Stubble retention

in cropping systems of the **Riverine Plains**

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UNITS OF MEASUREMENT

CONVERSION TABLE — IMPERIAL TO METRIC

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

TABLE 1. Units conversion

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
- hectares — ha
- kilograms — kg
- litres — L
- metres — m
- millimetres — mm
- tonnes — t

STATISTICAL ANALYSIS

Statistical tests (for example, Analysis of Variance — ANOVA, 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 '$P<0.05$'. If there is no significant difference, the P values are greater than 0.05.

REPLICATED TRIALS VS DEMONSTRATIONS

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.

Table 2 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.

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 because 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.

TABLE 2. 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

Riverine Plains Inc

RIVERINE PLAINS INC MEMBERSHIP AREA

Riverine Plains Inc was established in 1999 and is an independent farming systems group dedicated to improving the productivity of broadacre farming systems in north-east Victoria and southern New South Wales. Our membership is drawn from the eastern NSW–Victoria border region, known as the Riverine Plain.

Our members farm a geographical area that extends as far north as Lockhart and Henty in NSW to as far south as Euroa and Shepparton in Victoria. Our focus is on providing independent, timely and relevant information to our members through a rigorous research program and our annual schedule of events and publications.

Riverine Plains Inc specialises in farmer-driven research and extension that delivers on-the-ground benefits to members. We believe that providing quality information, leading in research and sharing ideas with our members is key to achieving more progressive and resilient farming communities.

Foreword

Most of us would prefer to be retaining stubbles in our largely no till cropping systems for reasons of improved long term soil health and/or the reduction of expensive and time consuming operations in relation to stubble removal prior to planting.

In medium and high rainfall zones in Australia, however, consistent retention of stubble from previous grain crops has proven difficult to achieve due to real and perceived difficulties associated with planting machinery operation in high stubble loads, disease pressure from the previous seasons' stubble and weed control difficulties just to name a few.

This project, conducted by Riverine Plains Inc and FAR Australia, as part of GRDC's wider initiative investigating stubble retention in medium and high rainfall zones in Australia, examines in considerable depth the short term effects stubble retention is having on subsequent crops, as well as the effect that both pre and post seeding interventions can have on crops grown in stubble retained systems. The results outlined herein have been obtained after considerable effort over a number of years by the project team and a considerable investment of funds by GRDC.

As with previous projects conducted by Riverine Plains and FAR Australia, this project has been conducted with integrity, rigour and an eye for detail. I commend the results and discussions detailed in this report and thank all those involved in bringing this project together.

Adam Inchbold
Project Supervisor

Introduction and acknowledgements

Managing stubble could be considered one of the most agronomically divisive issues for farmers in the medium — high rainfall zones. While grain growers in the low — medium rainfall zones generally agree that retained stubble is a positive for their farming systems, for higher rainfall zone farmers, including those of the Riverine Plains, the decision it is not so clear cut.

Similarly to other farmers around Australia, Riverine Plains region growers retain their stubbles over summer and so are able to capture benefits from increased water infiltration and retention, as well as improved soil protection. However, in the lead-up to sowing, farmers in higher rainfall zones must assess whether stubble can be retained through sowing, or whether high stubble loads must be managed to avoid interfering with the sowing operation or with establishment. While it would be easy to describe farmers according to whether they retain stubble or not, operational realities mean that many growers alternate between retaining stubble and managing high stubble loads using other tools. Decisions around stubble management are generally made on a paddock-by-paddock basis and depend on a range of factors including, stubble load, summer grazing, weed issues, pest and disease risks, seeder set-up and the following crop type. Further, the prevalence of acid soils across the region means that stubble management must also be considered alongside the need for strategic incorporation of lime to avoid pH stratification issues.

Therefore, the seemingly simple question of "Do you retain stubble?" is in reality a multi-faceted decision subject to every other element in the cropping process. While retaining stubble is an easy decision following seasons of low rainfall and low stubble loads, retaining a 10t/ha stubble after a good season introduces a lot more complexity into the system and helps explain why burning stubble remains a default option for many growers.

While the Grains Research and Development Corporation (GRDC) have contributed to many areas of related research, the specific investment into stubble-related research within the Riverine Plains region through the *Maintaining profitable farming systems with retained stubble in the Riverine Plains region* project (2013–18) provided a unique opportunity to evaluate several facets of stubble management, while providing a platform for strong farmer engagement.

The resulting breadth, integrity and relevance of this project can be in great part attributed to the early direction provided by then Riverine Plains Inc committee member and former chair, Adam Inchbold. As the initial

project leader, Adam was responsible for designing a research program which addressed a number of agronomic issues related to the retention of stubble in a way which could be assessed at a paddock scale. He was assisted in this through the support of Riverine Plains Inc project partner FAR Australia, led by Nick Poole. On behalf of Riverine Plains Inc, I would like to formally acknowledge the commitment and contribution made by both Adam and Nick in bringing this research to the region and in supporting its delivery over the five-year project life-span.

Any grower who has attended one of the *Stubble project* paddock walks or read the research reports published in *Research for the Riverine Plains*, would appreciate the huge amount of time and dedication which has gone into the delivery of this project. Michael Straight, FAR Australia, has done an incredible job in managing a large suite of field trials to an extremely high standard and we extend our sincerest appreciation. Quality data leads to quality research outcomes and FAR Australia's contribution to the *Stubble project* was both significant and important in generating project outcomes.

Furthermore, field trials cannot be conducted without the support and encouragement of farmer co-operators. As well as hosting the field trials, farmer co-operators also act as project advocates, event hosts and contribute to the management of the trials in a multitude of ways. Riverine Plains Inc extends our sincerest gratitude and appreciation to our large-plot 'focus farm' hosts; Peter Campbell (Henty), Ludeman Brothers (Dookie), Telewonga Pty Ltd (Yarrawonga) and Tomlinson Ag (Corowa/Coreen), whose contributions of time, trials area, expertise, equipment and labour ensured the trials were managed to the highest possible standard. In addition to hosting the trials, our large-plot 'focus farm' hosts also contributed to the outstanding success of the *Stubble project* program by hosting regular paddock walks and discussions. Their advocacy, expertise and willingness to share experiences and insights ensured these events were relevant, informative and well supported by the local farming community.

We also thank our small-plot hosts; the Bruce family (Barooga), the Davis family (Rennie), Harmer Farms (Dookie), the Inchbold family (Telford), Lilliput Ag (Rutherglen) and Trevethan Family Farms (Howlong) who supported a diverse range of trials and events over the course of the project. Each host provided an area for trials, logistical support, expertise and management and we sincerely appreciate their significant contribution to the project.

As with all research projects, progress is more of an evolution, with each research result often raising new questions. We are therefore grateful to the GRDC for committing further funds to allow the delivery of the *Stubble project* frost component, and to the Sustainable Agriculture Victoria — Fast Tracking Innovation Initiative, made possible with the support of the Foundation for Rural and Regional Renewal (FRRR) together with the William Buckland Foundation, for providing the opportunity to better understand key drivers behind the early season biomass lag in stubble retained systems.

The project was also supported by a large number of collaborators who provided both services and in-kind support. We acknowledge the support of project partners Precision Agriculture Laboratory, The University of Sydney, and specifically Brett Whelan, for contributions made early in the project. We also thank the University of Adelaide School of Agriculture, Food & Wine; the Centre for eResearch and Digital Innovation, Federation University Australia; Australian Precision Ag Laboratory and Precision Agriculture for their contributions to the precision agriculture component and the Graham Centre for Agricultural Innovation for economic analyses.

While extension and communication were an ongoing feature of the *Stubble project*, this was generally focused around current season results and was often influenced by the prevailing seasonal conditions. This publication is intended to complement previous communications by presenting an overview of the knowledge gained over the life of the *Stubble project*. Given the large body of detailed research results generated through this project, readers are directed to the research section of the Riverine Plains Inc website for further detail.

On behalf of all the staff and committee of Riverine Plains Inc, we hope that you find this book useful in providing an overview of current knowledge into maintaining profitability in stubble retained systems of the Riverine Plains.

Dr Cassandra Schefe
Research Co-ordinator and *Stubble Project* Extension Officer, Riverine Plains Inc

Paddock walks were held regularly at each of the four Stubble project *focus farms.*

Background to the *Stubble project*

The increased awareness and widespread adoption of conservation cropping principles has paved the way for the adoption of stubble retention in southern Australia. It is well understood that retaining stubble after harvest can deliver multiple benefits in cropping systems through capturing and storing rainfall during the summer fallow, protecting soils from wind and water erosion, and improving soil structure. On the other hand, high stubble loads can increase the frequency of blockages in sowing equipment and the risk of disease carryover, as well as 'tying-up' early-season nitrogen (N) when soil microbes use it as a source of fuel to break down stubble.

The benefits of no-till stubble retention (NTSR) became especially clear during the millennium drought (2002–10), when improvements in water-use efficiency (WUE) and erosion control helped maximise yield and protect soils. The lighter stubble loads during this period also reduced the volume of stubble burning across the Riverine Plains region. However, in the subsequent higher-rainfall years, increased yields led to an increase in cereal stubble loads. These greater stubble loads saw the benefits of stubble retention offset by a number of significant challenges, such as machinery blockages during sowing, crop emergence issues, reduced pre-emergent herbicide efficacy, more complex nitrogen management challenges as well as pest and disease issues[1]. These challenges have seen many farmers return to burning stubble during years of higher rainfall.

While there are many practical issues to address when dealing with high volumes of retained stubble, there is also a perception that establishing and growing higher yielding crops in stubble-retained systems is prone to more difficulties than when the paddock has been burnt. While stubble retention certainly requires a different agronomic approach compared with systems where stubble is burnt, much of the currently accepted understanding around stubble management was developed when the approach was first developed and so does not reflect the agronomy required for modern stubble-retained systems. In short, a knowledge gap existed between the accepted management practices of stubble-retained systems and the management practices currently required to improve the profitability and increase the adoption of stubble retention in modern systems.

Following a Grains Research and Development Corporation (GRDC) review, which identified the specific knowledge gaps regarding the impact of stubble retention in southern cropping systems, a five-year program was initiated during 2013. The GRDC commissioned 10 projects, involving 16 farming systems groups and research organisations, as part of a large initiative (dubbed the *Stubble Initiative*),which included CSIRO, Riverine Plains Inc, Central West Farming Systems (CWFS), Birchip Cropping Group (BCG), Eyre Peninsula Agricultural Research Foundation Inc (EPARF), FarmLink Research, Hart Field Site group, Irrigated Cropping Council (ICC), Lower Eyre Agricultural Development Association (LEADA), MacKillop Farm Management Group (MFMG), Mallee Sustainable Farming (MSF), South Australian Research and Development Institute (SARDI), Upper North Farming Systems (UNFS), Victorian No-Till Farmers Association (VNTFA) and Yeruga Crop Research. Each of these 10 projects focussed on locally relevant issues, which impact on the profitability of retained-stubble systems across a range of environments in southern Australia. The projects also aimed to develop regional guidelines and recommendations to assist local growers and advisors to consistently retain cereal stubbles while maintaining profitability.

1 For an exhaustive review of the benefits and issues associated with stubble retention, see Scott BJ, Podmore CM, Burns HM, Bowden PI, McMaster CL (2013). Developments in stubble retention in cropping systems in southern Australia. Report to GRDC on Project DAN 00170. (Ed. C Nicholls and EC (Ted) Wolfe). Department of Primary Industries, Orange NSW 103pp. Available at: **www.grahamcentre.net**

Project objectives

THE PROJECT SOUGHT TO:

1. investigate, demonstrate and extend cultural practices that would assist growers adopt no-till stubble retention (NTSR) in medium-rainfall and higher-rainfall environments;

2. build on findings from the previous Riverine Plains Inc water use efficiency (WUE) project; and

3. extend the frontier of agronomic knowledge for crops grown using NTSR systems.

Project overview

As part of the GRDC's *Stubble Initiative* investment, Riverine Plains Inc received funding to manage the project *Maintaining profitable farming systems with retained stubble in the Riverine Plains region* (the *Stubble project*). This project, which started during July 2013 and officially concluded during June 2018, was carried out as a partnership between Riverine Plains Inc and FAR Australia, with Riverine Plains Inc managing project delivery and extension, while FAR Australia managed all field trials and associated activities.

The project involved both large field trials (large-plot trials) and small-plot research at sites across the Riverine Plains from 2013–17, with each trial addressing a specific aspect of stubble management in a NTSR system.

LARGE-PLOT FIELD TRIALS

The project as a whole aimed to address and quantify the impact of stubble management on crop productivity by asking: "*How important is stubble management in defining yield potential?*". As a result, the large-plot trials were designed to test the long-term impact of a one-off change in management, with trials established at different sites every year (rather than applying the same treatments to the same plots every year).

The large-plot field trials, carried out from 2014–17, provided statistical comparisons of crop growth and yield under different stubble management systems, at a scale that reflected paddock practice. After the stubble treatments were imposed (i.e plots were either burned, left standing, incorporated or were cut at different heights), the host farmer took over all in-crop management using farm machinery (including sowing, pest and disease management and fertiliser application). Subject to machinery dimensions (the width of seeding equipment varied slightly), each plot was about 17m wide and 40m long, with the different treatments set up in a replicated trial design. A strip out of each plot was harvested with a small plot header to determine plot yields, with the host farmer harvesting the remainder of each trial plot.

SMALL-PLOT FIELD TRIALS

The small-plot field trials addressed a range of distinct issues related to the agronomic management of crops grown under NTSR systems. These included:

1. monitoring the performance of nitrogen application to wheat under full stubble retention;
2. early sowing and the interaction with row spacing, plant populations and cultivar in first wheat under full stubble retention;
3. the interaction between plant growth regulator (PGR) and nitrogen application in early-sown first wheat;
4. the interaction between fungicide application and in-crop nitrogen timing to control yellow leaf spot (YLS) in early-sown wheat; and
5. a stubble height trial, which investigated the interaction between stubble height, light interception and biomass lag at three stubble heights (in-canopy temperatures were also measured).

The YLS fungicide and PGR small-plot trials were conducted 2013–16, while the nitrogen response and row spacing small-plot trials were conducted 2014–16.

Dr Cassandra Schefe, Riverine Plains Inc, and Michael Straight, FAR Australia, worked together to deliver large and small plot research trials, farm walks and agronomic updates across the Riverine Plains region.

Paddock walks — project extension

In order to maintain the local relevance of the project, as well as to generate interest in the *Stubble project*, a program of discussion group *Paddock walks* was initiated across the region. The paddock walks were held at each large-plot field trial site, with visits occurring during both winter and spring to discuss the progress of the trial as well as any related management issues. The first event was held during July 2014, while the last paddock walk was held during June 2018.

DURING THE FIVE YEARS OF FIELD TRIALS AND EXTENSION ACTIVITIES, THE PARTNERSHIP BETWEEN RIVERINE PLAINS INC AND FAR AUSTRALIA DELIVERED

25
SMALL-PLOT REPLICATED FIELD TRIALS

8
AGRONOMIC UPDATES

33
PADDOCK WALKS

15
LARGE-PLOT REPLICATED FIELD TRIALS

4
REGIONAL GUIDELINES ON STUBBLE RETENTION ACROSS THE RIVERINE PLAINS

ADDITIONAL PROJECT ACTIVITIES

Two additional areas of research were investigated through GRDC-approved contract variations. These investigations looked at:

- the importance of retaining stubble on in-canopy temperature and frost risk; and
- gaining a greater understanding of in-paddock variability and prediction of plant-available water (PAW) for variable rate (VR) nitrogen applications.

This research is presented on page 44 and page 56, respectively.

CLAIMED ADVANTAGES AND DISADVANTAGES OF DIFFERENT STUBBLE MANAGEMENT TECHNIQUES

Stubble management technique	Perceived advantages ✓	Perceived disadvantages ✗
Long stubble (NTSR)	✓ High harvesting speeds ✓ Increased soil moisture retention ✓ Reduced soil losses through wind erosion ✓ Reduced rainfall run-off and higher infiltration rates ✓ Reduced evaporation ✓ Nutrient retained in stubble ✓ Good trellis for pulse crops ✓ Increased habitat for soil biology ✓ Improved potential for increasing soil carbon over burnt systems	✗ Equipment blockages at sowing ✗ Physical impediment to emergence ✗ Reduced efficacy of pre-emergent herbicides ✗ Perceived allelopathy in subsequent canola crops ✗ Stubble breakdown requires nutrients and moisture ✗ Changed pest and disease profile compared with burnt stubble
Short stubble (NTSR)	As per tall stubble, plus: ✓ reduced seeding equipment blockages compared with long stubble	As per tall stubble, plus: ✗ requires slower harvesting speeds compared with tall stubble
Burning (assumes burning is timed for early autumn, before sowing)	✓ Reduced shading of seedlings compared with long stubble ✓ Improved establishment of subsequent crops through removal of physical impediment ✓ Reduced nitrogen 'tie-up' following sowing compared with NTSR systems ✓ Low cost ✓ Effective control of stubble-borne diseases (e.g. YLS)	✗ Contribution of particulate pollution ✗ May contribute to losses of nutrients retained in stubble ✗ Fire permits becoming more difficult to acquire through local council procedures ✗ Requires optimum weather conditions; risk of delay due to poor weather ✗ Reduced surface moisture retention compared with NTSR retained systems ✗ Increased susceptibility to erosion compared with NTSR systems
Incorporating/ mulching	✓ Soil contact improves stubble breakdown (in presence of moisture) compared with standing stubble ✓ Reduced shading compared with standing stubble	✗ Requires extra machinery pass ✗ May require capital investment ✗ Timeliness of contractors
Straw removed	✓ Removes physical impediment to emergence in the subsequent crop ✓ Improved efficacy of pre-emergent herbicides compared with long stubble ✓ Straw can be baled and sold, or collected and moved to another area	✗ Requires extra machinery pass ✗ May require capital investment (e.g. a chaff cart) ✗ Greater export of product from paddock increases lime requirement

How did the weather affect the *Stubble project* trials?

In order to best represent the soil types, farming practices and rainfall environments experienced across the Riverine Plains region, the *Stubble project* research trial sites from 2013–17 spanned a large geographic area, with the southern-most site located at Dookie and the northern-most site at Henty. With such a diverse geography, the individual research sites experienced a wide range of environmental conditions during the trial period, with sites variably affected by rainfall deficits, waterlogging, frost and heat stress.

Following is a brief summary of the key climatic conditions that affected yield across the individual years of the project.

2013

The cumulative 12-month and growing season rainfall (GSR) across the Riverine Plains trial region was varied, with above-average rainfall received at Henty, Lockhart and Corowa, average rainfall received at Dookie, and below-average rainfall received at Yarrawonga (Table 3). The low autumn rainfall in some areas led to patchy emergence. Late frosts (-1.5°C was recorded on 18 October 2013 at Tocumwal) also caused variable levels of crop damage across the region.

TABLE 3. Rainfall received at the Yarrawonga* *Stubble project* small-plot row-spacing trial site during 2013

Period	Rainfall (mm)
January – March	91
GSR (April – October)	222
January – October	313

*Data is presented for Yarrawonga only as it was the only *Stubble project* research site during 2013

2014

There was an excellent start to the grain growing season during 2014, with most areas receiving decile 9 or 10 rainfall during April, which aided germination and establishment. Growing season rainfall (GSR) varied across the trial sites and ranged from decile 3 to decile 7 (Table 4). Heavy frosts during August caused stem frost in some cereal crops, with an estimated 10–20% yield damage in crops across the region.

2015

The cumulative 12-month and GSR across the Riverine Plains region for 2015 was higher than average. Above-average temperatures and rainfall during April resulted in an early start to the season and aided germination. January – February rainfall was above average, but was below average during September – October (Table 5). As a result of the dry spring conditions, and a heat event experienced during the first week of October (where temperatures reached 35–37°C), crop yields varied across sites. Early-sown crops were generally better able to withstand the warm and dry spring conditions than later-sown crops.

2016

During 2016 the region experienced its warmest autumn on record and a wet winter and spring period (Table 6). The warm autumn, combined with the substantial opening rains during May, resulted in high and even crop germination. The wet winter and spring caused widespread waterlogging, lodging and disease across the trial sites and affected yield. However, mild nights, high cloud cover and high rainfall meant frost damage was not problematic. Across the Riverine Plains region yields were varied, with high yields on well-drained soils and low yields on poorly drained soils. Increased cloudiness also reduced light interception to plants during 2016.

TABLE 4. Rainfall received at the Yarrawonga, Dookie, Henty and Corowa *Stubble project* trial sites during 2014

Period	Yarrawonga	Dookie	Henty	Corowa
	Rainfall (mm)			
January – March	114	78	85	70
GSR (April – October)	373	386	390	332.6
January – October	487	464	475	402.6

TABLE 5. Rainfall received at the Yarrawonga, Dookie, Henty and Corowa *Stubble project* trial sites during 2015

Period	Yarrawonga	Dookie	Henty	Corowa
	Rainfall (mm)			
January – March	120	76	114	152
GSR (April – October)	266	233	391	329
January – October	386	309	505	481

TABLE 6. Rainfall received at the Yarrawonga, Dookie, Henty and Corowa *Stubble project* trial sites during 2016

Period	Yarrawonga	Dookie	Henty	Corowa
	Rainfall (mm)			
January – March	125	130	145	80
GSR (April – October)	604	509	619	567
January – October	724	639	764	647

2017

During 2017 the region received average to below-average rainfall for the April – October growing season (Table 7). Significant rainfall events during harvest did not contribute to grain yield and caused widespread downgrading across the Riverine Plains area. The March break, combined with warm soil temperatures and stored soil moisture from 2016, provided ideal conditions for crop establishment. Follow-up rains during April kept crops growing, however this was followed by record low rainfall during June. Growing season rainfall (GSR) was well below average, at decile 1–3, with only 21 rainfall events with totals above 5mm. From June – October, there were more frost events compared with average, which significantly damaged crops in some areas. Crops in the region yielded better than expected, which was due in part to stored soil moisture and a relatively mild spring.

TABLE 7. Rainfall received at the Yarrawonga, Dookie, and Corowa *Stubble project* trial sites* during 2017

Period	Yarrawonga	Dookie	Corowa
	Rainfall (mm)		
January – March	88	82	107
GSR (April – October)	270	281	273
January – October	358	363	380

* The Henty site was not included in the 2017 *Stubble project* trials program

Research trials: large plot stubble management trials

TRIAL DESIGN AND LOCATION

Using large-scale trial plots (focus farms) the research team evaluated the impact of a single-year, one-off change in stubble management. The results from these trials helped 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 large-plot stubble management trials (2014–17) provided information on crop performance under a range of seasonal climatic conditions.

The focus farm trials during 2014 were located at Henty and Coreen/Daysdale, New South Wales (NSW), and Yarrawonga and Dookie, Victoria. During 2015 a site near Corowa was used, rather than Coreen/Daysdale, in order to maintain the same rotation position, with the trial moving back to Coreen for 2016. During 2017, the focus farm sites included Coreen, Yarrawonga and Dookie, with the Henty site discontinued due to high within-site variability and waterlogging (Figure 1).

Given the project aimed to identify the long-term impact of a one-off change in management, the trial sites were moved every year. 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
- 2017 trial site: time replicate 4

After each year of field trials, the site was returned to the farming co-operator and blanket-sown with a crop of their choice. At some sites the yield of the subsequent crop was also measured to determine whether a one-off strategic change had any impact on the following crop(s).

As there were differences in the stubble treatments imposed at each site, as well as actual stubble loading, sowing machinery and soil type differences between the sites, each site is reported on separately throughout this book.

Furthermore, as each year of field trial results has already been published in the *Research for the Riverine Plains* research compendium (all articles are available online at **www.riverineplains.org.au/research**), only the key elements of each trial are reported here.

FIGURE 1. Locations of the large block (focus farm) trials across the four years of field trials

2014	2015	2016	2017
COREEN/ DAYSDALE	COROWA	COREEN	COREEN
DOOKIE	DOOKIE	DOOKIE	DOOKIE
HENTY	HENTY	HENTY	YARRAWONGA
YARRAWONGA	YARRAWONGA	YARRAWONGA	

SPECIFIC QUESTIONS ADDRESSED IN THIS PUBLICATION

This book specifically addresses the following questions:

1. What was the impact of stubble management on plant growth and nitrogen uptake?
2. Did stubble management influence the detection of yellow leaf spot (YLS) disease?
3. Were there differences in grain yield and quality with stubble management?
4. Were there any residual impacts from a one-off change in stubble management on crop yield during subsequent years?

case study

Farmer
Denis Tomlinson, Tomlinson Ag

Location
Coreen, NSW

Soil types
Variable, heavy clays, clay loams to loams over clays

Enterprises
98% cropping with some sheep

Crop rotation
Five-year rotation: canola, wheat, wheat, barley and we are starting to use vetch

Q How do you usually manage your stubble?

We retain stubble where we can, but we need to burn or mulch where there are high stubble loads due to disease pressure, nitrogen tie-up and the physical difficulty of sowing into heavy stubble.

We retain 67% (two thirds) on average, however this can change from year to year. For example, during 2018 there were small stubble loads so we didn't burn any, whereas during 2017 we had heavy cereal stubble loads and burnt most of them.

Q At what height do you harvest cereals?

Where we retain stubbles, we harvest at 20–25cm and keep summer weeds under control to prevent blockages during sowing.

Where there are heavy stubble loads, which we are not planning to retain, we harvest as high as possible. Then we may mulch the stubble during February or March or wait until just before sowing and burn either the chaff rows or the whole paddock.

If cereal crops yield above 3t/ha we usually need to use a method to reduce the stubble load.

We also generally give stubbles a light graze over summer to pick up any residual grain on the ground. This also helps keep mice populations in check.

Q What sowing equipment do you use?

A DBS with a knife point and press wheels on 300mm spacings. We use a contractor for mulching and have invested in an auto-steer to allow us to inter-row sow, which gives us better establishment as we are sowing next to or into the previous year's stubble.

Q Has your approach to stubble management changed during the past 10 years?

We tried to retain all our stubbles 10 years ago and ran into problems with nitrogen tie-up. We also had a build-up of cereal disease and high stubble loads caused blockages in the seeder at sowing. So now we don't retain as much stubble and burn occasionally.

Q What benefits have you seen with stubble retention?

Where we have retained stubbles there is less dust and loss of top soil, better moisture retention and more friable and protected soils.

Q What drawbacks have you seen with stubble retention?

There are some problems as mentioned before, also pre-emergent herbicides are not as effective on weeds where stubble is retained.

Q As a host farmer for the *Stubble project* since 2014, have you changed your farming practice based on the result?

Probably being more strategic with burning. In our case we try to burn stubble when a wheat crop follows a wheat crop. This reduces the amount of nitrogen tie-up for the second wheat crop and allows us to get good use of the pre-emergent herbicide.

Faba beans were also incorporated into the trial and yielded well one year and benefitted the following crop, however in another year of the trial they didn't perform well and gave little benefit to the following crop.

While many of our soils are too acid for beans, the trial did show our system was low on nitrogen and we still need a suitable legume in the system. We are now re-introducing vetch in a small way to increase nitrogen because it provides us with a few options (i.e. grazed, brown manured or made into hay).

Q What do you feel has been one of the greatest learnings to come out of the *Stubble project* work for the Riverine Plains region?

The project looked at different stubble management strategies and we now understand what effect each strategy has on the system and if a strategy has a negative effect, we apply a practice that ameliorates that negative effect.

DAYSDALE/ COROWA/COREEN

Table 8 describes the stubble management treatments carried out at the large-plot sites from 2014–17 at Daysdale, Corowa and Coreen.

TABLE 8. Site and treatments details for the *Stubble project* large plot trials at Daysdale (2014), Corowa (2015) and Coreen (2016–17), NSW

Trial details	Time replicate 1 2014 (Daysdale)	Time replicate 2 2015 (Corowa)	Time replicate 3 2016 (Coreen)	Time replicate 4 2017 (Coreen)
Stubble treatments:	• NTSR • Cultivated (one pass) • Cultivated + 40kg N/ha# • Burnt	• NTSR • Cultivated (one pass) • Cultivated + 40kg N/ha# • Burnt	• NTSR • Cultivated (one pass) • Cultivated + 40kg N/ha# • Burnt	• NTSR • Cultivated (one pass) • Cultivated + 40kg N/ha# • Burnt
Additional treatments: • Pulse for grain • Pulse for manure	• Faba beans for grain and brown manure	• Faba beans for grain and brown manure	• Lupins for grain and brown manure	• Faba beans for grain and brown manure
Trial plot dimensions (m)	40 x 15	40 x 15	40 x 15	40 x 15
Soil type	Heavy grey clay	Red- brown earth	Loam over clay	Loam over clay
Sowing drill: **Aus seeder DBS D-300 tine seeder**	✓	✓	✓	✓
Row spacing (cm)	30	30	30	30
Stubble loading (t/ha)	6.4	6.4	7.0	10.1
Stubble height (cm)	33	35	26	42
Sowing date	24 April 2014	7 May 2015	4 May 2016	18 May 2017
Crop (cv)	Wheat (Whistler), Faba beans (Fiesta)	Wheat (Mace), Faba beans (Fiesta)	Barley (Hindmarsh), Lupins (Mandelup)	Wheat (Scepter), Faba beans (Samira)
Rotation	Second wheat	Second wheat	Second cereal	Second wheat
Rainfall GSR* (mm):	333	329	567	273
Summer rainfall (mm):	70	152	80	107
Soil nitrogen at sowing (0–60cm)^ (kg N/ha)	93	50	111	58

The extra 40kg N/ha was applied just prior to sowing (incorporated by sowing — IBS).

* GSR: Growing season rainfall (April – October)

^ As measured in NTSR treatment

WHAT WAS THE IMPACT OF STUBBLE MANAGEMENT ON PLANT GROWTH AND NITROGEN UPTAKE AT DAYSDALE, COROWA AND COREEN?

The cultivated treatment at Coreen during 2016.

There were a number of dry matter (DM) cuts and measures of nitrogen uptake made during each season, with these results providing context to the final yield and quality results. Given these results have already been analysed and published in the annual research compendium *Research for the Riverine Plains*, only the flowering and harvest DM and nitrogen uptake measures are reported here, as these are the ones that correspond best to differences in yield potential.

During **2014** there was no difference in DM or nitrogen uptake at flowering or harvest due to stubble management at Coreen. The average DM at harvest was 8.41 t/ha.

During **2015** the DM at flowering was greater in the burnt treatments than with NTSR, with no differences measured at harvest (Figure 2). The average DM at harvest was 8.90 t/ha. There were no differences in nitrogen uptake at flowering or harvest.

During **2016** the DM at flowering was greater in the cultivated treatments than with NTSR, with no differences measured at harvest. The average DM at harvest was 9.07t/ha. There were no differences in nitrogen uptake at flowering or harvest.

During **2017** the DM at flowering was greater in the burnt and cultivated + 40kg N/ha treatments than in the cultivated and NTSR treatments. The DM at harvest was greater with the burnt treatment (14.02t/ha) than all others. Nitrogen at flowering was greater in cultivated + 40kg N/ha treatment compared with all other treatments, and was least in the NTSR treatment. At harvest the nitrogen uptake was greatest in the burnt treatment.

KEY FINDING

1. Across four very different seasons, stubble management was not a key driver of total DM production at the Coreen site.

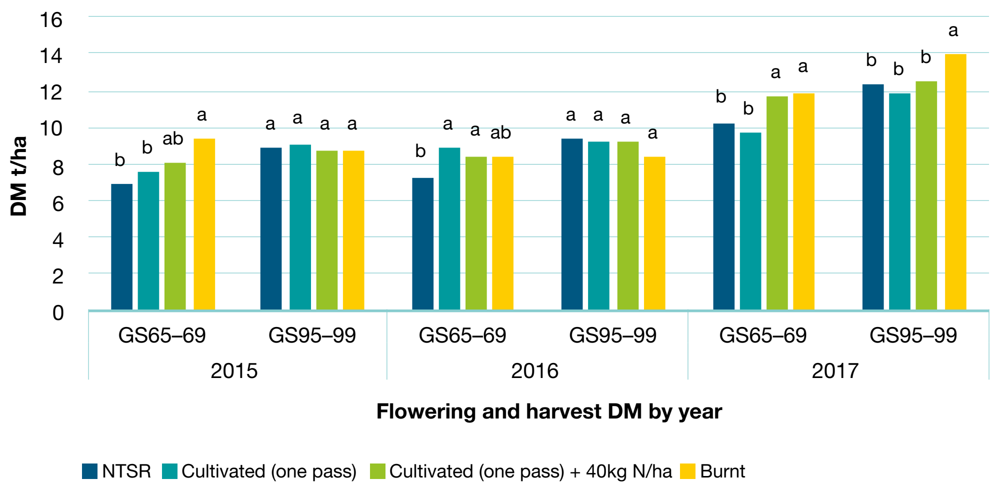


FIGURE 2. Dry matter at flowering (GS65–69) and harvest (GS95–99) by year at Coreen

Yield bars for the same year and DM assessment timing with different letters are regarded as statistically significant

2014 data not available

DID STUBBLE MANAGEMENT INFLUENCE THE DETECTION OF YELLOW LEAF SPOT (YLS) DISEASE AT DAYSDALE, COROWA AND COREEN?

During **2014** the severity of YLS (percentage of leaf area infected) at mid–late flowering (GS68–70) was greatest in the cultivated treatment at 1% on the flag leaf and 3% on flag-1, and lowest in the burnt treatment at 0.35% on the flag leaf and 1.5% on flag-1. The addition of 40kg N/ha at sowing to the cultivated treatment negated any difference in YLS incidence for this treatment.

During **2015** there was no difference in severity of YLS on flag-1 and flag-2 across the different stubble management treatments when measured at the end of stem elongation (GS39).

There was no data collected during **2016** because YLS did not increase above threshold levels.

During **2017** early disease progression was arrested by drier weather during late August and September. At GS39 YLS severity was very low, with the NTSR treatment having the highest level of infection, but this was still only 0.45% on flag-1.

NOTE: YLS is greatest in wheat plants which have been placed under stress. When nutrition is adequate, plants have a greater capacity to outgrow YLS.

KEY FINDING

1. YLS infection on flag, flag-1 and flag-2 was generally low across the four seasons. While some infection was found, the severity of infection was quite low and not significantly different across the different stubble management treatments.

WERE THERE DIFFERENCES IN GRAIN YIELD AND QUALITY ATTRIBUTABLE TO STUBBLE MANAGEMENT TECHNIQUE AT DAYSDALE, COROWA AND COREEN?

During **2014** there were no differences in grain yield and protein results between the stubble treatments (NTSR, cultivated, cultivated + 40kg N/ha, burnt), with an average yield of 3.19t/ha and an average 8.4% protein (Figure 3).

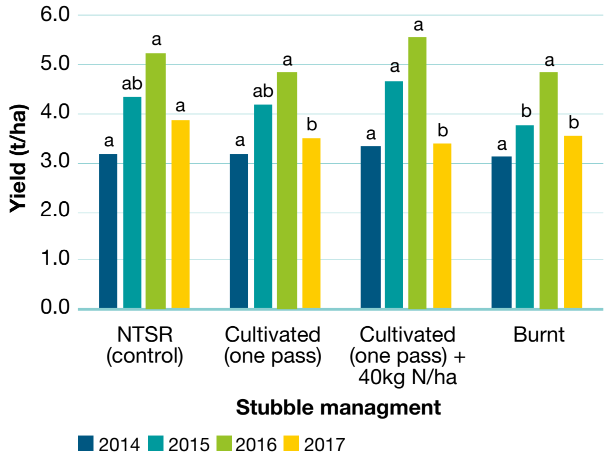


FIGURE 3. Yield data from time replicate trials 1, 2, 3 and 4 — the Daysdale (red brown earth), Corowa (heavy grey clay), Coreen (loam over clay) and Coreen (loam over clay) trials for 2014, 2015, 2016 and 2017 — cv Whistler (wheat) in 2014, cv Mace (wheat) in 2015, cv Hindmarsh (barley) in 2016, cv Scepter (wheat) in 2017

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

Note: The four 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, 2016 and 2017 a single pass was used

During **2015** the yield was lowest under the burnt treatment (3.77t/ha) and greatest under the cultivated + 40kg N/ha (4.69t/ha). There were no differences in grain protein between the treatments, with an average protein level of 11.3%.

During **2016** there were no significant differences in grain yield across treatments, with an average yield of 5.11t/ha. Protein levels were significantly lower with cultivation (8.5%), while the other treatments averaged 9.6% protein.

During **2017** the grain yield was greatest in the NTSR treatment (3.88t/ha), likely due to this treatment experiencing less frost damage than the burnt treatment (3.54t/ha) (see page 44 for frost results). Protein levels were lowest in the NTSR treatment at 9%, while the other treatments averaged 10.3%.

KEY FINDINGS

1. While some differences in grain yield due to stubble treatment were measured, they were not consistent across years.
2. Biomass (DM) production through the season does not provide a clear-cut indicator of yield potential, especially when seasonal challenges, such as heat stress or frost damage, can change grain yield potential significantly towards the end of the season.

WERE THERE ANY RESIDUAL IMPACTS FROM A ONE-OFF CHANGE IN STUBBLE MANAGEMENT ON CROP YIELD IN FOLLOWING YEARS AT DAYSDALE, COROWA OR COREEN?

The stubble management treatments imposed during the **2014** trial (time replicate 1) did not impact on yield during the year of trials, with no significant differences measured between treatments (Table 9). However, when a commercial wheat crop was subsequently sown over the site during 2015, the area previously under the burnt treatment (i.e. during 2014) had a lower yield (3.38t/ha) and higher screenings than other treatments. The area under faba beans during the 2014 trial produced a 2t/ha yield increase in the following wheat crop (2015) due to greater nitrogen availability.

The **2015** trial (time replicate 2) showed a significant increase in yield between the cultivated + 40kg N/ha treatment (4.69t/ha) compared with the burnt treatment (3.77t/ha) (Table 10). When this site was sown to a wheat crop the following year (during 2016), the area burnt during 2015 again had a lower yield (5.90t/ha), though this was not significantly different to the other stubble treatments. While the faba beans grown during the 2015 trials had poor nodulation and growth, they still contributed to a yield increase of up to 0.47t/ha in the following wheat crop.

TABLE 9. Effect of *Stubble project* time replicate 1 trial on 2014 yield and 2015 wheat (cv Corack) yield, Daysdale, NSW

2015 stubble treatments	2014	2015
	Wheat and faba beans	Wheat
	Yield (t/ha)	Yield (t/ha)
NTSR (control)	3.17^{a}	3.54^{bc}
Cultivated (two pass)	3.18^{a}	3.82^{b}
Cultivated (two pass) + 40kg N/ha	3.31^{a}	3.61^{bc}
Burnt	3.10^{a}	3.38^{c}
Faba beans (forage)	6.68	5.62^{a}
Faba beans (grain)	2.89	5.66^{a}
Mean	**3.19**	**4.27**
LSD	0.53	0.39

Figures followed by different letters are regarded as statistically significant

* Beans not statistically analysed alongside wheat

Note: 2016 canola crop was flooded and harvest was not possible

TABLE 10. Effect of *Stubble project* time replicate 2 trial on 2015 yield and 2016 wheat (cv Trojan) yield and 2017 canola (cv Bonito) yield, Corowa, NSW

2015 stubble treatments	2015	2016	2017
	Wheat and faba beans	Wheat	Canola
	Yield (t/ha)	Yield (t/ha)	Yield (t/ha)
NTSR (control)	4.33^{ab}	6.72^{ab}	2.06^{a}
Cultivated (one pass)	4.18^{ab}	6.53^{ab}	2.14^{a}
Cultivated (one pass) + 40kg N/ha	4.69^{a}	6.66^{ab}	2.18^{a}
Burnt	3.77^{b}	5.90^{b}	2.20^{a}
Faba beans (green manure)	-	7.03^{a}	2.09^{a}
Faba beans (grain)	1.40*	6.96^{a}	2.23^{a}
Mean	**4.24**	**6.63**	**2.15**
LSD	0.67	0.82	0.29

Figures followed by different letters are regarded as statistically significant.

* Beans not statistically analysed alongside wheat.

KEY FINDINGS

1. The inclusion of a pulse crop in the rotation, when sown into a first wheat stubble, contributed a disease break and nitrogen benefit to subsequent crops. This resulted in significant increases in the yield of the following wheat crop when compared to that of a third wheat (i.e. wheat on wheat on wheat), which would have been compromised both in terms of disease pressure and a limited nitrogen supply from residue breakdown.
2. The high nitrogen content of the pulse crop residue assisted in the break-down of the previous wheat crop stubble (which was still carried over in the wheat treatments). This indicates including a pulse can help 'clean up' excess stubble carried over from previous seasons, without any mechanical intervention or burning.

A faba bean crop was included in the trial during 2014 and 2015.

case study

Farmers
Jamie and Justin Cummins, Telewonga Pty Ltd

Location
Burramine, Victoria

Soil types
Red loam over clay

Crop rotation
Wheat, wheat, canola or wheat, barley, canola

Q How do you usually manage your stubble?

We try to retain as much stubble as we can without it becoming an issue at sowing. Improving soil health is our major reason for retaining stubble and we have seen better soil moisture retention and a more friable soil where we have retained stubble.

Although retaining stubble is important to us, it is not always practical in our system.

Our main challenges occur when the stubble load is heavy; it is harder to sow into with our tined machine. There can be problems getting through stubble, particularly when it's wet on heavy grey clay soil.

Each year is different. For example, during 2017 we burnt most of our cereal stubbles and during 2018 we did not burn any. Our approach depends on the season.

We assess the situation each year before sowing. If the stubble is going to cause an issue with sowing, then we burn it. About 50% of the time we burn cereal stubbles just before sowing. If the stubble is thick and marketable, we may consider making straw, which allows us to retain the stubble while make it easier to sow into without burning.

We are very keen to retain more stubble, but practicality and risk management dictates what we do.

Having canola in the rotation helps us minimise the amount of burning required.

Q At what height do you harvest cereals?

We harvest just below the head because we want to get harvest done as quickly as possible and harvesting lower takes longer.

Q What sowing equipment do you use?

We sow with a 12m DBS air seeder on 30.5cm spacings (12 inch). It is a tined machine and sometimes we inter-row sow, just next to the previous year's crop, while sometimes we go back in the same furrow. It depends on the conditions.

Q Has your approach to stubble management changed during the past 10 years?

We are continuously changing our approach to stubble management, depending on the season and climate. We still want to work towards stubble retention, but we need to be practical. We manage risk by trying to get everything done on time, so if stubble retention affects our timeliness of operations, it increases our exposure to risk and potential loss of income.

We have recently purchased a Brookfield chain, which will allow us to break up our stubble before sowing. This year (2019) we used the chain to incorporate stubble on about 1200 ha and we expect the chain will allow us to retain more stubble in the future.

Q What do you feel has been one of the greatest learnings to come out of the *Stubble project* work for the Riverine Plains region?

The *Stubble project* showed that results were different for different farmers at different sites and there were not a lot of definitive answers. The best option will depend on a range of factors, including the soil type, stubble load, the season, suitability of machinery and farmers' risk exposure.

There is no set recipe when it comes to stubble retention, however there are many benefits, so we will keep working towards it.

YARRAWONGA

Table 11 describes the stubble management treatments carried out at the large-plot sites from 2014–17 at Yarrawonga.

TABLE 11. Site and treatments details for the *Stubble project* large plot trials at Yarrawonga, Victoria from 2014–17

Trial details	Time replicate 1 2014	Time replicate 2 2015	Time replicate 3 2016	Time replicate 4 2017
Stubble treatments:	• NTSR — long stubble • NTSR — long stubble + 40kg N/ha# • Straw removed • Cultivated (one pass) • Cultivated + 40kg N/ha# • Burnt	• NTSR — long stubble • NTSR — long stubble + 40kg N/ha# • NTSR — short stubble (15cm) • Straw removed • Cultivated (one pass) • Cultivated + 40kg N/ha# • Burnt	• NTSR — long stubble • NTSR — long stubble + 40kg N/ha# • NTSR — short stubble (15cm) • Straw removed • Cultivated (one pass) • Cultivated + 40kg N/ha# • Burnt	• NTSR — long stubble • NTSR — long stubble + 40kg N/ha# • NTSR — short stubble (14cm) • Straw removed • Cultivated (one pass) • Cultivated + 40kg N/ha# • Burnt
Trial plot dimensions (m)	40 x 18	40 x 18	40 x 18	40 x 18
Soil type	Self-mulching red loam over grey clay	Self-mulching red loam over grey clay	Self-mulching red loam over grey clay	Self-mulching red loam over grey clay
Sowing drill: **Aus seeder DBS tine knife point**	✓	✓	✓	✓
Row spacing (cm)	32	32	32	32
Stubble loading (t/ha)	8.3	6.3	4.7	11.2
Stubble height (cm)	40	38	36	39
Sowing date	20 May 2014	13 May 2015	28 April 2016	7 May 2017
Crop (cv)	Wheat (Young)	Wheat (Young)	Wheat (Corack)	Wheat (Corack)
Rotation	Second wheat	Wheat after barley	Second wheat	Second wheat
Rainfall GSR* (mm):	373	266	604	270
Summer rainfall (mm):	114	120	125	88
Soil nitrogen at sowing^ (0–60cm) (kg N/ha)	60	98	64	63

The extra 40kg N/ha was applied just prior to sowing (incorporated by sowing — IBS).

* GSR: Growing season rainfall (April – October)

^ As measured in NTSR treatment

WHAT WAS THE IMPACT OF STUBBLE MANAGEMENT ON PLANT GROWTH AND NITROGEN UPTAKE AT YARRAWONGA?

During **2014** the NTSR — long stubble treatment had the least DM at flowering, while the burnt treatment had the most. However, by harvest the cultivated + 40kg N/ha treatment had the greatest DM at 9.2t/ha, with no difference between the burnt and NTSR treatments (Figure 4 and Figure 5). Nitrogen uptake at flowering was highest in treatments with added nitrogen; the cultivated + 40kg N/ha and NTSR + 40kg N/ha, but was least in the NTSR and straw-removed treatments. By harvest the nitrogen uptake was greatest in the cultivated + 40kg N/ha treatment and least in the straw-removed treatment.

During **2015** the NTSR treatments were expanded to look at whether the length of standing stubble had any bearing on the final outcomes and this saw the inclusion of both a NTSR — short stubble and NTSR — long stubble treatment in the Yarrawonga trials. Dry matter results at flowering showed the NTSR — long stubble + 40kg N/ha and burnt treatments had the most DM, while the least DM was measured in the NTSR — long stubble treatment. However, by harvest there were no differences in DM, with an average of 6.91t DM/ha. Nitrogen uptake at flowering was lowest in the straw-removed treatment, while at harvest the highest nitrogen uptake was measured in the cultivated + 40kg N/ha treatment.

During **2016** the NTSR — long stubble treatment had the least DM at flowering, with the highest DM being measured in the burnt and cultivated + 40kg N/ha treatments. By harvest the burnt treatment had the most DM (14.41t/ha), while the NTSR — long stubble + 40kg N/ha treatment (10.85t/ha) had the least. Nitrogen uptake at flowering was lowest in both the NTSR — long and NTSR — short stubble treatments, while at harvest, the greatest nitrogen uptake was measured in the cultivated and cultivated + 40kg N/ha treatments.

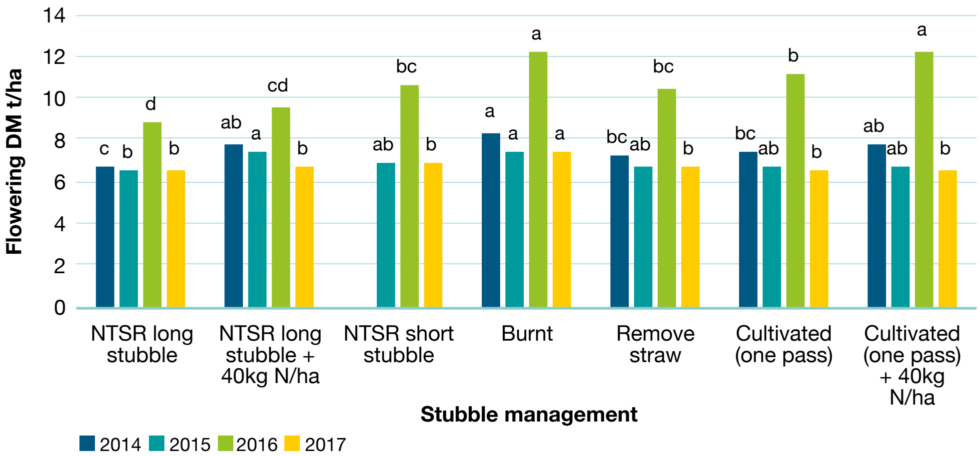


FIGURE 4. Dry matter at flowering (GS65–71) at the Yarrawonga trial site 2014–17

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

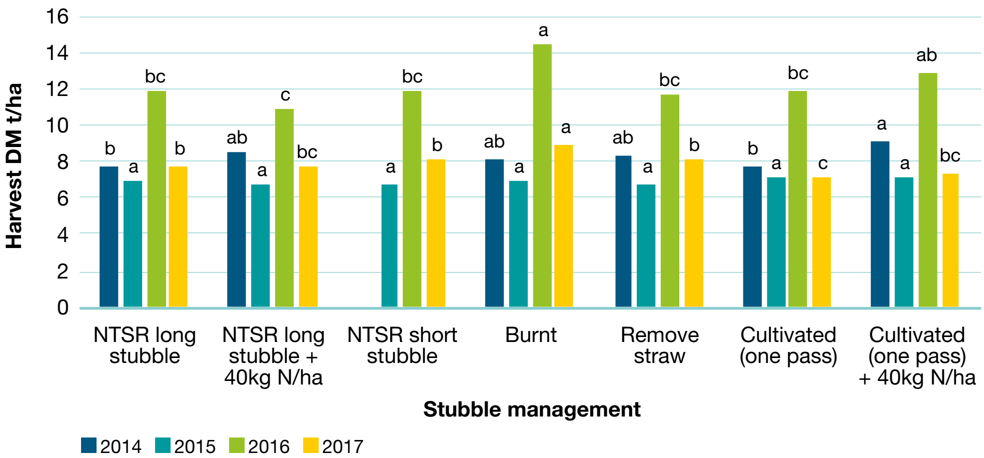


FIGURE 5. Dry matter at harvest (GS95–99) at the Yarrawonga trial site 2014–17

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

During **2017**, DM production was greatest in the burnt treatment when measured at both flowering (7.44 t/ha) and harvest (8.97t/ha). Nitrogen uptake was lowest in the NTSR — long stubble treatment at both flowering and harvest.

KEY FINDINGS

1. During both **2016** and **2017** the burnt treatment had the most DM at harvest.
2. Nitrogen uptake at harvest was assisted by additional nitrogen applied at sowing in the cultivated + 40kg N/ha treatment in three out of the four trial years.

DID STUBBLE MANAGEMENT INFLUENCE THE DETECTION OF YELLOW LEAF SPOT DISEASE AT YARRAWONGA?

During **2014**, when the severity (percentage of leaf area affected) of YLS on both flag-6 and flag-7 leaves was measured at stem elongation (GS30), the result was found to be significantly lower in the burnt treatment compared to the other treatments.

No data was collected at Yarrawonga during **2015** or **2016** because conditions weren't optimal for disease development.

Measurements taken during **2017** at flag leaf emergence (GS39) show YLS severity was significantly lower on the flag-1, -2 and -3 leaves in the burnt treatment compared to the other treatments.

KEY FINDING

1. While data is only presented for 2014 and 2017, these results show that YLS severity was consistently lower in the burnt treatment.

WERE THERE DIFFERENCES IN GRAIN YIELD AND QUALITY ASSOCIATED WITH STUBBLE MANAGEMENT AT YARRAWONGA?

During **2014**, there were no differences in yield between stubble treatments, with an average yield of 4.36t/ha (Figure 6). Protein levels were highest in NTSR + 40kg N /ha (12%) and cultivated + 40kg N/ha (11.1%) and lowest in the straw-removed treatment (9.6%).

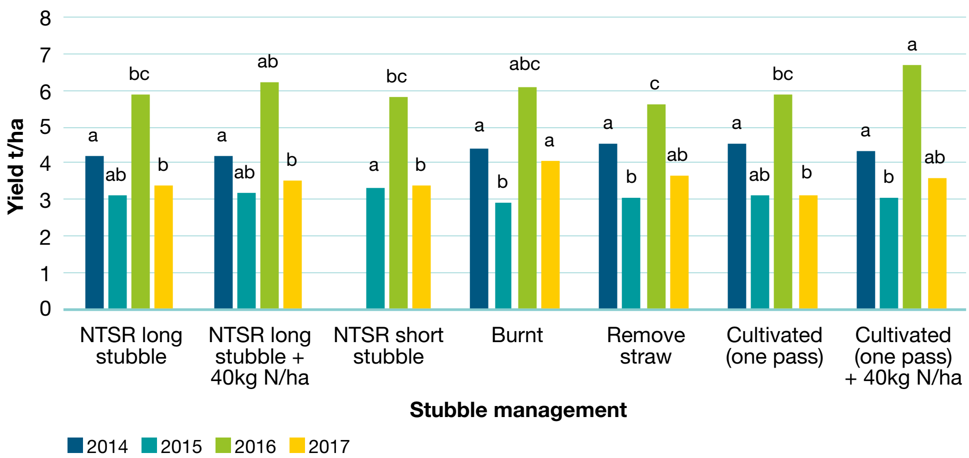


FIGURE 6. Wheat yield results from stubble management trials at Yarrawonga as part of the *Stubble project* 2014–17
Yield bars for the same year with different letters are regarded as statistically significant

During **2015**, the yield was highest in NTSR — short stubble treatment (3.35t/ha) and least in the burnt treatment (2.93t/ha). Protein levels were lowest in the NTSR — short stubble and cultivated treatments (14.8%) and highest in the cultivated + 40kg N/ha treatment (15.7%).

During **2016**, the yield was lowest when straw was removed (5.6t/ha) and highest in the cultivated + 40kg N/ha treatment (6.69t/ha). Protein was also highest in the cultivated + 40kg N/ha treatment (10%).

During **2017** the highest yield was measured in the burnt treatment at 4.08t/ha. The burnt treatment also had the lowest protein at 10.7%.

KEY FINDINGS

1. While differences in grain yields were measured under different stubble management treatments, the responses were not consistent across years.
2. While the inclusion of additional nitrogen at sowing increased yield during 2016 (2016 had the highest yield potential of any during the project term), this result was not replicated in other years. However, across three of the four years additional nitrogen at sowing did contribute to increased protein levels.

TABLE 13. Effect of *Stubble project* time replicate 2 trial on 2015 wheat (cv Young) yield, 2016 canola (cv Bonito) yield and 2017 wheat (cv Trojan) yield, Yarrawonga, Victoria

2015 stubble treatments	2015	2016	2017
	Second wheat	Canola	Wheat
	Yield (t/ha)	Yield (t/ha)	Yield (t/ha)
NTSR — long stubble	3.13[ab]	2.76[a]	4.25[a]
NTSR — long stubble + 40kg N/ha	3.20[ab]	2.73[a]	3.97[a]
NTSR — short stubble	3.35[a]	2.84[a]	4.20[a]
Straw removed	3.03[b]	2.72[a]	4.13[a]
Cultivated (one pass)	3.10[ab]	2.75[a]	4.03[a]
Cultivated (one pass) + 40kg N/ha	3.05[b]	2.69[a]	4.01[a]
Burnt	2.93[b]	2.73[a]	4.07[a]
Mean	**3.11**	**2.74**	**4.10**
LSD	0.29	0.42	0.36

Figures followed by different letters are regarded as statistically significant
Note: All blocks were burnt before the 2016 crop

WERE THERE ANY RESIDUAL IMPACTS FROM A ONE-OFF CHANGE IN STUBBLE MANAGEMENT ON GRAIN YIELD IN FOLLOWING YEARS AT YARRAWONGA?

Following the **2014** trial (time replicate 1), the site was burnt before a commercial barley crop was sown over the trial area during 2015. While a higher yield was observed from the area where straw was removed during 2014 compared with the cultivated area, neither of these yield results were significantly different to any of the NTSR or burnt treatment areas (which were not different to each other) (Table 12).

When the **2015** stubble management treatments (Time replicate 2, Table 13) were considered in terms of their effect on the following commercial canola crop during 2016 or on the following wheat crop during 2017, no differences were observed.

KEY FINDING

1. Neither stubble burning or NTSR had a significant impact on the grain yield of the crop sown following the year of the trial at Yarrawonga.

TABLE 12. Wheat yield of *Stubble project* management trials during 2014 and barley yield of the 2015 commercial crop following 2014 stubble management treatments at Yarrawonga, Victoria

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

Figures followed by different letters are regarded as statistically significant

case study

Farmers
Chris, Tony and Steve Ludeman

Location
Dookie, Victoria

Soil types
Range from light sandy loams to clays to self-mulching clays and red volcanic soils

Enterprises
100% cropping

Rotation
Pulse (faba beans/chickpeas/vetch), canola, wheat, canola, wheat

Q How do usually manage your stubble?

We generally retain stubble every four out of five years in the rotation and use a minimum tillage system. While we are working towards retaining all our stubble, we will strategically burn. Each year, we usually retain about 80% of our stubble, but this varies from year to year.

We use a stubble cruncher on canola stubble. For wheat going into a pulse crop, we harvest at 15cm and spread the chaff and sow the pulse straight in.

Where wheat stubble is going into canola, we burn the stubble, but in the future we hope not to burn during this part of the rotation.

Results from the *Stubble project* showed there was a yield detriment when sowing canola into tall wheat stubble, due to shading. However, if wheat is harvested short to overcome this problem, this may present another problem associated with short stubble, such as moisture loss through evaporation during summer. In this instance, burning wheat stubble just before sowing canola is a good option, because moisture is retained during summer and for as long as possible into autumn. Also, if a paddock needs to be levelled, or drainage works need to be done, burning the paddock is beneficial.

Q At what height do you harvest cereals?

For wheat going into pulse crops, we harvest at 15–20cm, while for wheat going into canola stubble we harvest at 10–15cm.

We have also been trialling harvesting as high as possible at harvest and then hiring a slasher to cut the wheat stubble down after harvest and before sowing pulses the following year. Although there is an extra cost associated with another operation, time and equipment wear and tear is saved at harvest.

Q What sowing equipment do you use?

We invested in a positive parallellogram system using a Boss air seeder bar with coulters at the front which also includes a depth gauge wheel. The seeder also contains a John Deere steerable hitch which enables us to inter-row sow.

Q What benefits have you seen with stubble retention?

The condition of the soil has changed. This has allowed us to dry sow because it's not too cloddy when the crops are dry sown. We also can retain more moisture, which is important as every drop counts. There is value in soil moisture, in trying to build up organic matter and in preventing evaporation losses. There are also cost savings due to less machinery hours. Also, we now see very little run off.

Q What drawbacks have you seen with stubble retention?

We have seen more insect damage, especially in canola from slugs, millipedes and earwigs.

Q What do you feel has been one of the greatest learnings to come out of the *Stubble project* work for the Riverine Plains region?

In the 2017 trial on our farm, canola sown into a tall wheat stubble had less early dry matter (DM) and was slower to reach the flowering stage, which was likely due to shading. This was also demonstrated in wheat sown into a tall wheat stubble. As a result of the project, growers can take measures to reduce their wheat stubble height to ensure there is no detrimental effect to the growth and yield of the following crop. For example, the wheat sown into a tall wheat stubble did not tiller very well due to the shading from the prior wheat stubble. This could be overcome by either cutting the preceding crop wheat stubble lower or by increasing sowing rates in the current wheat crop.

DOOKIE

Table 14 describes the stubble management treatments carried out at the large-plot sites from 2014–17 at Dookie.

TABLE 14. Site and treatments details for the *Stubble project* large plot trials at Dookie from 2014–17

Trial details	Time replicate 1 2014	Time replicate 2 2015	Time replicate 3 2016	Time replicate 4 2017
Stubble treatments:	• NTSR — long stubble • NTSR — short stubble • Straw removed • Cultivated (two passes) • Burnt	• NTSR — long stubble • NTSR — short stubble • Straw removed • Cultivated (one pass) • Burnt	• NTSR — long stubble • NTSR — short stubble • Straw removed • Cultivated (one pass) • Burnt	• NTSR — long stubble • NTSR — short stubble • Straw removed • Cultivated (one pass) • Burnt
Trial plot dimensions (m)	40 x 12	40 x 18	40 x 18	40 x 18
Soil type	Red clay	Red clay	Red loam over clay	Red loam
Sowing drill: **Simplicity seeder/knife point**	✓	✓	✓	✓
Row spacing (cm)	33.3	33.3	33.3	33.3
Stubble loading (t/ha)	7.4	8.7	7.9	7.1
Stubble height (cm)	45	38	34	39
Sowing date	16 May 2014	12 May 2015	12 May 2016	20 April 2017
Crop (cv)	Wheat (Corack)	Wheat (Mace)	Wheat (Corack)	Canola (ATR Stingray)
Rotation	Second wheat	Second wheat	Second wheat	Canola after wheat
Rainfall GSR* (mm):	386	233	509	281
Summer rainfall (mm):	78	76	130	82
Soil nitrogen at sowing^ (0–60cm)	75	56	110	58

* GSR: Growing season rainfall (April – October)

^ As measured in NTSR treatment

WHAT WAS THE IMPACT OF STUBBLE MANAGEMENT ON PLANT GROWTH AND NITROGEN UPTAKE AT DOOKIE?

From the initial establishment of the project during 2014, the Dookie site was the only site to have both the NTSR — long stubble and NTSR — short stubble treatments included in its original treatment list (it was added during 2015 at Yarrawonga).

During **2014** the NTSR — long stubble treatment had the lowest DM at both flowering (GS65) and harvest (GS99). The highest DM at harvest was measured in the burnt treatment (11.18t/ha) (Figure 7 and Figure 8). Nitrogen uptake at flowering was lowest in the NTSR — short stubble treatment, however there was no difference between treatments by harvest.

During **2015** there was no difference in DM between treatments at either flowering or harvest, with an average DM at harvest of 6.68t/ha. There was also no difference in nitrogen uptake between treatments at flowering, however the burnt treatment had the lowest nitrogen uptake result of any treatment at harvest.

During **2016** DM was measured at the watery ripe grain stage (GS71), at which time the NTSR — long stubble treatment had the least DM (10.3t/ha). By harvest however, there was no longer any difference in DM production between the treatments with an average DM of 13.2t/ha. The highest nitrogen uptake at the watery ripe grain stage was measured in the NTSR — short stubble treatment, however there were no differences between treatments measured at harvest.

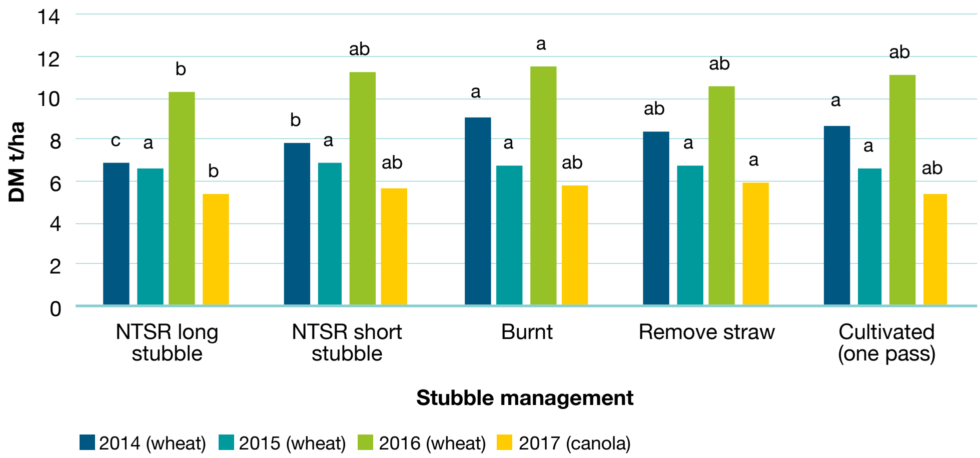


FIGURE 7. *Stubble project* DM yields at the flowering (GD65–GS71) stage for wheat (2014–16) and at 50% flowering (GS4.5) in canola (2017) at Dookie, Victoria

Notes: During 2014, the cultivation treatments were established with two passes of a multidisc while in 2015, 2016 and 2017 a single pass was used

In 2017, canola was sown

Yield bars for the same year with different letters are significantly different

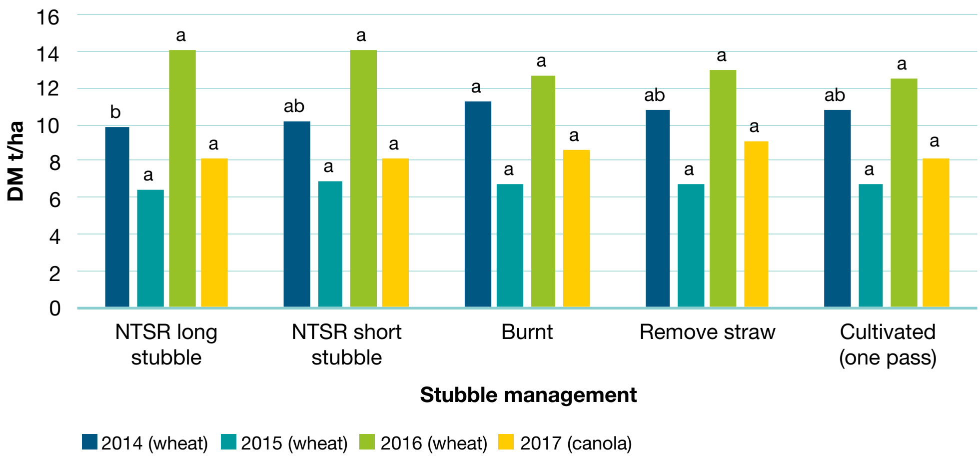


FIGURE 8. *Stubble project* DM yields at physiological maturity (GD95–GS99) for wheat (2014–16) and the most-seeds-black-but-soft (GS6.7) stage in canola (2017) at Dookie, Victoria

Note: During 2014, the cultivation treatments were established with two passes of a multidisc while in 2015, 2016 and 2017 a single pass was used

In 2017, canola was sown

Yield bars for the same year with different letters are significantly different

During **2017** the trial site was sown to canola. At the 50% flowering stage (GS4.5) the lowest DM was observed in the NTSR — long stubble treatment, with no difference in DM observed between treatments at the most-seeds-black-but-soft (GS6.7) assessment (which had an average DM of 8.41t/ha). The highest nitrogen uptake at GS4.5 was measured in the burnt treatment, while the highest uptake at GS6.7 was observed in the cultivated and straw-removed treatments.

KEY FINDINGS

1. The NTSR — long stubble treatment had lower DM at flowering compared with the burnt treatment in three of four years, but only had lower DM at harvest in a single year compared with the burnt treatment (2014). This developmental delay for the NTSR — long stubble treatment is referred to as a *biomass lag* (see information on Biomass lag with retained stubble on page 36).
2. Differences in timing of plant development were clearly seen during 2017, whereby flowering of canola was delayed in the NTSR — long stubble and NTSR — short stubble plots compared with the burnt plots. However, this did not impact DM at harvest.

DID STUBBLE MANAGEMENT INFLUENCE THE DETECTION OF YELLOW LEAF SPOT DISEASE AT DOOKIE?

Wheat was grown in the Dookie trials from 2014–16. The only differences in YLS incidence detected over this period occurred during 2015, with results showing the severity of YLS on flag-2 and flag-3 was greatest in the NTSR — long stubble treatment when measured at GS39. As the site was sown to canola during 2017 no YLS assessments were made.

KEY FINDING

1. There were limited differences in YLS severity between the different stubble management treatments over three years at the Dookie trial site.

WERE THERE DIFFERENCES IN GRAIN YIELD AND QUALITY ASSOCIATED WITH DIFFERENT STUBBLE MANAGEMENT TECHNIQUES AT DOOKIE?

During **2014** the NTSR — long stubble treatment yielded less than the other treatments (4.98t/ha) compared with an average of 5.6t/ha for the other treatments, probably due to the lack of tillering in the NTSR — long stubble plots (Figure 9). Given its lower yield, the NTSR — long stubble treatment had the highest resulting protein of all treatments (11.6%).

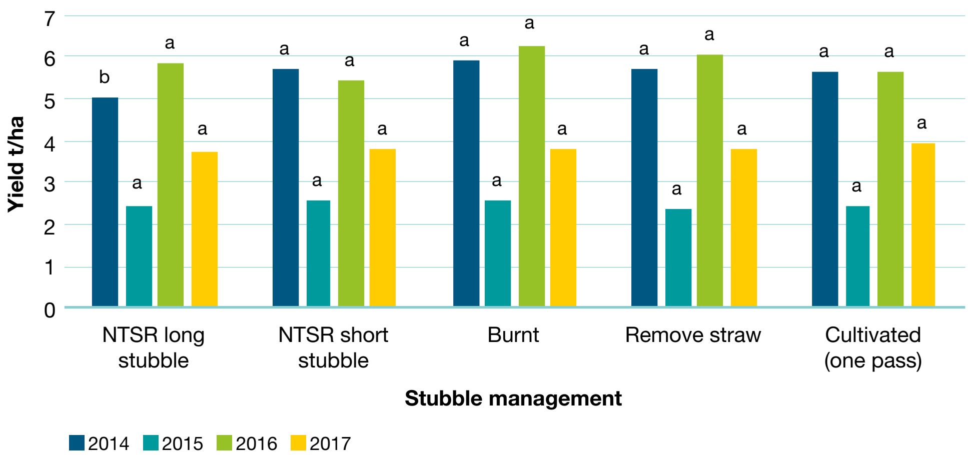


FIGURE 9. Wheat yield results (2014–16) and canola yield (2017) from large-plot field trials carried out as part of the *Stubble project* in the wheat-on-wheat rotation position cv Corack (2014), cv Mace (2015) and cv Corack (2016) and in canola (cv ATR Stingray) following wheat at Dookie, Victoria

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

During **2015** there were no differences in grain yield between treatments, with the trial yielding an average 2.42t/ha. The NTSR — long stubble treatment had the highest protein (15%).

During **2016** there were no differences in grain yield or protein between treatments, with the trial yielding an average 5.8t/ha, and having an average protein of 10.9%.

During **2017** there were no differences in canola yield between the different stubble management treatments, with an average yield of 3.76t/ha.

KEY FINDING

1. Stubble management technique had a limited effect on crop yield or protein at Dookie. A yield penalty due to stubble retention only incurred once, during 2014, when wheat plants in the NTSR — long stubble treatment had reduced tiller numbers, most likely due to a high degree of shading early during the season. This response has not been replicated in other years or sites.

WERE THERE ANY RESIDUAL IMPACTS FROM A ONE-OFF CHANGE IN STUBBLE MANAGEMENT ON CROP YIELD IN FOLLOWING YEARS?

The site of the **2014** trial at Dookie (time replicate 1) was burnt before being sown to a commercial crop of canola during 2015. The area that had been under the lower-yielding NTSR — long stubble plots during 2014 produced significantly higher canola yields during **2015** than was measured in the burnt plot areas (Table 15). The subsequent increase in yield following the NTSR — long stubble treatment during 2015 may have been due to water savings at depth in this treatment, which would have been of particular value during the dry spring of 2015.

TABLE 15. Wheat yield of *Stubble project* management trials during 2014 and canola yield of the 2015 commercial crop following 2014 stubble management treatments at Dookie, Victoria

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

Figures followed by different letters are regarded as statistically significant

KEY FINDING

1. If a specific stubble management approach incurs a yield penalty in the year of practice, it may result in a yield benefit the following year. This can act to mitigate any impact of a specific stubble management technique on production due to the particular seasonal conditions experienced.

case study

Farmer
Peter Campbell

Location
Pleasant Hills

Soil types
Red brown earths

Enterprises
Cropping and Merino sheep

Crop rotation
Five years pasture followed by 5–7 years cropping: canola, wheat, pulse, arrow-leaf clover and sometimes barley

Q How do you usually manage your stubble?

We usually retain 100% of our stubble. The odd burn is used occasionally. For example, at the end of the cropping rotation when pasture is under-sown into a barley crop, the previous year's cereal stubble is burnt to ensure the pasture germinates.

It is all to do with rotations. We rarely sow cereal on cereal and instead try to sow canola on wheat stubble or a pulse crop on a wheat stubble. This allows us to retain our wheat stubble most of the time.

We also graze heavily during summer with sheep. Sometimes we add lupins to the stubble to encourage the sheep to eat more of the stubble, then we sow straight into the stubble.

We have to learn how to retain stubble properly as it allows us to lock in moisture and sow early. Retaining stubbles also provides soil protection against heavy rain events and helps prevent damage to soil from sheep feet trampling it. Where stubble is retained, carbon is not released to the atmosphere through burning and the nutrients in the stubble are retained, which may also allow us to cut back on nutrients in our system.

Q At what height do you harvest cereals?

We harvest at the highest height possible to get through harvest.

Q Sowing equipment

We use a John Deere 1590 Disc seeder with 17.8cm (7 inch) spacings.

Q What benefits have you seen with stubble retention?

We can sow earlier. Our yields are better when we sow early, as long as we manage the dates around varieties and frost tolerance. We are now more confident in sowing by a calendar date, which we were never able to do before, and can start sowing pastures on 25 March, canola in the first week of April, grazing wheats on 15 April, Gregory and Trojan on 26 April and Beckom from 7–10 May.

Q What drawbacks have you seen with stubble retention?

Wet sowing can be an issue as it can be difficult to get crops to emerge, however that usually isn't a problem as most of our crops are sown during April. The disc machines seem to require a lot of maintenance for wear and tear.

Also we have more problems with slugs in canola and need to bait every canola paddock.

Q Is improving soil health a factor in your decision to retain stubble?

We have mapped our soil carbon over time and carbon levels are increasing because of the pasture phase. The research shows that stubble retention generally holds the soil carbon levels where they are.

We have also measured deep soil nitrogen (DSN) levels over time and we are getting more mineralisation with our system. Even though we are getting more nitrogen mineralised, we are putting more nitrogen out in the canola phase, as we are chasing yield, but if the canola doesn't use it, it is available for the next cereal crop.

Q What do you feel has been one of the greatest learnings to come out of the *Stubble project* work for the Riverine Plains region?

The stubble walks during the project were well attended and generated good discussion among local farmers. A couple of farmers in the area are considering moving to a full stubble retention disc system, however there is a high cost of changing the machinery over.

HENTY

Table 16 describes the stubble management treatments carried out at the large-plot sites from 2014–16 at Henty.

TABLE 16. Site and treatments details for the *Stubble project* large plot trials at Henty, NSW from 2014–16

Trial details	Time replicate 1 2014	Time replicate 2 2015	Time replicate 3 2016
Stubble treatments:	• NTSR — long stubble • NTSR — long stubble + 40kg N/ha# • Mulched • Mulched + 40kg N/ha# • Cultivated (one pass) • Cultivated + 40kg N/ ha#	• NTSR — long stubble • NTSR — long stubble + 40kg N/ha# • Mulched • Mulched + 40kg N/ha# • Cultivated (one pass) • Cultivated + 40kg N/ ha#	• NTSR — long stubble • NTSR — long stubble + 40kg N/ha# • Mulched • Mulched + 40kg N/ha# • Cultivated (one pass) • Cultivated + 40kg N/ ha#
Trial plot dimensions (m)	40 x 15	40 x 15	40 x 15
Soil type	Yellow–brown earth		Yellow–brown earth
Sowing drill: John Deere 1590 disc seeder	✓	✓	✓
Row spacing (cm)	19	19	19
Stubble loading (t/ha)	7.8	8.3	6.6
Stubble height (cm)	47		47
Sowing date	16 April 2014	21 April 2015	10 April 2016
Crop (cv)	GT50 RR Canola	314 TT Monola	650 TT Canola
Rotation	Following wheat	Following triticale/ arrowleaf clover	Wheat stubble
Rainfall GSR* (mm):	390	391	619
Summer rainfall (mm):	85	114	145
Soil nitrogen at sowing (0–60cm)^	62	44	106

The extra 40kg N/ha was applied just prior to sowing (incorporated by sowing — IBS).

* GSR: Growing season rainfall (April – October)

^ As measured in NTSR treatment

WHAT WAS THE IMPACT OF STUBBLE MANAGEMENT ON PLANT GROWTH AND NITROGEN UPTAKE AT HENTY?

The Henty site was the only trial site to have a mulched treatment instead of a burnt treatment, which reflects the preferred farming practices in the area. Furthermore, given the wheat-on-wheat rotation is not commonly practiced by the host farmer, the three years of the trial were carried out in canola sown into wheat stubble.

During **2014** there were no differences in DM at mid pod set (GS5.5) (Figure 10) or harvest (GS6.9) (Figure 11), with an average harvest canola DM across all treatments of 9.29t/ha. Neither were there any differences in nitrogen uptake between treatments at flowering or at harvest.

During **2015** there were no differences in DM production of monola sown into any wheat stubble treatment at either mid flowering (GS4.5), mid pod set (GS5.5) or harvest (GS6.9), with an average harvest DM of 3.84t/ha. There were no differences in nitrogen uptake across treatments either at flowering or at harvest.

During **2016** the NTSR — long stubble (control) treatment had less DM at flowering than the cultivated and cultivated + 40kg N/ha treatments. However, by harvest, there were no differences in DM production

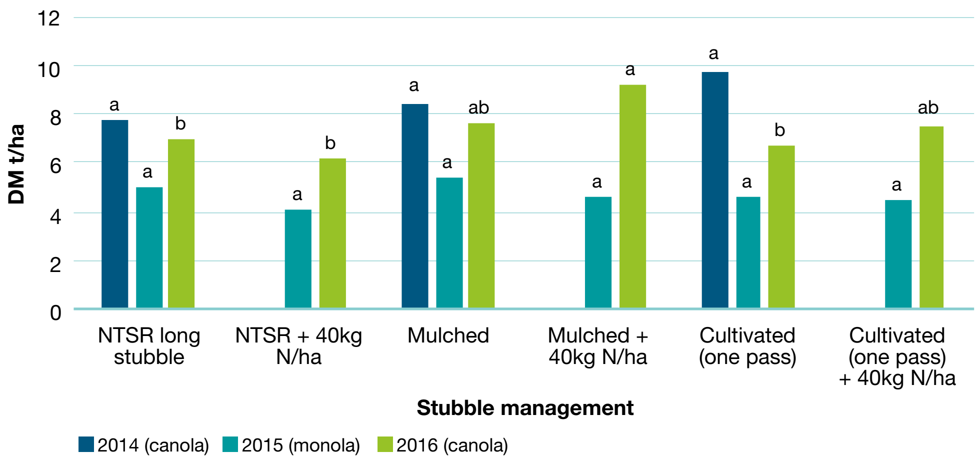


FIGURE 10. Dry matter at mid pod set (GS5.5) for canola grown 2014, monola 2015, and canola 2016 at Henty

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

The full data set for 2014 is not presented, however there were no significant differences between + nitrogen and nil nitrogen treatments. The reliability of DM data during 2015 was affected by waterlogging between replicates

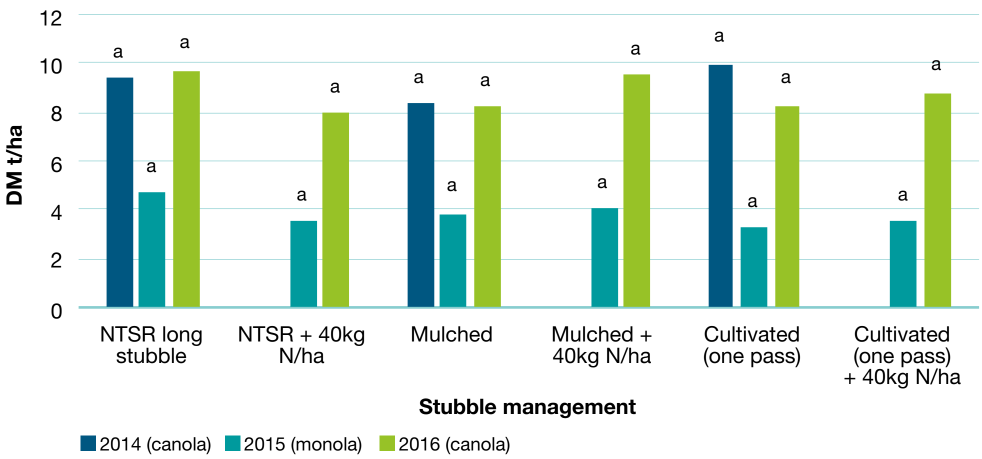


FIGURE 11. Dry matter at harvest (GS6.9) for canola grown 2014, monola 2015, and canola 2016 at Henty

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

The full data set for 2014 is not presented, however there were no significant differences between + nitrogen and nil nitrogen treatments. The reliability of DM data during 2015 was affected by waterlogging between replicates between the treatments, with the trial averaging 8.81t DM/ha. Nitrogen uptake was highest in the mulched + 40kg N/ha and cultivated + 40kg N/ha treatments.

The trial was discontinued during 2017 due to ongoing high levels of within-trial variability and consistent waterlogging of the sites through spring.

KEY FINDING

1. There were no differences in DM production between the treatments at Henty when measured at harvest across all three years. In terms of nitrogen uptake, the only statistically significant result was seen during 2016, when treatments with additional nitrogen may have been better able to withstand the extended periods of waterlogging.

WERE THERE DIFFERENCES IN GRAIN YIELD AND QUALITY ASSOCIATED WITH DIFFERENT STUBBLE MANAGEMENT TECHNIQUES AT HENTY?

During **2014** the cultivated + 40kg N/ha treatment had the highest yield (2.63t/ha) while the NTSR — long stubble (control) treatment had the lowest yield (2.02t/ha) (Figure 12). There were no differences in oil content across treatments, with an average 43.4% oil.

During **2015** there was no difference in grain yield between the different stubble management treatments, with an average trial yield of 1.36t/ha. The NTSR — long stubble + 40kg N/ha treatment had less oil (41%) compared with the average of the other treatments (43.9%).

During **2016** there were no differences in grain yield between treatments, with an average yield of 2.53t/ha.

Canola sown into the cultivated treatment at Henty during 2015.

KEY FINDING

1. The addition of nitrogen to the cultivated treatment increased early plant vigour and DM production during 2014 at Henty (a year in which there was an early break followed by ongoing moist conditions throughout autumn).
2. The grain yield results across the years of the trial (2014–16) were variable. In all three years, the trial site was subjected to varied levels of waterlogging, which was particularly problematic during early spring across all three years.

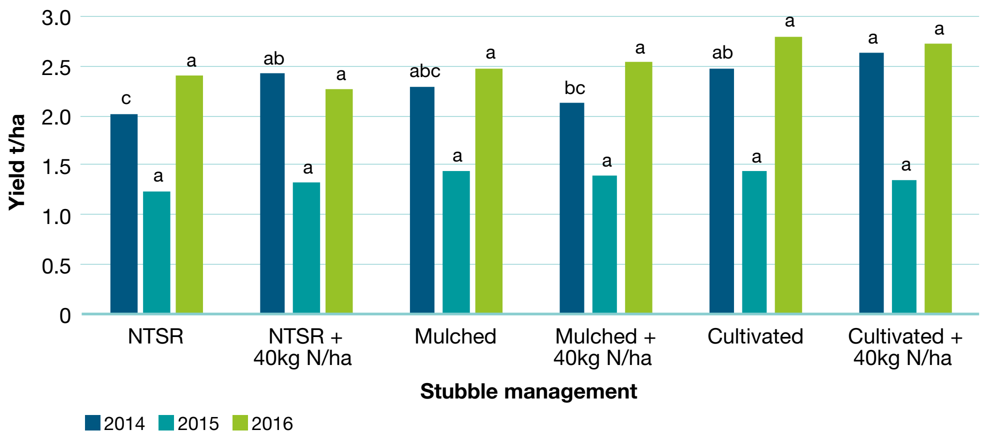


FIGURE 12. Yield data* from 2014, 2015 and 2016 stubble management trials carried out in canola as part of the *Stubble project*, cv GT50 RR (2014), cv 314 TT Monola (2015) and cv Hyola 650 TT (2016) at Henty, NSW

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

WERE THERE ANY RESIDUAL IMPACTS FROM A ONE-OFF CHANGE IN STUBBLE MANAGEMENT ON CROP YIELD IN FOLLOWING YEARS AT HENTY?

The **2014** trial site was sown to a commercial crop of oats during 2015 using NTSR. The 2014 stubble cultivation treatments (with and without nitrogen) significantly increased oat yields during 2015 compared with the NTSR treatment without nitrogen (Table 17).

TABLE 17. Canola yield of *Stubble project* management trials during 2014 and oat yield of the 2015 commercial crop following 2014 stubble management treatments at Henty, NSW

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

Figures followed by different letters are regarded as statistically significant

KEY FINDING

1. The increased yield of an oat crop following the 2014 trial in the areas which had been under cultivation may have been due to increased mineralisation of stubble-derived nutrients as a result of to greater stubble–soil contact.

Growers inspecting the treatments at a paddock walk during 2014.

Michael Straight, FAR Australia, at a Henty paddock walk during 2016.

Summary of findings from the large-plot field trials

WHAT DID THE RESULTS TELL US?

Large-plot field trials were located across four ‘focus farms’ at Henty and Daysdale/Corowa/Coreen in NSW and Yarrawonga and Dookie in Victoria from 2014–17. These trials evaluated a range of stubble management approaches to be used as a single-year management tool within an otherwise NTSR system.

A key finding was that stubble height influenced crop architecture, especially tillering, with high stubble height in the NTSR — long stubble treatment (45cm) negatively impacting wheat yield compared with the NTSR — short stubble (15cm), burnt, straw-removed and cultivated treatments at the Dookie site during **2014**.

A dry spring during **2015** and a heat event during the first week of October saw temperatures reach 35–37°C. After this event, visual assessments of green leaf retention and physiological maturity made at all sites showed the burnt stubble treatments had matured earlier than NTSR treatments (which stayed greener for longer).

Little difference was seen between treatments and across sites during **2016** due to the excessively wet conditions.

During **2017**, some yield differences were observed due to repeated frost events at flowering. While treatment differences were sometimes seen through physiological measurements made through the growing season, there were generally no consistent yield differences between NTSR and burnt or cultivated treatments across sites and seasons.

The high number of frost events experienced during the spring of 2017 meant most crops experienced some degree of frost damage, however the degree of frost damage depended on the stage the crop was at in relation to the flowering window. Crops grown in the burnt stubble treatment had a different flowering date to the NTSR — long stubble or NTSR — short stubble plots and therefore experienced differential rates of frost damage (depending on when the frost occurred). Frost and temperature results are discussed in detail from page 44.

KEY MESSAGES

1. Stubble management *per se* is not the primary driver influencing crop production, providing seeding equipment and stubble management are compatible (see Compatible equipment on page 35).
2. Growers could manipulate stubble height to spread their flowering window within each variety and paddock, and thus spread their frost risk.

COMPATIBLE EQUIPMENT

Sowing equipment needs to be able to physically manage stubble residue left over from harvest. Where equipment has poor stubble-handling capabilities, clumping, thick layers of stubble or hair-pinning can cause poor seed–soil contact, which will affect crop emergence, growth and yield.

When setting up tined sowing equipment for stubble-retained systems, consider the following recommendations, as published in the GRDC *Stubble Management* fact sheet:

- Maximise spacing between the tines. A seeder bar should generally have at least five ranks spaced at least 50cm apart. This allows for space to clear material if it builds up.
- Match the spacing between the tines to stubble length. Spacing between tines should be about twice the stubble length. If the inter-tine clearance is small, stubble will need to be cut short.
- Using press wheels improves seed–soil contact, improving germination rates and aiding water harvesting in furrows.
- Arrange tines to minimise the chance of clumping of stubble in front of following tines.
- Locating press wheels too close to the back row of tines can also cause stubble build-up.
- Position wheels to maximise stubble flow, with nearby tines located in front of the wheel.
- Where possible, plan to sow into heavy stubbles when dry as blockages can be more common when stubbles get wetter (including from falling dew).
- Use lower-reaching narrow points (such as knife points) and shallow tillage depths to maximise clearance.
- Slow operating speeds reduce the risk of stubble clumping and blockages, but specific speeds vary between equipment and management practices (e.g. row width).
- Fitting poly or exhaust pipe (40–50mm diameter) to tine shanks reduces stubble build-up.

When setting up disced sowing equipment for stubble-retained systems, consider the following recommendations from the GRDC *Stubble Management* fact sheet:

- Use residue-avoidance techniques, such as inter-row sowing into tall standing stubble and consider row cleaners/residue managers.
- Maximise residue-cutting capacity using a sharp disc opener set at optimum depth and operating in dry stubble and firm soil conditions.
- If sowing into wet stubble and soft soil, disc openers can push residue into the furrow, rather than being cut (hair pinning). This reduces seed–soil contact and causes patchy establishment.
- Inter-row sowing with +/- 2cm RTK accuracy guidance and auto steer can increase the volume of stubble handled and improve establishment

feature

BIOMASS LAG WITH RETAINED STUBBLE

Across the 2014–15 seasons, the stubble-retained treatments had lower DM production rates during the earlier growth stages compared with the other treatments. However, by flowering time there was little difference between DM production in the NTSR — long stubble or short stubble treatments or where the stubble had been burnt or cultivated. The impact of this delay in biomass production on the overall physiological development of the plant was unknown.

This led to questions such as: "Were the plants growing in NTSR systems at the same growth stage, but with less biomass?", or: "Was there a difference in growth stage development caused by the treatments?". If there was a difference in physiological development of plants between the NTSR and the burnt or cultivated systems, could this then relate to differences in how the crops handle frost and heat stress, based on a shift in the flowering window?

In order to understand if this *biomass lag* was simply a difference in the rate of DM accumulation, or if it was related to differences in growth stage, a series of growth-stage assessments were carried out at the Coreen, Yarrawonga and Dookie sites during 2016.

At the Yarrawonga site, these assessments showed that stubble management did ***not*** influence plant growth and development until the stem elongation stage (which commenced 11 July 2016) for all treatments except the tall stubble treatment, which took an extra three weeks to move into stem elongation.

The Dookie site showed differences in development from the seedling stage onwards, with treatment differences evident from 27 June 2016. At this assessment, plants in the burnt treatment were slightly more developed than the other treatments, with this increase largely maintained for the next four weeks. Plants in the NTSR — long stubble treatment lagged in their development from 27 June 2016 and showed minimal advances in development by the next reading on 4 July 2016. By 18 July, development in the NTSR — long stubble treatment had caught up to the short stubble and disced treatments, while the burnt treatment was still slightly ahead.

In comparison, there were no significant differences in growth stage development observed at the Coreen site, with plants in the stubble standing, disced and burnt treatments all developing at the same rate. Note: stubble was shorter at Coreen during 2016 (26cm) than at the other sites (Yarrawonga 36cm, Dookie 34 cm, Henty 47cm).

This work demonstrated that stubble management ***could*** have an impact on physiological maturity, which means the presence of stubble could change flowering date. But, what exactly caused this change? Was it the actual physical presence of the stubble, or was it something that changed in the environment in the presence or absence of stubble?

The three factors most likely to influence wheat growth in the presence or absence of stubble were considered to be:

1. in-canopy temperature
2. in-crop nitrogen supply
3. light availability to the crop.

While in-canopy temperatures and nitrogen supply were also measured during the *Stubble project* (see page 44 for frost research), a key learning from 2017 was the connection between the *length* of standing stubble and the *flowering date* of the subsequent crop.

This led to light measurements being undertaken during June 2017, using a

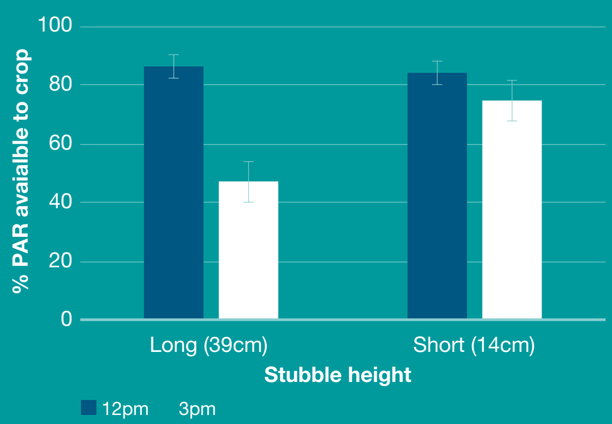


FIGURE 13. Influence of stubble treatment on availability of photosynthetically active radiation for wheat sown into wheat stubble in north–south facing rows at 12pm on 20 June 2017 (GS22) and 3pm on 28 June 2017 (GS23) at the *Stubble project* site, Yarrawonga, Victoria

ceptometer, to measure the effect of stubble shading on light interception by the establishing crop. Results from the 2017 stubble trial at Yarrawonga showed that long stubble (40+cm) reduced the amount of plant available radiation (PAR) to the young wheat crop by up to 50% (when measured mid-afternoon, with the crop sown in a north–south direction) (Figure 13).

An additional trial site was established at Rennie, NSW specifically to test the impact of stubble height on light interception and in-canopy temperature, with canola sown into wheat stubble in an east–west direction. The long stubble (42cm) significantly reduced light availability early during development (Figure 14) and led to a delay in plant development and biomass production, which then delayed flowering. Temperature observations from the Rennie trial showed no difference in in-canopy temperature under the different stubble height treatments (Figure 15). Despite the developmental delays observed in the long stubble treatment there were no differences in yield across the stubble height treatments (Table 18).

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

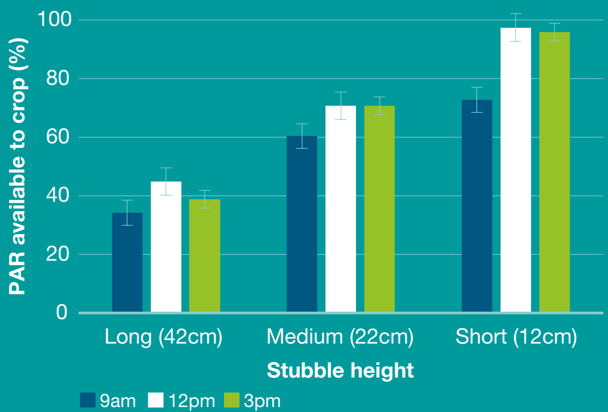


FIGURE 14. Influence of stubble height on availability of photosynthetically active radiation for canola sown into wheat stubble in east–west facing rows at 9am on 6 June 2017, 12pm on 13 June and 3pm on 19 June 2017 (GS23) at the *Stubble project* site, Rennie, NSW

TABLE 18. Grain yield and quality at harvest (GS6.9) for canola sown into short (12cm), medium (22cm) and long (42cm) stubble in an east–west facing trial at Rennie NSW, 2017

Treatment	Yield and quality	
	Yield (t/ha)	Oil (%)
Short (12cm)	1.57[a]	46.1[a]
Medium (21cm)	1.47[a]	46.6[a]
Long (42cm)	1.69[a]	45.6[a]
Mean	**1.58**	**46.1**
LSD	0.39	1.1

Figures followed by a different letter are regarded as statistically significant

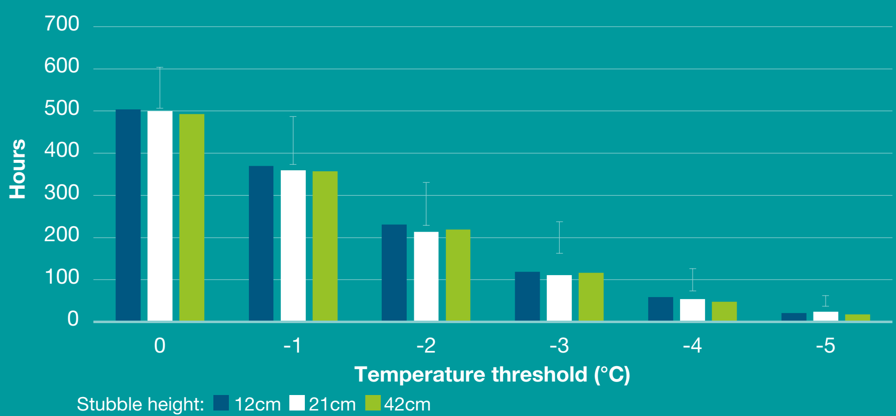


FIGURE 15. Hours spent below each temperature threshold for canola grown into short (12cm), medium (21cm) and long (42cm) stubble height treatments from 17 May – 21 November 2017 at the *Stubble project* site at Rennie, NSW

Summary of results from the small-plot field trials

All the detail around the small-plot field trials has been reported in the *Research for the Riverine Plains* publications, in the year following the year of the trial. Rather than reproducing all the technical results from each trial here, a short summary of findings from each set of trials are reported below. The full articles are available via the Riverine Plains Inc website at **https://riverineplains.org.au/research/maintaining-profitable-farming-systems-retained-stubble-riverine-plains-region/**

The small-plot field trials for 2014, 2015 and 2016 were carried out in wheat.

There were no grain yield or quality penalties when wheat was sown during mid-April on 30cm spacings compared with 22.5cm from 2014–16.

KEY FINDINGS:

EARLY-SOWN WHEAT AND THE INTERACTION BETWEEN ROW SPACING AND VARIETY

Within the GRDC-funded *Water Use Efficiency Initiative,* Riverine Plains Inc managed the project *Improved water use efficiency (WUE) in no-till cropping and stubble-retained systems in spatially and temporally variable conditions in the Riverine Plains.* This project clearly demonstrated that when first wheat was sown within the traditional sowing window of late May – early June in the Riverine Plains region, there was a yield penalty for crops sown on row spacings exceeding 22.5cm, as reported in the *Between the Rows publication (2015).* However, as many growers in the Riverine Plains region now dry-sow their wheat early (around mid-April), the relevance of those results was questioned. Hence, further row spacing trials were carried out within the *Stubble project* using early-sown wheat varieties.

The small-plot row spacing trials were undertaken as part of the *Stubble project* from 2014–16 at Barooga, NSW and Yarrawonga, Victoria. Results from these trials showed no grain yield or quality penalties associated with sowing at 30cm spacings compared with 22.5cm during mid-April for 2014, 2015 and 2016 (Yarrawonga results Figure 16). However, early-sown (mid-April) first wheat on row spacings wider than 30 cm incurred a yield penalty during 2016 at Yarrawonga (the Barooga trial was abandoned due to waterlogging), with varietal differences measured for yield across all row spacings. As a result of lower yields for 2016, the 37.5cm row spacing also had significantly poorer WUE than the 30cm row spacing.

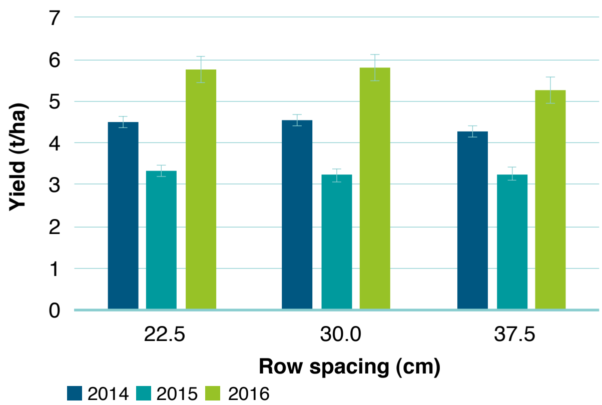


FIGURE 16. Influence of row spacing on grain yield in early-sown first wheat (average of four varieties) sown as part of the *Stubble project* during 2014, 2015 and 2016, Yarrawonga, Victoria

Error bars presented as a measure of LSD

The results from these early-sown wheat *Stubble project* trials are different to results from the *Water Use Efficiency* project, which showed that later-sown wheats (sown late May – early June) on a 22.5cm spacing produced more dry matter (DM) than the 30cm spacing, which led to more yield.

KEY POINT

1. Row spacing (22.5cm or 30cm) is less important in determining wheat yield in early-sown (mid-April) crops compared with later-sown crops (late May – early June).

KEY FINDINGS:

INTERACTION BETWEEN PLANT GROWTH REGULATOR (PGR) AND NITROGEN APPLICATION IN EARLY SOWN FIRST WHEAT

Plant growth regulators (PGR) are routine inputs for high-yielding cereal crops grown elsewhere in the world to shorten the crop, prevent lodging and avoid yield penalties.

Small-plot field trials were sown at Redlands (Corowa) and Yarrawonga during 2014, at Dookie during 2015 and at Yarrawonga during 2016 as part of the *Stubble project* to determine if larger crop canopies associated with early sowing, or higher rates of nitrogen, would benefit from PGR application.

Across the three years of trials (2014, 2015 and 2016), applying a PGR (Moddus and Chlormequat) did not result in any significant yield benefits, even when tested across a range of nitrogen application levels (Figure 17).

For all years, except 2016, applying a PGR (Moddus + chlormequat) reduced crop height by up to 8cm without influencing DM production compared with the control. However, during 2016 applying a PGR reduced the crop DM at harvest and decreased crop height by up to 5cm across the nitrogen treatments (Figure 18).

During 2014, PGR application did not affect quality. During 2015 there was a small but significant increase in test weight and a significant reduction in screenings with PGR application. While the differences were small, during 2016 applying a PGR significantly increased screenings and decreased test weight.

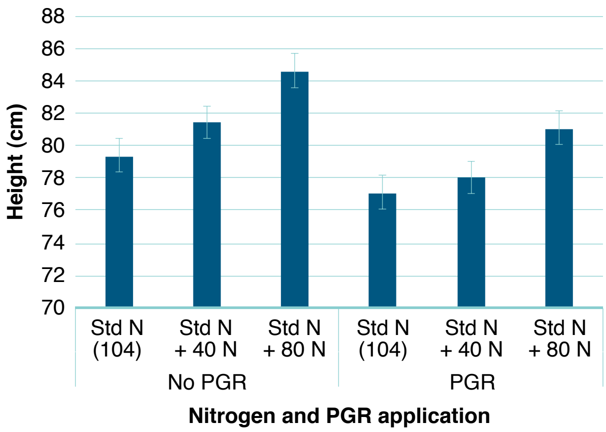


FIGURE 18. Impact of the interaction between nitrogen rate and PGR application on crop harvest height at Yarrawonga, 2016

Error bars presented as a measure of LSD

Normalised difference vegetation index (NDVI) readings, measured with a handheld GreenSeeker®, were lower with PGR application. This suggests the PGR either altered the 'greenness' of the crop canopy or changed the orientation of the leaves, making them more upright (and producing lower reflectance).

KEY POINTS

1. Three years of trials across a range of seasonal conditions did not provide evidence to suggest applying PGR delivers any positive yield effects or consistent quality effects.
2. During the three years of trials, applying a PGR reduced crop height without influencing DM production, except during 2016 where harvest DM was significantly lower.

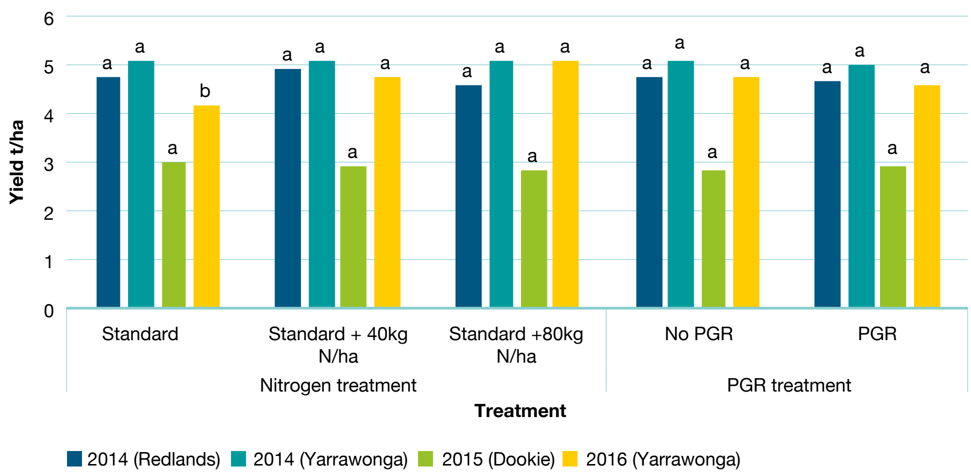


FIGURE 17. Wheat yields from 2014–16 under variable nitrogen application rates, and with and without PGR application

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

KEY FINDINGS:

MONITORING THE PERFORMANCE OF NITROGEN APPLICATION TO WHEAT UNDER FULL STUBBLE RETENTION

Small-plot field trials were carried out during 2014 and 2015 at Yarrawonga and Dookie, and during 2016 at Corowa and Dookie to investigate whether additional nitrogen offered value to stubble-retained systems. The trials measured the effect of nitrogen application rate and timing on yield and quality of first wheat grown under full stubble retention (Figure 19 and Figure 20).

During **2014**, there were significant yield increases where nitrogen was applied, however timing of application did not affect yield. Yield was also not affected by whether nitrogen was applied as a split or single dose. The NDVI assessments revealed no difference in crop reflectance due to nitrogen application timing, however there were differences due to the rate applied at key growth stages. Nitrogen timing variably affected tiller and head numbers, although a split application produced a taller canopy. Higher rates of nitrogen produced more harvest DM at Dookie, but not at Yarrawonga.

During **2015**, there was no yield advantage from additional nitrogen due to the hot and dry conditions between ear emergence (GS59) and the end of flowering (GS69). At both Yarrawonga and Dookie there was significantly higher DM and greater nitrogen uptake as a result of applying nitrogen, though the timing of application did not affect DM production. The NDVI scores at Dookie showed a more rapid senescence in the 120kg N/ha plots than the unfertilised or 60kg N/ha plots.

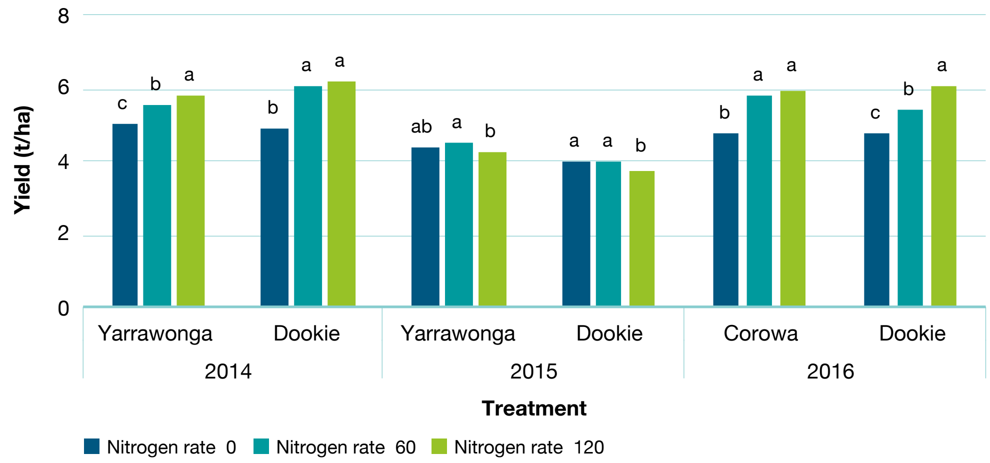


FIGURE 19. Yield of *Stubble project* wheat sown as part of trials evaluating the response to 0, 60 or 120 kg N/ha in stubble-retained systems at Yarrawonga, Dookie and Corowa for 2014, 2015 and 2016

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

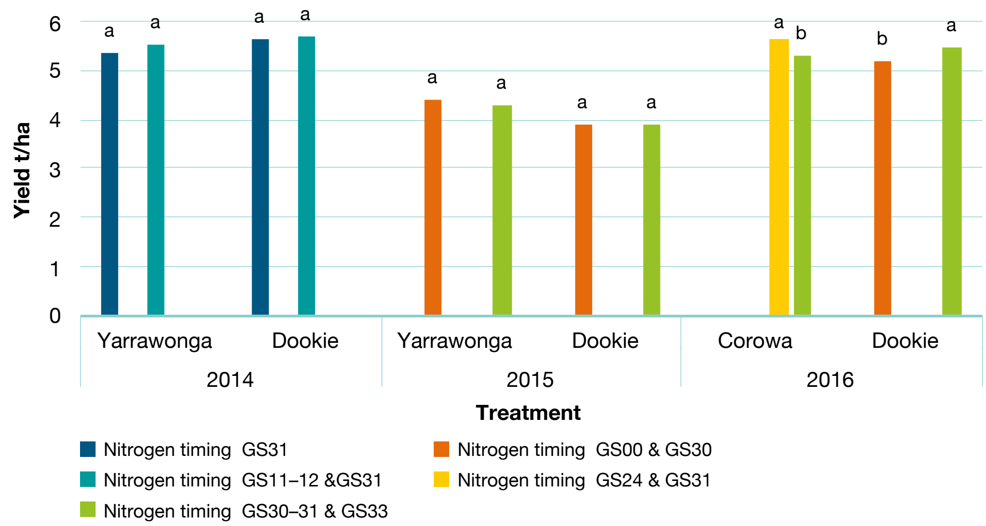


FIGURE 20. Yield of *Stubble project* wheat sown as part of trials evaluating the response to nitrogen timing in stubble-retained systems at Yarrawonga, Dookie and Corowa for 2014, 2015 and 2016

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

During **2016**, there were significant yield responses to applied nitrogen at both Dookie and Corowa. At Corowa, there was no difference in DM production when nitrogen was applied compared to the control plots. However, there were significant differences in NDVI readings, with the early split timing at tillering (GS24) and first node (GS31) being greener at stem elongation (GS30) and third node stage (GS33) compared with a later nitogen application strategy (GS31 and GS33). At Dookie, there were differences in DM production between crops that received either 60 or 120kg N/ha compared with the nil-nitrogen crops. The NDVI readings were also higher in the 120kg N/ha crops at GS33 and at the start of grain fill (GS71).

KEY POINTS

1. While applying nitrogen increased yield potential, the timing of the actual nitrogen application (split, single dose) did not consistently influence yield.
2. As there is no penalty for applying nitrogen as a split application, this approach may be beneficial under different seasonal conditions. A high rate of nitrogen up front, or early, would be valuable under wetter conditions (to promote vigour and early growth, provided fertiliser wasn't applied under waterlogged conditions) while a lower rate of early nitrogen would reduce upfront costs when dry sowing, or where the break is late (with later applications subject to seasonal forecasts).

KEY FINDINGS:

INTERACTIONS BETWEEN FUNGICIDE APPLICATION AND IN-CROP NITROGEN TIMING FOR THE CONTROL OF YLS IN EARLY-SOWN WHEAT

Small-plot field trials were carried out at Yarrawonga during 2013, Coreen during 2014, Corowa during 2015 and Coreen during 2016, to assess the interaction between fungicide applications and timing of nitrogen application on yellow leaf spot (YLS) disease in susceptible wheat cultivars sown into wheat stubble. The most severe YLS infection was observed during 2016.

During **2013**, fungicide applied at third node (GS33) gave better YLS control and green leaf retention than at tillering (GS23), however the improved control with a single-spray timing did not lead to a significant yield increase (Table 19). There was a yield advantage when both spray timings were sequenced in a two-spray program.

During **2014**, positive yield results were obtained from control, despite YLS not exceeding 10% on the top three leaves. There was a yield response from two fungicide applications made at late tillering (GS25) and second node (GS32), corresponding to better disease control and increased crop canopy greenness. Although single fungicide timings produced little evidence of YLS control, significant yield increases were measured. During 2014, applying nitrogen at either tillering (GS22) or first node (GS30) did not impact disease levels, yield or quality.

During **2015**, applying fungicide at tillering (GS22) or first node (GS31) provided less than 50% control at most assessments. Applying fungicide at third node (GS33) was more effective at preventing YLS infection on the top three leaves than a tillering application and generated a yield increase over the untreated control. Applying fungicide at tillering and third node stage gave no advantage over a single application at GS33. There was no effect on yield from nitrogen applied at GS22 or GS31.

During **2016**, fungicides applied at either first node (GS31) or third node (GS33) achieved control of between 25–50%. There was no significant yield response to fungicide application, possibly due to the effects of crop waterlogging. There were no differences due to fungicide product. Delaying the main nitrogen dose from GS31 until GS33 significantly decreased yield during 2016.

TABLE 19. Average grain yield for nitrogen application, fungicide timing to control YLS, and product treatments at Coreen, Corowa and Yarrawonga, 2013–16

Treatment	Grain yield (t/ha)			
	Yarrawonga, Victoria	Coreen, NSW	Corowa, NSW	Yarrawonga, Victoria
	2013	2014	2015	2016*
Target nitrogen timing				
GS22		2.71[a]	3.81[a]	3.78[a]
GS31		2.70[a]	3.64[a]	3.26[b]
LSD		0.04	0.19	0.18
Target fungicide timing				
Untreated control	1.79[b]	2.58[c]	3.57[b]	3.42[a]
GS23–25	1.88[b]	2.72[b]	3.62[b]	3.52[a]
GS32–33	1.89[b]	2.71[b]	3.97[a]	3.55[a]
GS23–25 and GS32–33	2.06[a]	2.81[a]	3.74[ab]	3.59[a]
LSD	0.15	0.07	0.26	0.25
Product				
Prosaro	1.96[a]	2.73[a]	3.65[a]	3.54[a]
Tilt	1.85[a]	2.67[b]	3.8[a]	3.5[a]
LSD	0.77	0.03	0.19	0.18
Mean	**1.91**	**2.70**	**3.73**	**3.52**

* As a result of the wet conditions experienced during winter 2016, nitrogen and fungicide applications targeted for GS22–25 and GS32–33 were delayed until GS31 and GS33 respectively

Figures followed by different letters are regarded as statistically significant

Four years of work has shown that using either Prosaro tebuconazole/prothioconazole) or Tilt (propiconazole) rarely exceeded 50% disease control, being more typically in the range 25–50%. Despite this, there were small but consistent positive yield effects, with the maximum response to fungicide being 0.25t/ha during 2013, 0.21h/ha during 2014, 0.4t/ha during 2015 and 0.17t/ha during 2016 in response to two applications of fungicide and later spray timings during stem elongation (GS30) or third node (GS33).

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

KEY POINTS

1. Varietal susceptibility, disease pressure, environmental factors and fungicide choice play a role in determining the value of fungicide application for YLS control.
2. A single fungicide application for YLS at late tillering was of limited value, with greater control and yield benefit from a later fungicide application
3. During 2013 and 2014 a two-spray fungicide program achieved the best YLS control.
4. As a general rule, the use of fungicides for YLS early in the season may not be economic, however during a wet spring it may be beneficial to protect the top leaves from disease.
5. Sowing resistant varieties and employing rotations that include break crops, such as canola and pulses, will help control YLS.

Key findings from the small-plot field trials

The small-plot field trials resulted in the following key findings for the 2014–16 cropping seasons:

KEY FINDINGS

1. Early-sown first wheat on row spacings wider than 30cm incurred a yield penalty, with varietal differences measured in yield across all row spacings.
2. Applying PGR had no impact on yield across the three years of the trial.
3. Applying nitrogen increased yield potential, however the timing of the nitrogen application (split, single dose etc) did not influence yield.
4. While applying either Prosaro (tebuconazole/prothioconazole) or Tilt (propiconazole) typically provided YLS disease control in the range 25–50 per cent in a susceptible wheat-on-wheat situation, small but consistent positive yield effects were common across the four years of trials. These yield increases were associated with two applications of fungicide or later spray timings.

Does stubble retention influence in-canopy temperature and frost risk? Key findings from the *Stubble project*

BACKGROUND AND AIM

There is a perception among growers that retained stubble decreases in-canopy temperatures and increases the risk and severity of frost.

To date, most frost-related research has been done in Western Australia in regions of lower yields and stubble loads than those experienced across the Riverine Plains. The *Stubble project* frost research component therefore aimed to understand the impact of stubble retention on in-canopy temperatures and associated risk of frost in cropping environments with high yields and high stubble loads.

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

METHOD

Three large stubble management field trials (at Corowa and Yarrawonga, NSW and Dookie, Victoria) were chosen for this work. Their large plot sizes (approximately 15m wide x 40m long) ensured a minimal 'edge effect'. All plots were sown into wheat stubble and most were located on flat, relatively uniform and frost-prone positions in the landscape.

Tinytag battery-operated sensors (loggers), which recorded temperature every 15 minutes, were located within the canopy at each site. The sensors were not shaded from direct sunlight and measured higher temperatures than a weather station (where the temperature sensor is shaded). While these loggers provide accurate measurements of minimum temperatures, they cannot be used to accurately show maximum daily temperatures.

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

Tinytag temperature loggers installed in the NTSR — short stubble treatment at Dookie, 2015. The 50mm and 300mm loggers are attached to the PVC tube, with the pink flagging tape marking the logger buried 50mm under the soil surface.

In-crop monitoring of canopy temperatures started during June 2015 and continued throughout 2016 and 2017.

RESULTS

A summary of results from each site is reported here. Full details of each year are reported in the annual trial summaries provided in *Research for the Riverine Plains*.

For this publication, the key questions addressed are:

1. Did plants get colder under retained stubbles?
2. Did stubble retention increase risk of frost damage?

> **Frost risk is determined by the duration and severity of frost events and includes the amount of time the crop experiences sub-zero temperatures as well as how cold it actually gets. The Tinytag sensors were used to record both the duration and severity of the frost events at the site across the different treatments.**

Tinytag measurements across treatments and years are described in Table 20, Table 23 and Table 26.

COROWA/COREEN

TABLE 20. Temperature monitoring at Coreen from 2015–17

	2015	2016	2017
	Corowa	Coreen	Coreen
Logger installation dates	17 July – 18 November	27 May – 21 November	16 May – 27 November
Logger heights	• 300mm height, moved to 600mm on 6 September	• 50mm height • 300mm height, moved to 600mm on 25 August	• 50mm height • 300mm height
Treatments monitored	• NTSR* • Cultivated • Burnt	• NTSR • Cultivated • Burnt	• NTSR • Cultivated • Burnt

* No-till retained stubble

DID PLANTS GET COLDER UNDER RETAINED STUBBLES AT COROWA/COREEN?

During **2015** the Tinytag data showed the no-till stubble retained (NTSR) treatment was exposed to a significantly longer period below zero, and each degree below, compared with the burnt and cultivated treatments, which largely held similar temperatures (Figure 21).

In contrast, the **2016** season experienced mild nights, high cloud cover and high rainfall. Despite the low frost risk under these conditions, a series of frost events was recorded during the first two weeks of temperature monitoring. These frosts occurred as three distinct sub-zero temperature events on 29, 30 and 31 May, when the wheat was at the seedling and early tillering growth stages. Frost events at these early growth stages serve to 'harden' the plant, increasing its ability to withstand subsequent frost events.

During 2016 there were no differences in the duration or intensity of cold between stubble treatments at Coreen.

The **2017** season was significantly colder than the 2015 and 2016 seasons, with about 500 hours spent below 0ºC. However, even under such cold conditions there were no differences in the amount of time each stubble treatment spent below each threshold temperature.

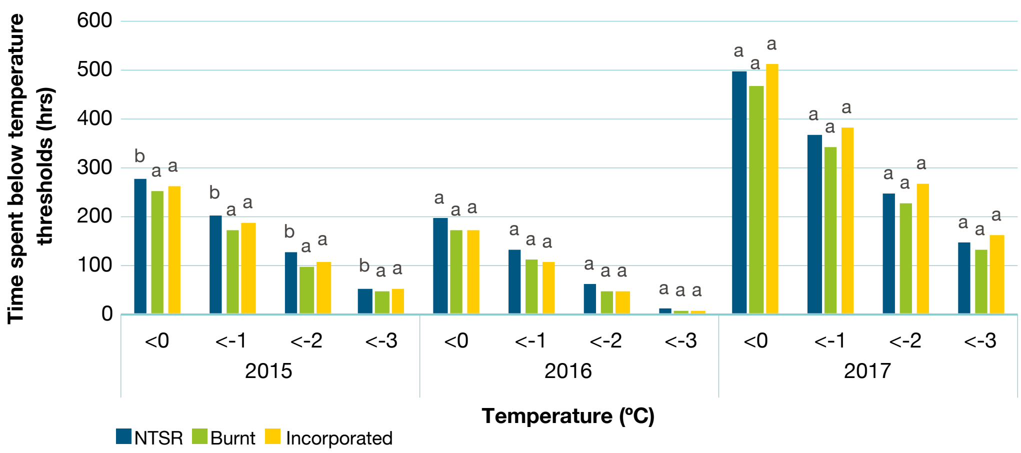


FIGURE 21. The effect of stubble treatment on the duration of in-canopy temperatures at zero and each degree below^, 2015–17 at Corowa*

^Data not presented for temperatures <-3°C

*Tinytag temperature measurements taken from a height of 300mm

Time spent below temperature threshold bars for the same temperature and year with different letters are regarded as statistically different

DID STUBBLE RETENTION INCREASE THE RISK OF FROST DAMAGE AT COROWA/COREEN?

While the monitoring data provides information about how cold the plants got, the other aspect of this work was to understand the degree to which the plants experienced frost damage through frost-induced sterility.

During **2015** there were no frosts experienced during flowering, however, there were extreme heat events during October 2015, which stressed plants. While there were differences in the minimum temperatures experienced within each stubble management treatment during the season, these differences were not of physiological importance.

Frost did not damage grain during the **2016** season, rather, low light conditions caused by high cloud cover and waterlogging were the key plant stressors.

The **2017** season was extremely cold, with regular and significant frost events. As seen in Figure 22, the temperature frequently fell below 0ºC through winter and spring, and during the flowering period. However, during the coldest frost event of the season on July 1 (minimum temperature of -7.96ºC) there was no temperature difference between treatments (Figure 23). It would be expected that if temperature differences existed between the different stubble treatments, then such a cold year would provide the evidence to support this, however this was not the case.

Although there was no difference in minimum temperature recorded between stubble treatments during 2017, there were differences in the level of frost damage observed between treatments. The proportion

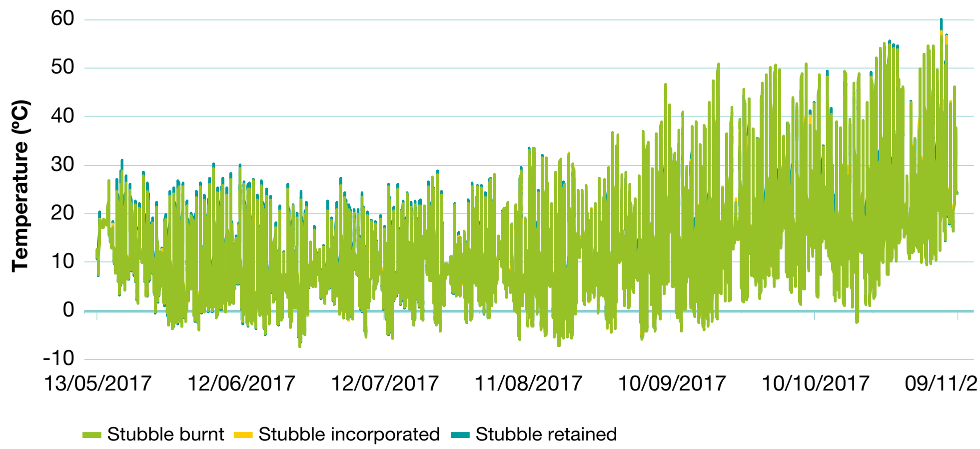


FIGURE 22. Averaged in-canopy temperatures measured by the 300mm loggers from 16 May – 27 November 2017 at Coreen

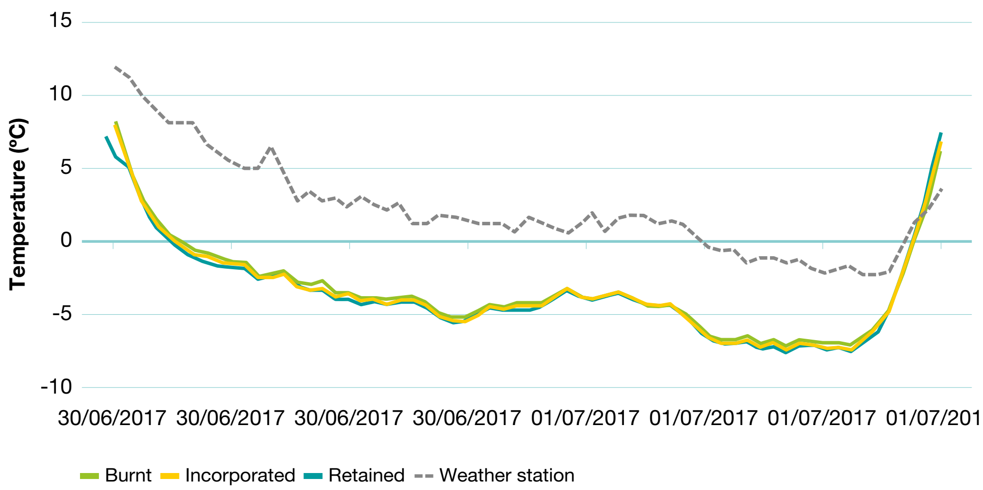


FIGURE 23. Temperatures recorded by loggers at 300mm height above the soil during the coldest two-day period of the 2017 season at Coreen

of damage was determined by collecting wheat head samples before harvest and assessing individual florets within heads collected from each treatment. Based on a sub-sample of 90 heads per plot (360 heads per treatment), the burnt treatment had more frosted florets than the cultivated treatment, which in turn had more frosted florets than the NTSR treatment (Table 21). This indicates actual temperature is not the only driver for differences in frost damage between treatments.

HOW COLD DID IT GET AT COREEN?

The Tinytag data highlighted the differences between the minimum temperatures reached within the crop canopy, those measured by the weather stations installed adjacent to the plots and those measuring the temperature at a height above ground level of 1.2m (Table 22).

TABLE 21. Frost scores at harvest (GS99) from the different stubble management treatments at Coreen, 2017

Treatment	Frost score (%) *
Stubble retained	3.4[a]
Stubble incorporated	5.4[b]
Stubble burnt	7.9[c]
Mean	**5.6**
LSD	1.4

* Frost score calculated as: number of frosted florets per head/total florets per head x 100.

Figures followed by different numbers are regarded as statistically significant.

KEY POINTS: COREEN

1. From three seasons of monitoring, there was only one year of data (2015) in which plants experienced colder conditions under retained stubble compared with cultivated or burnt treatments. Despite the stubble-retained treatments being colder during 2015, there was no difference in frost damage between treatments.
2. While extremely cold conditions were measured at Coreen, results showed it is not just the duration and intensity of cold experienced, nor the minimum temperature reached that leads to frost damage, rather, crops at a frost-susceptible growth stage when a frost event occurs are most at risk of damage.
3. The increased level of frost damage measured in the burnt treatment at Coreen during 2017 is likely to reflect the different time of flowering under the burnt treatment compared with the flowering date of the stubble-retained treatment.

Nick Poole and Michael Straight, FAR Australia, discussing frost damage in wheat.

TABLE 22. Coldest temperatures recorded at Coreen, averaged for each treatment and compared with adjacent weather station data, 2015–17

Date (time)	4 August 2015 (5:30am)	26 August 2016 (7:30am)	1 July 2017 (7am)
	Temperature °C		
50mm height:			
• NTSR	Not measured	-0.92	-6.50
• Cultivated	Not measured	-1.64	-7.72
• Burnt	Not measured	-1.34	-7.18
300mm height:			
• NTSR	-6.53	-4.02	-7.47
• Cultivated	-6.20	-3.63	-7.34
• Burnt	-6.02	-3.73	-7.08
Weather station (1.2m)	0.31	4.75	-1.81
Total hours below 0°C[#]	270 hours	200 hours	500 hours

[#] Measured at 300mm height

YARRAWONGA

TABLE 23. Temperature monitoring at Yarrawonga from 2015–17

	2015	2016	2017
Logger installation dates	17 July – 18 November	27 May – 7 December	16 May – 24 November
Logger heights	• 300mm height, moved to 600mm on 9 September	• 50mm height • 300mm height, moved to 600mm on 25 August	• 50mm height • 300mm height
Treatments monitored	• NTSR — long • NTSR — short • Burnt • Cultivated	• NTSR — long • NTSR — short • Burnt • Cultivated	• NTSR — long • NTSR — short • Burnt • Cultivated

* No-till stubble retention

DID PLANTS GET COLDER UNDER RETAINED STUBBLES AT YARRAWONGA?

During **2015**, the Yarrawonga site recorded a similar range of temperatures to the Coreen site. Data from the Yarrawonga Tinytag loggers showed the burnt stubble treatment spent less time below each temperature threshold compared with the other treatments, while the incorporated and NTSR — short stubble treatments recorded similar temperatures (Figure 24). The NTSR — long stubble treatment only showed an increased time below each temperature threshold compared with the incorporated and NTSR — short stubble treatments at the 0, -1 and -6ºC temperature thresholds, while there was no difference within the other temperature ranges.

The temperature threshold results for **2016** showed no difference between the NTSR — short and NTSR — long stubble treatments in terms of the amount of time spent below 0°C. This contrasts with 2015, when the NTSR — long stubble treatment spent more time below 0°C than the NTSR — short stubble treatment. During 2016, temperatures recorded during frost events from 28–31 May showed colder temperatures in the NTSR — short stubble treatment than in the NTSR — long stubble treatment. This is likely due to the presence of a layer of chopped straw on the ground, created when the tall stubble was cut to create the short stubble treatments, which may have had an insulating effect and stopped warm air from the soil moving into the canopy overnight.

The NTSR — long stubble treatment was colder than the burnt treatment at all temperature thresholds, except for the -3ºC threshold. The 2016 season was milder than the

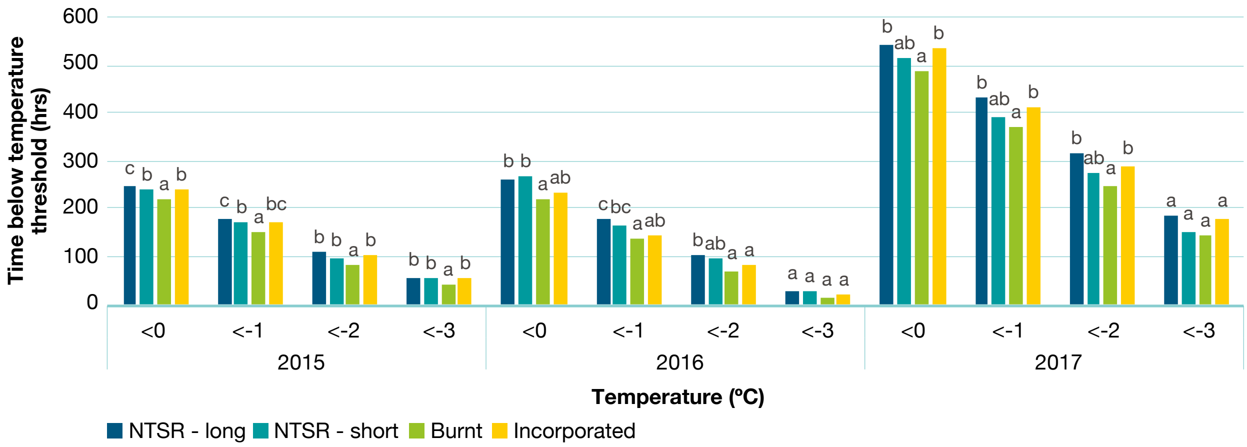


FIGURE 24. T The effect of stubble treatment on the duration on in-canopy temperatures at zero and each degree below^, 2015–17 at Yarrawonga*

^ Data not presented for temperatures <-3°C

* Tinytag temperature measurements taken from a height of 300mm.

Time spent below temperature threshold bars for the same temperature and year with different letters are regarded as statistically different

2015 season, with less time overall spent below -4ºC (the burnt treatment only spent 0.25 hours below -4ºC, while the NTSR – treatment was below -4ºC for 3.56 hours).

Differences in canopy temperatures between treatments were also observed at Yarrawonga during **2017**. The time spent below the 0, -1, -2 and -4ºC thresholds was significantly less in the burnt stubble treatment compared with the incorporated and NTSR — long stubble treatments, while the NTSR — short stubble treatment was similar to all treatments. However, the actual difference in the number of hours at each threshold was relatively small considering the crop spent about 500 hours below 0ºC during the season, with the stubble burnt and NTSR — long stubble treatment spending 56 hours and 86 hours respectively below -4ºC.

DID STUBBLE RETENTION INCREASE RISK OF FROST DAMAGE AT YARRAWONGA?

As for Coreen, no frosts occurred at the Yarrawonga site during the **2015** flowering period. Instead, the heat events, which occurred during October 2015, contributed to plant stress during this period.

The **2016** season was characterised by high in-season rainfall (decile 10 at Yarrawonga), with associated high cloud cover and mild conditions. The cloud cover had an insulating effect, which prevented temperatures from dropping overnight and reduced overall frost risk.

While the NTSR — long stubble treatment significantly impacted in-canopy temperature during both 2015 and 2016, there did not appear to be any physiological effect due to the increased cold, because the frost events did not occur during flowering.

There was a high frequency of frost events during flowering in 2017. Assessment of the number of frosted florets in each head showed that while all treatments had frost damage, there was less frost damage in the burnt and cultivated treatments than both NTSR — long stubble and NTSR — short stubble treatments (Table 24). Given the relatively small difference in temperatures observed between the stubble treatments (Figure 25), the difference in frost damage was not likely due to the temperature and could instead have been caused by differences in the timing of flowering, which may in turn have been influenced by stubble management strategy.

HOW COLD DID IT GET AT YARRAWONGA?

The coldest temperatures measured during each year of the trial at the Yarrawonga site are presented in Table 25.

TABLE 24. Frost scores at harvest (GS99) from the different stubble management treatments at Yarrawonga, 2017

Treatment	Frost score (%) *
Stubble burnt	11.1[b]
Stubble incorporated	12.5[b]
NTSR — short stubble	17.2[a]
NTSR — long stubble	15.4[a]
Mean	**14.1**
LSD	2.78

* Frost score calculated as: number of frosted florets per head/total florets per head x 100.

Figures followed by different numbers are regarded as statistically significant

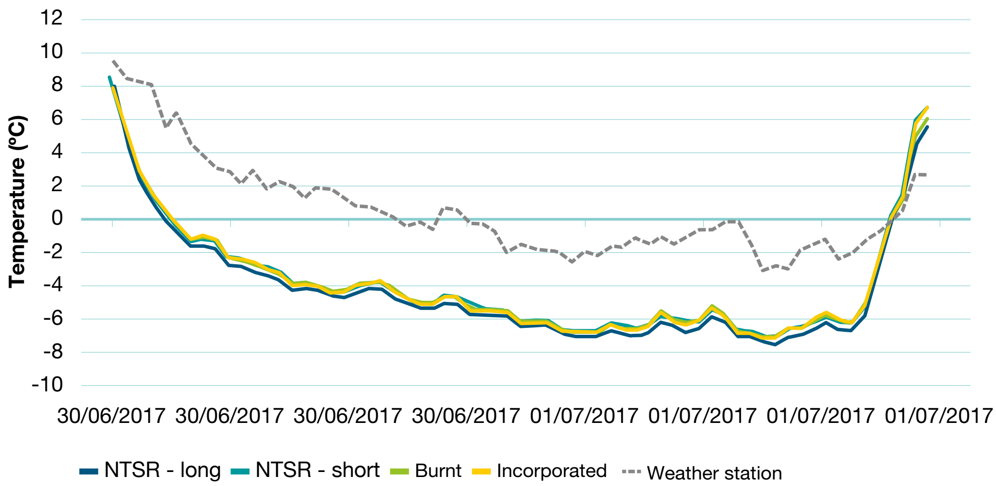


FIGURE 25. Temperature recorded by loggers at 300mm during the coldest period of the 2017 season at Yarrawonga

TABLE 25. Coldest temperatures recorded at Yarrawonga, averaged for each treatment and compared with the adjacent weather station data 2015–17

Date (time)	4 August (2015 7:30am)	27 August 2016 (6:45am)	1 July 2017 (7am)
	Temperature °C		
50mm height:			
• NTSR — long		-0.46	-7.03
• NTSR — short		-0.52	-7.47
• Cultivated		-0.18	-8.07
• Burnt		-0.22	-7.69
300mm height:			
• NTSR — long	-6.42	-3.81	-7.51
• NTSR — short	-6.27	-3.84	-7.13
• Cultivated	-6.34	-3.99	-7.12
• Burnt	-5.93	-3.76	-6.96
Weather station (1.2m)	-1.5	-0.06	-1.25
Total hours below 0 °C	250	270	550

KEY POINTS: YARRAWONGA

1. Differences in canopy temperatures between stubble treatments were measured across all three seasons at Yarrawonga. While these differences were statistically significant, the differences were small and were unrelated to differences in measurable frost damage. If stubble treatment was a large driver of in-canopy temperature this should have been evident during 2017, but it was not. This suggests that during particularly cold winters, stubble management has little effect on in-canopy temperature.
2. The data suggests that in-canopy temperature differences during flowering did not drive the difference in frost damage between the burnt and NTSR — long stubble and NTSR — short stubble crops during 2017.

The Yarrawonga large-plot site, July 2017, showing the Tinytag loggers (left foreground) and the weather station (back left).

DOOKIE

TABLE 26. Temperature monitoring applied at Dookie from 2015–17

	2015	2016	2017
Logger installation dates	24 June – 24 November	8 June – 1 December	9 May – 10 November
Logger heights	• Buried 50mm depth • 50mm height • 300mm height, moved to 600mm on 9 September	• Buried 50mm depth • 50mm height • 300mm height, moved to 600mm on 25 August	• Buried 50mm depth • 50mm height • 300mm height, moved to 600mm on 9 September
Treatments monitored	• NTSR — long • NTSR — short • Burnt • Cultivated	• NTSR — long • NTSR — short • Burnt • Cultivated	• NTSR — long • NTSR — short • Burnt • Cultivated

DID PLANTS GET COLDER UNDER RETAINED STUBBLES AT DOOKIE?

During **2015**, the burnt and incorporated treatments spent a similar amount of time below each temperature threshold, while the NTSR — long stubble treatment generally spent more time at each minimum temperature than the other treatments (Figure 26). The NTSR — short stubble treatment was similar to the other treatments, except for the -5 and -6ºC temperature thresholds, when it was higher than the burnt treatment.

The impact of temperature logger position was evident at Dookie (Figure 27). During early 2015 the 50mm loggers recorded comparable temperatures to the 300mm loggers, but as plants reached 50mm, the insulating effect of the canopy meant the 50mm loggers didn't measure the extremes of cold or heat recorded by the 300mm loggers. The buried loggers showed even less temperature variation throughout the season.

Consistent with the trends observed during 2015, the burnt treatments spent less time below each temperature threshold during **2016** compared with the NTSR — long stubble treatment in the 0, -2 and -4ºC thresholds. The NTSR — short stubble treatment did not differ significantly to the burnt treatment for any threshold, other than the -2ºC threshold.

The **2017** Dookie trial was situated on the side of a hill, with replicated blocks positioned at increasing elevation. This change in elevation across replicates significantly impacted the in-canopy temperature measurements and meant the site did not experience the same number, or intensity, of frost as a flat paddock. The temperature range measured across the different replicates of each

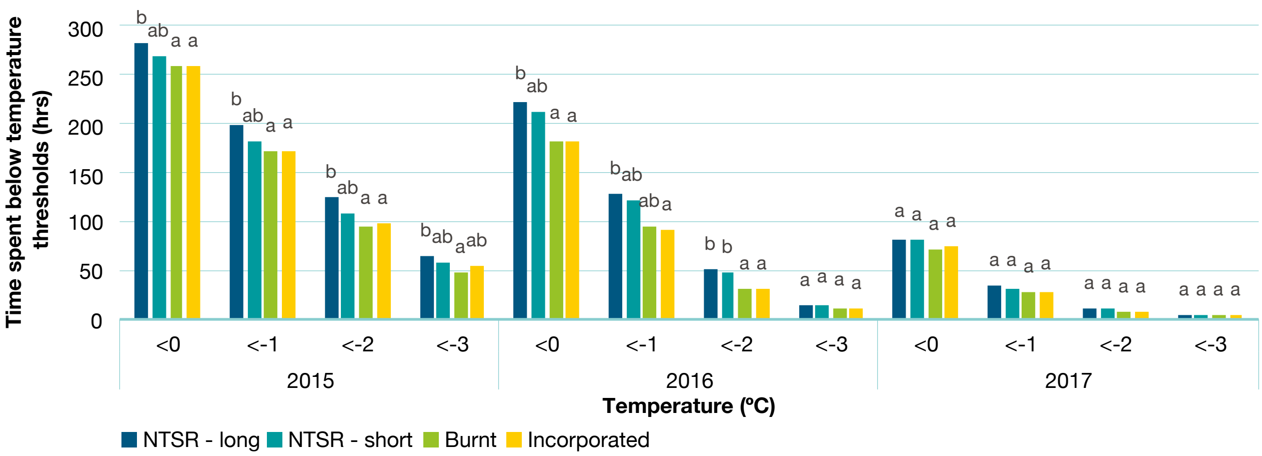


FIGURE 26. T The effect of stubble treatment on the duration of in-canopy temperatures at zero and each degree below^, 2015–17 at Dookie*

^ Data not presented for temperatures <-3°C

* Tinytag temperature measurements taken from a height of 300mm

Time spent below temperature threshold bars for the same temperature and year with different letters are regarded as statistically different

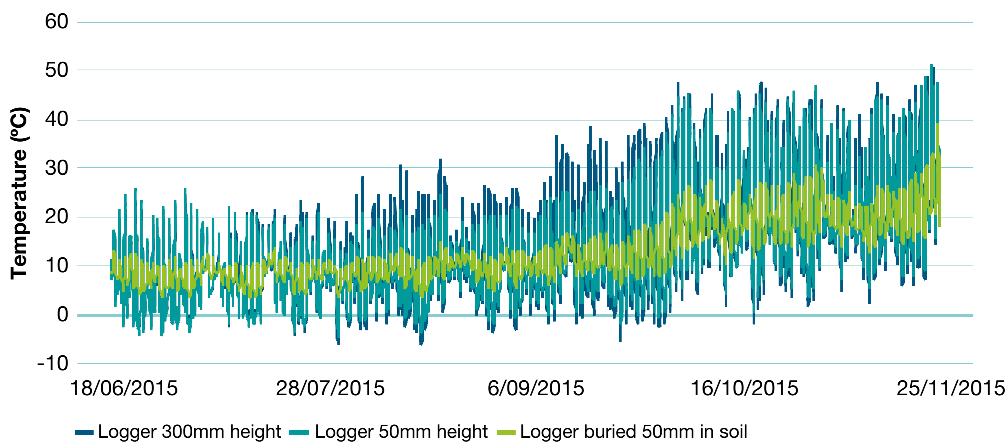


FIGURE 27. The impact of temperature logger position at the NTSR — short stubble treatments at Dookie, 2015

treatment, and the resulting high variability, meant there were no significant differences between treatments.

DID STUBBLE RETENTION INCREASE RISK OF FROST DAMAGE AT DOOKIE?

As with the Coreen and Yarrawonga sites, there were no frost events experienced during flowering at Dookie during 2015. Plants were instead subjected to heat stress during October **2015**.

The mild conditions experienced during **2016**, and the lack of frosts during flowering, meant no frost damage occurred in any treatment during 2016.

During **2017** the Dookie site only recorded about 80 hours below 0ºC due to its high and variable altitude compared with around 500 hours below 0ºC at the Coreen and Yarrawonga sites. Potential frost-related damage to the canola seed pods was not assessed as canola will continue to flower to compensate for flowering stress, with the variation in altitude also meaning any damage could not be clearly attributed to stubble management.

HOW COLD DID IT GET AT DOOKIE?

The Dookie site experienced cold conditions in each year of measurement, with the coldest conditions recorded during 2015 (Table 27). Temperature logger position impacted on measured temperature, with the coldest temperatures always measured in the loggers placed at 300mm height above the soil. The hill-side location of the 2017 Dookie stubble trial meant elevation had more bearing on the temperature than stubble treatment, which resulted in high variability within stubble treatments. Temperature measurements at Dookie were also higher than at Corowa and Coreen during 2017 due to increased elevation.

KEY POINTS: DOOKIE

1. While differences in in-canopy temperature were measured between treatments at the Dookie site, these differences were small and unrelated to differences in measurable frost damage. This is consistent with data from Coreen and Yarrawonga.
2. The lack of measurable frost damage in canola at Dookie during 2017, and the high within-trial variance, meant there were no clear relationships between in-crop temperature and frost damage.

Tinytag loggers and weather station at the Dookie site, July 2017. Note, the hill-side location meant that elevation had more bearing on temperature than stubble treatment.

TABLE 27. Coldest temperatures recorded at Dookie, averaged for each treatment, compared with the adjacent weather station data, 2015–17

Date (time)	4 August, 2015 (8am)	24 July, 2016 (7:15am)	1 July, 2017 (7am)
	Temperature °C		
Buried 50mm depth:			
• NTSR — long	3.42	5.80	6.07
• NTSR — short	3.07	6.67	4.83
• Cultivated	3.28	6.18	4.98
• Burnt	2.71	5.62	4.59
50mm height:			
• NTSR — long	-4.61	-3.31	-1.17
• NTSR — short	-5.17	-4.17	-1.42
• Cultivated	-5.48	-2.98	-2.09
• Burnt	-4.17	-3.19	-1.43
300mm height:			
• NTSR — long	-6.97	-4.35	-3.60
• NTSR — short	-6.99	-4.25	-3.34
• Cultivated	-6.52	-3.72	-3.30
• Burnt	-6.41	-3.85	-3.46
Weather station (1.2m)	-0.56	1.44	3.31
Total hours below 0 °C*	275	224	82

* Measured in the NTSR — long treatment

DID STUBBLE RETENTION INCREASE RISK OF FROST DAMAGE IN THE RIVERINE PLAINS FROM 2015–17?

In some years there were statistically significant increases in the number of hours spent under different temperature thresholds in the NTSR — long stubble compared to the burnt treatments. However, the differences were relatively small and inconsistent. Moreover, these differences were not large enough to reduce the actual number of frost events experienced by the different treatments.

For example, the coldest temperature measured at Coreen during 2017 was -7.47ºC at 7am under NTSR, while the burnt treatment recorded a minimum temperature of -7.08ºC — a difference of 0.39ºC. For the same event, the Yarrawonga loggers recorded a minimum of -7.51ºC in the NTSR —long treatment and -6.96ºC in the burnt treatment — a difference of 0.55ºC. Although there were small differences in the total duration of cold experienced across treatments, these were not large enough to impact the overall presence or absence of frost damage. In short, if a plant was to be damaged by frost (i.e. stem or flowering frost), the damage would occur regardless of the stubble treatment imposed because the magnitude of frost damage would be similar across treatments (especially in the -7.08 – 7.47ºC range).

Stubble project results indicate plant development and timing of flowering can be manipulated through stubble height.

At Coreen during 2017 there was no difference in the overall number of frost events that occurred between the stubble burnt and NTSR treatments, and only minimal decreases in temperature under the NTSR treatment at selected events.

The key impact of stubble management on frost risk came down to the timing of the actual frost event. The physiological development of the plants in the burnt treatment advanced more rapidly throughout early winter than the plants under the tall stubble treatment, due to differences in light availability and the shading effect of tall stubble combined with small increases in the accumulation of thermal time. This meant plants in the burnt treatment flowered before the plants in retained stubble. Given this delay in development, differences in frost damage between treatments can be attributed to the timing of flowering in relation to the frost event; if flowering and a frost event happened to coincide, then frost damage would occur regardless of the treatment imposed. This explains why the burnt treatment experienced more frost damage at Coreen, while the NTSR — long plants experienced greater frost damage at Yarrawonga during 2017 (Table 21 and Table 24).

KEY POINT

1. The *Stubble project* results indicate plant development and timing of flowering can be manipulated through stubble height. A difference in stubble height of even 5–10cm across an otherwise even paddock can change the flowering date by a few days, potentially reducing the risk of the whole paddock being decimated by a single significant frost event.

TIP: Short stubble (15cm height) could offer an alternative to management practices such as full stubble retention, burning or incorporating stubble in terms of managing frost risk. Plant growth and yield measurements support the theory that short stubble seems to provide all the benefits of full stubble retention, while being easier to manage and less likely to cause issues at sowing.

HOW DO THESE RESULTS COMPARE WITH FROST RESEARCH CONDUCTED IN WA, WHERE STUBBLE HAS BEEN SHOWN TO BE A KEY DRIVER OF FROST RISK?

Winters across the Riverine Plains region can result in intense and prolonged periods below 0ºC, with winter temperatures commonly recorded down to around -7ºC (an in-canopy minimum temperature of -10ºC was recorded at Yarrawonga during 2018). This means plants become 'hardened' to the cold while in a vegetative state. Moreover, the daytime temperature during winter across the Riverine Plains may not rise above 10ºC, with temperature patterns generally involving a gradual overnight decrease to a minimum (reached about 7am), which may be below 0ºC, before a gradual increase to the maximum temperature (reached about 2pm). This gradual temperature fluctuation reduces plant stress, allowing it to become acclimatised to the conditions and means significant damage to the plant usually only occurs when these frost events coincide with key phenological growth stage. For cereals, the most susceptible growth stages occur when the growing point is exposed within stem (risk of stem frost), or at flowering.

In contrast, winters across WA can involve maximum temperatures higher than 20ºC and minimums of around 0ºC. The predominantly sandy soils in WA can store day-time heat and then release the heat back into the crop canopy overnight. The heat exchange from the soil buffers the rapid change in ambient temperature and acts to reduce the shock to the plant. Under such conditions, stubble on the soil surface has an insulating effect, reducing the soil's capacity to release stored heat back into the canopy at night. This means crops under retained stubble are exposed to a greater temperature change shock and exposed to significantly colder temperatures at night, placing them at a greater frost risk.

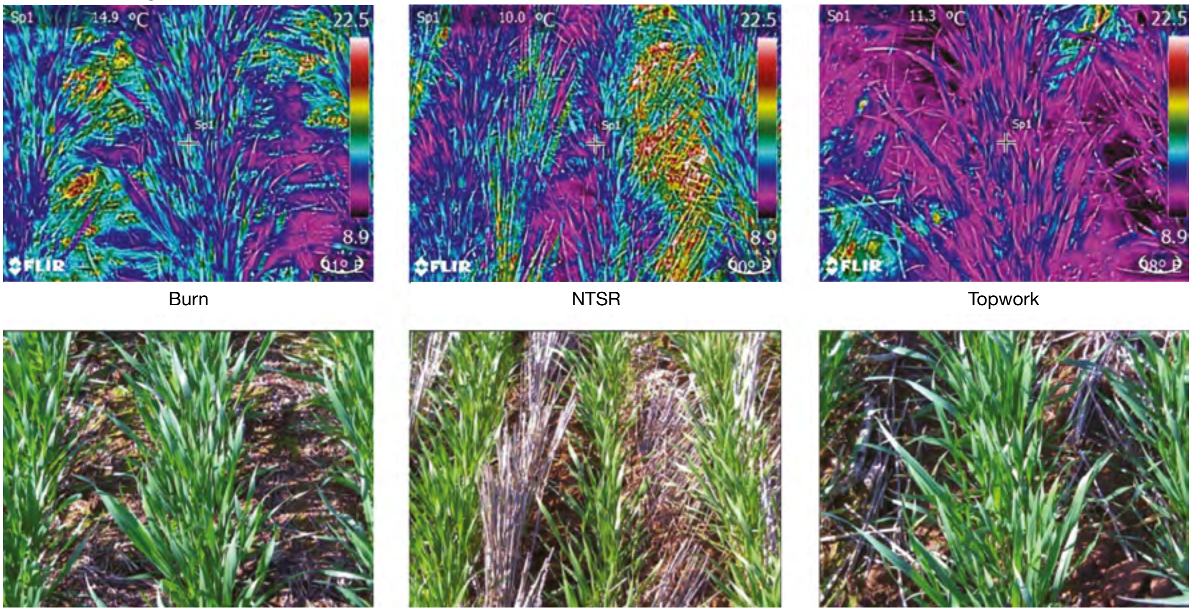
KEY POINTS

1. Climatic and soil conditions across the Riverine Plains differ from those of WA, where the bulk of frost research has previously been carried out.
2. For the Riverine Plains region, the method used to manage stubble has less impact on frost risk, in terms of the minimum temperature reached.
3. Stubble management affects the rate of crop development, with delays in development in stubble-retained systems caused by shading and light interception, which may lead to a delay in the time of flowering compared with burnt systems.
4. The level of damage caused by an individual frost event depends on the timing of the frost event and whether it coincides with a highly susceptible growth stage for the plant. Burning all stubble will not prevent frost damage to the crop.

TIP: Consider stubble management as just one management tool to mitigate frost risk, in partnership with sowing dates and variety selection.

THERMAL IMAGING

Corowa 28 July 2015



Dookie 30 July 2015

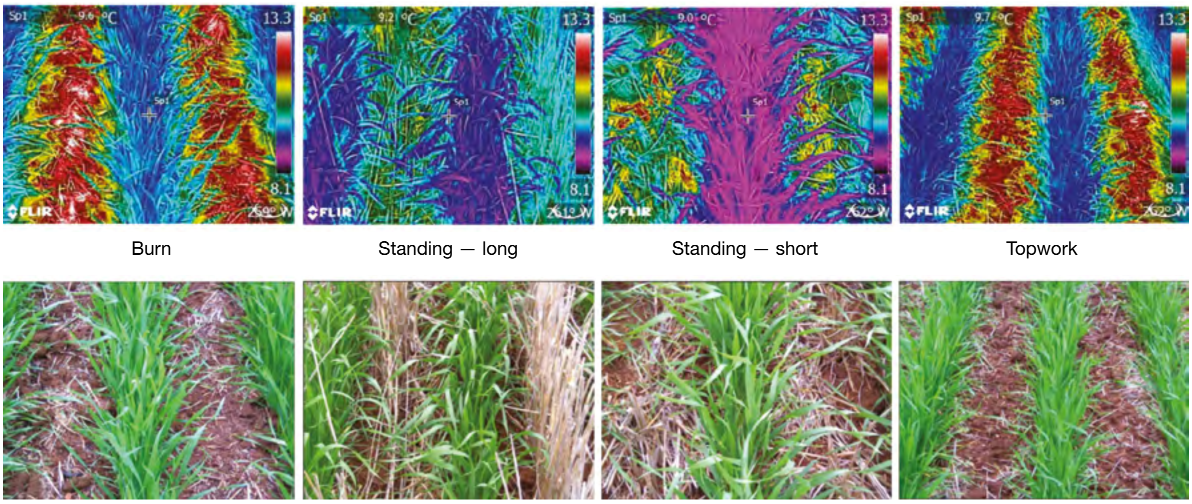


FIGURE 28. Images captured with a thermal imaging camera during 2015 clearly shows how the presence or absence of stubble changes the temperature of the soil and plant material

Note: The difference in surface temperatures did not impact the in-canopy temperature at the time of measurement

The colour scale on the right hand side of each thermal image indicates the temperature range

Precision agriculture — within-paddock variability and variable rate nitrogen

BACKGROUND

Grain growers have readily adopted precision agriculture (PA) technologies, such as GPS-guidance, controlled-traffic and yield mapping. As a result, they are now the custodians of large datasets, including EM38 surveys (EM), yield maps, normalised difference vegetative index (NDVI) maps and soil analytical results. The oft-heard question from early adopters of PA technology is "I have filing cabinets and hard-drives full of data, but what can I do with it?".

The research described here evolved from discussions with Riverine Plains region growers to understand if their existing datasets could be used to create something greater. This search involved analysing the existing datasets to determine if they could be used to predict in-paddock variability, and in particular predict variation in plant-available water (PAW) across a paddock. If shown to be successful, this research could then be applied to create meaningful nutrient management zones (especially relating to nitrogen).

To better understand the potential, Riverine Plains Inc, through the Grains Research and Development Corporation (GRDC) investment in the PA component of the *Stubble project*, partnered with several organisations to explore the value of this approach. Unique to this aspect of the project was the collegial approach, where all parties appreciated the significance of the work and contributed considerable in-kind support to see the results realised. Riverine Plains Inc, as project manager, identified the required inputs (through grower consultation), managed the data and drove the interpretation of results.

All the field work for this component was completed during 2017. While predicting in-paddock variability by interrogating existing datasets is still being developed, the various datasets collected through this work tell an interesting story around in-paddock variability and how everything is inter-connected.

While a large volume of data was collated during this part of the *Stubble project*, only a snapshot is presented here.

METHOD

Four paddocks were selected at Howlong (canola), Rutherglen (wheat), Telford (wheat) and Yabba South (wheat). Existing EM38 maps were used to generate high, medium, and low EM zones for each paddock. A weather station was located in each paddock, with 1.4m depth soil moisture probes installed in the 'high' and 'low' zones to determine the comparative depth and degree of moisture extraction by plants.

Incremental soil sampling to 0.6m was carried out for spatial soil chemistry, while intact cores were taken for PAW measurements. Incremental deep soil nitrogen (DSN) and dry matter (DM) sampling was carried out during the growing season and post-harvest. Subsamples from intact cores were used to measure PAW by water extraction, with subsamples processed through mid-infrared (MIR) spectral scanning and regression models to predict PAW directly from the spectra. This means the PAW of soils was tested directly and also predicted by MIR, which may provide a cost-effective alternative in the future.

Two sets of NDVI satellite images were taken across each paddock during 2017 to understand variability in plant 'greenness', which may be correlated to nitrogen supply. Where possible, yield maps were accessed from previous years, with yield map data also collected during 2017. All datasets were then collated, aligned and interpolated in order to layer the data in a web-based mapping tool, and so interrogate and determine any relationships. This analysis is still in-train, subject to ongoing funding.

The dates at which the project activities were carried out are listed in Table 28.

TABLE 28. Dates of activities at the Howlong, Rutherglen and Yabba South trial paddocks in 2017

Activity	Date
Soil chemistry sampling	16/5/17
Intact core sampling for PAW	7 and 8/6/17
End of tillering soil nitrogen, plant number, tiller number, DM cuts	29 and 30/8/17
Satellite NDVI	31/8/17
Satellite NDVI	15/10/17
Flowering DSN and DM cuts	24/10/17
Howlong harvest	7/12/17
Rutherglen harvest	15/12/17
Yabba South harvest	18/12/17

RESULTS

A full summary of results has been reported in *Research for the Riverine Plains*, 2018.

For this publication, the key questions addressed are:

1. How do soil parameters, including PAW, vary across a paddock?
2. What was the value of zonal management of nitrogen, supported by NDVI, in selected paddocks during 2017?

HOW DO SOIL PARAMETERS, INCLUDING PAW, VARY ACROSS A PADDOCK?

While four paddocks were monitored for this work, technical issues with the EM38 survey conducted in the Telford paddock meant the associated spatial data could not be reliably connected with a specific paddock zone. Hence, results from the Telford paddock are not reported here.

Within the remaining three paddocks, intact cores were taken for PAW from 15 locations within each paddock and grouped according to EM zone. For the three paddocks, there were clear differences between the PAW measurements taken from the high and low EM zones (Figure 29 a, b, c), with the medium zone sometimes being similar to the PAW measurements from the high zone, and sometimes similar to the low zone.

A key determinant of PAW storage and water availability is the cation exchange capacity (CEC) of the soil, which is strongly associated with the clay content of the soil, as most cation exchange occurs on clay surfaces. The CEC results (Figure 30), show an almost inverse relationship between CEC and PAW across the three sites. As clay content increases there is less PAW because water is strongly adsorbed (held) onto clay surfaces. The lower CEC in the low zone of each paddock relates to the lower clay content and correlates well with the higher PAW measurements. It follows that the high EM zone has a higher CEC, with more clay, and a lower PAW content.

However, the PAW values do not fully consider the strength with which the soil adsorbs water. While the low EM zone has a higher PAW, and therefore a higher capacity to hold water, it also dries out faster than heavier soils with a higher clay content. The dry spring conditions during 2017 likely meant the lighter soils in the low EM zone ran out of soil moisture before the high EM zone.

KEY FACT: Because clay soils hold on more tightly to water, a clay soil will have lower PAW than a lighter soil (e.g. sandy soil). While there is less PAW in a clay soil, the water that is present will become slowly available over time, and will continue to be released slowly under drying conditions. In comparison, a lighter, sandy soil will have a higher PAW, but the moisture will be released more quickly, leaving nothing in a tight finish.

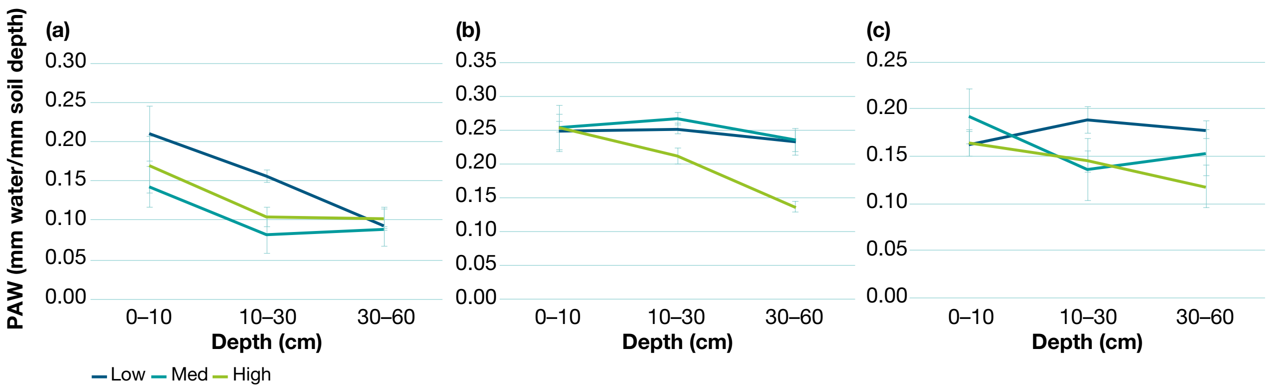


FIGURE 29. Plant available water across three zones to depth, measured as millimetres of water per millimetre of soil depth during 2017 at a) Yabba South, b) Rutherglen and c) Howlong

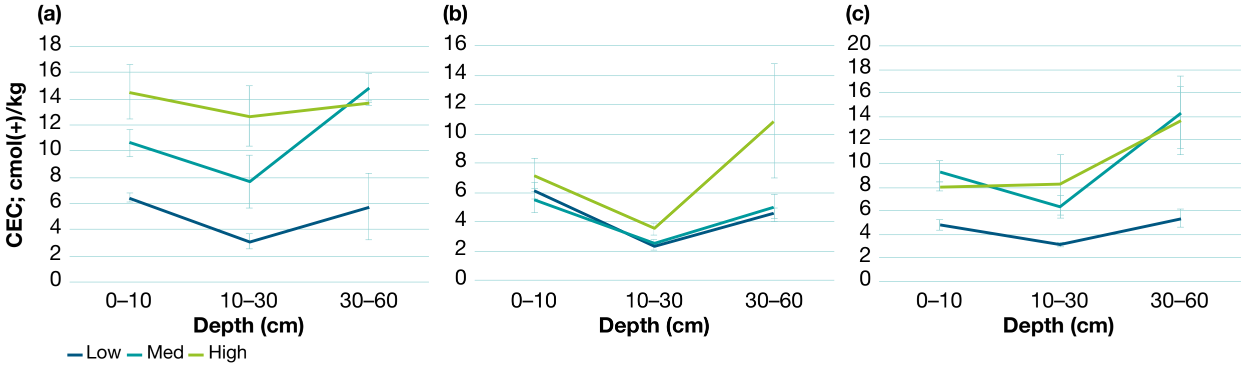


FIGURE 30. Effective CEC across three zones to depth at a) Yabba South, b) Rutherglen and c) Howlong measured as part of the *Stubble project* during 2017

Bars are measures of standard error

A subset of the spatial data is presented in Figure 31. As shown in the Yabba South images (Figure 31a), the EM zones created at the start of the 2017 season (left) align with the NDVI values collected in-crop (middle), as well as with the yield map (right). The yield map clearly shows the variation in productivity across the paddock, to the degree that assigning average yield values for each zone would be of limited value. The NDVI imagery from October 2017 clearly shows the lighter soils present in the low EM zone (middle of the paddock as indicated by dark red colouring) was being depleted of moisture, which in turn led to less DM and a yield penalty compared with the high EM zone.

While the datasets presented here indicate the potential for variance in PAW, CEC or EM maps to be used to guide variable rate application (VRA) of nutrients such as nitrogen, a key learning is that it does not capture the whole picture. For example while a paddock may show a variation in PAW, it could be that sodicity or subsoil acidity is the key limiting factor in plant performance, not water availability per se. As such, variations in plant growth across a paddock need to be examined holistically, rather than just focussing on one variable.

KEY FINDINGS

1. While PAW provides an indication of the capacity of the water storage 'bucket' across different soil types, it does not capture the degree to which the soil holds onto that water.
2. Any subsoil constraints should be quantified before investing in VRA of nitrogen. Differences in PAW and even EM surveys cannot provide a clear understanding of the presence and extent of constraints such as subsoil acidity and sodicity, both of which will significantly reduce the effectiveness with which the plant roots can extract water.

Dookie high EM zone, June 2017.

Dookie low EM zone, June 2017

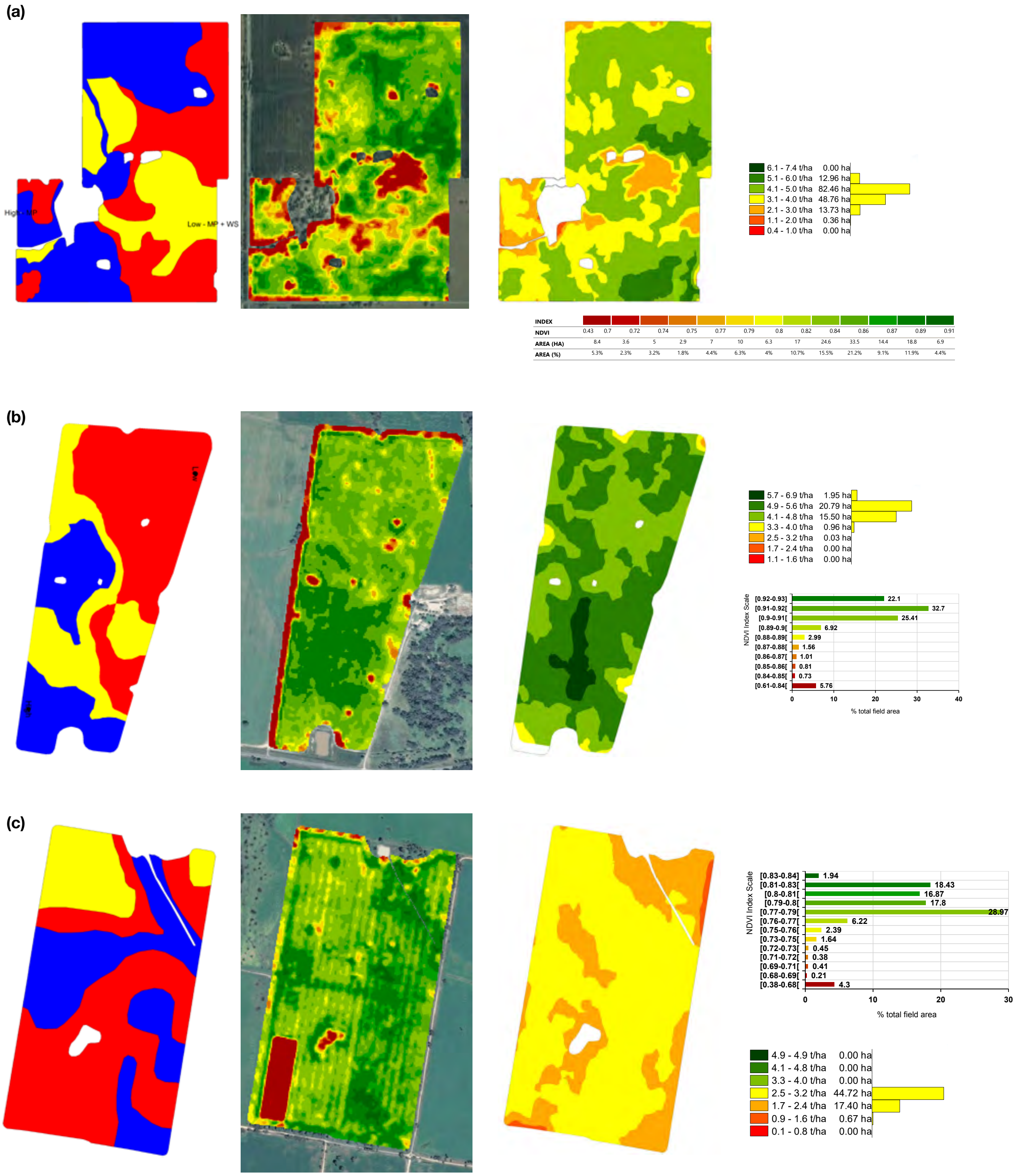


FIGURE 31. The allocation of zones and location of the weather station and soil moisture probes, NDVI satellite imagery 15–21 October 2017 and 2017 paddock yield map for *Stubble project* sites at a) Yabba South, b) Rutherglen, c) Howlong.

Stubble project conclusions

ECONOMIC OUTCOMES

Across the 15 large-plot stubble management trials carried out as part of the *Stubble project* from 2013–17, there were no consistent differences in yield due to stubble management (burnt, cultivated, NTSR, mulched, cut for straw and with or without additional nitrogen). These results show that a range of stubble management techniques can be employed strategically through the cropping rotation to address issues such as sowing efficiency, pests and diseases, or to manage herbicide-resistant weeds. Any given stubble management approach should be considered as a strategic and flexible tool in the production system, rather than a fixed element to be managed around.

At the start of this project there was a widespread perception that stubble retention in NTSR systems increases the risk of frost damage. Monitoring of in-canopy temperature across nine trials over three years has shown that while some in-canopy temperature differences were measured between the NTSR — long stubble and the burnt treatments, these differences were minimal, and not consistently related to frost damage (as measured in individual florets on wheat heads). A key finding from this work was that long stubble shades the establishing crop during early winter, which delays plant development following through to a delay in flowering date. The likelihood of frost damage is therefore directly connected with the date of flowering and depends on whether a susceptible stage of development coincides with a frost event on that date. Therefore, establishing a range of stubble heights across a paddock, or managing frost risk by employing a range of sowing dates, can spread the risk of frost damage across a paddock and minimise the chance of a frost event causing a complete crop failure.

ENVIRONMENTAL OUTCOMES

Many growers have committed to NTSR on the basis that they believe it is better for the soil environment.

While NTSR has many benefits, two of the main issues faced by growers adopting NTSR includes the stratification of nutrients in the surface soil (accumulating through litter/ash return to the surface without incorporation) and the increase in subsoil acidity (due to lime being broadcast without incorporation). Both of these issues are significant, with subsoil acidity becoming a major limiting factor to plant growth and potentially impacting the future sustainability of cropping on those soils.

The large-plot replicated stubble management trials carried out in this project demonstrated the strategic use of shallow incorporation at certain 'pinch points' in the rotation can be beneficial, where stubble loads, disease, weeds etc become an issue. This will not cause long-term harm to the soil, is unlikely to incur a yield penalty, and can instead provide significant benefit in mixing of nutrients through the topsoil, and in moving lime down the profile. Growers can be confident they can make incorporation ‘count’, by weighing up other elements, such as applying lime and gypsum in front of incorporation and/or timing incorporation to assist in the control of summer weeds.

THE MAJOR FINDINGS FROM THIS PROJECT WERE

1. Stubble management is not a key driver of yield.
   RECOMMENDATION: Retain stubble where possible, but use other tools, such as straw removal, mulching or incorporation, to manage stubble to optimise the efficiency of the farming system and machinery. Try to use burning as a strategic tool only when necessary.
2. Row spacing (22.5cm or 30cm) is less important in determining wheat yield in early-sown (mid-April) crops compared with later-sown crops (late May – early June).
3. During the four years of trials, applying a PGR did not deliver any positive yield effects or consistent quality effects.
4. Applying nitrogen increased yield potential, however the timing of the nitrogen application (split, single dose etc) did not influence yield.
   RECOMMENDATION: As there is no penalty for applying nitrogen in a split application, a high rate of nitrogen up front, or early, could be valuable under wetter conditions, while a lower rate of early nitrogen could reduce upfront costs when dry sowing, or where the break is late.
5. Applying either Prosaro (tebuconazole/prothioconazole) or Tilt (propiconazole) typically provided yellow leaf spot (YLS) control in the range 25–50%, which led to small, but consistent, positive yield effects.
   RECOMMENDATION: Use fungicides to control YLS during a wet spring, however sowing resistant varieties and employing rotations that include break crops, such as canola and pulses, also can help control YLS.
6. Long stubble shades the emerging crop, resulting in a delay in flowering and maturity.
   RECOMMENDATION: Growers can use this to their advantage by sowing crops earlier into long stubble and having them still flower in the right window, thus spreading the sowing window. If using two headers in a paddock, changing stubble height between headers will spread the flowering window of the following crop within the paddock over several days. This will reduce the risk of economic frost damage across a whole paddock/ variety.
7. Long stubble does not significantly increase the risk of frost in the Riverine Plains region. While in-canopy temperatures differences were measured across the Stubble project trials, these were not physiologically significant. Rather, the difference in flowering date due to shading in high stubble meant either the burnt or retained treatments had more frost damage during 2017, depending on which treatment was flowering at the time of the frost event.
8. Soil sampling should be conducted at repeatable GPS-referenced locations across different soil types.
   RECOMMENDATION: Avoid the bulking together of soil samples that commonly occurs with transect sampling and instead adopt incremental sampling. This will provide a greater opportunity to detect changes in soil properties over time.
9. Variable rate nitrogen management is of highest value in seasons where water is limiting and when there are strong changes in clay content/CEC across a paddock.
   RECOMMENDATION: Zones developed through EM surveys need to be ground-truthed in order to determine which soil properties are likely to drive or limit production in each zone.

Summary: Comparable yields can be achieved in stubble retained and burnt systems. Even if full stubble retention is not feasible due to machinery, weeds or disease constraints, there are other options such as shallow incorporation, cutting short or straw removal which can provide flexibility, reduce the frequency of burning and address timeliness related issues.

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