (nil N applied) had the least number of tillers, this was not statistically different to Treatment 2 (Easy N 50kg N/ha @ sowing, 50kg N/ha @GS31) or Treatments 4, 5 or 10, which had between 100 and 150kg N/ha added. The highest number of tillers was measured in Treatment 6, in which 100kg N/ha had been applied by the GS33 assessment (which was equivalent to Treatment 4 at GS33), with the remainder of the treatments falling in between.

Head numbers

The key result from the head number assessment is that the control (nil N applied) and Treatment 3 (100kg N/ha @ sowing) were significantly lower than the Easy N treatment (Treatment 2), and Treatments 5, 6, 8, 9 and 10, all of which had a large proportion of their nitrogen allocation applied at first and third node (GS31, GS33). This result was likely due to the wet winter and spring of 2016, with nitrogen applied at sowing being subject to higher losses through leaching and denitrification.

ii) Dry matter production and nitrogen uptake

Dry matter

The differences in DM production are shown in Table 3. Measures of DM were taken early in the season, at mid-tillering (GS23), when the average DM was 0.61t/ha, and also at stem elongation (GS30), when the average DM was 0.86 t/ha. However, as there were no significant differences in DM at these times, the results are not shown in the table.

The DM production across the different treatments shows a clear trend when measured at flag leaf–start of booting (GS39–43) and at harvest (GS99). The control (nil N applied) performed as expected, producing less DM compared with the fertilised treatments. However Treatment 3 (100kg N/ha @ sowing) also performed poorly and was statistically comparable to the control, following the trend in head numbers, whereby high rates of nitrogen applied at sowing did not translate into DM production.

Nitrogen uptake

Nitrogen uptake of the crop under different fertiliser regimes is shown in Table 4. Measures of nitrogen uptake were taken early in the season at mid-tillering (GS23) and stem elongation (GS30). However, as there were no significant differences in DM at these times, the results are not shown.

Due to variation across treatments at each growth stage, nitrogen uptake across flag leaf–start of booting (GS39–45) and the start of flowering (GS61) are considered together. The treatments with consistently high nitrogen uptake are Treatment 7 (50kg N/ha @ sowing, 100kg N/ha @ GS31), Treatment 8 (NDVI1 100% yield potential: 171kg N/ha) and Treatment 10 (N budget: 204kg N/ha). The common theme across these treatments is the high rates of nitrogen applied at first node (GS31). Other treatments with high nitrogen at GS31 (Treatments 5 and 9) also showed high nitrogen uptake by the start of flowering (GS61) assessment.

TABLE 3 Dry matter 25 August 2016, third node (GS33); 15 September 2016, flag leaf fully emerged/start of booting (GS39/43); 6 October 2016, start of flowering (GS61) and 1 December, harvest (GS99)

Treatment	Nitrogen treatments				Dry matter (t/ha)			
	Total N applied (kg N/ha)	Sowing (GS00)	First node (GS31)	Third node (GS33)	GS33	GS39–45	GS61	GS99
1 Control	Nil nitrogen				1.90	3.44[c]	6.08	6.95[c]
2 Easy N	100	50	50		2.40	4.32[ab]	5.95	10.22[a]
3 Urea	100	100			2.60	3.96[abc]	6.99	7.37[bc]
4 Urea	100	50	50		2.20	4.33[a]	7.58	10.10[a]
5 Urea	100		100		2.00	3.52[bc]	6.46	9.71[ab]
6 Urea	150	50	50	50	2.20	4.47[a]	6.01	11.19[a]
7 Urea	150	50	100		2.00	4.33[a]	6.36	9.37[abc]
8 Urea: NDVI 1	171	50	115	6	2.00	4.62[a]	6.92	10.42[a]
9 Urea: NDVI 2	133	50	79	4	2.60	4.58[a]	7.34	10.69[a]
10 Urea: N budget	204	50	100	54	2.50	4.62[a]	7.34	9.69[ab]
Mean					**2.24**	**4.22**	**6.70**	**9.57**
LSD					n.s.	0.80	n.s.	2.47

Figures followed by different letters are regarded as statistically significant.

TABLE 4 Nitrogen uptake in wheat 25 August 2016, third node (GS33); 15 September 2016, flag leaf fully emerged–start of booting (GS39–43); 6 October 2016, start of flowering (GS61) and 1 December, harvest (GS99)

Treatment	Nitrogen treatments				Nitrogen uptake in crop (kg N/ha)			
	Total N applied (kg N/ha)	Sowing (GS00)	First node (GS31)	Third node (GS33)	GS33	GS39–45	GS61	GS99
1 Control	Nil nitrogen				34[e]	58[d]	57[c]	35[e]
2 Easy N	100	50	50		64[abc]	78[c]	76[c]	46[e]
3 Urea	100	100			53[bcd]	69[cd]	77[c]	34[e]
4 Urea	100	50	50		50[cd]	75[cd]	112[b]	67[bcd]
5 Urea	100		100		49[cd]	97[b]	129[ab]	70[bcd]
6 Urea	150	50	50	50	55[bcd]	99[b]	72[c]	52[de]
7 Urea	150	50	100		66[ab]	132[a]	127[ab]	86[b]
8 Urea: NDVI 1	171	50	115	6	57[a-d]	131[a]	150[a]	66[cd]
9 Urea: NDVI 2	133	50	79	4	71[a]	99[b]	141[ab]	116[a]
10 Urea: N budget	204	50	100	54	47[de]	127[a]	153[a]	72[bc]
Mean					**55**	**96**	**110**	**64**
LSD					15	18	31	19

Figures followed by different letters are regarded as statistically significant.

iii) Green leaf retention differences (NDVI)

There were eight NDVI readings carried out, using the hand-held Greenseeker, between 18 July and 6 October. These were done in order to understand the key timings where differences in treatments might be detected due to differences in plant green leaf retention. When all treatments are combined it is difficult to identify key differences (Figure 1).

As such, it may be of more value to focus on different sets of treatments in order to address specific questions.

In all of the following results, the control (nil N applied) results are shown to provide a benchmark to compare against.

Q1. *Are there differences in NDVI between Easy N and urea, when applied at the same rate and timing in wheat?*

The wheat crop was significantly 'greener' in the Easy N fertiliser treatment than the wheat treated with granular urea when the NDVI was measured at 18 and 24 August 2016, and 29 September 2016 (Figure 2).

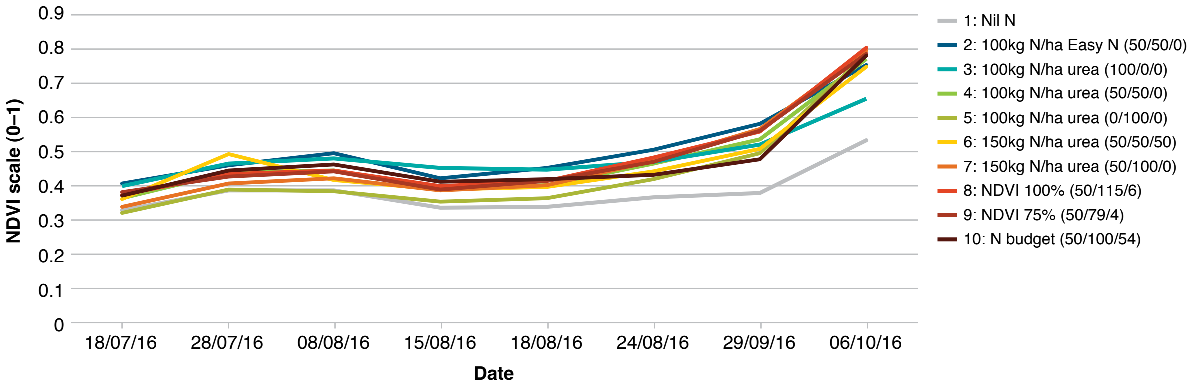


FIGURE 1 Influence of applied nitrogen timing and rate on NDVI in wheat, showing all treatments

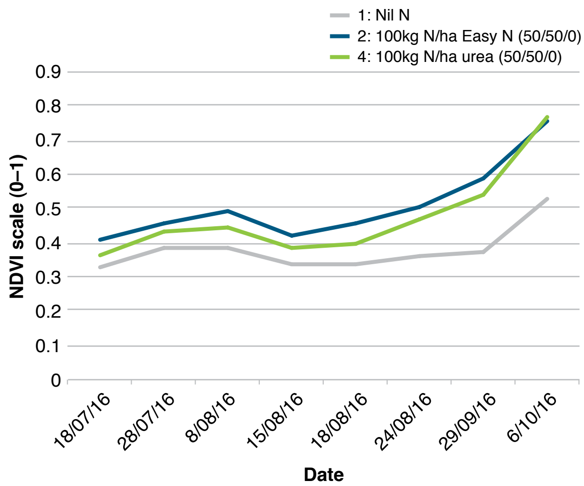


FIGURE 2 Influence of liquid Easy N compared with granular urea on NDVI in wheat*

*The first node (GS31) nitrogen was applied on 15 August 2016.

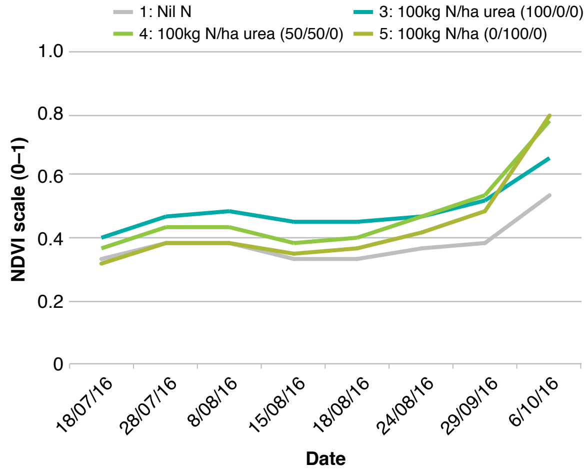


FIGURE 3 Influence of timing of urea on NDVI in wheat, showing treatments with the same total rate (100kg N/ha), at different timings*

*The first node (GS31) nitrogen was applied on 15 August 2016.

Q2. *Can NDVI pick up differences in the timing of nitrogen application in wheat, with the same total amounts applied?*

At the first NDVI reading (18 July 2016) Treatment 3 (100kg N/ha @ sowing) was significantly 'greener' than the other treatments (Figure 3). On 8 August 2016 both Treatment 3 (100kg N/ha @ sowing) and Treatment 4 (50kg N/ha @ sowing, 50 kg N/ha @ GS31) were greater than Treatment 5 (100kg N/ha @ GS31), which had not yet received any fertiliser.

Treatment 3 continued to measure significantly greater NDVI values on 15 and 18 August 2016, with Treatment 3 and 4 again 'greener' than Treatment 5 on 24 August 2016. However, at the 6 October reading Treatments 4 and 5 were significantly 'greener' than Treatment 3.

It is likely much of the applied nitrogen at sowing was lost through denitrification and leaching during the wet winter, resulting in reduced nitrogen supply to the crop through spring. Splitting the nitrogen application between sowing and first node (Treatment 4) gave a consistent plant response, while reducing the magnitude of nitrogen loss through the wet winter.

Q3. *Can NDVI pick up differences in rates of urea applied at the same timings in wheat?*

There were no differences between NDVI measurements when 100kg N/ha was applied compared to the 150kg N/ha rate (when applied at the same timings) until the final reading on 6 October 2016. At the final assessment, Treatment 7 (50kg N/ha @sowing, 100kg N/ha @GS31) had a small but significantly higher NDVI reading than Treatment 4 (50kg N/ha @ sowing, 50kg N/ha @GS31) (Figure 4).

These results suggest that plant nitrogen requirements were met with the lower application rate until late spring.

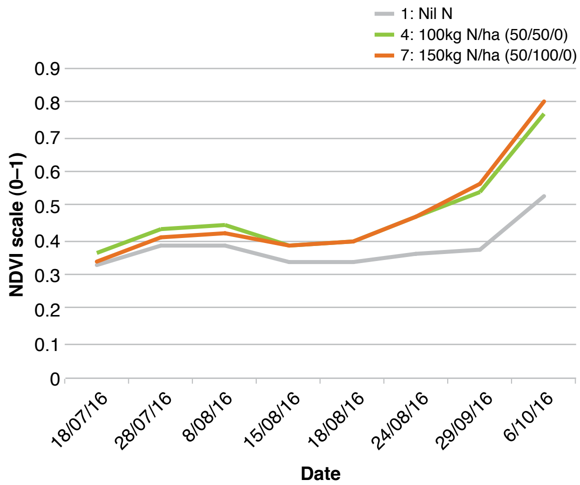


FIGURE 4 Influence of rates of urea on NDVI in wheat, showing treatments with different total rates (100 vs 150kg N/ha), at the same timings*

*The first node (GS31) nitrogen was applied on 15 August 2016. The application targeted for third node (GS33) was delayed by very wet conditions and was applied on 15 September 2016 when the crop was at the flag leaf fully emerged/start of booting (GS39/43) stage.

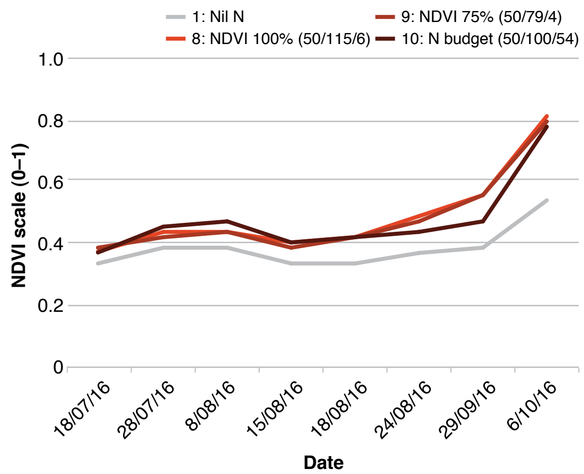


FIGURE 5 Influence of method of determining nitrogen application in wheat, showing the two NDVI-derived treatments (100% yield potential, 75% yield potential) and the nitrogen budgeting method*

*The first node (GS31) nitrogen was applied on 15 August 2016. The application targeted for third node (GS33) was delayed by very wet conditions and was applied on 15 September 2016 when the crop was at the flag leaf fully emerged/start of booting (GS39/43) stage.

***Q4.** Are there any differences in the 'alternative methods' of determining nitrogen application rates; using NDVI to determine rates required for 100% and 75% potential yield, and the highest rates applied through a nitrogen budget approach in wheat?*

The three treatments shown in Figure 5 vary in total nitrogen application from 133kg N/ha to 204kg N/ha. However, there are only limited differences in their NDVI readings. On 28 August Treatment 8 (NDVI1 100% yield potential: 171kg N/Ha), had an NDVI reading significantly higher than Treatment 10 (nitrogen budget: 204kg N/ha), while on 29 September 2016 both Treatments 8 and 9 (NDVI1 and NDVI2) had higher readings than the nitrogen budget method.

These results clearly demonstrate the value of using in-crop NDVI measurements (or satellite derived NDVI) when calculating the crop nitrogen requirements to reduce over-supply, which is further supported by the following yield data.

iv) Yield and grain quality

Yield

The lowest-yielding treatments were the control (nil N applied) and Treatment 3 (100kg N/ha@ sowing) (Table 5), both of which also had the lowest head counts (Table 2).

Due to the wet winter and spring, nitrogen losses through denitrification and leaching would likely have been high, particularly for nitrogen applied early in the season.

TABLE 5 Wheat yield, protein, test weight and screenings 11 December 2016, at harvest (GS99)

Treatment	Nitrogen treatments				Yield and quality			
	Total N applied (kg N/ha)	Sowing (GS00)	First node (GS31)	Third node (GS33)	Yield (t/ha)	Protein (%)	Test weight (kg/hL)	Screenings (%)
1 Control	Nil nitrogen				3.11^{g}	7.5^{f}	82.1^{ab}	1.0^{ab}
2 Easy N	100	50	50		4.53^{bcd}	7.8^{ef}	82.5^{a}	0.9^{ab}
3 Urea	100	100			3.55^{fg}	7.7^{ef}	82.6^{a}	1.0^{ab}
4 Urea	100	50	50		4.31^{cde}	8.6^{def}	82.1^{ab}	1.0^{ab}
5 Urea	100		100		3.85^{ef}	10.8^{bc}	81.0^{cd}	1.2^{a}
6 Urea	150	50	50	50	4.16^{de}	9.2^{de}	82.2^{ab}	0.9^{ab}
7 Urea	150	50	100		4.07^{def}	10.7^{bc}	81.2^{cd}	1.1^{a}
8 Urea: NDVI 1	171	50	115	6	4.72^{bc}	11.9^{ab}	80.9^{de}	0.9^{ab}
9 Urea: NDVI 2	133	50	79	4	5.37^{a}	10.0^{cd}	81.6^{bc}	0.8^{b}
10 Urea: N budget	204	50	100	54	4.87^{ab}	13.0^{a}	80.2^{e}	0.8^{b}
Mean					**4.25**	**9.7**	**81.6**	**1.0**
LSD					0.54	1.5	0.7	0.4

Figures followed by different letters are regarded as statistically significant.



While the other treatments would have also suffered considerable losses, having a spread of application timings (sowing, GS31 and GS33) would ensure there was recently-applied nitrogen available as the crop needed it. In comparison, applying all the nitrogen up-front means there is no further opportunity to replace nitrogen lost from the system.

The top four yielding treatments were: Treatment 8 (NDVI 1: 100% yield potential, 171kg N/ha), Treatment 9 (NDVI 2: 75% yield potential, 133kg N/ha), Treatment 10 (N budget: 204kg N/ha) and Treatment 2 (Easy N, 100kg N/ha), with Treatment 9 (NDVI 2: 75% yield potential, 133kg N/h) yielding significantly more than all others (Table 5). While the Easy N treatment yielded well, it was not significantly higher yielding than the solid urea treatment at the same rates and timings.

Protein

Treatment 10 (N budget: 204kg/ha) received 154kg N/ha between the first and third node growth stages (GS31 and GS33) and as expected, had significantly higher protein levels than all other treatments (Table 5).

The top four treatments in terms of protein levels (Treatments 5, 7, 8, 10) all had at least 100kg N/ha applied at first node (GS31).

Test weight and screenings

While significant differences were measured between the treatments for test weights and screenings, the range of values between treatments is low (Table 5).

Barley

The list of nitrogen treatments applied to barley is shown in Table 6. The treatments for barley are the same as for wheat, except for those dependent upon NDVI readings (Treatments 8 and 9), which have less total nitrogen applied compared with the wheat trial.

i) Establishment and crop structure

Plant establishment and tiller numbers

There were no differences in plant establishment or tiller number between treatments (Table 7). While there may be trends, the high variance across each replicate and within each treatment, means there is as much variability within each treatment as there is between treatments. This was likely due to the excessively wet conditions during the 2016 season.

Head numbers

The only differences in barley plant development between treatments were measured at harvest (GS99) (Table 7). Treatment 5 (100kg N/ha N @ GS31), which received all nitrogen at first node (GS31) had significantly more head numbers than all other treatments, while the lowest number of heads was measured in the control (nil N applied) and Treatment 3 (100kg N/ha @ sowing).

Due to the wet season, it is likely much of the nitrogen applied at sowing was lost through leaching or denitrification before the plant required it.

ii) Dry matter production and nitrogen uptake

Dry matter

The amount of DM produced with each nitrogen fertiliser strategy is shown in Table 8. Measures of DM were also taken earlier in the season at tillering–stem elongation (GS24–30) and again at stem elongation–first node (GS30–31), with mean values of 0.78t/ha and 0.96t/ha respectively. There were no significant differences between treatments and these results are not shown in Table 8.

There were no significant differences in DM production between each treatment due to the high variability within treatments.

TABLE 6 Nitrogen treatments applied to barley, Riverine Research Centre, 2016

Treatment no.	Total N applied (kg N/ha)	Sowing (GS00)	First node (GS31)	Third node (GS33)
1 Control	Nil nitrogen			
2 Easy N	100	50	50	
3 Urea	100	100		
4 Urea	100	50	50	
5 Urea	100		100	
6 Urea	150	50	50	50
7 Urea	150	50	100	
8 Urea: NDVI 1	140	50	85	5
9 Urea: NDVI 2	117	50	63	4
10 Urea: N budget	204	50	100	54

TABLE 7 Plant counts 16 May 2016, three leaf – one tiller (GS13–21); tiller counts 25 August 2016, third node (GS33) and head counts 1 December 2016, harvest (GS99)

Treatment	Nitrogen treatments				Plant counts		
	Total N applied (kg N/ha)	Sowing (GS00)	First node (GS31)	Third node (GS33)	Plants/m² (GS13–21)	Tillers/m² (GS33)	Heads/m² (GS99)
1 Control	Nil nitrogen				124	573	428^{d}
2 Easy N	100	50	50		112	580	521^{bcd}
3 Urea	100	100			115	496	442^{d}
4 Urea	100	50	50		124	630	558^{bcd}
5 Urea	100		100			611	728^{a}
6 Urea	150	50	50	50		570	501^{cd}
7 Urea	150	50	100			502	682^{ab}
8 Urea: NDVI 1	140	50	85	5		534	611^{abc}
9 Urea: NDVI 2	117	50	63	4		613	654^{abc}
10 Urea: N budget	204	50	100	54		529	554^{bcd}
Mean					**119**	**564**	**568**
LSD					n.s.	n.s.	168

TABLE 8 Dry matter 25 August 2016, third node (GS33); 15 September 2016, mid-booting (GS45); 6 October 2016, start of grain fill (GS71) and 1 December, harvest (GS99)

Treatment	Nitrogen treatments				Dry matter (t/ha)			
	Total N applied (kg N/ha)	Sowing (GS00)	First node (GS31)	Third node (GS33)	GS33	GS45	GS71	GS99
1 Control	Nil nitrogen				2.50	3.94	6.10	9.04
2 Easy N	100	50	50		2.90	5.00	8.61	10.94
3 Urea	100	100			2.80	4.57	8.44	9.72
4 Urea	100	50	50		3.30	3.93	9.19	10.54
5 Urea	100		100		2.40	3.66	8.00	8.26
6 Urea	150	50	50	50	3.10	4.57	9.93	10.56
7 Urea	150	50	100		2.80	3.84	8.62	9.56
8 Urea: NDVI 1	140	50	85	5	2.80	4.27	9.67	10.38
9 Urea: NDVI 2	117	50	63	4	3.10	4.61	8.76	11.69
10 Urea: N budget	204	50	100	54	3.50	4.87	11.37	9.75
Mean					**2.93**	**4.33**	**8.87**	**10.04**
LSD					n.s.	n.s.	n.s.	n.s.

Nitrogen uptake

Nitrogen uptake at mid-booting (GS45) was statistically similar in Treatments 5–10 (Table 9). However, by the start of grain fill (GS71), Treatments 8 (NDVI 1) and 10 (N budget) had the highest nitrogen uptake values, while the control (nil N applied) and Treatment 3 (100kg N/ha @sowing) had the lowest uptake values. The total nitrogen uptake values across the treatments had dropped by harvest (GS99), with NDVI 1, NDVI 2 and the N budget treatment (Treatments 8–10) having the highest values.

iii) Green leaf retention differences (NDVI)

There were eight NDVI readings carried out, using the hand-held Greenseeker, taken between 18 July and 6 October. This was done in order to understand the key timings where differences in treatments might be detected, due to differences in plant green leaf retention. When all treatments are combined it is difficult to pick out key differences (Figure 6).

Of interest is that the range of NDVI readings is less for barley than for wheat. While the wheat measurements ranged from 0.32–0.81 with a total range of 0.49, the barley measurements ranged from 0.39–0.73 with a total range of 0.34. The barley NDVI measurements also do not show the sharp rise in NDVI values on 29 September that is seen in the wheat.

The smaller range of NDVI values in barley suggests that either plant requirements were met with a number of

Table 9 Crop nitrogen uptake 25 August 2016, third node (GS33); 15 September 2016, mid-booting (GS45); 6 October 2016, start of grain fill (GS71) and 1 December, harvest (GS99)

Treatment	Nitrogen treatments				Nitrogen uptake in crop (kg N/ha)			
	Total N applied (kg N/ha)	Sowing (GS00)	First node (GS31)	Third node (GS33)	GS33	GS45	GS71	GS99
1 Control	Nil nitrogen				46^{d}	66^{c}	57^{g}	39^{f}
2 Easy N	100	50	50		79^{abc}	90^{bc}	111^{ef}	70^{cde}
3 Urea	100	100			57^{cd}	79^{c}	93^{fg}	47^{ef}
4 Urea	100	50	50		75^{abc}	68^{c}	136^{c-f}	71^{cde}
5 Urea	100		100		59^{cd}	101^{abc}	160^{b-e}	55^{ef}
6 Urea	150	50	50	50	77^{abc}	102^{abc}	119^{def}	64^{def}
7 Urea	150	50	100		93^{a}	117^{ab}	172^{bc}	87^{bcd}
8 Urea: NDVI 1	140	50	85	5	77^{abc}	121^{ab}	209^{ab}	100^{ab}
9 Urea: NDVI 2	117	50	63	4	85^{ab}	99^{abc}	169^{bcd}	94^{abc}
10 Urea: N budget	204	50	100	54	66^{bcd}	134^{a}	237^{a}	115^{a}
Mean					**71**	**98**	**146**	**74**
LSD					23	37	52	27

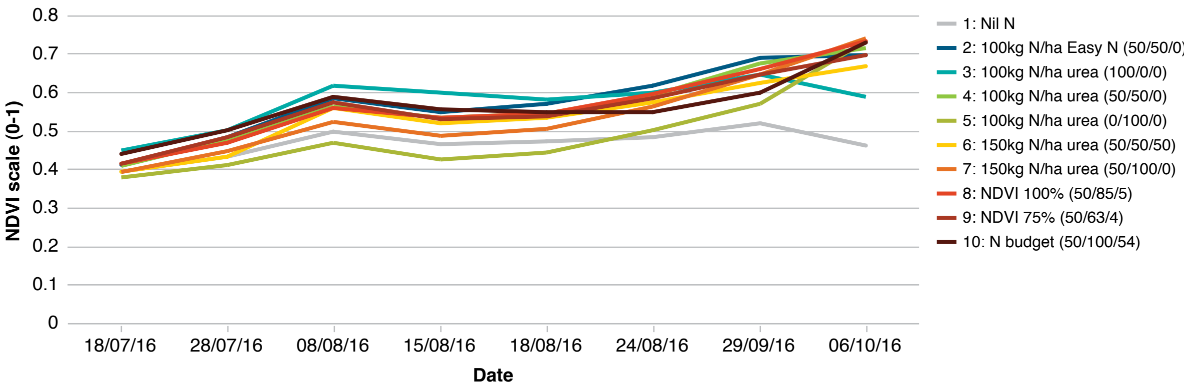


FIGURE 6 Influence of applied nitrogen timing and rate on NDVI in barley, showing all treatments

*The first node (GS31) nitrogen was applied on 15 August 2016. The nitrogen N application targeted for GS33 was delayed by very wet conditions and was applied 15 September 2016 when the crop was at mid-booting stage (GS45).

different treatments, or that the greenness of the barley plant is not as sensitive to nitrogen supply, as is the wheat plant.

As in the wheat trials, it may be of more value to focus on different sets of treatments in order to address specific questions. In all of the results shown below, the control (nil N applied) results are shown to provide a benchmark to compare against.

Q1. *Are there differences in NDVI between Easy N and urea, when applied at the same rate and timing in barley? How does this compare to wheat?*

As shown in Figure 7, there were no significant differences in green leaf retention between Easy N and urea in barley. In comparison, the Easy N treatment showed an increase in NDVI values at three measurement points in wheat, compared with urea.

Q2. *Can NDVI pick up differences in the timing of nitrogen application, with the same total amounts applied? Is this different to wheat?*

At the first NDVI measurement taken 18 July 2016 there was a significantly higher NDVI reading for Treatment 3 (100kg N/ha @ sowing) compared with Treatment 5 (100kg N/ha @ GS31), which is expected as Treatment 5 had not yet had nitrogen applied (Figure 8).

Treatments 3 (100kg N/ha @ sowing) and 4 (50kg N/ha @ sowing, 50kg N/ha @ GS31) were significantly 'greener' than Treatment 5 (100kg N/ha @ GS31) at 28 July 2016 and at 8 August 2016. On 15 August 2016 Treatment 3 (100kg N/ha @ sowing) had a significantly higher NDVI reading than Treatment 4 (50kg N/ha @ sowing, 50kg N/ha @ GS31), which was higher than Treatment 5 (100kg N/ha at GS31). From 18 to 29 August 2016, readings from Treatments 3 and 4 were significantly higher than

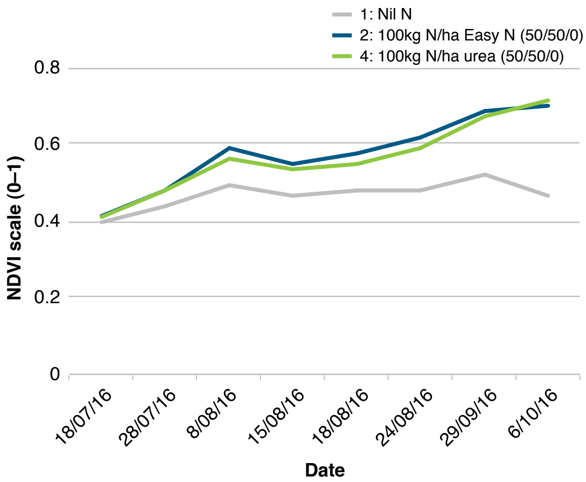


FIGURE 7 Influence of liquid Easy N compared with granular urea on NDVI in barley*

*The first node (GS31) nitrogen was applied on 15 August 2016.

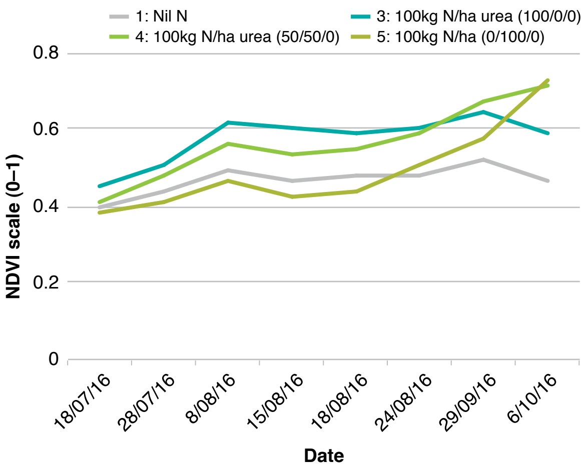


FIGURE 8 Influence of timing of urea on NDVI in barley, showing treatments with the same total rate (100kg N/ha), at different timings*

*The first node (GS31) nitrogen was applied on 15 August 2016.

Treatment 5, while at the final reading on 6 October the NDVI readings for Treatment 3 were lower than the other treatments.

These results demonstrate that the NDVI method can pick up differences in plant response to the timing of nitrogen applications in barley, as in wheat. Splitting the nitrogen between sowing and first node (GS31) gave the most consistent plant response to NDVI (Treatment 4), compared to putting all nitrogen up front at sowing (Treatment 3) and delaying application until first node (Treatment 5).

3. *Can NDVI pick up differences in rates of urea applied at the same timings?*

There were no significant differences in NDVI readings when urea was applied to barley at 50kg N/ha at sowing, and 50 or 100kg N/ha applied at first node (Figure 9). This may be due to barley nitrogen requirements being met at 100kg N/ha, with the added 50kg N/ha in Treatment 7 being above requirements.

This result is similar to that in wheat, in which the increased rate of nitrogen only showed a significant increase in NDVI at the last reading on 6 October.

Q4. *Are there any differences in the 'alternative methods' of determining nitrogen application; using NDVI to determine rates required for 100% and 75% potential yield, and the highest rates applied through a nitrogen budget approach? How does this compare to wheat?*

There were no differences in NDVI between the 100% crop potential NDVI treatment (Treatment 8) and the 75% crop potential NDVI treatment (Treatment 9). The only difference in NDVI readings between the two NDVI-derived treatments and the nitrogen budget treatment (Treatment 10), was on 29 August when the 100% NDVI treatment was significantly 'greener' than the nitrogen budget treatment. This suggests that all of these treatments added surplus nitrogen beyond what was required for plant growth (Figure 10).

The wheat and barley NDVI results were similar when comparing the alternative methods of determining nitrogen application rates, with no added plant response from the large rate in the nitrogen budget treatment.

A key finding from the results (Figure 10) is that using the NDVI hand-held Greenseeker sensor to guide decisions on plant-nitrogen requirements provided the barley crop

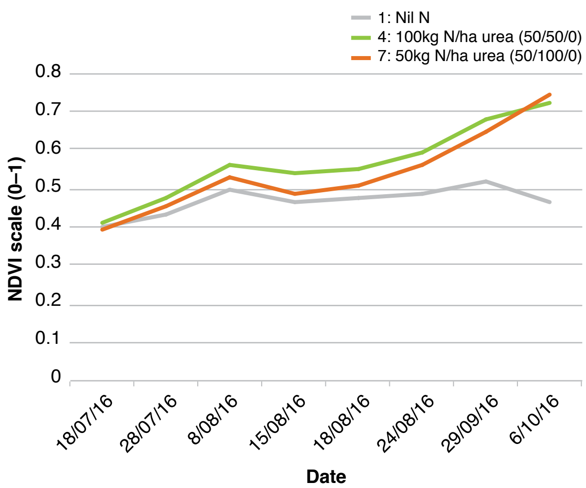


FIGURE 9 Influence of rates of urea on NDVI in barley, showing treatments with different total rates (100 vs 150kg N/ha), at the same timings*

*The first node (GS31) nitrogen was applied on 15 August 2016. The N application targeted for GS33 was delayed by very wet conditions and was applied 15 September 2016 when the crop was at mid-booting stage (GS45).



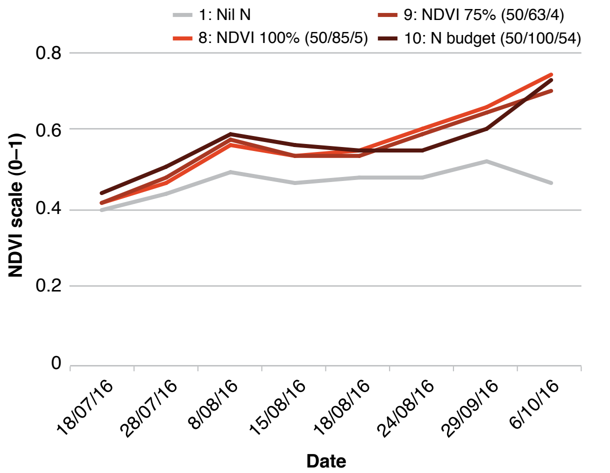


FIGURE 10. Influence of method of determining nitrogen application in barley, showing the two NDVI-derived treatments (100% yield potential, 75% yield potential) and the nitrogen budgeting method*

*The first node (GS31) nitrogen was applied on 15 August 2016. The N application targeted for GS33 was delayed by very wet conditions and was applied 15 September 2016 when the crop was at mid-booting stage (GS45)

with adequate nutrition. This was achieved at a lower rate per hectare than if nitrogen was applied following the nitrogen budget scenario. This is also supported in the yield results.

iii) Lodging

Lodging of the barley was assessed on 1 December 2016, just before harvest. While there was a range of lodging scores measured, from 9–64 (severity x per cent of plot), the high variability meant there were no significant treatment effects (data not shown).

iv) Yield and grain quality

Yield

Most of the treatments had comparable yields (Table 10). The control (nil N applied) treatment yielded significantly less than all the other treatments, with Treatment 3 (100kg N/ha @ sowing) having the next lowest yields.

The yield data largely matches the comparisons made in NDVI measurements; where the NDVI readings showed no significant differences, the yield data showed the same result.

Protein

The protein results were strongly driven by nitrogen splits with high levels of fertiliser applied from first node (Table 10). The highest protein levels were measured in treatments where 50kg N/ha was applied at sowing, which were then followed up with large (85–100kg N/ha) applications at first node (Treatments 7, 8, 10).

The protein levels in the nitrogen budget treatment (Treatment 10), were significantly higher than all others, which is somewhat expected as a total of 204kg N/ha was applied, with 154kg N/ha applied from first to third node (GS31–33).

The lowest protein levels were measured in Treatments 1–4, which had either nil or 100kg N/ha applied, with at least half of the nitrogen applied at sowing.

Test weight and screening

While the range in test weights was low (4.1kg/hL), screenings were significantly higher when more than 50kg N/ha was applied at first node (GS31) (Table 10).

TABLE 10 Barley yield, protein, test weight and screenings 11 December 2016, at harvest (GS99)

Treatment	Nitrogen treatments				Yield and quality			
	Total N applied (kg N/ha)	Sowing (GS00)	First node (GS31)	Third node (GS33)	Yield (t/ha)	Protein (%)	Test weight (kg/hL)	Screenings (%)
1 Control	Nil nitrogen				3.55^{c}	8.0^{e}	64.3^{ab}	2.5^{c}
2 Easy N	100	50	50		5.27^{a}	8.5^{de}	64.1^{ab}	5.5^{bc}
3 Urea	100	100			4.33^{b}	8.4^{de}	65.3^{a}	4.3^{bc}
4 Urea	100	50	50		5.18^{a}	8.6^{de}	65.7^{a}	5.8^{bc}
5 Urea	100		100		5.13^{a}	9.6^{c}	63.5^{ab}	9.9^{a}
6 Urea	150	50	50	50	4.85^{ab}	9.2^{cd}	63.7^{ab}	4.3^{bc}
7 Urea	150	50	100		5.18^{a}	10.7^{ab}	63.2^{ab}	10.0^{a}
8 Urea: NDVI 1	140	50	85	5	5.23^{a}	10.6^{b}	63.0^{ab}	9.6^{a}
9 Urea: NDVI 2	117	50	63	4	5.21^{a}	9.2^{cd}	62.1^{b}	7.4^{ab}
10 Urea: N budget	204	50	100	54	5.37^{a}	11.5^{a}	61.6^{b}	11.0^{a}
Mean					**4.93**	**9.4**	**63.7**	**7.1**
LSD					0.73	0.8	2.9	3.7

Figures followed by different letters are regarded as statistically significant.

Conclusions

The extremely wet winter and spring of 2016 led to transient waterlogging at the trial site. While this was a statistically designed, replicated trial, waterlogging varied randomly across the site, following the microtopography. This explains the relatively high LSD (least significant difference) values across the site, and why some nitrogen treatments did not behave consistently.

Therefore, rather than one particular treatment being considered the best, it is more the general strategy which is more useful to consider.

In both wheat and barley, the timing of the fertiliser application was important in achieving a greater crop response in most parameters, including NDVI and yield.

There was little difference in plant performance between the liquid Easy N and comparable urea rate. While an increase in plant greenness was detected with the Easy N at several NDVI measurement points in wheat, this did not correspond to any increase in final DM or yield.

As the greatest protein responses for both wheat and barley were seen with Treatment 10 (nitrogen budget approach), it is difficult to know if this is due more to the total rate of nitrogen applied (204kg N/ha), or if the 54kg N/ha applied at third node (GS33) was the key factor.

The NDVI method of assessing nitrogen status in-crop, and using these numbers to determine the rate and timing of nitrogen applied (Treatment 8 and 9) aligned well with final yield responses in both wheat and barley. This indicates the total amount of nitrogen applied could be better aligned with crop requirements using this tool, which could result in cost savings. However, for this to work in-crop, a nitrogen-rich strip needs to be used in each paddock in order to provide a benchmark NDVI reading for a non-nitrogen limited crop.

This trial was run at the Riverine Research Centre (RRC), an independent and dedicated crop research site located near Yarrawonga, Victoria. The RRC is a partnership between Riverine Plains Inc and FAR Australia and is supported by RRC hosts, the Cummins family.

Contact

Dr Cassandra Schefe Riverine Plains Inc

T (03) 5744 1713

E cassandra@riverineplains.org.au



Harvest weed seed control for the southern high-rainfall zone

Kate Coffey[1], Michael Straight[2], Roger Lawes[3]

[1] Riverine Plains Inc

[2] FAR Australia

[3] CSIRO Agriculture

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.
- Where pre-emergent or in-crop herbicides have not been applied, ryegrass weeds are shedding before wheat is harvested.

Aim

The aim of this work is to understand if growers can reduce soil weed seedbanks in high-yielding high-rainfall zones by adopting harvest weed seed control (HWSC) practices.

Background:

The four-year project (2015–18), aims to investigate the efficacy of HWSC practices across southern Australia through partnerships with Southern Farming Systems, Mackillop Farm Management Group, Riverine Plains Inc and Farmlink. The project includes four small plot trials and six on-farm demonstration sites across the different regions.

The small plot trials are investigating the impact of harvest height on weed seedbanks. The height of the weed seed within the crop determines the harvest height required to collect most weed seeds.

The on-farm demonstration sites are investigating the impact on weed seedbanks of narrow windrow burning (harvest low 15cm), using a weed seed mill (harvest 15cm) and a grower treatment involving the separation of chaff and straw, with the chaff dropped on top of the straw and then baled. These treatments will be compared against a traditional blanket burn.

Method

The Riverine Plains Inc small plot trial was established at Yarrawonga, Victoria during 2016.

Soil weed seedbanks were measured before sowing, and annual ryegrass was sown to reflect commercial grower experiences of: nil (no ryegrass sown), 25 plants/m^2, 50 plants/m^2 and 75 plants/m^2. This was done to offset the spatial variability in weed seed across a paddock, ensuring a relatively even distribution of weed seeds across the various treatments.

The site was sown to wheat (cv Corack) on 28 April 2016. No pre-emergent or in-crop herbicides were applied.

The crop was sown into a wheat stubble with 75kg MAP at sowing and 100kg of urea applied by plane on 10 August 2016 at first node (GS31).

The trial was a split plot randomised design with the main plot being harvest height with residue removed (15cm and 30cm) and the split plot being ryegrass density.

The plots were replicated five times and were 2m wide and 15m long.

Residue was collected by attaching a fertiliser bulk bag to the back of the plot harvester and regularly unloading straw and chaff away from the plots. The straw and chaff was burnt after harvest. The removal of residue replicates weed seed capture using a broadacre HWSC technique, such as a chaff cart.

Annual ryegrass plant numbers were measured when the wheat was at the two leaf stage (GS12) and again when the wheat had three tillers (GS23). Ryegrass seed shedding was measured weekly from 11 November 2016, which was when the ryegrass was mid-flowering (GS65), until the wheat was harvested on 11 December 2016. Seed shedding was measured by counting the number of seeds that fell into two small trays placed in each plot.

Data were analysed with an analysis of variance (ANOVA), where data were log transformed for normality if needed and 95% confidence intervals were estimated from the statistical analysis.

Results

Soil seedbank tests on the site prior to sowing indicated ryegrass populations of 3.42 plants/m^2. Actual ryegrass emergence in nil ryegrass sown plots indicated a much higher seedbank (an average of 46.9 plants/m^2 when the wheat was at the two-leaf stage (GS12)).

Ryegrass plant densities averaged 57 plants/m^2 when the wheat was at the two-leaf stage (GS12) and 77 plants/m^2 when the wheat had three tillers (GS23) (Table 1). When measured again at the wheat hard dough stage (GS87), the number of ryegrass spikelets averaged 804 spikelets/m^2. This equates to approximately 4824 seeds/m^2, based on an average number of six seeds per spikelet.

The weekly number of seeds shed by the ryegrass prior to harvest commenced with an average of 506 seeds/m^2 during the second week of November and increased to an average of 1355.22 seeds/m^2 by the first week in December (Table 2).

The wheat yielded 3.03t/ha with protein of 8.16% and screenings of 1.94% (Table 3). There were high numbers of ryegrass seeds in the harvest sample.

Observations and comments

The decile 9 growing season rainfall (GSR) of 604mm experienced during 2016 significantly impacted yield due to waterlogging at the trial site. The extremely wet season also made it difficult to apply adequate nitrogen to the crop.

Sowing the HWSC plot trials, May 2017.

TABLE 1 Ryegrass density measured at wheat two-leaf stage (GS12) on 20 May, wheat three-tiller stage (GS23) on 27 June, and wheat hard-dough stage (GS87) on 24 November 2016 at Yarrawonga

Measurement	Ryegrass plants/m^2	Ryegrass plants/m^2	Ryegrass spikelets/m^2
Assessment timing (wheat growth stage)	GS12	GS23	GS87
Mean	56.57	76.52	803.93
Confidence interval (95%)*	33.00 – 96.94	49.38 – 118.59	266.34 – 2426.59

* The confidence interval shows the range of measurements around the mean and gives an indication of the variability of the measure, in this case, ryegrass numbers.

TABLE 2 Ryegrass weekly seed shedding measurements at Yarrawonga during November and December 2016

Measurement	Ryegrass seed shed/m^2	Ryegrass seed shed/m^2	Ryegrass seed shed/m^2	Ryegrass seed shed/m^2
Assessment timing	11/11/2016	18/11/2016	24/11/2016	2/12/2016
Mean	506.00	427.10	1359.24	1355.22
Confidence interval (95%)*	339.67–753.79	246.41–740.27	983.02–1879.43	955.28–1922.60

* The confidence interval shows the range of measurements around the mean and gives an indication of the variability of the measure, in this case, ryegrass numbers.

TABLE 3 Wheat density, yield, protein and screenings Yarrawonga, 11 December 2016

	Density (plants/m^2)	Yield (t/ha)	Protein (%)	Screenings (%)
Mean	130.56	3.03	8.16	1.94
Confidence interval (95%)*	75.18 – 185.93	2.75 – 3.32	7.40 – 8.92	1.25 – 2.63

* The confidence interval shows the range of measurements around the mean and gives an indication of the variability of the measure, in this case, ryegrass numbers.

Weeds (mainly ryegrass, with some Paterson's curse, brome grass and volunteer canola) thrived at the site. Many of the ryegrass weed seed heads lodged on the ground, making them difficult to pick up with the header.

As there were no other weed control treatments besides harvest removal of residue, any inferences as to the efficacy of weed seed control through variable harvest height cannot be made until the end of 2017. However, the data collected indicates that when there are high populations of ryegrass (>20 plants/m^2), the large amount of ryegrass seed shed prior to harvest limits the amount that can be collected during the harvesting process. This means where ryegrass weed populations are high, harvest weed seed control cannot be used as the only weed control strategy, but needs to be integrated with other strategies for effective control.

Much of the data on ryegrass weed populations has been collected in the low-to-medium rainfall zones. This project is collecting information to understand the most cost-effective ways to manage ryegrass populations in the high-rainfall zone.

Sponsors

This project is funded by GRDC project SFS00032 *Harvest weed seed control for the southern high rainfall zone and led by Southern Farming Systems*. Thanks also go to Baker Seed Co, the Trevethan family and the Inchbold family as farmer co-operators during 2015 and 2016.

Contact

Kate Coffey Riverine Plains Inc
T: (03) 5744 1713
E: kate@riverineplains.org.au

Seasonal soil moisture and nitrogen availability — Rutherglen and Boorhaman regions

Dr Cassandra Schefe[1] and Stephen Lowe[2]

[1] Riverine Plains Inc

[2] Stony Creek Vineyard

Key points

- Soils in the Rutherglen region of Victoria are highly variable.
- While most soils across the region increase in clay content in the subsoil, there is a vein of sandy subsoil running through the Boorhaman region.
- The wet winter and spring of 2016 resulted in nitrogen (N) movement to depth through leaching.
- 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 in the profile, and how readily plants can access it.

Background

During June 2015, the North East Catchment Management Authority (NECMA) provided funds to 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 was for growers to better understand how knowledge of stored soil moisture levels can inform their decisions about applying fertiliser. For example, if the soil profile has sufficient moisture, growers might 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 depend entirely on in-crop rainfall events to reach maturity. The project also involved measurements of DSN post-harvest and pre-sowing to account for the amount of nitrogen mineralised during summer.

Additional funding from The Sustainable Agriculture Victoria: Fast-Tracking Innovation initiative, made possible with the support of Foundation for Rural and Regional Renewal (FRRR) together with the William Buckland Foundation, allowed DSN sampling (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).

The *Connecting Fertiliser Requirements with Soil Water Storage and Soil Type in Cropping Systems* project started during 2016 and extends upon the work undertaken during 2015. This project was funded by NECMA through the Australian Government's National Landcare Programme.

Some of the soil moisture probes from the original *Soil Moisture Probe Network Project* were relocated into the Boorhaman area through a partnership with the Boorhaman Landcare Group. Soil moisture monitoring continued until sowing 2017, with DSN sampling also continuing until pre-sowing 2017.

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 re-installed at 11 sites across the Rutherglen-Boorhaman region during July 2016. Probes were removed for harvest (November 2016) and again in preparation for sowing (late March 2017). Each probe measured up to four depth intervals (10, 30, 50 and 90cm below the soil surface), with data 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 July 2016, and January and April 2017 (Figure 1). The July DSN sampling was timed to coincide with the typical sampling programs of the region's growers, who use the results to identify how much nitrogen they need to apply to meet crop demand through spring. The post-harvest January sampling provided a measure of post-crop residual nitrogen, while the April sampling provided information on the amount of nitrogen lost or mineralised during the summer months.

Sampling at each of the 11 soil moisture probe sites consisted of one core sample, which was split into increments (0–10, 10–30, 30–60cm) before being

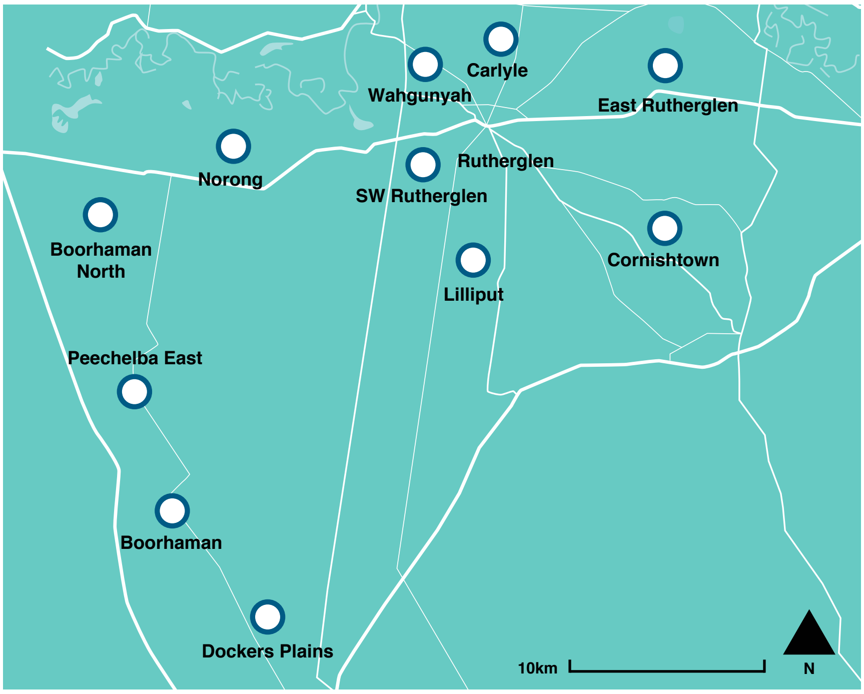


FIGURE 1 Locations of 11 soil moisture probes installed across the Rutherglen and Boorhaman areas.

analysed at the laboratory for mineral nitrogen (nitrate + ammonium) and total nitrogen (includes organic and inorganic forms — i.e. the total nitrogen soil bank).

The data from the nitrogen samples cannot be statistically analysed because the collection was not replicated. While the results provide an indication of nitrogen availability, they are sampled from only one point in the paddock and there is the possibility the results are not representative of the rest of the paddock.

Results

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.

Soil mineral nitrogen is comprised of nitrate and ammonium, both of which are measured in a standard soil test. These nitrogen fractions are added together to give a total *mineral nitrogen* value. As the ammonium fraction is sensitive to waterlogging (it becomes elevated under anaerobic, waterlogged conditions), only the nitrate-nitrogen fraction is presented to allow comparison between very wet and dry periods of sampling.

The monthly rainfall data for Rutherglen is presented in Figure 2. Winter and spring were wetter than average, with September 2016 receiving more than double the long-term median rainfall. In comparison, the 2016–17 summer was dry, with little soil moisture available to aid mineralisation (the microbial conversion of organic nitrogen into plant-available, *mineral* nitrogen).

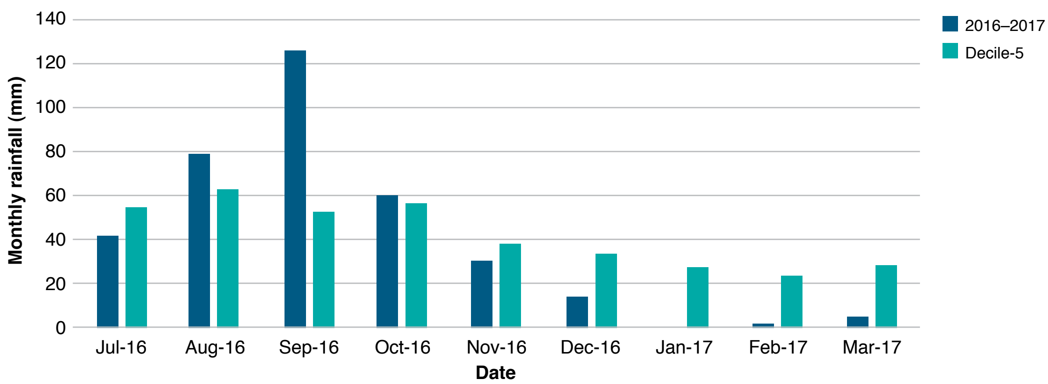


FIGURE 2 Monthly rainfall recorded at Rutherglen, July 2016 – March 2017, compared with the long-term decile-5 (median) rainfall

Location: Dockers Plains

2015 crop and stubble practice: Wheat, stubble burnt
2016 crop and yield: Wheat, 4t/ha
2016 nitrogen applied: 8kg N/ha MAP, 92kg N/ha urea
Timing of 2016 in-crop N application: June, August
2016 stubble management (post-harvest): Sown to lucerne

The Dockers Plains site maintained high soil moisture through most of the growing season, as would be expected (Figure 3). Based on the soil moisture probe, the surface soil appears free draining with the 10cm sensor showing short increases in moisture content after rainfall, before returning to a steady level. The common soil moisture levels for the 10cm and 30cm layers indicate they are both quite light textured, with plants easily extracting water from these layers when conditions started to dry out during October. Plants also accessed the 50cm layer from mid-October onwards, as seen by the drop in soil moisture in the 50cm layer by the end of the season. The 90cm layer likely contains a higher clay content, with no measurable water uptake by plants.

The July nitrate-nitrogen results show that nitrate was leached, moving to 30–60cm depth with the high winter rainfall (Figure 4). Depletion of this nitrogen at depth, combined with higher clay contents at depth (which would minimise further leaching), suggest plant roots accessed this nitrogen during the second half of the season.

Mineralisation of organic nitrogen to nitrate-nitrogen was measured during summer and was more evident in the April 2017 sampling.

The increased nitrate-nitrogen in the surface soil in the absence of fertiliser, with minimal nitrogen at depth, is indicative of mineralisation.

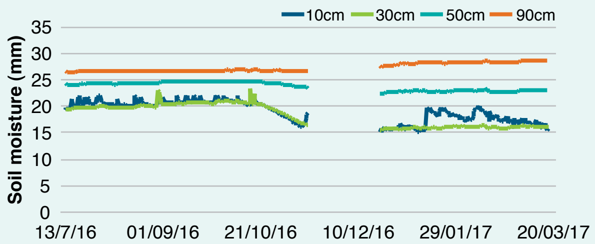


FIGURE 3 Soil moisture levels at Dockers Plains, Victoria, July 2016 – March 2017

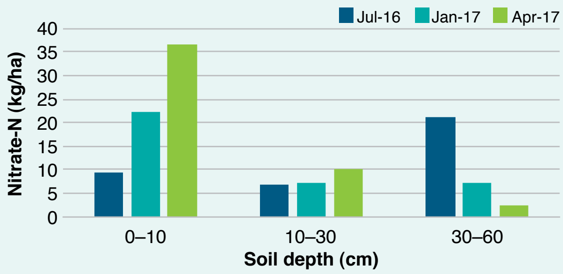


FIGURE 4 Plant-available (nitrate) soil nitrogen levels at Dockers Plains, Victoria, July 2016 – April 2017

Location: Boorhaman

2015 crop and stubble practice: Wheat, baled straw
2016 crop and yield: Canola, 2t/ha
2016 nitrogen applied: 8kg N/ha MAP, 115kg N/ha urea
Timing of 2016 in-crop N application: Early June, mid-July
2016 stubble management (post-harvest): Sheep grazed, harrowed, burnt

The Boorhaman site showed high soil moisture through the season, with the same water content shown in the 10cm and 30cm depths. The soil at 30cm depth is of a heavier texture than the surface soil (Figure 5) and while the plants extracted water down to 30cm, more water was extracted from the surface soil. As the Boorhaman soil moisture probe was only installed during July 2016, there is no historical data of subsoil moisture extraction. Therefore, it is not known if the 50cm, and 90cm depths were saturated, or if they would remain at the same level in dry seasons, in which case there is a possibility the water is not percolating to depth due to physical constraints or a strong texture change to a heavy clay.

The low value of nitrate-nitrogen measured during July in the 0–10cm and 10–30cm layers indicates the urea applied in early June may have been largely lost (Figure 6). This highlights the value of split applications, as a follow-up urea application during mid-July (after soil sampling) was needed to meet plant requirements for the rest of the season.

There is some evidence plant roots moved deeper than the 30cm layer, based on the bulge of nitrate-nitrogen measured in the 30–60cm depth in July 2016 (Figure 6), which was likely due to leaching and which had largely disappeared by January 2017.

Mineralisation of organic nitrogen into mineral available nitrogen over summer was high at this site, with 95kg N/ha of mineral nitrogen measured in the 0–10cm depth at the start of sowing.

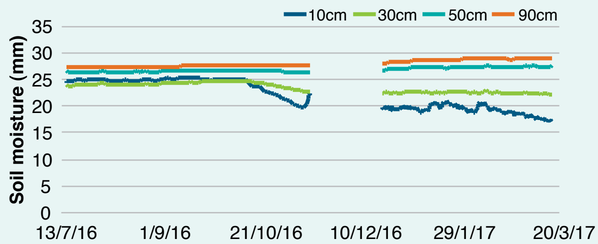


FIGURE 5 Soil moisture levels at Boorhaman, Victoria, July 2016 – March 2017

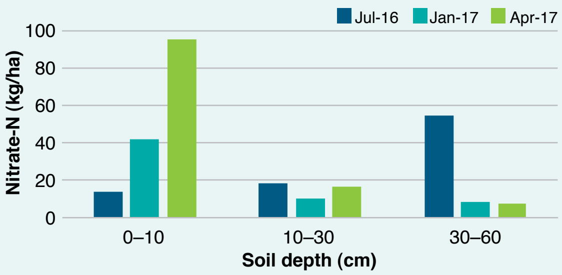


FIGURE 6 Plant-available (nitrate) soil nitrogen levels at Boorhaman, Victoria, July 2016 – April 2017



Location: Peechelba East

2015 crop and stubble practice: Wheat, burnt

2016 crop and yield: Wheat, 4.5t/ha

2016 nitrogen applied: 9kg N/ha MAP, 129kg N/ha urea

Timing of 2016 in-crop N application: Sowing, end June, mid-August

2016 stubble management (post-harvest): 50% retained, 50% burnt

The surface soil at Peechelba East is light textured, as seen by the large fluctuations in soil moisture levels in the 0–10cm layer and the low base level of soil moisture measured, which was less than 10mm by mid-March 2017 (Figure 7). The 30cm layer is a heavier soil type and it showed a much smaller change in soil moisture after harvest. The lack of change in soil moisture in the heavier clay subsoil indicates the plant roots did not access significant water at that depth.

Levels of nitrate-nitrogen were low at all depths in July 2016 (Figure 8), which suggests some of the urea applied at the end of June was lost by leaching or denitrification (gaseous nitrogen loss). The follow-up urea application in mid-August was needed to replace the lost nitrogen and meet crop needs.

Summer mineralisation of nitrogen was supported at Peechelba East by the rainfall in December 2016. While some nitrate-nitrogen was measured at depth in July 2016, this was not detected in the January 2017 sampling.

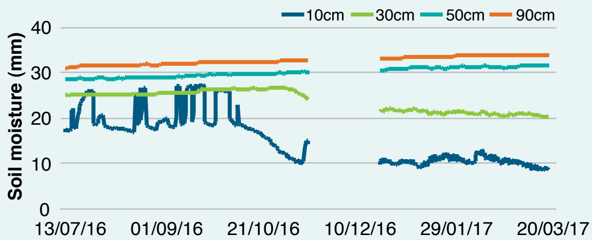


FIGURE 7 Soil moisture levels at Peechelba East, Victoria, July 2016 – March 2017

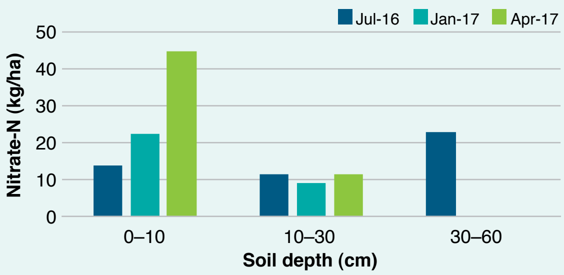


FIGURE 8 Plant-available (nitrate) soil nitrogen levels at Peechelba East, Victoria, July 2016 – April 2017

A high nitrate reading (63kg N/ha) measured for the 30–60cm depth in April 2017 was considered to be an analytical error and removed

Location: Boorhaman North

2015 crop and stubble practice: Wheat, windrowed and baled

2016 crop and yield: Canola, 1.5 t/ha

2016 nitrogen applied: 10kg N/ha MAP, 92kg N/ha urea

Timing of 2016 in-crop N application: Early June

2016 stubble management (post-harvest): Retained

The Boorhaman North site has a sandy loam surface soil, with a sand layer at the 10–30cm depth. This can be seen in the soil moisture graph (Figure 9), which shows substantial storage and extraction of water from the surface soil, but a lower soil moisture storage at 30cm depth. The lack of fluctuation in the 30cm layer through the wet season suggests this layer reached field capacity early in the season and did not dry out until late in October, after the 10cm layer started to deplete.

Nitrate-nitrogen concentrations were at low levels during July, likely due to high movement of nitrogen to depth as well as lateral movement through the sand layer (Figure 10). While some mineralisation was measured in the 0–10cm layer in January 2017, this was the only site to not show increased nitrate-nitrogen levels during April 2017 due to summer/autumn mineralisation. This suggests that the soil sampling carried out at this site in April may have not been representative of the paddock, or that some of the 0–5cm soil (where most of the nitrogen is), had been accidentally removed.

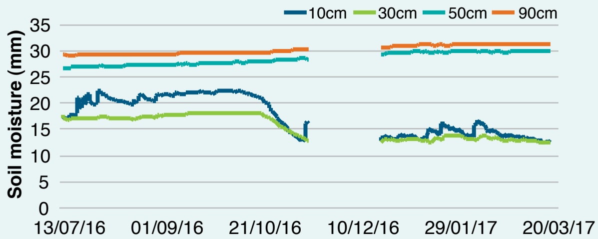


FIGURE 9 Soil moisture levels at Boorhaman North, Victoria, July 2016 – March 2017

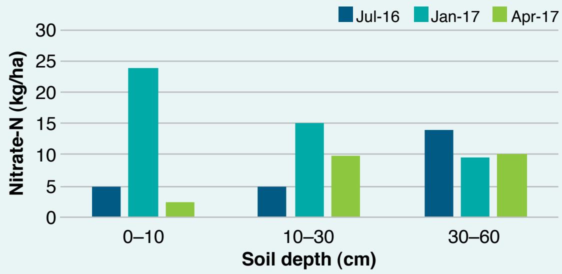


FIGURE 10 Plant-available (nitrate) soil nitrogen levels at Boorhaman North, Victoria, July 2016 – April 2017

Location: South-west Rutherglen

2015 crop and stubble practice: Wheat, burned
2016 crop and yield: Canola, 1.7t/ha
2016 nitrogen applied: 10kg N/ha MAP, 69kg N/ha urea
Timing of 2016 in-crop N application: Mid-July
2016 stubble management (post-harvest): Burnt patches

The soil moisture profile at the South-west Rutherglen site (Figure 11) shows this soil has a high capacity to store and release water, based on the range of fluctuation in the 10–30cm layers, and to a lesser degree in the 50cm layer. As at the Boorhaman North site, this soil has a lighter-textured layer at 30cm, which shows less capacity to store water than the 10cm layer.

By the end of the season the roots had accessed most of the available water from the 10 and 30cm layers, however data from 2015–16 (*Research for the Riverine Plains 2016,* p73) showed both layers have usable stored water down to 13–15mm.

This soil type has a lighter texture at 30cm, and can easily leach nitrate-nitrogen as is shown by the low nitrogen values during July (Figure 12). The soil samples were taken on 19 July, likely just prior to the mid-July fertiliser application. Nitrogen mineralised over summer/autumn most probably moved down to the 10–30cm depth, due to the light texture of the soil and high capacity of nitrogen to move through the 0–30cm layer.

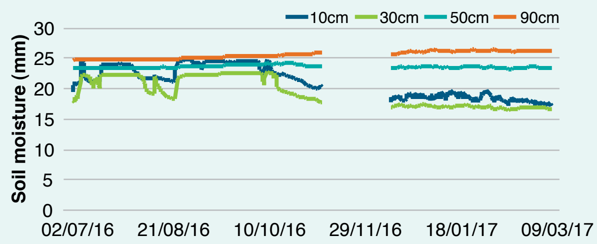


FIGURE 11 Soil moisture levels at south-west Rutherglen, Victoria, July 2016 – March 2017

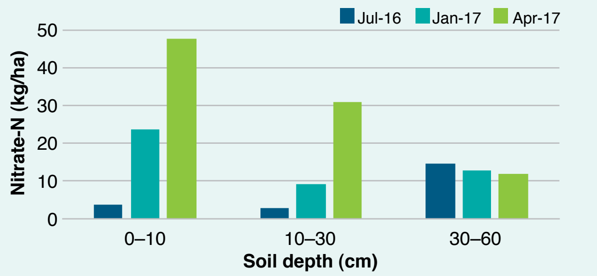


FIGURE 12 Plant-available (nitrate) soil nitrogen levels at south-west Rutherglen, Victoria, July 2016 – April 2017

Location: Wahgunyah

2015 crop and stubble practice: Wheat, burned
2016 crop and yield: Triticale, 4.2t/ha
2016 nitrogen applied: 10kg N/ha MAP, 92kg N/ha urea
Timing of 2016 in-crop N application: Early June, late August
2016 stubble management (post-harvest): Burnt

The soil moisture levels at the Wahgunyah site remained high for most of the season, with plant roots starting to visibly extract soil water from late October 2016 (Figure 13). While a soil pit has not been dug at this site, the range in soil moisture in the 10cm layer suggests a loam-type soil, with the ability to hold a significant amount of plant-available water. Plants also accessed soil moisture in the 30 and 50cm layers.

Based on the 2015–16 results (which showed more movement in the soil moisture levels in the 50cm layer), there may be still appreciable amounts of plant-available water stored at depth, which could be accessed during 2017.

The amount of nitrate-nitrogen in the 0–10cm layer was low during July 2017, with a slight increase in the 30–60cm layer (Figure 14). The light texture of this soil means if the urea applied during early June was not used immediately by the crop, then it may have leached vertically, as well as being lost through denitrification. The decrease in nitrate-nitrogen between July 2016 and January 2017 at the 30–60cm layer means the nitrogen was either extracted by roots (which is likely based on the soil moisture patterns), or was lost to deep leaching (which is less likely given the high clay content at 90cm).

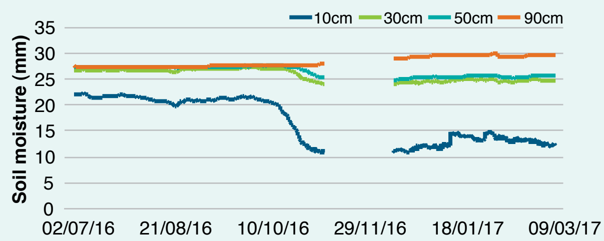


FIGURE 13 Soil moisture levels at Wahgunyah, Victoria, July 2016 – March 2017

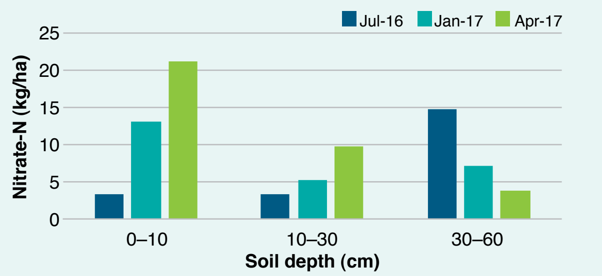


FIGURE 14 Plant-available (nitrate) soil nitrogen levels at Wahgunyah, Victoria, July 2016 – April 2017



Location: Carlyle

2015 crop and stubble practice: Wheat, cut for hay
2016 crop and yield: Triticale, cut for hay 6.9t/ha
2016 nitrogen applied: 10kg N/ha MAP, 69kg N/ha urea
Timing of 2016 in-crop N application: July
2016 stubble management (post-harvest): Multidisc

The lack of change in soil moisture at the Carlyle site suggests it is a heavy clay soil, which means run-off is likely due to limited infiltration following saturation (Figure 15). While some movement in soil water was evident at the end of the season, the range of fluctuation in moisture levels remained narrow.

While the site remained wet all winter, nitrate-nitrogen levels were low prior to the July fertiliser application, with some nitrogen moving to depth by July 2016 (Figure 16). Denitrification rates were likely high at this site due to the consistently high soil moisture content.

While some mineralisation of organic nitrogen did occur before the January 2017 sampling, this did not increase further before sowing. This was in contrast to many of the sites and suggests some of this nitrogen may have been left over from the in-crop applications.

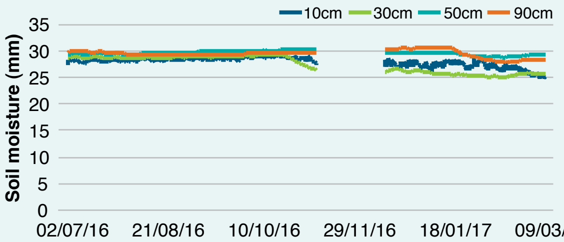


FIGURE 15 Soil moisture levels at Carlyle, Victoria, July 2016 – March 2017

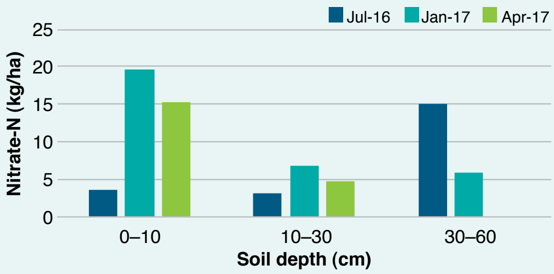


FIGURE 16 Plant-available (nitrate) soil nitrogen levels at Carlyle, Victoria, July 2016 – April 2017

Location: East Rutherglen

2015 crop and stubble practice: Wheat, burnt
2016 crop and yield: Canola, 2t/ha
2016 nitrogen applied: 7.5kg N/ha MAP, 101kg N/ha urea
Timing of 2016 in-crop N application: late May, early July
2016 stubble management (post-harvest): Retained

The East Rutherglen site was wet through winter and spring 2016. The 10cm depth stayed wet until mid-October 2016 when it started to drain, while the 30cm layer appeared to be saturated from July to September (Figure 17). This is likely due to the increasing clay content to depth, which would have slowed drainage.

The separation of the lower depth soil moisture levels from pre-harvest to post-harvest, indicates the canola may have actively extracted moisture down to 50cm.

Although the clay content increases to depth in this soil, water movement did still occur as shown in the nitrate-nitrogen results (Figure 18). A large amount of nitrate moved to the 30–60cm depth by July (67kg N/ha), however about two-thirds of this nitrogen was likely extracted by plant roots through the season (the high clay content would minimise further leaching), as shown by the reduced concentrations at depth post-harvest.

While mineralisation of organic nitrogen post-harvest was comparable with most other sites, it appears less in Figure 18 due to the scale of the graph. Furthermore, as the 0–10cm nitrogen values were higher during January than April 2017, it is possible some of this summer nitrogen remained from the in-crop applications, with the amount decreasing over summer due to microbial or gas losses.

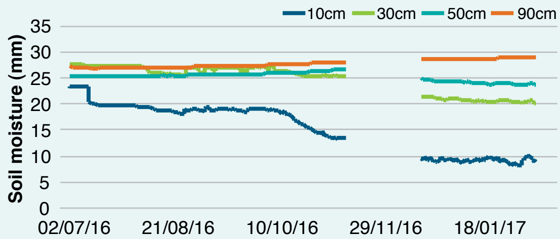


FIGURE 17 Soil moisture levels at East Rutherglen, Victoria July, 2016 – March 2017

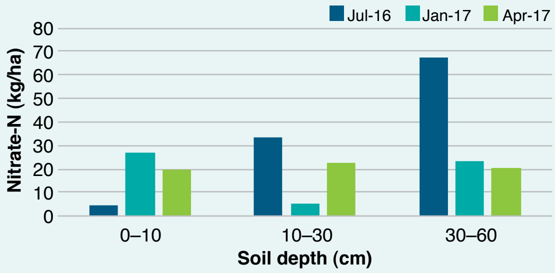


FIGURE 18 Plant-available (nitrate) soil nitrogen levels at East Rutherglen, Victoria, July 2016 – April 2017

Location: Cornishtown

2015 crop and stubble practice: Wheat, burnt
2016 crop and yield: Faba beans, 3t/ha
2016 nitrogen applied: 14kg N/ha DAP
Timing of 2016 in-crop N application: None
2016 stubble management (post-harvest): Sheep grazed, then burnt

The soil type at Cornishtown increases in clay content with depth to 90cm (Figure 19). While results from the previous year showed water extraction from the 50cm layer, this was less evident in the 2016–17 measurements; likely due to the wetter conditions. From mid-October onwards, plant roots quickly took up water from the 10cm layer, drawing more slowly from the 30cm depth. At the end of the season there was still at least 5mm soil moisture still in reserve in the 30 and 50cm layers (based on previous results).

The Cornishtown nitrate-nitrogen values were relatively low at depth during July 2016 and January 2017 (Figure 20). The 2016 faba bean crop led to significant nitrogen mineralisation, resulting in a high starting mineral nitrogen level for the 2017 crop. Of particular interest is that the increase in available nitrogen was mostly between January and April 2017, when little rain fell. This likely coincides with the period of sheep grazing, demonstrating the potential for the combination of pulse crops and sheep grazing of stubble to increase mineral nitrogen values during summer.

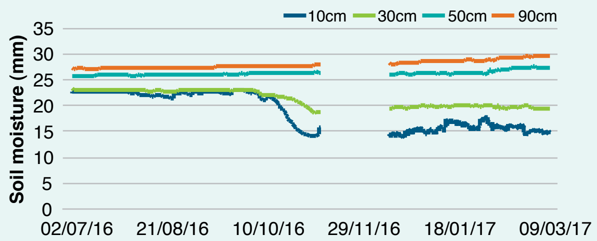


FIGURE 19 Soil moisture levels at Cornishtown, Victoria, July 2016 – March 2017

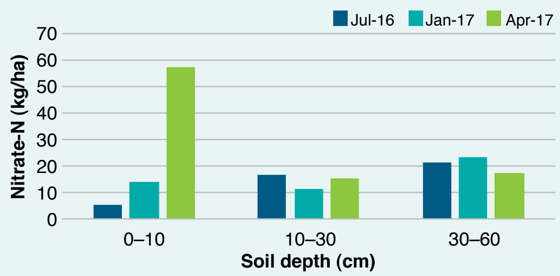


FIGURE 20 Plant-available (nitrate) soil nitrogen levels at Cornishtown, Victoria, July 2016 – April 2017

Location: Lilliput

2015 crop and stubble practice: Wheat, burnt
2016 crop and yield: Faba beans, 2.5t/ha
2016 nitrogen applied: None
Timing of 2016 in-crop N application: None
2016 stubble management (post-harvest): Retained

The Lilliput site has a lighter-textured surface soil, which appears to drain well, allowing plant roots to extract water throughout the wet winter (Figure 21). If it were not free draining, the extraction of moisture by plant roots would not be as obvious. The 30cm layer contains more clay, but is still readily accessed by plant roots. The 50cm layer is again lighter than the 30cm layer, a grey-coloured material that occurs through the landscape around Black Dog Creek, before moving into a heavy clay at 90cm. The profile dried out quickly when rainfall stopped in October, showing the texture contrast between the 10 and 30cm layers.

While some nitrate-nitrogen moved to depth early in the season, levels were low at all depths during July 2016 (Figure 22). This was expected given there was no nitrogen applied to the faba bean crop during 2016.

As with the Cornishtown results, the 2016 faba beans resulted in significant nitrogen mineralisation during summer–autumn, even with low summer rainfall.

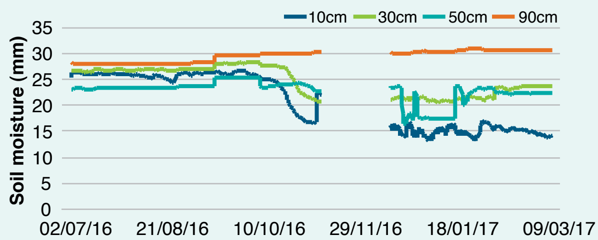


FIGURE 21 Soil moisture levels at Lilliput, Victoria, July 2016 – March 2017

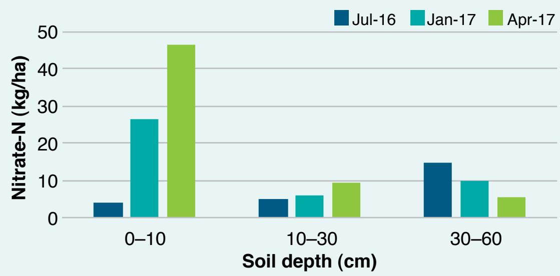


FIGURE 22 Plant-available (nitrate) soil nitrogen levels at Lilliput, Victoria, July 2016 – April 2017



Location: Norong

2015 crop and stubble practice: Wheat, retained
2016 crop and yield: Canola, 1.1t/ha
2016 nitrogen applied: 10kg N/ha MAP, 92kg N/ha urea
Timing of 2016 in-crop N application: Sowing, mid-July
2016 stubble management (post-harvest): Some burnt

The soil moisture probe at Norong confirmed the site remained wet throughout winter, with only the 10cm layer releasing water easily when the season dried out (Figure 23). The post-harvest results show some separation of the soil layers, which indicates roots extracted water from the 30cm layer (and also the 50cm layer) in the lead-up to harvest. This soil is challenged by having a large texture change in the subsoil, with a large increase in clay content. This change means water and nutrients move slowly into the subsoil.

The nitrate-nitrogen results show that some nitrogen did move into the subsoil during July (Figure 24). While plant roots did not need to actively extract water from depth during 2016, they did appear to access the nitrogen that had moved, as evidenced by the decreased nitrate-nitrogen levels in the 30–60cm layer post-harvest.

The lack of change in nitrate-nitrogen levels in the 0–10cm depth between January and April 2017 suggests that while mineralisation of nitrogen did contribute, some of this nitrogen may be residual from the 2016 crop.

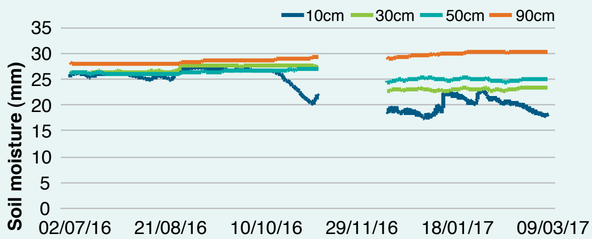


FIGURE 23 Soil moisture levels at Norong, Victoria, July 2016 – March 2017

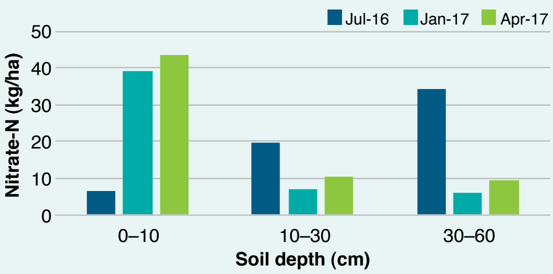


FIGURE 24 Plant-available (nitrate) soil nitrogen levels at Norong, Victoria, July 2016 – April 2017

Observations

Across the Rutherglen–Boorhaman region there is a range of soil types. While the typical duplex, texture contrast soil type dominates (characterised by a sharp increase in clay content in the subsoil), a range of features appears through the landscape, with a new adventure in every soil pit!

Some key features observed in soil pits are: dispersive subsoils just under the surface, sand layers at depth, and dense clays just below the surface. The key theme is one of high variability in soil type across the region. Understanding this variability is key to optimising nitrogen fertiliser management in different paddocks in difficult years (too dry, too wet).

The 2015–16 measurements, taken as part of the *Soil Moisture Probe Network Project*, indicated most of the soil nitrate nitrogen was present in the surface soil, with little nitrogen generally being measured at depth.

In comparison, the 2016–17 measurements showed how quickly nitrogen could move to depth, even in clay-based soils, with a general depletion of nitrogen in the surface soil by July 2016.

While these two sets of measurements show different numbers, a key point to consider is that if a general 0–60cm depth soil sample for nitrogen had been taken in these soils, we may have received the same answer for the two different seasons. For example, in July 2016 the soil test may say there is adequate nitrogen, but if that nitrogen is present below a clay layer in a soil subject to waterlogging, it may be months before the soil dries out enough for roots to reach that depth. Splitting the soil sample into two increments (a 0–30cm and a 30–60cm depth sample) can provide more accurate information on the availability of nitrogen as the season progresses, supporting better and more timely fertiliser decisions.

Acknowledgements

This project was funded by the North East Catchment Management Authority (NECMA) through funding from the Australian Government's National Landcare Programme. The project was also supported by Boorhaman Landcare and Riverine Plains Inc.

Contact

Dr Cassandra Schefe Riverine Plains Inc
T (03) 5744 1713
E cassandra@riverineplains.org.au

Detecting frost damage in wheat

Kirsten Barlow, Eileen Perry, Glenn Fitzgerald and James Nuttall
DEDTJR, Victoria

Key points

- Differences between frosted and non-frosted wheat crops have been detected soon after frost events in a paddock using remote sensing, including spectral reflectance, fluorometer, multispectral, and thermal infrared instruments.
- Sensor measurements indicate differences in responses among wheat varieties. Likewise, there are differences in the responses across plant components (leaves, heads, and stems).
- Most of the 2016 measurements were made on plants or canopies where the frost treatments were visible to the eye. Additional analysis is being made on frost treatments where initial damage is not visible.
- Some measurements indicate a change in response over time following a frost treatment, highlighting the importance of the timing of measurements following a frost event.
- Further research will correlate the sensor readings with the level of frost damage incurred by plants and the impact on harvested grain.

Background

Across Australia's cropping regions, frost damage is a significant challenge for wheat growers. Frost can result in substantial wheat yield losses, estimated at between $100 and $300 million each year, across Australia's eastern cropping region alone. A similar scale of loss has been reported across South Australia and Western Australia in recent decades.

Currently, determining if frost damage has occurred requires physically assessing the crop within five to seven days after a suspected frost event, which is labour intensive. If non-destructive sensors could make a more rapid, spatial assessment of frost damage, this could allow more timely management decisions on whether to continue growing the crop for grain, reduce costly inputs, or cut portions (or all) of a paddock for hay.

This project aims to assess the potential for a range of sensors to detect frost damage through non-destructive measurement of leaf/canopy reflectance, chlorophyll fluorescence, and radiometric surface temperatures.

Research goal

The results reported here are part of a larger research project, which aims to increase the understanding of frost risk and frost damage at the national scale through three key research activities to examine:

1. available satellite and other spatial information to develop high resolution frost risk maps at different resolutions (i.e. 5km, 30m, 5m and sub 1m (where feasible)) for case studies across the Australian wheat belt.
2. effective ways to rapidly assess post-event damage. The research will consider a range of techniques including static, unmanned aerial vehicle (UAV), satellite or vehicle-mounted sensors to identify frost damaged, or potentially damaged, plants and areas.
3. the frost damage information derived from the national frost trials in order to improve current representations of frost damage in biophysical models.

Aim

The aim of this trial was to assess the potential of a range of sensors to detect changes in wheat after a frost event. This is the first step in determining the potential of remote sensing to be used as a tool to detect and manage frost impacts on farm.

Method

The experimental work presented here was carried out at Horsham and Yarrawonga, Victoria during 2016.

2016: Yarrawonga

The Yarrawonga site aimed to provide a large-scale opportunity to assess a range of sensors after a natural frost event. Collaborating with Riverine Plains Inc, we accessed four treatments in their Yarrawonga stubble management trial (part of the GRDC-funded *Stubble project*): long stubble, short stubble, cultivated, and burnt. These treatments were selected to provide a spread in frost severity (due to differences in canopy temperature) when a frost event occurred. Unfortunately, the site was only partially instrumented, as high rainfall resulted in waterlogging, which made accessing crops to install the large frost protection chambers difficult. However, CSIRO Arducrop radiometers were installed to monitor canopy surface temperature (Figure 1a) and one frost exclusion chamber (1m x 1m) was deployed (Figure 1b); along with the Tinytag sensors, already installed by Riverine Plains Inc, to measure air temperature in the canopy.

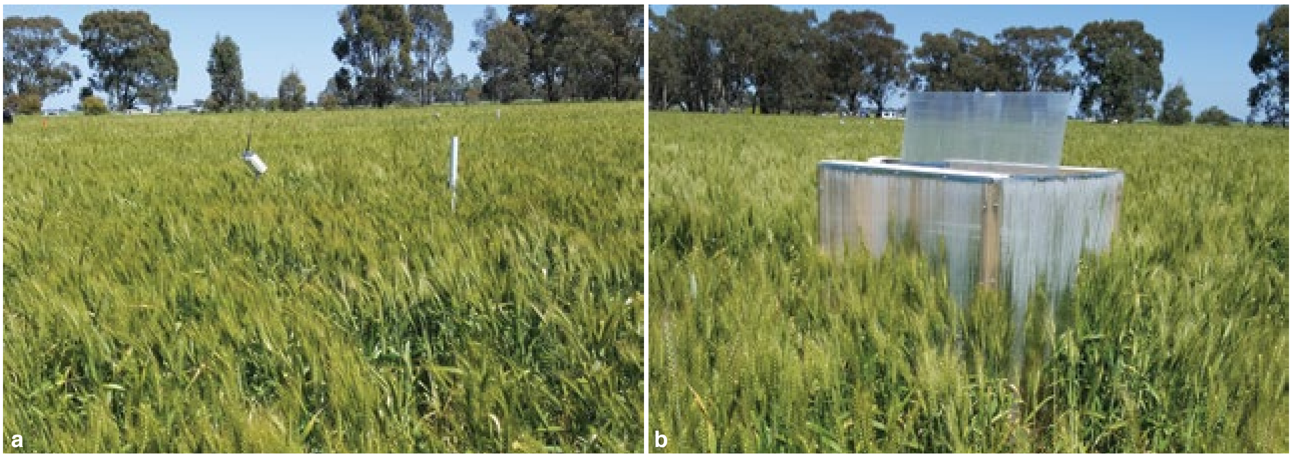


FIGURE 1 Instrumentation of the Riverine Plains Inc field site at Yarrawonga included (a) ArduCrop sensors, and (b) frost protection chambers

2016: Artificial frost trial, Horsham

A research trial was established at Horsham as part of the Regional Research Agronomists Program. The impact of simulated frost on wheat production was investigated by applying temperatures below 0ºC to wheat using specially designed chambers and dry ice (Figure 2).

The experimental design consisted of cold treatments applied at heading (GS55) and flowering (GS65) (Table 1). At heading (GS55) three different cold scenarios were applied to wheat (*cv.* Yitpi) with chilling applied over one, two and three consecutive nights between 21 and 23 October, 2016. At flowering (GS65) six different cold scenarios were applied to wheat (*cv.* Yitpi). The first set of three frost treatments (1–3) was applied over a single night (31 October) with increasing intensity of chilling and a second set of treatments (4–6) were applied over

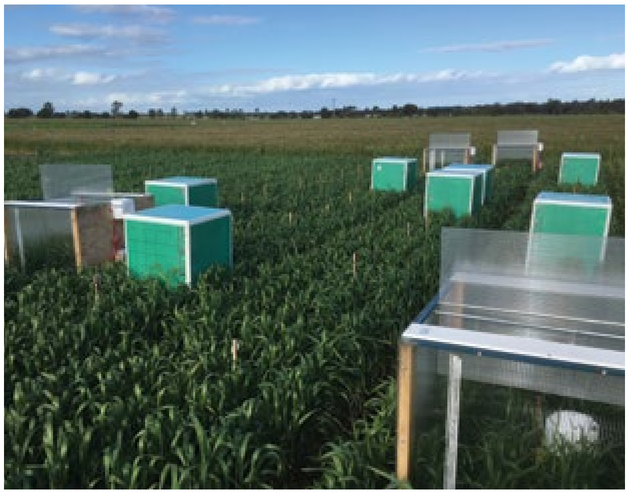


FIGURE 2 Simulated frost chambers in the field experiment, Horsham, Victoria, 2016

TABLE 1 Artificial frost treatments applied to wheat at heading (GS55) and flowering (GS65), their corresponding minimum temperatures and the frost exposure calculated by the total number of hours in which the canopy temperature was below 0°C multiplied by the temperature below 0°C (cold sum)

Frost treatment	Date	Duration (nights)	Minimum (ºC)	Cold sum (ºC.hr <0ºC)
Heading (GS55)	**Control**		**-2.4**	**20.0**
	21/10 – 23/10	1	-8.0	45.0
		2	-8.1/-8.4	101.0
		3	-9.9/-8.3/-7.2	161.0
Flowering (GS65)	**Control**		**>0**	**0.0**
	31/10	1	-2.2	8.6
			-2.8	12.0
			-3.4	12.0
	01/11 – 02/11	2	-1.4/-1.0	5.0
			-2.5/-1.3	12.0
			-2.6/-1.6	13.0

two consecutive nights (1 and 2 November), also with increasing intensity. These treatments were compared with two sets of control plots, constituting wheat growing in ambient air.

The following measurements were collected:

- Canopy temperatures were monitored using thermocouples installed at canopy (head) height, and temperature was logged at five-minute intervals using external temperature and relative humidity probes.
- The level of frost exposure was determined by the total number of hours in which the canopy temperature was below 0°C multiplied by the temperature below 0°C, expressed as the 'cold sum' (°C.h). Biomass cuts were used to assess dry matter and grain yield differences across plots.
- Canopy reflectance was measured using a handheld spectroradiometer and a six-band multispectral camera following each frost treatment.
- Canopy reflectance was also acquired with a multispectral camera flown on a multi-rotor UAV on 28 October and 3 November 2016.
- Fluorometer measurements were made to determine the amount of light emitted from the chlorophyll in plants, and were made on several dates before the start of the frost treatments, and continuing through until the end of the season (harvest).

The reflectance spectra from the spectroradiometer and the multispectral camera were used to calculate a range of indices to see if differences between frosted and non-frosted plants could be detected. These indices (including NDVI) are calculated from the reflectance measured from the crop at a range of different wavelengths.

Results

Frost was not a widespread issue for Victorian growers during 2016. Warm temperatures throughout winter led to limited frosts and when combined with above-average rainfall resulted in strong winter growth. However, some low-lying areas of the Wimmera were still impacted by frost during spring.

2016: Yarrawonga

For the Yarrawonga site there were no recorded frost events at the trial site between crop flowering and maturity. The coolest canopy temperatures recorded by the Arducrop sensors was 0.5–2.5°C for several nights during October (Figure 3).

The lack of frost events meant no measurements of frost damage could be taken at this site. However, differences in canopy temperatures were detected between different stubble treatments on the paddock using the Arducrop sensors. Consistent with previous results reported by Riverine Plains Inc. as part of their GRDC *Stubble project*, the long stubble treatment was colder overnight than the other treatments. While there was only one Arducrop sensor per treatment, the average difference in temperature (calculated for overnight temperatures (10pm-6am) during September and October) was 0.5°C warmer in the burnt treatment than the long stubble and 0.7°C warmer in the short and cultivated treatments (±0.5°C standard deviation). However, differences of up to 2.5°C were recorded between the burnt and long stubble treatments on individual nights.

2016: Artificial frost trial, Horsham

The research trial established at Horsham used specially-designed chambers to replicate a radiant frost event in field plot trials. The frost chambers effectively reduced

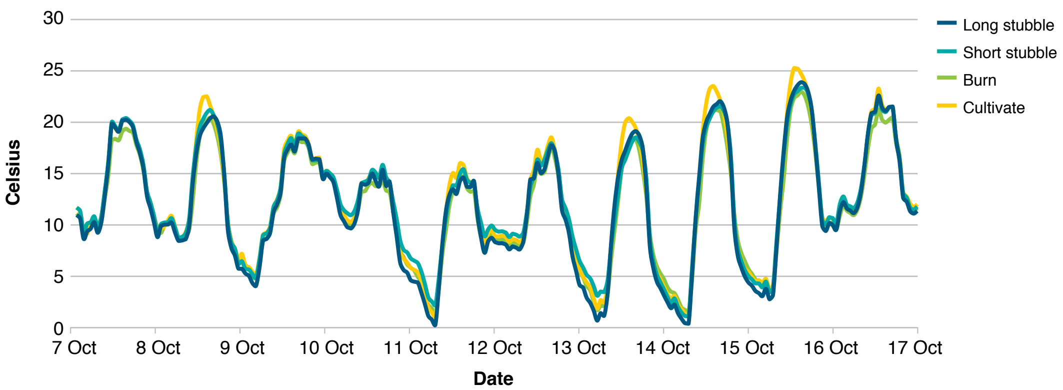


FIGURE 3 Canopy temperatures at the Yarrawonga field site measured using the Arducrop sensors for the period 7–16 October 2016. Results are shown for short stubble (aqua), long stubble (dark blue), burnt (green) and cultivated (yellow)

canopy temperature of wheat to below zero degrees and could produce different levels of cooling, as per Table 1 (treatment list). The heading (GS55) frost treatments had minimum temperatures from -6.6 – -9.6°C, with cumulative time and temperature below zero (cold sums) ranging from 0 (control plots) to 174 °C.hr (<0°C). The flowering (GS65) frost treatments produced a milder frost with average minimum temperatures ranging from -2.2 – -3.4°C, which corresponded to a range in cold sums of 8.6 – 11.8°C.hr (< 0°C).

Reflectance measurements made following the heading frost treatments showed obvious treatment differences the day after the frost (Figure 4), before there were any visible treatment differences. Four days after the heading frost treatment there were highly visible differences in the multispectral and thermal imaging obtained from the UAV (Figure 5), along with visible damage to the leaves of the crop. However, the heading frost treatments were quite severe, producing visible damage within days. The guidelines for detecting frost damage suggest a 5–7 day timeframe before damage is visible, with damage to the stem and head requiring some dissection of the plant before it can be identified.

To further test the potential for sensors to detect milder, non-visual frost damage the severity of the applied frost was reduced for the flowering frost treatment. The results from the flowering frost were used to test a number of parameters/indices (including NDVI) to see if there was a relationship between the magnitude of frost exposure (cold sum – Table 1) the crop was exposed to and the measured reflectance of the crop. Two of the indices appeared promising, showing a significant relationship between frost exposure and reflectance measured on the flag leaves. However, the indices computed from the UAV measurements (for the whole canopy) showed little response of the indices to the cold treatments. This suggests that while these indices have potential to detect frost damage further research is needed to test their application in the field, specifically in terms of the timing (number of days after frost) and scale (individual leaf versus canopy) of measurement to best identify frost damage.

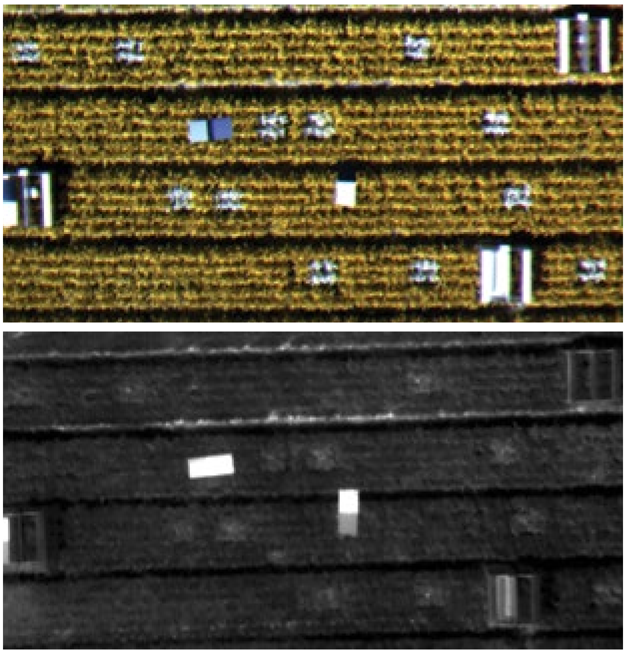


FIGURE 5 Multispectral imagery (top panel) and thermal imagery (bottom panel) both clearly show changes in the canopies reflectance of light (pale squares in the top photo) and temperature profile (white squares in the bottom photo) following artificial frost treatments imposed at Horsham Victoria. These measurements were taken on 28 October 2016, five days after the frost event. At this point the treated canopy was showing visible differences

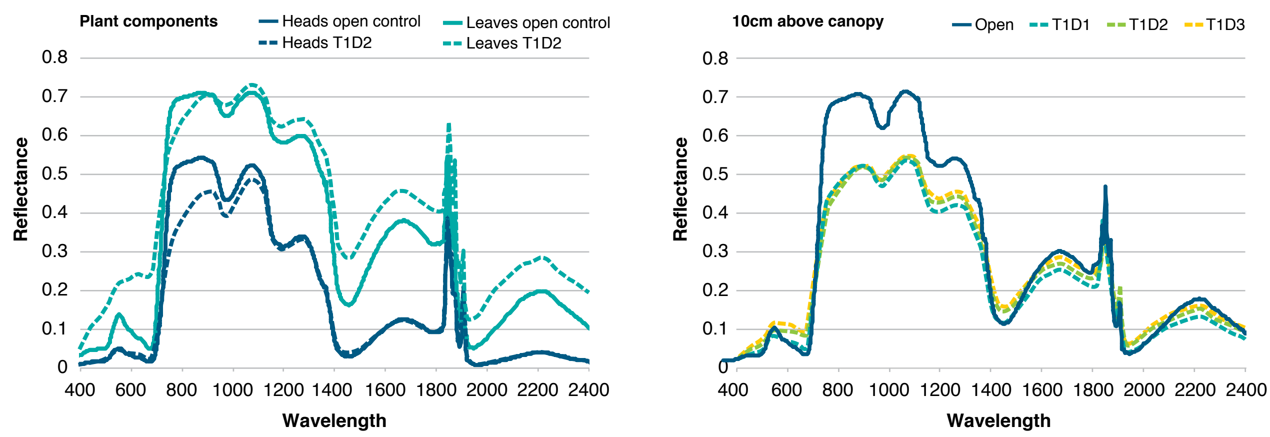


FIGURE 4 Reflectance measurements acquired on 24 October 2106, one day after the heading frost treatments. The reflectance spectra clearly show differences between the open control (non-frosted) plots and the plots with frost treatments. (T1 = heading frost (GS55); D1-D3 – 1–3 frost nights applied)

Further research will focus on correlating the sensor readings with the level of frost damage incurred by plants and the impact on final grain yield.

Conclusions

Improvements in the ability to measure frost damage in crops requires natural frost events to occur regularly. While 2016 was a successful year for growers, with no significant spring frosts across most of Victoria, this limited the research possible at the Yarrawonga site. However, through the use of chambers designed to simulate radiant frost events in the field we started testing the potential of a range of sensors to detect frost damage. If through further research we can identify sensors and appropriate methods for their use, this would allow for a more rapid, spatial assessment of frost damage across a paddock or property. This would then allow growers to make more timely management decisions on whether to continue growing the crop for grain, reduce costly inputs, or cut portions (or all) of a paddock for hay.

Acknowledgements

This work was funded by GRDC and Agriculture Victoria Research, DEDJTR through the *Spatial Temperature Measurement and Mapping Tools to Assist Growers, Advisors and Extension Specialists Manage Frost Risk at the Farm Scale* project as part of the National Frost Initiative, and the *Improving Practices and Adoption Through Strengthening D&E Capability and Delivery in the Southern Region* Regional Research Agronomists program (GRDC DEDJTR Bilateral Research Agreement). We also gratefully acknowledge Ashley Purdue and Russell Argall for their technical support. This work contributes to the broader industry knowledge associated with managing frost induced sterility in wheat and links with other national frost research programs within the GRDC's National Frost Initiative.

Contact

Kirsten Barlow

E: Kirsten.Barlow@ecodev.vic.gov.au



An in-depth look at ameliorating soil acidity

Dr Jason Condon, Dr Guangdi Li and Dr Sergio Moroni

Graham Centre for Agricultural Innovation (alliance between Charles Sturt University and New South Wales Department of Primary Industries)

Key points

- Acidic subsoils are common in the Riverine Plains region.
- Previous trials have shown deep placement of amendments can improve wheat and canola production.
- Replicated field trials have been established near Rutherglen, Victoria to test innovative methods to address subsoil acidity in the Riverine Plains region.
- A large-scale on-farm site near Rutherglen is planned for 2018.

Introduction

Subsoil acidity (deeper than 10cm below the soil surface) is a major constraint to crop production in the high-rainfall (500–800mm) cropping zone. While acidic surface soil (0–10cm) can be effectively addressed by incorporating surface-applied lime, ameliorating the subsoil has not been practical.

A current project funded by the Grains Research and Development Corporation (GRDC) aims to identify and evaluate a range of innovative products, which may be used to overcome the effects of subsoil acidity. A series of trials is being conducted in New South Wales and Victoria, two of which are long-term trials established in Rutherglen and Cootamundra.

Aim

To quantify the yield limitation caused by subsoil acidity and evaluate innovative soil amendments to address subsoil acidity.

Rutherglen site

Method

A three-year field trial was established in Rutherglen, Victoria during March 2017.

The initial soil profile of the selected site exhibited severe subsoil acidity (Table 1). Preliminary estimates

TABLE 1 Initial pH and exchangeable aluminium percentage for Rutherglen field trial, prior to treatments, January 2017.

Soil depth (cm)	Soil pH ($CaCl_2$)	Al%
0–10	4.55	12
10–20	4.22	30
20–30	4.32	10
30–40	5.05	3

of exchangeable aluminium (Al) indicate potentially growth-limiting concentrations in the surface soil (0–30cm), with the greatest concentrations present in the 10–20cm soil layer.

Fourteen treatments were applied in a randomised complete block design, with three replicates and plot dimensions of 5 x 20m: a nil control, surface (0–10cm) incorporated lime (to a target pH 5.5) and a range of deep (10–30cm) placed ameliorants including: deep ripping only, lime, dolomite, magnesium silicate (at two rates), reactive rock phosphate (at two rates), phosphorus (P) applied as a liquid, phosphorus with lime, and lucerne pellets (at two rates).

The surface soil (0–10cm) in all plots receiving deep amendments was adjusted to pH 5.0 by incorporating lime. All deep ameliorants were applied at rates sufficient to achieve a pH of 5.0 ($CaCl_2$) from 10–30cm as determined by laboratory incubation studies carried out at Charles Sturt University, Wagga Wagga, NSW.

Soil chemical properties and moisture content will be monitored during the 2017–19 seasons. The site was sown to canola in 2017, wheat in 2018 and possibly barley will be grown in 2019. Plant establishment, dry matter (DM) during the season and grain yield at the end of the season will be measured each year.

Cootamundra site

Method

A similar trial was established at Cootamundra, NSW during 2016. The treatments were applied in March, and included: deep-placed (10–30cm) ameliorants of lime, lucerne pellets, lime with lucerne pellets, with a control of no amendment, deep ripping only, and surface (0–10cm) liming.

Four crops were grown on treated plots: barley, wheat, canola and field peas. These crops will be rotated within the field each year on a four-year rotation.

Plots were sampled for moisture content, soil chemical properties and crop attributes, such as establishment, DM production and final grain yield.

The trial was implemented as a randomised block design with three replications. Plots are 5 x 20m in size.

Results

The initial soil samples taken at the Cootamundra site showed that subsoil acidity had caused high levels of exchangeable aluminium in the 10–20cm layer of the profile (Figure 1).

Deep ripping (to a depth of 30cm) reduced the physical strength of the soil, as measured by a penetrometer (Figure 2) in one replicate of the wheat plots. Penetrometers measure the force required to move a cone shaped probe through the soil. This was conducted across the plot on a transect perpendicular to the rip line to a depth of 50cm.

It seems the effect of deep ripping with lucerne pellets was beyond the ripping depth (30cm). Further research is required to ascertain the reasons for this but it is possible some of the breakdown products of the organic material are soluble and therefore, mobile.

At harvest, there were significant differences in wheat yield between treatments ($P < 0.05$), with the deep lucerne pellet treatment delivering the highest yield (Figure 3). This is probably due to extra nutrients released into the soil from lucerne pellets.

Soil test results during late August 2016 showed the two lucerne pellet treatments increased the amount of mineral nitrogen (N) available to crops by about 70–100kg N/ha, compared with all other treatments.

However, no yield advantage was observed in the lucerne pellet treatments for canola and barley. The combination of high nitrogen levels and ideal spring

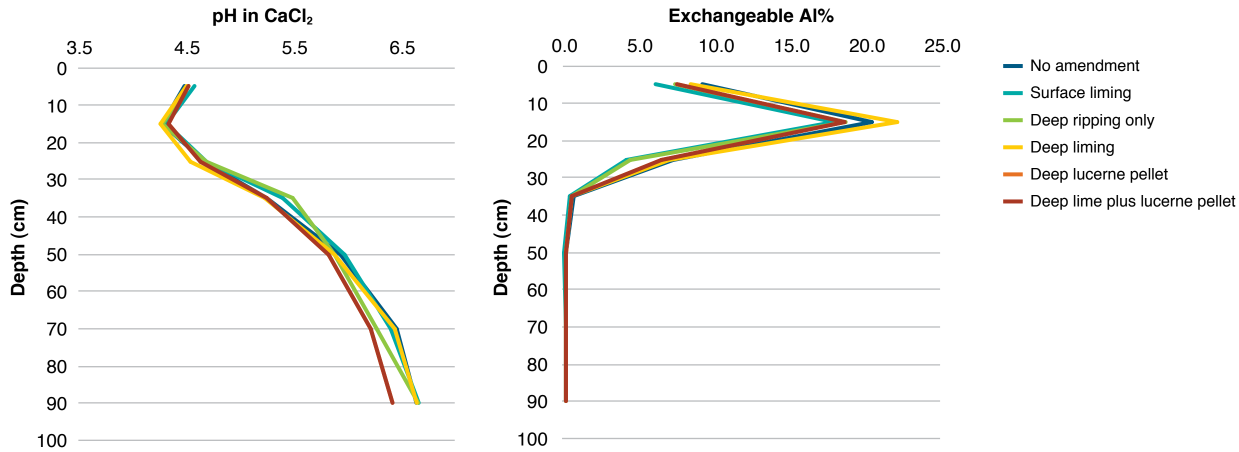


FIGURE 1 Initial soil pH and exchangeable aluminium (% of effective cation exchange capacity — ECEC) within the soil profile at Cootamundra, NSW for a range of treatments during 2016

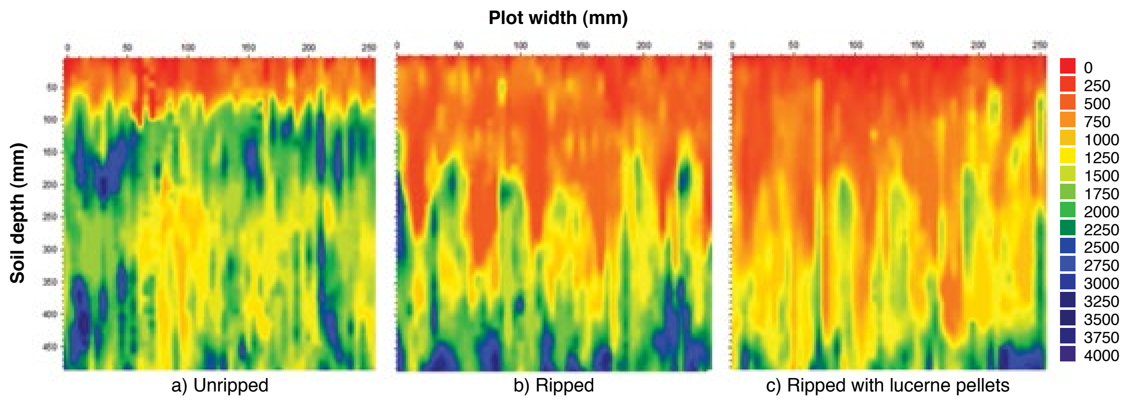


FIGURE 2 Penetrometer readings (kPa) taken September 2016 from one replicate of wheat plots a) unripped; b) deep ripped to 30cm and c) deep ripped + lucerne pellets.

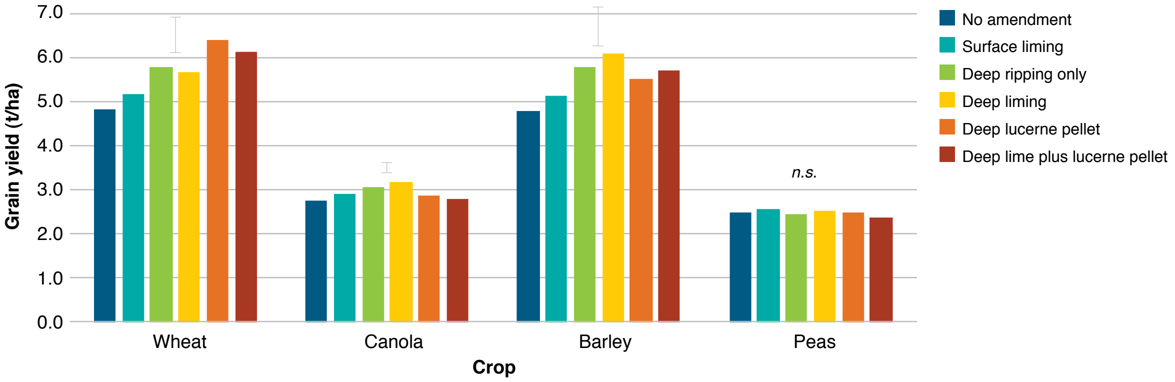


FIGURE 3 Treatment effect on grain yield at Cootamundra, NSW during 2016
Least significant difference (P<0.05) bars are shown for each crop type

growing conditions resulted in severe lodging after flowering. There were also no treatment effects on field pea grain yield.

Observations and comments

Subsoil amendment treatments applied at Cootamundra resulted in large visual benefits to growth in terms of DM production. The resulting increase in biomass relative to the control caused excessive lodging in canola and barley as the crop matured.

As a number of field trials are being established in different regions, including the Riverine Plains, to test the potential for ripping and deep placement of amendments to overcome the effects of subsoil acidity, more information will become available in the coming years on effective options for managing subsoil acidity in cropping systems.

A second trial will be established in the Rutherglen region during 2018, which will be managed by Riverine Plains Inc, using farm-scale large plots to further validate these results.

Sponsors

This project is funded by NSW Department of Primary Industries with financial support from GRDC: *Innovative approaches to managing subsoil acidity in the southern grain region* (DAN00206) and supported by Riverine Plains Inc, Farmlink Research, Southern Farming Systems and the Holbrook Landcare Network. Thanks to farmer co-operator Stephen Chambers. Technical staff: Richard Lowrie, Alek Zander, Adam Lowrie.

Contact

Dr Jason Condon
T: (02) 6933 2278
E: jcondon@csu.edu.au

Evaluating the regional adaptation of new longer-season wheat varieties under different levels of agronomic management

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

Key points

- New winter wheat lines (RAC2341, LRPB Kittyhawk and V09150-01) produced yields similar or superior to EGA Wedgetail, with up to 15% increases in yield.
- RAC2341 produced the highest yields and gave the most consistent yield performance across the different management regimes.
- RAC2341 was the fastest-developing cultivar of the four tested and was faster than the EGA Wedgetail control.
- There was no statistical interaction in terms of yield between cultivar and management regime, suggesting all cultivars responded similarly to the management regime imposed.
- Simulated grazing (mechanical removal) significantly reduced the yield of all cultivars by an average of 1.3t/ha compared with the ungrazed control.
- Normalised difference vegetation index (NDVI) and green leaf retention data from simulated grazing showed that compensation was slow and the crop canopy never recovered, most likely due to transient waterlogging.

Location: Riverine Research Centre, Yarrawonga
Sowing date: 18 April 2016
Rotation: First wheat following canola
Variety: EGA Wedgetail (control), RAC2341, LRPB Kittyhawk and V09150-01
Stubble: Canola unburnt
Rainfall: GSR: 642.8mm (April–November)

Method

A trial was carried out at the Riverine Research Centre (RRC) near Yarrawonga, Victoria, to evaluate regional adaptation of new longer-season wheat varieties under different levels of agronomic management. Three new winter wheat cultivars (RAC2341, LRPB Kittyhawk and V09150-01) sown on 20 April 2016 were compared against EGA Wedgetail (control) under five management regimes, which varied the insecticide, fungicide and grazing inputs. The research trial was subject to a growing season rainfall (GSR) of 642.8mm, with 138mm falling during September.

Simulated grazing was achieved by mowing plots to a height of 5–7cm. A light grazing (by mowing) was carried out at tillering (GS23–24), which left around 0.29t/ha of dry matter (DM). A moderate grazing was simulated by mowing plots at pseudo stem erect stage (GS30), which left around 0.8t/ha DM.

Treatments

Four wheat cultivars (Table 1) were treated with five management regimes replicated four times (Table 2). The trial was set up as a split plot design, with management level as the main plot and cultivar as the subplot.

Results

Influence of cultivar

Dry matter production among the four cultivars was similar, with RAC 2341 and LRPB Kittyhawk producing the highest total DM offtakes from the combined simulated grazing (2210 and 2160kg DM/ha respectively), though differences were only statistically significant at the earlier grazing (Figure 1). LRPB Kittyhawk produced significantly higher DM at the tillering cut than the other cultivars.

All three new winter wheat cultivars showed yield potentials similar or superior to EGA Wedgetail (Table 3) depending on the management regime.

Averaging the yields across all management regimes, the yield advantage of the new cultivars over EGA Wedgetail ranged from 2.1–15.7%, with RAC2341 being the highest

TABLE 1 Wheat cultivars evaluated at Yarrawonga, 2016

	Cultivar	Breeder
1	EGA Wedgetail	EGA
2	V09150-01	AGT
3	RAC2341	AGT
4	LRPB Kittyhawk	Advanta Seeds



TABLE 2 Input management levels evaluated at Yarrawonga, 2016

Management level	Management regimes and timings				
	At sowing	Tillering (GS23 – 24)	Pseudo stem erect (GS30)	First node (GS31)	Flag leaf emergence (GS39)
1	Flutriafol 400	BYDV insecticide	–	–	–
2	–	BYDV insecticide	–	–	–
3	Flutriafol 400	–	–	–	–
4	–	BYDV insecticide	–	Folicur 290	Opus 500
5	–	BYDV insecticide Light graze	Moderate graze	–	–

Flutriafol® 400 — applied in furrow on MAP at double strength loading equivalent to 200g ai/ha Flutriafol® at sowing 18 April
BYDV insecticide — Trojan® insecticide applied (15g/L gamma-cyhalothrin @ 15mL/ha) at tillering (GS23–24), 1 June
Grazing — First light grazing carried out at tillering (GS23–24), 16 June, followed by moderate grazing at the pseudo stem erect stage (GS30), 20 July
Fungicide — Folicur® applied (290mL/ha) at first node (GS31), 8 August
— Opus® applied (500mLl/ha) at flag leaf emergence (GS39), 6 September

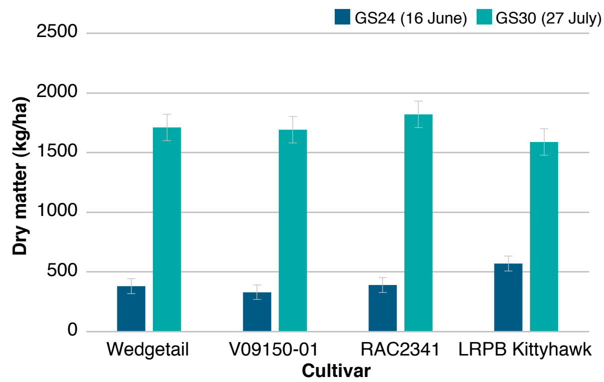


FIGURE 1 Influence of cultivar on dry matter mechanical grazing offtakes at tillering (GS23–24) and pseudo stem erect (GS30)
Error bars are a measure of LSD

yielding and most consistent cultivar across the different management regimes.

When cultivars were compared within each management regime, RAC2341 yielded significantly more than EGA Wedgetail when the Management 2 and Management 5 regimes were applied.

Influence of management regime

There was no statistical interaction in terms of yield between cultivar and management regime with all cultivars responding similarly to the management regime imposed. However, the management regime itself did produce highly significant differences in crop performance due to simulated grazing (Management regime 5).

Simulated grazing (mechanical removal) significantly reduced the yield of all cultivars by an average of 1.3t/ha compared with an ungrazed control. There is evidence from normalised difference vegetation index (NDVI) and green leaf retention (data not shown) that compensatory growth from simulated grazing was slow and the crop canopy never properly recovered. Where waterlogging effects were most severe the regrowth following grazing was slower again. All three new cultivars under the simulated grazing management produced higher yields than EGA Wedgetail, but only with RAC 2341 was the difference statistically significant.

Although the foliar fungicide and insecticide treated management regime (Management 4) produced the highest yields if all cultivars were averaged (5.23t/ha), the differences between the other management regimes were not significant.

Conclusions

The three new winter wheat cultivars tested (RAC 2341, LRPB Kittyhawk and V09150-01) measured grain yields and DM offtakes equal to or significantly better than EGA Wedgetail.

In terms of development the RAC2341 cultivar developed the fastest, and was quicker to reach maturity than the EGA Wedgetail control. This trait would be more useful in a tight finish or if the sowing date was later than planned. There were generally smaller differences in development with the other cultivars. Dry matter offtake at tillering (GS23–24) and the start of stem elongation (GS30) was greater with RAC2341 and LRPB Kittyhawk than EGA Wedgetail, exceeding 2000kg/ha. Dry matter offtake with simulated mechanical grazing at tillering and the start of stem elongation significantly reduced grain yield across all four cultivars tested by an average of 1.3t/ha, a factor thought to be associated with transient waterlogging.

Management regimes that varied fungicide timings (upfront or in crop) and insecticide input did not create significant yield differences, although there was evidence the highest-yielding management regime was where two foliar fungicides had been used. The foliar fungicide-treated plots were also noted to have significantly greater green leaf retention during grain fill, particularly with LRPB Kittyhawk.

TABLE 3 Influence of management regime on grain yield and quality

Management regime	Yield (t/ha)	Protein (%)	Test weight (kg/hL)	Screenings (%)
Management 1				
EGA Wedgetail	5.07^{ab}	9.8^{abc}	78.3^{gh}	0.9^{cde}
V09150-01	5.43^{a}	9.8^{abc}	77.4^{h}	1.1^{cd}
RAC2341	4.87^{ab}	10.2^{ab}	79.2^{d-g}	0.6^{fg}
LRPB Kittyhawk	4.57^{abc}	9.8^{abc}	81.0^{bc}	1.7^{a}
Management 2				
EGA Wedgetail	4.30^{bcd}	10.0^{abc}	78.2^{gh}	1.0^{cde}
V09150-01	4.93^{ab}	9.4^{abc}	78.6^{fgh}	1.1^{cd}
RAC2341	5.50^{a}	9.8^{abc}	80.4^{cd}	0.5^{fg}
LRPB Kittyhawk	4.63^{abc}	10.1^{abc}	82.3^{ab}	1.6^{a}
Management 3				
EGA Wedgetail	4.50^{abc}	9.9^{abc}	77.8^{gh}	1.2^{bc}
V09150-01	4.93^{ab}	10.0^{abc}	77.9^{gh}	1.1^{cd}
RAC2341	5.27^{ab}	10.4^{a}	79.9^{c-f}	0.5^{g}
LRPB Kittyhawk	4.27^{bcd}	10.2^{ab}	80.9^{bc}	1.5^{ab}
Management 4				
EGA Wedgetail	5.20^{ab}	9.5^{abc}	78.7^{fgh}	0.8^{def}
V09150-01	4.90^{ab}	10.9^{a}	78.0^{gh}	0.8^{def}
RAC2341	5.57^{a}	9.5^{abc}	80.4^{cd}	0.5^{fg}
LRPB Kittyhawk	5.23^{ab}	8.4^{c}	82.6^{a}	1.4^{ab}
Management 5				
EGA Wedgetail	2.90^{e}	9.9^{abc}	78.9^{efg}	0.8^{efg}
V09150-01	3.37^{de}	9.6^{abc}	78.2^{gh}	1.0^{cde}
RAC2341	4.20^{bcd}	8.5^{bc}	80.2^{cde}	0.7^{efg}
LRPB Kittyhawk	3.70^{cde}	9.3^{abc}	82.2^{ab}	1.5^{ab}
LSD	**1.116**	**1.74**	**1.4**	**0.32**

Figures followed by different letters are regarded as statistically significant

Acknowledgements

This trial was jointly funded by Advanta Seeds, Australian Grain Technologies and FAR Australia. This trial was run at the Riverine Research Centre (RRC), an independent and dedicated crop research site located near Yarrawonga, Victoria. The RRC is a partnership between Riverine Plains Inc and FAR Australia and is supported by RRC hosts, the Cummins family.

Contact

Nick Poole Foundation for Arable Research, Australia

E: Nick.Poole@far.org.nz

Local Land Services
Murray

MURRAY LOCAL LAND SERVICES

WHAT DO WE DO?

Murray Local Land Services 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.

AGRICULTURAL PRODUCTION

Murray Local Land Services 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.

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.

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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.

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We have offices in:

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Albury - 931 Garland Ave
Corowa - 74 Short St
Tumbarumba - cnr Bridge & Winton streets
Jerilderie - 6 Jerilderie St
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National Landcare Programme

Applying liquid nitrogen through different nozzles, with and without fungicide

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

Key points

- In a low-yielding (3–4 t/ha) wheat trial (cv Trojan) affected by transient waterlogging, applying liquid nitrogen (N), in the form of Easy N®, through flat fan jets was slightly more damaging than streaming jets in terms of phytotoxicity to the key upper leaves, though this was not significant.
- The level of damage was exacerbated when the liquid fertiliser was mixed with fungicides; particularly when applied at booting (GS43).
- The amount of phytotoxicity measured when a fungicide was added depended on the formulation and the angle and leaf layer of the canopy leaf exposed to the spray.
- An emulsifiable concentrate (EC) formulation of fungicide generated twice the level of damage to that observed with suspension concentrate (SC) formulations.
- There were small differences between SC formulations of fungicides but in the main these were non-significant.
- Adding extra water reduced leaf scorch, but the effect was small relative to other differences observed. Similar effects were seen when an adjuvant was added to the SC formulation.
- The variable nature of the yield results did not allow significant comment to be made on yield data.

Location: Riverine Research Centre, Yarrawonga
Sowing date: 18 April 2016
Rotation: First wheat following canola
Variety: Trojan
Stubble: Canola unburnt
Rainfall: GSR: 642.8mm April–November

Introduction

'Easy N®' liquid fertiliser by Incitec Pivot is an alternative nitrogen source to solid urea. The product offers operational efficiencies, such as chemical compatibility with other products, such as fungicides, to allow a single pass multitask application, providing growers with time and labour efficiencies. While Easy N is more expensive than urea, these efficiencies may provide value in themselves.

This research trial aimed to provide data for the Riverine Plains region to demonstrate the relative compatibility of these products, the degree of associated foliar damage and the relative impact of this leaf damage on crop yield.

Objectives

The aim of this trial was to assess any damage to the top four leaves of the wheat crop canopy (as a percentage of leaf area affected [LAA]) seven days after treatment application at second node (GS32) and booting (GS43) stages with different forms of nitrogen. The specific objectives were to:

- assess the phytotoxicity (scorch) of liquid Easy N versus solid urea at GS32 and GS43
- compare the impact of applying liquid Easy N through streaming nozzles and flat fan spray jets
- assess the impact of co-applying emulsifiable concentrate (EC) or suspension concentrate (SC) formulations of foliar fungicides with liquid Easy N
- examine the influence of water rate on scorch at both application timings.

Method

The research trial was carried out near Yarrawonga, Victoria at the Riverine Research Centre. The trial was sown to wheat (cv Trojan) on 17 May 2016. Treatments were applied at two timings: on 17 August at second node (GS32) and again at booting (GS43) on 16 September (Table 1). The trial site was wet at both application timings

The products used were:

- Easy N (normal water rate: 100L/ha water) at 38kg N/ha
- Easy N (200L/ha water) at 38kg N/ha
- Tilt 250® EC fungicide (an EC formulation) at 500mL/ha
- Amistar Xtra® fungicide (an SC formulation) at 800mL/ha

- Prosaro® fungicide (an SC formulation) at 300mL/ha
- Prosaro fungicide + BS1000® (a wetting agent) at 0.25% (v/v).

Note: With damage to the flag leaf being regarded as more important than early-season damage, more treatments were trialled at the later booting timing (GS43) compared with the second node (GS32) timing. Prosaro with and without adjuvant was only assessed at GS43.

The trial received growing season rainfall (GSR) for April – November of 642mm, with 138.2mm of rainfall recorded during September. The trial site was subject to transient waterlogging, particularly in replicate four of all treatments, the results from which were removed from the final statistical analysis of wheat yield and quality. All other assessment data is based on the four replicates in the trial.

Treatments

Treatments are presented in Table 1.

Results

i) Phytotoxicity (levels of leaf damage)

Measurement of foliar damage seven days after the second node (GS32) application showed minimal effects when Easy N was applied in isolation (Table 2). The greatest phytotoxic ratings of 3–3.2% on flag-4 were measured when Easy N was applied in conjunction with either fungicide.

The larger crop canopy at booting (GS43) resulted in greater overall levels of foliar damage seven days after application (Table 3), compared with that recorded at GS32 (Table 2). On the flag leaf there was no significant difference between stream jets and flat fan nozzle application systems. The increase in water rate also didn't have any significant effect on leaf damage.

When fungicide was added with Easy N at booting (GS43) using the flat fan nozzles, the application of Tilt 250 EC resulted in significantly greater leaf damage on the flag leaf (26%) compared with the SC fungicides (Table 3). While the damage with Amistar Xtra was approximately half that measured with Tilt 250 EC (14%), it was still significantly greater than when Easy N was applied without any fungicide. Adding Prosaro caused the least damage to the flag, similar to that of Easy N alone. The addition of the BS1000 wetting agent to Prosaro increased the damage slightly, but not significantly.

There was no significant impact of nozzle type or water rate on leaf damage when Easy N was applied to flag-1. The pattern of leaf damage due to product was similar on flag-1, with Tilt 250 EC causing significantly greater leaf damage (14%) compared with SC fungicide products.

While flag-2 leaf showed a significant relative effect of leaf damage due to fungicide treatments, the actual values were low (<3.5%), likely due to this leaf receiving less product due to obstruction of the upper leaves.

ii) Disease control

Despite the wet spring during 2016, the wheat (cv Trojan) remained disease free in this trial. All plots received two fungicide applications (Prosaro 150ml/ha + Hasten 1%v/v on 17 August followed by Tilt on 16 September) at the

TABLE 1 Treatments applied to trial, Yarrawonga, 2016

No.	Nitrogen application	Fungicide	Rate	Timing
1.	Control 1 (standard N @ GS33)	---		GS32
2.	Urea @ 38kg N/ha	---		GS32
3.	Easy N stream nozzle @ 38kg N/ha	---		GS32
4.	Easy N flat fan nozzle @ 38kg N/ha	---		GS32
5.	Easy N flat fan nozzle @ 38kg N/ha	Tilt 250 EC	500 mL/ha	GS32
6.	Easy N flat fan nozzle @ 38kg N/ha	Amistar Xtra 280 SC	800 mL/ha	GS32
7.	Control 2 (standard N @ GS33)	---		GS43
8.	Urea @ 38kg N/ha	---		GS43
9.	Easy N stream nozzle @ 38kg N/ha	---		GS43
10.	Easy N flat fan nozzle @ 38kg N/ha	---		GS43
11.	Easy N flat fan nozzle @ 38kg N/ha (200L/ha water)	---		GS43
12.	Easy N flat fan nozzle @ 38kg N/ha	Tilt	500mL/ha	GS43
13.	Easy N flat fan nozzle @ 38kg N/ha	Amistar Xtra	800mL/ha	GS43
14.	Easy N flat fan nozzle @ 38kg N/ha	Prosaro 420SC / BS1000	300mL/ha / 0.25%	GS43
15.	Easy N flat fan nozzle @ 38kg N/ha	Prosaro 420 SC	300mL/ha	GS43

All treatments received a solid urea application of 39kg N/ha on 26 August, when the crop was at GS33.

TABLE 2 Phytotoxicity severity (% leaf area affected — LAA) on flag-2, flag-3 and flag-4, and green leaf retention (GLR) on flag-4, 23 August, at third node (GS33) seven days after application (7DAA) at second node (GS32)

Nitrogen application	Fungicide	Timing	Flag-2	Flag-3	Flag-4	
			Phytotoxicity (% LAA)	Phytotoxicity (% LAA)	Phytotoxicity (% LAA)	GLR (%)
-	-	GS32	0^{b}	0^{c}	0^{c}	83.9^{a}
Urea @ 38kg N/ha	-	GS32	0^{b}	0^{c}	0^{c}	83.5^{a}
Easy N stream nozzle @ 38kg N/ha	-	GS32	0.7^{a}	0.6^{bc}	0.6^{c}	88.7^{a}
Easy N flat fan nozzle @ 38kg N/ha	-	GS32	0.1^{b}	0.6^{bc}	1.6^{b}	83.6^{a}
Easy N flat fan nozzle @ 38kg N/ha	Tilt 250 EC 500mL/ha	GS32	0^{b}	1.2^{b}	3^{a}	84.6^{a}
Easy N flat fan nozzle @ 38kg N/ha	Amistar Xtra 280 SC 800mL/ha	GS32	0.2^{b}	2.3^{a}	3.2^{a}	89.3^{a}
Mean			**0.2**	**0.8**	**1.4**	**6.9**
LSD p=0.05			0.4	0.6	0.9	85.6
P value			0.024	<0.001	<0.001	0.303

Figures followed by different letters are regarded as statistically significant

TABLE 3 Phytotoxicity severity (% LAA) on the flag, flag-1 and flag-2, 23 September start of head emergence (GS51); seven days after application (7DAA) at booting (GS43)

Nitrogen application	Fungicide	Timing	Flag	Flag-1	Flag-2
			Phytotoxicity (% LAA)	Phytotoxicity (% LAA)	Phytotoxicity (% LAA)
-	-	GS43	0.0^{c}	0.0^{e}	0.0^{d}
Urea @ 38kg N/ha	-	GS43	0.0^{c}	0.0^{e}	0.1^{d}
Easy N stream nozzle @ 38kg N/ha	-	GS43	5.7^{bc}	2.8^{de}	2.0^{bc}
Easy N flat fan nozzle @ 38kg N/ha	-	GS43	3.2^{c}	3.5^{cde}	1.8^{bc}
Easy N flat fan nozzle @ 38kg N/ha (200L/ha water)	-	GS43	2.4^{c}	2.0^{e}	0.9^{cd}
Easy N flat fan nozzle @ 38kg N/ha	Tilt 250 EC 500mL/ha	GS43	25.7^{a}	14.1^{a}	3.4^{a}
Easy N flat fan nozzle @ 38kg N/ha	Amistar Xtra 800mL/ha	GS43	13.7^{b}	7.0^{bc}	2.3^{abc}
Easy N flat fan nozzle @ 38kg N/ha	Prosaro 300mL/ha, BS1000 0.25%	GS43	6.2^{bc}	6.4^{bcd}	2.7^{ab}
Easy N flat fan nozzle @ 38kg N/ha	Prosaro 300mL/ha	GS43	4.6^{c}	7.8^{b}	3.5^{a}
Mean			**6.8**	**4.8**	**1.8**
LSD			8.8	3.9	1.4

Figures followed by different letters are regarded as statistically significant.

same time as individual treatments received fungicide with liquid fertiliser. These fungicides were applied as a separate pass with flat fan jets applied with a hand boom. There was no observable difference in disease level due to how the fungicide was delivered, however this maybe partly due to the disease resistance shown by Trojan.

iii) Grain yield and quality

The high variability within treatments means there are no statistically significant treatment effects on yield.

There was a significant replicate effect on yield that resulted in the fourth replicate being excluded from the analysis due to waterlogging, however transient waterlogging was a general feature of the spring in Yarrawonga during the 2016 season, which contributed to the high in-trial variability.

When liquid and solid nitrogen applied at second node (GS32) were compared, there was no evidence to suggest the form of nitrogen influenced grain protein content. There were also no significant differences in test weight or screenings (Table 4).

When nitrogen was applied at booting (GS43) there was a non-significant trend for the solid urea treatment to be higher yielding compared with the Easy N treatments, but the high variability means no clear treatment effects were seen. In addition, there was no clear yield penalty in treatments measuring higher phytotoxic effects (i.e.

TABLE 4 Yield, protein, test weight and screenings on 11 December, 2016, at harvest (GS99)

Nitrogen application	Fungicide	Yield and quality				
		Timing	Yield (t/ha)	Protein (%)	Test weight (kg/hL)	Screenings (%)
-	-	GS32	3.78^{abc}	10.8^{cd}	81.3^{a}	1.2^{a}
Urea @ 38kg N/ha	-	GS32	3.58^{bc}	12.2^{a}	81.2^{a}	1.0^{a}
Easy N stream nozzle @ 38kg N/ha	-	GS32	4.01^{abc}	12.1^{abc}	80.5^{a}	1.2^{a}
Easy N flat fan nozzle @ 38kg N/ha	-	GS32	3.72^{abc}	12.1^{ab}	80.0^{a}	1.2^{a}
Easy N flat fan nozzle @ 38kg N/ha	Tilt 500mL/ha	GS32	4.51^{a}	$11.5^{a\text{-}d}$	81.2^{a}	0.9^{a}
Easy N flat fan nozzle @ 38kg N/ha	Amistar Xtra 800mL/ha	GS32	4.04^{abc}	10.9^{bcd}	81.1^{a}	1.2^{a}
-	-	GS43	3.92^{abc}	$11.3^{a\text{-}d}$	81.1^{a}	1.1^{a}
Urea @ 38kg N/ha	-	GS43	4.37^{ab}	10.4^{d}	81.4^{a}	1.1^{a}
Easy N stream nozzle @ 38kg N/ha	-	GS43	3.82^{abc}	12.0^{abc}	80.4^{a}	1.1^{a}
Easy N flat fan nozzle @ 38kg N/ha	-	GS43	3.16^{c}	12.2^{a}	80.7^{a}	0.9^{a}
Easy N flat fan nozzle @ 38kg N/ha (200L water)	-	GS43	3.13^{c}	11.8^{abc}	80.4^{a}	1.2^{a}
Easy N flat fan nozzle @ 38kg N/ha	Tilt 500mL/ha	GS43	3.49^{bc}	12.0^{abc}	80.5^{a}	1.1^{a}
Easy N flat fan nozzle @ 38kg N/ha	Amistar Xtra 800mL/ha	GS43	3.28^{c}	12.1^{ab}	79.9^{a}	1.1^{a}
Easy N flat fan nozzle @ 38kg N/ha	Prosaro 300mL/ha BS1000 0.25%	GS43	3.73^{abc}	12.4^{a}	79.9^{a}	1.0^{a}
Easy N flat fan nozzle @ 38kg N/ha	Prosaro 300mL/ha	GS43	3.52^{bc}	12.1^{ab}	80.2^{a}	1.0^{a}
Mean			**3.74**	**11.7**	**80.7**	**1.1**
LSD			0.92	1.3	2.2	0.4

scorch) such as the Tilt 250 EC treatment, which showed a comparable average yield to those treatments with minimal leaf damage, such as the Easy N flat fan.

The grain protein contents in the Easy N treatment tended to be higher than the solid urea treatment, however, this was also non-significant.

Conclusions

In a low-yielding field trial, affected by transient waterlogging during spring, it was shown that applying liquid nitrogen through flat fan nozzles, compared with streaming nozzles, showed no consistent differences in leaf damage when assessed on the top four leaves of the canopy. However while the yields in this trial were variable, with flat fan nozzles targeting the leaves with the nitrogen application, there was a trend for yields to be lower than using streaming nozzles, where a greater percentage of nitrogen applied would be taken up from the soil.

When the liquid fertiliser was mixed with fungicides the level of damage increased, particularly when applied at booting (GS43). The extent of phytotoxicity when a fungicide was added depended on the formulation of the fungicide and the angle of the canopy leaf exposed to the spray. The EC formulation resulted in at least twice the level of damage than that observed with SC formulations.

There were only small differences between the different SC formulations.

Increasing the water rate at the booting (GS43) application had no significant effect on phytotoxicity effects (leaf scorch), nor did adding adjuvant to one of the SC formulations.

The variable nature of the yield results does not allow significant comments to be made on yield.

Funding acknowledgement

This research was carried out at the Riverine Research Centre by FAR Australia, on behalf of Incitec Pivot Fertilisers, a sponsor of Riverine Plains Inc.

This trial was run at the Riverine Research Centre (RRC), an independent and dedicated crop research site located near Yarrawonga, Victoria. The RRC is a partnership between Riverine Plains Inc and FAR Australia and is supported by RRC hosts, the Cummins family.

Contact

Michael Straight Foundation for Arable Research, Australia

E: michael.straight@far.org.nz



North east Victoria National Variety Testing Trials 2016

Trials conducted by Agrisearch, Shepparton

Data collated by Katherine Hollaway (Astute Ag, Horsham), Johanna Couchman (DEDJTR, Horsham) and Dale Grey (DEDJTR, Bendigo) from data provided by the NVT website.

Note: In 2016 all trials experienced mild frosting during flowering and this may have affected yields. Interpret with caution.

TABLE 1 Long-term predicted wheat yield (main season) in north east Victoria for 2012–16

Predicted mean yield across trial sites and varieties (t/ha)		2012	2013	2014	2015	2016	2016	2016
		3.72	4.21	5.78	3.61	6.80	Predicted mean yield (t/ha)	% of LRPB Scout
	No. sites	3	3	3	4	4		
Variety	Site years	% of average across trial sites and varieties						
Beckom	14	107	110	110	111	108	7.34	103
Cobalt	8	106	111	111	109	108	7.34	103
LRPB Trojan	17	105	107	108	106	107	7.28	102
QAL2000	13	102	95	104	96	107	7.28	102
Cutlass	8	104	106	108	105	106	7.21	101
LRPB Cobra	17	101	107	108	108	106	7.21	101
LRPB Flanker	9	107	104	110	98	106	7.21	101
Coolah	5	106	102	109	99	105	7.14	100
Cosmick	13	103	106	104	105	105	7.14	100
LRPB Scout	17	103	102	104	104	105	7.14	100
LRPB Viking	11	105	105	109	97	105	7.14	100
Scepter	8	105	107	102	112	105	7.14	100
Impala	16	105	98	100	100	104	7.07	99
LRPB Phantom	16	100	101	103	102	104	7.07	99
Gazelle	8	97	94	98	96	102	6.94	97
Sunmate	10	104	97	101	101	102	6.94	97
Barham	15	102	89	97	89	101	6.87	96
Elmore CL Plus	16	102	98	101	97	101	6.87	96
Harper	15	101	99	99	98	101	6.87	96
Suntop	17	107	101	104	101	101	6.87	96
DS Pascal	14	90	91	96	95	100	6.80	95
Estoc	15	99	99	97	102	100	6.80	95
Magenta	16	99	102	98	99	100	6.80	95
EGA Gregory	16	104	102	104	94	99	6.73	94
Gascoigne	12	98	100	100	101	99	6.73	94
LRPB Arrow	8	97	101	97	105	99	6.73	94
Condo	17	101	108	102	105	98	6.66	93
Correll	15	102	100	97	96	98	6.66	93
Derrimut	17	98	97	96	98	98	6.66	93
Chara	8	96	100	101	97	97	6.60	92
Corack	17	99	106	97	108	97	6.60	92
LRPB Reliant	9	108	103	102	94	97	6.60	92

TABLE 1 Long-term predicted wheat yield (main season) in north east Victoria for 2012–16 (continued)

Predicted mean yield across trial sites and varieties (t/ha)		2012	2013	2014	2015	2016	2016	2016
		3.72	4.21	5.78	3.61	6.80		
	No. sites	3	3	3	4	4	Predicted mean yield (t/ha)	% of LRPB Scout
Variety	Site years	% of average across trial sites and varieties						
DS Darwin	17	95	99	96	101	96	6.53	91
DS Newton	10	92	94	94	95	96	6.53	91
LRPB Lancer	13	95	93	98	91	96	6.53	91
Justica CL Plus	15	94	96	92	98	95	6.46	90
LRPB Lincoln	15	90	98	93	100	95	6.46	90
Mace	14	97	105	97	106	95	6.46	90
Wallup	17	96	102	99	100	95	6.46	90
Yitpi	12	96	97	94	94	95	6.46	90
Grenade CL Plus	15	97	93	90	96	94	6.39	90
Kord CL Plus	12	98	99	93	99	94	6.39	90
Emu Rock	15	95	101	93	104	93	6.32	89
Gladius	16	93	97	91	99	93	6.32	89
LRPB Gauntlet	16	98	100	98	96	93	6.32	89
LRPB Merlin	15	96	95	91	96	92	6.26	88
LRPB Spitfire	16	94	95	91	97	91	6.19	87
Dart	6	95	94	88	96	89	6.05	85
Steel	8	92	103	93	100	87	5.92	83
Axe	15	93	101	90	96	85	5.78	81

  

TABLE 2 Long-term predicted wheat yield (long season) in north east Victoria for 2012–16*

Predicted mean yield across trial sites and varieties (t/ha)		2012	2013	2015	2016	2016	2016
		4.88	6.31	6.20	5.37		
	No. sites	1	1	1	1		
Variety	Site years	% of average across trial sites and varieties				Predicted mean yield (t/ha)	% of Preston
RGT Accroc	2	108	136	118	111	5.96	107
Cutlass	2	112	117	105	110	5.91	106
LRPB Trojan	3	116	111	108	110	5.91	106
Coolah	2	111	111	105	108	5.80	104
LRPB Flanker	2	109	106	98	107	5.75	103
Beckom	2	111	108	108	106	5.69	102
LRPB Phantom	3	107	107	102	106	5.69	102
LRPB Viking	4	106	103	100	104	5.58	100
Preston	4	106	110	108	104	5.58	100
QAL2000	4	102	112	105	104	5.58	100
Suntop	2	108	100	103	104	5.58	100
Beaufort	2	104	115	113	103	5.53	99
Kiora	4	104	110	108	103	5.53	99
Sentinel	2	104	105	103	103	5.53	99
SF Adagio	2	100	121	112	103	5.53	99
Elmore CL Plus	4	102	104	101	102	5.48	98
EGA Gregory	4	102	97	95	101	5.42	97
SQP Revenue	4	97	116	109	101	5.42	97
Chara	4	102	99	102	100	5.37	96
DS Darwin	4	103	92	95	100	5.37	96
Bolac	4	98	103	102	99	5.32	95
DS Pascal	3	96	109	107	99	5.32	95
EGA Wedgetail	4	93	106	100	99	5.32	95
Gascoigne	3	101	92	95	99	5.32	95
Gazelle	4	94	110	103	99	5.32	95
SF Ovalo	3	92	110	101	99	5.32	95
Forrest	3	91	109	102	98	5.26	94
LRPB Lancer	4	101	94	100	98	5.26	94
LRPB Gauntlet	4	100	86	95	97	5.21	93
Sunlamb	2	95	99	99	97	5.21	93
DS Newton	2	97	89	97	96	5.16	92
Manning	3	93	109	111	96	5.16	92
Kellalac	3	89	97	96	95	5.10	91
LRPB Kittyhawk	2	91	100	101	95	5.10	91
SF Scenario	2	86	104	102	93	4.99	90
Mansfield	3	79	86	92	87	4.67	84

*Data from 2014 has been excluded from this table due to the high variability of the results.

TABLE 3 Yield and quality of wheat (main season) at Dookie for 2016

Variety	Yield (t/ha)	Test weight (kg/hL)	Protein (%)	Screenings <2.0mm (%)	Seed size (g/1000 seeds)	Height (cm)	Heading year day*
Beckom	7.67	79.2	8.0	2.3	40	85	262
LRPB Flanker	7.61	76.2	8.5	2.6	53	110	259
LRPB Cobra	7.60	79.8	8.7	2.0	50	85	257
Impala	7.59	80.8	8.2	1.7	44	100	259
LRPB Phantom	7.54	80.2	8.4	4.2	47	105	273
Coolah	7.51	78.4	8.9	6.1	48	105	264
Cobalt	7.46	81.2	8.8	3.5	43	95	264
Scepter	7.44	77.2	9.1	2.9	50	95	273
QAL2000	7.43	77.2	9.7	2.1	46	105	269
Cutlass	7.42	77.8	8.2	2.8	50	100	276
LRPB Scout	7.38	78.2	8.8	2.8	47	90	262
LRPB Trojan	7.38	80.4	8.7	4.5	44	90	264
Cosmick	7.32	78.6	8.0	3.1	42	95	262
Magenta	7.29	82.2	9.1	2.7	53	100	273
Barham	7.24	76.4	8.2	3.1	43	110	262
EGA Gregory	7.17	79.2	8.7	2.8	50	110	266
LRPB Viking	7.11	79.2	8.7	3.5	51	105	264
DS Pascal	7.08	80.8	9.1	2.5	43	90	269
LRPB Arrow	7.08	80.2	8.5	3.7	55	80	266
Suntop	7.07	81.2	8.9	2.0	46	105	259
Emu Rock	7.06	79.2	9.1	5.3	57	90	259
Corack	7.03	80.4	9.5	1.7	52	85	262
Estoc	7.03	80.2	8.8	2.5	49	95	280
DS Darwin	7.02	80.2	9.1	6.0	51	90	264
LRPB Lincoln	7.02	78.6	8.8	3.8	49	100	269
Mace	7.01	81.2	9.0	3.0	48	95	255
Condo	7.00	80.6	9.4	5.0	49	100	245
Harper	6.98	79.6	8.8	3.8	51	105	280
LRPB Merlin	6.98	79.4	8.8	2.3	42	95	259
Grenade	6.96	78.2	8.6	3.1	55	95	257
Elmore CL Plus	6.92	81.8	8.8	3.4	43	95	264
DS Faraday	6.87	81.4	8.9	2.7	45	100	259
Correll	6.85	79.0	9.4	3.0	47	105	264
LRPB Spitfire	6.85	76.4	8.3	2.9	40	95	259
Gladius	6.84	79.2	9.2	2.3	53	90	259
Lancer	6.84	81.6	9.6	2.5	45	90	266
Justica	6.83	80.2	8.7	1.8	49	90	262
LRPB Reliant	6.81	81.2	9.1	3.5	51	100	255
Yitpi	6.80	80.4	8.8	3.7	50	115	273
Wallup	6.75	79.6	9.5	1.0	49	90	266
Derrimut	6.71	79.0	8.7	3.3	44	85	259
LRPB Gauntlet	6.68	80.0	8.6	1.8	51	90	264
Kord	6.60	77.2	9.3	4.4	58	90	255
Steel	6.47	81.4	8.8	1.7	57	95	257
Axe	6.11	78.6	10.8	1.5	53	90	262

Sown 17 May 2016	**Site mean (t/ha)** 7.13	**F prob**	<0.001	**pH ($CaCl_2$)**	5.20
Harvest 12 December 2016	**CV (%)** 2.30	**LSD (t/ha)**	0.30	**GSR (Apr–Oct)**	485mm

* Heading year day is the calendar day of the year on which the crop heads emerged.
Fungicides were applied during July, August and September.



TABLE 4 Yield and quality of wheat (main season) at Wunghnu for 2016

Variety	Yield (t/ha)	Test weight (kg/hL)	Protein (%)	Screenings (%)	Seed size (g/1000 seeds)	Height (cm)	Lodging (1–9)	Heading year day*
Beckom	7.35	79.6	9.3	0.6	47	75	0	250
LRPB Trojan	7.31	80.0	9.2	0.7	57	90	3	259
LRPB Cobra	7.29	79.4	10.5	8.2	41	80	7	250
DS Pascal	7.03	80.6	9.8	0.7	50	95	0	255
LRPB Flanker	7.03	81.2	9.6	0.8	44	105	3	252
Scepter	7.00	79.0	10.0	0.8	44	95	0	255
QAL2000	6.96	76.4	9.2	0.7	46	105	3	259
Coolah	6.93	80.8	9.3	0.8	50	100	0	259
Impala	6.93	79.2	9.4	1.2	39	95	0	250
Suntop	6.93	79.8	10.6	1.1	46	100	0	259
LRPB Scout	6.92	80.2	10.2	0.9	49	95	0	257
Estoc	6.91	81.4	10.8	0.7	43	90	0	262
Harper	6.91	80.6	9.9	1.6	50	105	3	266
Cutlass	6.90	79.6	9.9	0.9	55	95	0	264
LRPB Arrow	6.88	75.8	10.3	0.5	46	90	0	259
Cosmick	6.87	81.0	9.6	0.9	45	95	0	257
LRPB Viking	6.87	81.2	10.2	1.1	48	95	3	262
Cobalt	6.80	79.6	10.2	0.9	50	80	0	250
Elmore CL Plus	6.78	80.4	9.8	1.1	46	90	0	259
LRPB Phantom	6.76	78.8	9.3	1.2	43	105	0	252
Barham	6.73	77.0	9.4	0.7	54	95	0	255
DS Faraday	6.59	80.0	9.6	0.9	46	100	0	259
Lancer	6.51	80.8	10.6	0.7	53	80	0	252
Condo	6.50	80.0	10.5	0.7	55	90	3	252
LRPB Reliant	6.50	80.0	10.3	1.2	45	90	3	252
Justica CL Plus	6.49	77.6	10.1	0.4	43	85	0	266
Derrimut	6.47	80.4	10.0	1.3	43	85	0	250
Emu Rock	6.42	79.2	11.0	1.1	49	80	0	243
Grenade CL Plus	6.42	79.8	10.1	0.6	43	85	0	248
LRPB Gauntlet	6.40	79.6	10.0	0.8	46	80	3	262
Correll	6.30	78.0	10.3	12.0	52	95	3	259
EGA Gregory	6.30	80.0	9.5	0.7	53	105	0	262
DS Darwin	6.28	80.2	10.7	0.4	52	85	3	262
Wallup	6.27	78.6	11.0	0.3	50	90	0	257
Magenta	6.24	79.8	9.5	1.4	42	95	3	259
Kord CL Plus	6.20	79.0	10.9	0.5	56	90	3	262
Corack	6.17	78.6	11.6	0.6	51	90	3	248
LRPB Lincoln	6.16	79.8	9.7	1.0	52	90	0	255
Mace	6.12	79.0	10.4	0.5	47	85	3	257
LRPB Merlin	6.05	80.6	11.3	0.8	55	80	7	257
Gladius	6.00	78.0	10.4	0.5	58	90	0	257
Yitpi	6.00	79.8	10.7	1.3	49	105	3	252
LRPB Spitfire	5.89	80.6	11.4	1.0	46	95	3	262
Steel	5.86	76.0	11.4	0.7	42	90	7	250
Axe	5.34	77.2	12.6	0.3	60	85	0	241

Sown	4 May 2016	**Site mean (t/ha)**	6.65	**F prob**	<0.001	**pH ($CaCl_2$)**	4.50
Harvest	17 December 2016	**CV (%)**	3.6	**LSD (t/ha)**	0.43	**GSR (Apr–Oct)**	498mm

* Heading year day is the calendar day of the year on which the crop heads emerged.

Fungicides were applied during July, August, September and October.

TABLE 5 Yield and quality of wheat (main season) at Yarrawonga for 2016

Variety	Yield (t/ha)	Test weight (kg/hL)	Protein (%)	Screenings (%)	Seed size (g/1000 seeds)	Height (cm)	Heading year day*
QAL2000	6.26	77.8	8.4	3.6	54	90	276
Scout	6.24	82.6	9.8	4.5	53	95	264
Scepter	6.02	80.6	9.2	4.0	53	80	269
Cosmick	6.01	81.8	9.5	4.9	48	95	269
Trojan	5.89	81.4	9.6	3.5	48	80	273
Viking	5.87	83.2	9.2	2.4	46	100	269
Barham	5.86	79.6	9.4	3.5	41	95	276
Cutlass	5.86	81.0	9.4	2.1	42	95	278
Suntop	5.86	80.8	10.5	3.4	50	100	266
Coolah	5.81	80.6	9.0	3.3	38	95	273
Magenta	5.81	81.6	9.7	5.2	48	95	273
Yitpi	5.77	80.6	9.4	5.3	46	100	276
LRPB Flanker	5.74	81.4	9.3	3.1	44	105	271
Beckom	5.65	81.0	9.5	3.8	50	70	266
Phantom	5.65	79.8	8.9	4.8	43	95	271
Lincoln	5.62	80.0	9.4	6.5	47	95	276
EGA Gregory	5.60	82.4	9.3	3.9	44	105	271
Cobalt	5.59	81.6	9.3	3.9	46	90	269
Correll	5.54	80.0	9.9	6.6	40	95	271
Cobra	5.53	79.8	10.0	5.1	43	85	262
DS Faraday	5.53	82.4	9.2	4.1	49	90	273
LRPB Reliant	5.53	82.4	9.7	4.9	52	100	264
Derrimut	5.52	81.6	9.6	4.6	55	80	271
Condo	5.47	80.6	10.3	6.5	46	90	250
Elmore	5.42	82.6	9.2	4.4	51	90	269
Harper	5.40	80.4	9.7	5.3	51	100	276
DS Darwin	5.17	81.4	9.6	4.8	47	80	273
Gauntlet	5.13	81.8	9.8	6.0	46	85	264
Impala	5.13	80.4	9.4	3.5	40	90	276
LRPB Arrow	5.13	82.0	10.8	1.9	42	80	271
Steel	5.11	78.8	11.1	3.2	41	95	259
Grenade CL Plus	5.09	80.8	10.1	3.0	48	80	269
Estoc	5.02	82.4	9.5	4.7	52	85	276
Spitfire	5.02	81.6	10.2	5.6	48	85	255
Wallup	4.96	80.2	10.2	1.4	39	75	264
Justica	4.95	78.6	9.8	3.6	51	85	273
Lancer	4.92	80.0	10.2	4.0	47	80	276
Mace	4.91	80.2	10.2	3.3	54	90	264
Kord	4.84	78.6	10.2	7.2	55	85	273
Corack	4.64	80.6	9.8	4.1	50	80	259
Merlin	4.61	81.2	10.7	5.4	48	85	248
DS Pascal	4.52	79.4	9.5	4.1	41	85	271
Emu	4.48	80.0	10.2	6.7	50	80	250
Gladius	4.43	78.6	10.0	4.3	51	75	271
Axe	4.31	79.6	11.0	4.5	53	65	252
Sown 18 May 2016		**Site mean (t/ha)** 5.45		**F prob** <0.001		**pH ($CaCl_2$)** 5.40	
Harvest 19 December 2016		**CV (%)** 5.7		**LSD (t/ha)** 0.56		**GSR (Apr–Oct)** 604mm	

* Heading year day is the calendar day of the year on which the crop heads emerged.

Fungicides were applied during July, August and September.



TABLE 6 Yield and quality of irrigated wheat (main season) at Numurkah for 2016

Variety	Yield (t/ha)	Test weight (kg/hL)	Protein (%)	Screenings (%)	Seed size (g/1000 seeds)	Height (cm)	Lodging (1–9)	Heading year day*
Cobalt	9.48	78.8	12.1	0.3	49	90	3	250
LRPB Trojan	9.11	79.4	11.3	0.3	54	90	0	255
Cosmick	8.84	79.8	12.4	0.6	44	95	0	252
Cutlass	8.79	80.0	12.1	0.5	58	100	0	280
Estoc	8.55	80.8	12.8	0.8	62	90	0	259
QAL2000	8.52	77.0	11.1	0.7	60	90	0	248
LRPB Cobra	8.48	79.2	13.3	0.3	54	90	0	245
Coolah	8.43	79.6	11.7	0.5	53	100	0	252
LRPB Viking	8.43	80.8	12.1	0.4	48	95	0	259
Scepter	8.42	78.8	12.3	0.5	66	85	0	250
Condo	8.34	80.0	12.8	0.3	64	100	0	235
Impala	8.34	78.6	11.7	0.7	39	100	0	245
Beckom	8.31	78.6	11.3	0.6	48	95	0	248
DS Pascal	8.23	79.4	12.0	0.4	60	90	0	250
LRPB Scout	8.18	80.2	12.0	0.6	46	95	0	252
LRPB Phantom	8.04	78.2	10.9	0.9	60	90	0	250
Magenta	8.03	78.8	12.5	1.0	50	95	0	255
Suntop	8.02	79.8	12.1	1.2	62	100	0	250
Yitpi	8.02	79.0	12.2	0.8	48	95	0	252
Justica	7.98	77.4	12.4	0.6	58	90	0	252
LRPB Flanker	7.98	80.2	12.1	0.3	52	100	0	257
Lancer	7.92	79.8	12.7	0.5	55	90	0	252
Kord	7.91	78.0	13.4	0.4	62	95	0	255
Grenade	7.83	78.6	12.5	0.4	50	90	0	248
Elmore	7.82	80.8	12.1	0.9	48	95	0	250
Gladius	7.81	77.2	13.4	0.4	54	85	0	223
DS Darwin	7.75	79.8	13.1	0.4	46	95	0	245
LRPB Arrow	7.74	79.4	13.4	0.1	52	85	0	257
Harper	7.67	77.8	12.7	2.4	46	100	0	250
EGA Gregory	7.66	79.2	12.5	0.6	63	95	0	259
LRPB Gauntlet	7.59	80.0	12.0	0.5	62	95	0	248
Emu	7.55	77.2	13.0	0.8	58	85	0	234
Correll	7.40	76.6	12.8	0.7	60	95	0	252
LRPB Lincoln	7.38	78.8	12.2	0.8	56	105	3	257
Derrimut	7.34	79.8	12.3	1.1	50	70	0	259
Barham	7.30	75.6	12.1	0.7	56	80	0	252
LRPB Spitfire	7.25	79.6	13.0	0.9	64	100	0	241
LRPB Merlin	7.22	79.6	13.7	0.7	60	90	0	233
Wallup	7.21	74.8	12.1	0.9	52	100	4	252
LRPB Kittyhawk	7.08	80.8	12.2	1.0	53	85	0	273
Mace	6.93	77.8	13.3	0.5	56	85	0	255
Corack	6.81	77.8	13.5	0.2	64	90	0	241
Axe	6.10	76.6	14.5	0.4	42	85	0	215
Steel	6.05	74.8	13.6	0.4	47	70	0	241

Sown	28 April 2016	**Site mean**	8.04t/ha	**F prob**	<0.001	**pH ($CaCl_2$)**	5.70
Harvest	15 December 2016	**CV (%)**	4.2	**LSD (t/ha)**	0.56	**GSR (Apr–Oct)**	498mm

* Heading year day is the calendar day of the year on which the crop heads emerged.

Fungicides were applied during July, August, September and October.

TABLE 7 Yield and quality of wheat (long season) at Rutherglen for 2016

Variety	Yield (t/ha)	Test weight (kg/hL)	Protein (%)	Screenings (%)	Seed size (g/1000 seeds)	Height (cm)	Heading year day*
Viking	6.00	80	9.9	3.2	50	85	261
Preston	5.96	76	9.3	4.9	42	80	250
Cutlass	5.82	78	9.4	5.1	41	90	271
RGT Accroc	5.82	76	8.5	5.8	55	85	290
LRPB Flanker	5.75	80	8.9	3.5	48	80	261
Coolah	5.74	78	8.8	3.9	53	90	257
QAL2000	5.67	76	8.6	6.7	50	85	248
SF Adagio	5.62	75	8.9	6.3	51	100	285
SQP Revenue	5.60	76	8.5	8.6	36	90	290
Suntop	5.60	79	9.4	5.6	47	65	252
Chara	5.49	78	9.2	3.5	47	90	269
SF Ovalo	5.49	76	9.1	7.8	40	85	297
Trojan	5.49	80	9.3	3.2	43	85	259
DS Faraday	5.48	81	9.1	4.6	47	95	261
Kiora	5.47	78	8.5	6.5	48	80	271
Bolac	5.38	78	9.4	5.6	48	80	261
Phantom	5.25	76	10.3	4.8	51	80	261
Elmore CL Plus	5.23	80	9.0	5.5	44	75	261
Gazelle	5.22	73	8.7	3.8	40	80	271
Beckom	5.11	78	8.8	5.7	43	90	259
DS Pascal	5.08	78	10.0	3.4	45	85	261
DS Darwin	5.02	80	9.7	3.8	53	90	248
Forrest	4.99	78	9.4	6.3	40	100	287
LRPB Kittyhawk	4.97	79	8.8	6.0	44	80	283
Lancer	4.89	79	9.2	4.9	51	75	269
EGA Wedgetail	4.87	77	9.5	4.0	44	90	280
EGA Gregory	4.75	78	8.6	5.0	47	90	271
Manning	4.66	72	9.0	7.8	49	100	300
SF Scenario	4.64	74	9.4	8.4	52	85	303
Gauntlet	4.63	80	9.6	3.5	43	60	250
Sunlamb	4.53	77	10.2	5.9	39	90	297

Sown	2 May 2016	**Site mean (t/ha)**	5.36	**F prob**	<0.001	**pH ($CaCl_2$)**	6.10
Harvest	19 December 2016	**CV (%)**	6.2	**LSD (t/ha)**	0.57	**GSR (Apr–Oct)**	493mm

* Heading year day is the calendar day of the year on which the crop heads emerged.
Fungicides were applied in August, September and October

TABLE 8 Long-term predicted barley yield in north east Victoria for 2012–16

Predicted mean yield across trial sites and varieties (t/ha)		2012	2013	2014	2015	2016	2016	2016
		3.53	3.77	5.54	2.43	7.28	Predicted mean yield (t/ha)	% of Hindmarsh
	No. sites	1	1	1	1	1		
Variety	Site years	% of average across site and variety						
Malt barley								
Charger	5	111	103	105	111	101	7.35	102
Fairview	5	100	99	99	82	101	7.35	102
Granger	5	102	101	100	97	101	7.35	102
La Trobe	5	101	103	100	120	100	7.28	101
Navigator	3	94	94	100	78	100	7.28	101
Wimmera	2	92	99	95	83	100	7.28	101
Baudin	5	88	96	95	88	99	7.21	100
Commander	5	94	95	100	95	99	7.21	100
Westminster	5	98	98	98	81	99	7.21	100
Bass	5	87	98	94	94	98	7.13	99
Buloke	5	94	99	97	101	98	7.13	99
Flinders	5	95	100	97	97	98	7.13	99
Scope	5	95	98	98	102	97	7.06	98
Macquarie	4	92	94	98	85	95	6.92	96
Gairdner	5	91	95	97	92	94	6.84	95
Flagship	4	74	92	89	95	90	6.55	91
Schooner	4	75	92	89	95	89	6.48	90
Feed barley								
RGT Planet	1	131	112	110	103	112	8.15	113
Explorer	1	120	106	108	108	106	7.72	107
Rosalind	3	121	110	108	128	106	7.72	107
Maltstar	5	104	101	102	87	104	7.57	105
Oxford	5	99	99	99	77	103	7.50	104
Alestar	5	108	103	102	97	102	7.43	103
Henley	2	103	101	101	96	101	7.35	102
Fathom	5	92	98	98	110	100	7.28	101
Hindmarsh	5	101	104	99	123	99	7.21	100
Skipper	2	90	97	97	112	97	7.06	98
Maritime	1	90	96	97	103	94	6.84	95
Barley under malt evaluation								
Spartacus CL	3	100	104	99	123	100	7.28	101
Compass	5	104	101	104	126	99	7.21	100
SY Rattler	5	108	103	102	104	99	7.21	100

TABLE 9 Yield of barley varieties at Wunghnu for 2016

Variety	Yield (t/ha)	Test weight (kg/hL)	Protein (%)	Plumpness (>2.5mm)	Screenings (<2.2mm)	Seed size (g/1000 seeds)	Height (cm)	Heading year day*
RGT Planet	8.18	67.6	8.2	94	1.4	54	95	257
Rosalind	7.86	69.3	8.7	93	0.6	48	85	257
Compass	7.78	68.6	8.8	97	0.8	52	85	255
Oxford	7.70	70.0	8.6	91	0.2	44	75	273
Charger	7.63	68.9	8.8	96	0.4	53	80	255
Granger	7.61	70.5	9.5	98	0.1	48	95	257
Navigator	7.60	69.0	9.0	97	1.1	46	95	273
Fathom	7.54	70.1	9.2	96	0.9	49	90	255
Westminster	7.53	72.0	9.4	98	0.2	52	100	259
Explorer	7.41	67.3	8.8	95	1.1	48	85	257
Maltstar	7.29	70.3	7.9	92	0.4	41	85	262
Scope	7.29	70.1	9.7	91	0.5	48	95	257
Buloke	7.27	69.7	8.8	89	0.6	49	90	255
SY Rattler	7.23	70.2	9.5	96	0.2	45	95	257
Commander	7.21	69.9	8.3	95	1.5	52	95	259
Spartacus CL	7.21	71.4	9.6	90	2.1	44	80	255
Alestar	7.18	70.6	8.7	97	0.3	49	85	262
Bass	7.08	72.0	9.8	98	0.1	55	75	262
La Trobe	6.97	71.7	9.5	91	0.6	45	70	255
Baudin	6.93	71.8	9.6	98	0.2	49	75	257
Hindmarsh	6.86	71.8	9.9	91	0.8	52	85	255
Flinders	6.49	71.0	9.2	98	0.4	46	70	262
Gairdner	6.36	71.7	9.2	93	1.2	43	105	259
Fairview	6.17	69.9	9.7	93	1.2	46	85	270
Sown 23 May 2016		**Site mean (t/ha)** 7.31		**F prob** 0.0167			**pH ($CaCl_2$)** 4.5	
Harvest 29 November 2016		**CV (%)** 7.7		**LSD (t/ha)** 0.94			**GSR (Apr–Oct)** 498mm	

* Heading year day is the calendar day of the year on which the crop heads emerged.
Fungicides were applied during July, August and September.

TABLE 10 Long-term predicted oat yield in north east Victoria for 2012–16

Predicted mean yield across trial sites and varieties (t/ha)		2012	2013	2014	2015	2016	2016	2016
		3.25	4.06	3.73	2.37	6.34		
	No. trials	2	3	2	2	1	Predicted mean yield (t/ha)	% of Mitika
Variety	Site years	% of average across trial sites and varieties						
Wandering	1	99	113	102	77	138	8.75	131
Bannister	10	119	120	113	95	136	8.62	130
Williams	10	127	122	117	97	130	8.24	124
Potoroo	4	108	113	106	91	127	8.05	121
Dunnart	10	107	111	106	91	125	7.93	119
Echidna	7	111	114	107	87	122	7.73	116
Wombat	10	120	115	112	99	119	7.54	113
Quoll	4	116	114	109	86	115	7.29	110
Kojonup	1	120	113	112	102	113	7.16	108
Possum	10	103	104	102	107	110	6.97	105
Euro	2	107	106	105	97	108	6.85	103
Mitika	10	93	98	97	110	105	6.66	100
Yallara	10	98	98	99	92	97	6.15	92
Carrolup	1	102	100	100	92	96	6.09	91
Durack	8	90	92	94	107	92	5.83	88
Numbat	2	95	78	91	104	32	2.03	30



TABLE 11 Yield of oat varieties at Dookie for 2016

Variety	Yield (t/ha)	Test weight (kg/hL)	Protein (%)	Screenings (%)	Seed size (g/1000 seeds)	Height (cm)	Heading year day*
Bannister	7.51	52	7.9	4.9	39	115	280
Potoroo	7.34	49	8.3	9.0	40	110	273
Williams	7.24	53	8.7	13.7	34	135	273
Dunnart	7.22	52	8.3	2.2	38	125	280
Echidna	6.94	52	8.5	8.9	39	110	285
Wombat	6.89	51	8.4	8.3	43	100	280
Possum	5.83	48	9.4	7.3	34	95	276
Mitika	5.35	50	10.0	4.8	44	85	271
Durack	5.26	54	10.6	2.04	39	120	262
Yallara	5.24	53	9.2	7.23	36	125	271
Sown 17 May 2016		**Site mean (t/ha)** 6.32		**F prob** <0.001		**pH ($CaCl_2$)** 5.2	
Harvest 12 December 2016		**CV (%)** 2.70		**LSD (t/ha)** 0.30		**GSR (Apr–Oct)** 485mm	

* Heading year day is the calendar day of the year on which the crop heads emerged.
Fungicides were applied during July and September.
The Yarrawonga oat trial has been discontinued in NVT testing.

TABLE 12 Long-term predicted yield of mid-season conventional canola in north east Victoria for 2012–16

Predicted mean yield across trial sites and varieties (t/ha)		2012	2013	2014	2015	2016	2016	2016
		2.63	1.62	2.97	1.19	3.07	Predicted mean yield (t/ha)	% of Diamond
	No. trials	1	1	1	1	1		
Variety	Site years	% of average across trial sites and varieties						
AV Garnet	5	103	98	99	95	106	3.25	104
Nuseed Diamond	5	103	112	110	138	102	3.13	100
Victory V3002	3	104	103	102	102	101	3.10	99
Hyola 50	3	106	109	107	109	97	2.98	95
CB Tango C	2	99	98	97	96	96	2.95	94
AV Zircon	4	102	99	98	89	95	2.92	93
CB Agamax	2	99	101	99	109	92	2.82	90

TABLE 13 Yield of mid-season conventional canola at Wunghnu for 2016

Variety	Yield (t/ha)	Oil (%)	Seed protein (%)	Seed size (g/1000 seeds)	50% flowering (year day)	Lodging (1–9)	Height (cm)
AV Garnet	3.29	47.3	18.1	3.2	230	2	135
Nuseed Diamond	3.15	47.7	18.2	3.4	215	4	133
Sown 5 May 2016		**Site mean (t/ha)** 3.24		**F prob** 0.915 NS		**pH ($CaCl_2$)** 4.80	
Harvest 29 November 2016		**CV (%)** 7.0		**LSD (t/ha)** 0.36		**GSR (Apr–Oct)** 498mm	

Fungicide was applied during June and August.

TABLE 14 Long-term predicted yield of imidazolinone-tolerant (IMI) canola (mid-season) in north east Victoria for 2012–16

Predicted mean yield across trial sites and varieties (t/ha)		2012	2013	2014	2015	2016	2016	2016
		2.70	2.04	2.95	1.71	3.12	Predicted mean yield (t/ha)	% of Hyola 474CL
	No. trials	2	2	2	2	2		
Variety	Site years	% of average across trial sites and varieties						
Banker CL	5	106	108	112	113	119	3.71	116
Pioneer 45Y88 (CL)	10	102	102	105	102	112	3.49	109
Hyola 577CL	7	97	99	103	96	111	3.46	108
Archer	8	104	105	103	95	104	3.24	101
Hyola 474CL	9	96	100	102	96	103	3.21	100
Pioneer 44Y89 (CL)	4	103	104	104	111	102	3.18	99
Hyola 575CL	10	95	100	101	95	102	3.18	99
Pioneer 45Y86 (CL)	8	104	105	102	102	99	3.09	96
Pioneer 44Y87 (CL)	6	102	101	100	103	99	3.09	96
Rimfire CL	5	102	105	102	97	98	3.06	95
Carbine	4	99	96	96	102	93	2.90	90
Pioneer 44Y84 (CL)	4	103	100	97	101	91	2.84	88

TABLE 15 Yield and quality of imidazolinone-tolerant (IMI) canola (mid-season) at Wunghnu for 2016

Variety	Yield (t/ha)	Oil (%)	Seed protein (%)	Seed size (g/1000 seeds)	50% flowering year day*	Height (cm)
Pioneer 45Y91 CL	3.78	47.5	17.7	3.0	241	135
Banker CL	3.66	47.4	18.6	3.3	241	130
Hyola 474 CL	3.61	46.2	18.3	3.5	236	150
Pioneer 45Y88 CL	3.58	46.2	17.6	3.4	236	145
Hyola 575 CL	3.17	46.4	18.3	2.7	231	150
Sown 5 May 2016	**Site mean (t/ha)** 3.60		**F prob** 0.0417		**pH ($CaCl_2$)** 4.80	
Harvest 29 November 2016	**CV (%)** 6.2		**LSD (t/ha)** 0.36		**GSR (Apr–Oct)** 498mm	

*50% flowering year day is the calendar day of the year on which 50% of the crop flowered.
Fungicide was applied during June and August.

TABLE 16 Yield and quality of imidazolinone-tolerant (IMI) canola (mid-season) at Yarrawonga for 2016

Variety	Yield (t/ha)	Oil (%)	Seed protein (%)	Seed size (g/1000 seeds)	50% flowering year day*	Height (cm)
Hyola 577 CL	3.44	46.0	20.1	4.1	241	155
Pioneer 45Y91 CL	3.32	45.8	19.2	4.2	244	140
Banker CL	3.25	46.7	19.2	3.7	245	135
Pioneer 45Y88 CL	2.83	44.9	18.9	4.0	241	150
Hyola 575 CL	2.61	45.5	20.5	4.0	241	145
Sown 12 May 2016	**Site mean (t/ha)** 3.23		**F prob** <0.001		**pH ($CaCl_2$)** 5.02	
Harvest 1 December 2016	**CV (%)** 6.1		**LSD (t/ha)** 0.32		**GSR (Apr–Oct)** 604mm	

*50% flowering year day is the calendar day of the year on which 50% of the crop flowered.
Fungicide was applied during June and August.



TABLE 17 Long-term predicted yield of triazine tolerant (TT) canola (mid season) in north east Victoria for 2012–16

Predicted mean yield across trial sites and varieties (t/ha)		2012	2013	2014	2015	2016	2016	2016
		2.70	2.04	2.95	1.71	3.12	Predicted mean yield (t/ha)	% of Hyola 559TT
	No. trials	2	2	2	2	2		
Varieties	Site years	% of average across trial sites and varieties						
SF Turbine TT	4	100	100	104	110	107	3.34	103
Hyola 650TT	7	97	102	104	95	107	3.34	103
Hyola 555TT	4	98	99	102	101	104	3.24	101
Crusher TT	4	103	97	99	100	104	3.24	101
Hyola 656TT	4	99	100	101	98	104	3.24	101
ATR Wahoo	10	100	94	96	91	104	3.24	101
Thumper TT	4	90	88	92	83	104	3.24	101
Hyola 559TT	10	101	104	104	105	103	3.21	100
DG 560TT	4	102	101	100	105	99	3.09	96
Pioneer 45T01TT	7	103	100	99	103	99	3.09	96
ATR Bonito	10	102	95	96	101	99	3.09	96
Hyola 725RT	5	101	101	99	92	98	3.06	95
ATR Gem	10	100	94	95	95	98	3.06	95
ATR Mako	6	101	98	97	100	97	3.03	94
Monola 416TT	6	95	91	93	96	97	3.03	94
ATR Stingray	4	93	89	93	99	97	3.03	94
Hyola 450TT	4	96	99	99	97	96	3.00	93
Hyola 525RT	8	97	96	96	99	95	2.96	92
Pioneer Atomic TT	6	104	101	97	99	92	2.87	89
CB Henty HT	4	100	101	95	83	92	2.87	89
Pioneer Sturt TT	4	93	89	89	97	88	2.75	85
Monola 515TT	6	89	88	87	78	88	2.75	85
Monola 314TT	6	95	86	84	90	81	2.53	78
CB Nitro HT	4	98	98	92	98	80	2.50	77
CB Jardee HT	4	98	95	88	87	80	2.50	77
Monola 413TT	4	93	84	81	85	79	2.46	76

TABLE 18 Yield and quality of triazine tolerant (TT) canola (mid season) at Wunghnu for 2016

Variety	Yield (t/ha)	Oil (%)	Seed protein (%)	Seed size (g/1000 seeds)	50% flowering year day*	Lodging (1–9)	Height (cm)
InVigor T 4510	3.31	47.3	17.9	3.5	234	3	132
SF Ignite TT	3.27	47.9	17.4	3.3	241	1	140
Hyola 650 TT	3.17	48.1	17.9	6.1	234	3	128
DG 670 TT	3.14	46.7	19.4	3.4	238	2	125
ATR Bonito	2.93	48.6	18.4	3.2	227	5	110
SF Turbine TT	2.92	45.9	19.0	3.8	231	6	127
Monola 416 TT	2.79	47.7	19.5	3.1	231	7	133
Hyola 525 RT	2.74	44.0	19.5	3.6	238	1	140
Hyola 559 TT	2.71	47.7	18.8	3.8	231	5	130
Pioneer 45T01TT	2.70	47.8	19.3	3.2	234	6	150
ATR Wahoo	2.68	48.9	17.1	4.2	241	2	120
ATR Gem	2.66	48.6	17.7	2.7	234	4	130
Hyola 725 RT	2.64	47.8	17.9	3.1	236	5	150
ATR Mako	2.61	46.1	18.7	3.0	222	3	120
DG 560 TT	2.44	44.2	18.9	3.2	234	7	120
Monola 515 TT	2.30	47.3	19.0	3.2	231	6	110

Sown 05 May 2016 **Site mean (t/ha)** 2.83 **F prob** <0.001 **pH ($CaCl_2$)** 4.80
Harvest 29 November 2016 **CV (%)** 7.9 **LSD (t/ha)** 0.37 **GSR (Apr–Oct)** 498mm

*50% flowering year day is the calendar day of the year on which 50% of the crop flowered.
Fungicide was applied during June and August.

TABLE 19 Yield and quality of triazine tolerant (TT) canola (mid season) at Yarrawonga for 2016

Variety	Yield (t/ha)	Oil (%)	Seed protein (%)	Seed size (g/1000 seeds)	50% flowering year day*	Height (cm)
InVigor T 4510	3.83	45.5	19.5	3.8	241	130
DG 670 TT	3.74	44.4	20.1	4.5	245	135
SF Ignite TT	3.66	46.3	18.9	4.4	241	145
Hyola 350 TT	3.48	45.5	21.0	4.6	228	135
Hyola 650 TT	3.44	46.8	19.3	4.6	245	135
SF Turbine TT	3.34	43.8	20.2	3.9	236	130
ATR Wahoo	3.28	46.4	19.3	4.6	245	135
Hyola 725 RT	3.24	47.1	19.2	4.2	245	170
Pioneer 45T01TT	3.19	47.2	20.3	4.0	240	140
ATR Mako	3.18	44.5	19.8	4.8	228	135
ATR Gem	3.16	46.6	19.7	4.2	241	135
DG 560 TT	3.15	44.2	19.5	4.4	237	130
Hyola 525 RT	3.15	46.3	19.6	5.2	241	135
Hyola 559 TT	3.12	46.5	19.6	4.8	241	140
ATR Bonito	2.98	48.2	18.4	4.0	237	105
Monola 416 TT	2.77	46.8	19.8	3.8	237	130
Monola 515 TT	2.49	45.2	20.2	4.6	241	120

Sown 12 May 2016 **Site mean (t/ha)** 3.26 **F prob** <0.001 **pH ($CaCl_2$)** 5.02
Harvest 1 December 2016 **CV (%)** 5.9 **LSD (t/ha)** 0.32 **GSR (Apr–Oct)** 493mm

*50% flowering year day is the calendar day of the year on which 50% of the crop flowered.
Fungicide was applied during June and August.



TABLE 20 Long-term predicted yield of Roundup Ready (RR) canola in north east Victoria for 2012–16

Predicted mean yield across trial sites and varieties (t/ha)		2012	2013	2014	2015	2016	2016	2016
		2.70	2.04	2.95	1.71	3.12		
	No. trials	2	2	2	2	2	Predicted mean yield (t/ha)	% of Nuseed GT-50
Variety	Site years	% of average across trial sites and varieties						
Pioneer 45Y25 (RR)	9	108	112	115	111	120	3.74	107
Pioneer 45Y22 (RR)	4	104	108	110	101	115	3.59	103
Nuseed GT-53	4	114	119	117	116	113	3.53	101
Nuseed GT-50	10	109	108	110	116	112	3.49	100
Pioneer 44Y24 (RR)	10	106	108	110	114	112	3.49	100
InVigor R 5520P	4	107	100	104	114	110	3.43	98
DG 460RR	4	102	104	106	104	110	3.43	98
Hyola 504RR	4	98	108	109	100	110	3.43	98
Pioneer 43Y23 (RR)	4	107	111	111	117	109	3.40	97
Hyola 400RR	4	101	104	107	110	108	3.37	96
Hyola 600RR	5	107	111	109	100	107	3.34	96
IH52 RR	7	102	104	105	102	107	3.34	96
Hyola 500RR	4	99	107	108	104	106	3.31	95
Victory V5002RR	7	102	105	105	97	106	3.31	95
Pioneer 44Y26 (RR)	4	109	106	105	108	105	3.28	94
CB Frontier RR	4	96	103	105	100	105	3.28	94
DG 550RR	5	97	103	104	95	105	3.28	94
VICTORY V5003RR	7	105	104	104	103	104	3.24	93
Nuseed GT-41	4	101	98	101	115	102	3.18	91
Hyola 404RR	10	103	105	105	114	101	3.15	90
IH50 RR	6	102	104	103	103	100	3.12	89
IH51 RR	6	106	102	100	107	98	3.06	88
GT Cobra	4	99	95	96	102	97	3.03	87
Monola 513GT	8	99	96	95	100	94	2.93	84
Monola G11	7	106	107	102	113	91	2.84	81
GT Viper	4	94	87	85	91	83	2.59	74

TABLE 21 Yield of Roundup Ready (RR) canola at Wunghnu for 2016

Variety	Yield (t/ha)	Oil (%)	Seed protein (%)	Seed size (g/1000 seeds)	50% flowering year day*	Lodging (1–9)	Height (cm)
Pioneer 45Y25 RR	3.58	47.0	19.3	4.6	241	1	140
Nuseed GT-53	3.23	45.8	18.7	2.5	236	2	145
Pioneer 44Y24 RR	3.20	46.9	20.2	3.8	234	1	150
DG 460 RR	3.16	48.8	19.2	4.0	228	2	150
InVigor R 5520P	3.15	47.8	17.0	2.7	236	5	140
Nuseed GT-50	3.08	46.7	18.7	3.1	232	5	135
Nuseed GT-42	2.96	46.0	19.3	3.5	222	5	130
IH52 RR	2.91	45.1	19.2	3.1	236	5	140
VICTORY V5003 RR	2.89	47.8	18.6	3.5	236	1	140
Hyola 404 RR	2.81	49.2	17.3	3.7	226	7	120
IH30 RR	2.73	46.7	18.6	3.8	217	1	135
IH51 RR	2.59	44.7	19.4	3.3	234	7	125
Monola G11	2.47	49.1	18.6	2.2	218	8	130

Sown	5 May 2016	**Site mean (t/ha)**	2.99	**F prob**	<0.001	**pH (CaCl₂)**	4.80
Harvest	29 November 2016	**CV (%)**	7.4	**LSD (t/ha)**	0.37	**GSR (Apr–Oct)**	498mm

*50% flowering year day is the calendar day of the year on which 50% of the crop flowered.
Fungicide was applied during June and August.

TABLE 22 Yield of Roundup Ready (RR) canola at Yarrawonga for 2016

Variety	Yield (t/ha)	Oil (%)	Seed protein (%)	Seed size (g/1000 seeds)	50% flowering year day*	Lodging (1–9)	Height (cm)
Hyola 506 RR	3.57	48.0	17.9	4.0	238	0	140
InVigor R 5520P	3.47	48.2	17.7	3.6	241	2	135
Pioneer 45Y25 RR	3.41	47.4	19.4	4.5	245	2	140
Nuseed GT-53	3.35	46.3	19.1	3.8	241	3	150
Hyola 600 RR	3.31	47.8	19.1	4.4	242	1	155
DG 460 RR	3.26	47.7	19.4	4.2	238	1	140
Pioneer 44Y24 RR	3.00	47.0	19.7	3.9	239	1	130
VICTORY V5003 RR	2.88	45.4	20.1	3.7	245	3	135
Hyola 404 RR	2.86	48.1	18.5	4.4	237	7	140
Nuseed GT-42	2.81	46.2	19.9	4.6	234	5	130
Nuseed GT-50	2.81	47.4	18.5	4.1	238	4	155
IH52 RR	2.79	45.4	19.2	4.0	239	1	130
Monola G11	2.76	47.4	18.5	3.7	231	9	125
IH51 RR	2.64	44.8	19.8	3.6	237	5	135

Sown	12 May 2016	**Site mean (t/ha)**	3.08	**F prob**	<0.001	**pH (CaCl₂)**	5.02
Harvest	1 December 2016	**CV (%)**	6.3	**LSD (t/ha)**	0.32	**GSR (Apr–Oct)**	604mm

*50% flowering year day is the calendar day of the year on which 50% of the crop flowered.



TABLE 23 Long-term predicted yield of faba beans in north east Victoria for 2012–15

Predicted mean yield across trial sites and varieties (t/ha)		2012	2013	2014	2015
		3.53	3.91	2.00	1.59
	No. trials	1	1	1	1
Variety	Site years	% of average yield across trial sites and varieties			
BA Zahra	4	113	107	109	102
PBA Samira	4	109	103	105	101
Fiesta VF	4	105	106	105	99
Farah	4	104	103	106	100
Nura	4	100	91	102	95
PBA Rana	4	99	91	97	89

Faba beans and lupins are no longer being NVT tested in north east Victoria.

RiverinePlains

4/97–103 Melbourne Street Mulwala NSW 2647
PO Box 214 Mulwala NSW 2647
T: (03) 5744 1713
E: info@riverineplains.org.au
W: www.riverineplains.org.au