Between the rows

A study of crop row spacing in wheat and canola rotations of the Riverine Plains region

Riverine Plains Inc

Riverine Plains Inc is a not-for-profit, farming systems research and extension organisation servicing grain and mixed farming operators in north-east Victoria and southern New South Wales.

The group has a membership base of more than 315 farming families, spread across a wide geographical area. Riverine Plains Inc members farm as far north as Lockhart and Henty in NSW and as far south as Euroa and Shepparton in Victoria. Most members are dryland farmers, though a number also have access to irrigation.

The geographical area we service is known as the Riverine Plains, and it is from this region that the group takes its name.

The research work that underpins this report was carried out at Bungeet, Coreen, Barooga and Yarrawonga.

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1.0 Introduction

An esteemed researcher said to me a couple of years ago that after a set of data was reported in a paper it was often difficult to glean at first glance how well that particular trial had gone and consequently how reliable the data being reported actually was. The same researcher went on to say that the data being generated in this project was extremely significant and deserved to be recognised and valued as such.

Given the above, this booklet is an attempt to make a lasting record of the Riverine Plains Inc 'Water Use Efficiency (WUE) project', funded by the Grains Research and Development Corporation (GRDC), so that its legacy is perhaps more accessible than if the results were just confined to a filing cabinet or indeed somewhere in the *My Documents* section of a few computers. The booklet describes results from a series of trials that we believe were run at the highest standard. Furthermore, they are set in the context of commercial farming systems, a link in the research and development chain that is sometimes weak. Not all project results finish up in this form, but it is the hope of all involved here that this final effort will bring a last little bit of value to those who have funded the project and more broadly those who are interested in the work.

On behalf of Riverine Plains Inc, and all others involved in this project, I would like to sincerely thank the GRDC for the opportunity to undertake this work. Riverine Plains Inc generally only applies for project funding when an area of work is deemed particularly relevant to the region, and so is genuinely grateful for the funding required to undertake such a significant project.

This project has been a success because of the high calibre of people that worked at various levels on the project team. As a humble farmer, it has been enlightening and exciting to have had the privilege of working with, and more to the point learning from, such a group of people including the farmer co-operators, the staff at Riverine Plains Inc, the trial contractors, both the researchers who worked intimately on the trials and those who provided pearls of genuine wisdom from afar.

It is frought with danger to single anyone out, but it would be remiss to not mention Nick Poole. Nick has been the overarching brains and whipcracker during the course of this project, and a huge amount of its incredible success is due to the extremely high standards he sets for himself and others. It is pleasing to think back now and know this project was the start of what has turned out to be an enduring relationship between Riverine Plains Inc and Nick and the organisation he now leads (FAR Australia).

This project was run under a national initiative looking at ways to improve WUE on farms by 10%. It was extremely exciting to hear that this initiative was recognised by winning a 2014 Australian Museum Eureka Prize! The prize is for excellence in Australian science and science communication and is a feather in the cap of all who were involved in the initiative.

So it's all gone very well, and it is my sincere hope this booklet provides you with some helpful information and ideas.

Adam Inchbold
Project Supervisor

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.

Conversion table (imperial to metric)

Conversion of inches to centimetres		Conversion of feet to metres	
Inches	**Centimetres**	**Feet**	**Metres**
7	17.8	25	7.6
8	20.3	30	9.1
9	22.9	35	10.7
10	25.4	40	12.2
11	27.9	45	13.7
12	30.5	50	15.2
13	33.0	55	16.8
14	35.6	60	18.3
15	38.1	65	19.8
18	45.7	90	27.4
24	61.0	120	36.6

Trial site host farmer profile — Coreen: Jarrod Hanrahan

Farm detail

- Business: South Mahonga Trading Company
- Location: Coreen, Daysdale, NSW
- Farm size: 5000ha
- Soil types: Red rising loams, self-mulching clays and sands
- Enterprise mix: 5 years crop with 3–5 years pasture phase

Cropping enterprise

The Hanrahan's mixed farming enterprise runs 3600 Merino ewes on either a lucerne or clover-based pasture phase depending on soil type. This pasture phase runs for between three and five years depending on the health of the pasture and the weed burden. Canola is the principal break crop and is followed by two cereal crops; wheat takes the first cereal slot with either triticale or barley being the second cereal depending on soil type. Barley is usually reserved for the lighter red soils with triticale going on the heavier soils. The two cereals are followed by another canola crop on the heavier soils and lupins on the lighter sands. The break is followed by another wheat crop before re-entering the pasture phase.

Farming philosophy

Jarrod believes inputs should be targeted at improving productivity. He acknowledges the environmental responsibility that goes with being a farmer and sees his role as achieving a balance between protecting the environment and maintaining and improving farm profitability. He believes that increasingly farmers must be ready to adapt, as the goal posts (whether they are agronomic or market-based) are constantly moving.

Sowing equipment

- **Seed drill type**
  12.1m 1895 disc-based John Deere drill fitted with 48 openers on two ranks. There is a third rank of discs at the front of the machine for fertiliser placement.
- **Opener**
  Single disc openers
- **Row spacing**
  25cm row spacing

Establishment system

The Riverine Plains project results on row spacing convinced Jarrod that a 25cm row spacing was as wide as they should go with their commercial rig. So the new drill was fitted with openers at 25cm. They operate a full stubble retention system and he sees 25cm row spacing as being the best compromise for seasons with different yield potential. While Jarrod traditionally employs a full stubble retention system, he sees the need to be flexible depending on the season and variety. Sometimes burning stubble is necessary in order to successfully establish the next crop. With a variety such as Gregory the stubbles tend to be more problematic in terms of residue flow, so Jarrod might burn those stubbles more often. Jarrod employs his no-till system with concentrated fertiliser banding at a 50cm row spacing. A single cultivation pass with a tined cultivator is employed when the pasture phase is returned to crop in order to relieve some of the compaction that builds up from the livestock phase. Jarrod has found that introducing a forage cereal, such as oats, in the autumn after the pasture phase, grazing it in spring and running a spray fallow for the remainder of the season has given a better entry back into the cropping phase.

Crop agronomy

Hosting the row spacing trials gave Jarrod a better insight into the role of row spacing in biomass production and final grain yields. In many ways the research provided the confidence not to change the establishment system or in-crop agronomy. Prior to the research, Jarrod and his family were considering moving to a wider row spacing.

Trial site host farmer profile — Bungeet: John Alexander

Farm detail

- Business: Yaccoole Pty Ltd (Farm partnership between John and his brother Peter)
- Location: Bungeet, Victoria
- Farm size: 2810ha (1470 owned, 370 leased and 970 share farmed)
- Soil types: Duplex soils running from red soils to self-mulching clays and light loams with sand seams
- Enterprise mix: 100% cropping with the exception of a small area of hill country

Cropping enterprise

Other than 160ha of hill country the enterprise is 100% cropping under a no-till establishment system. Full stubble retention has been reviewed in light of recent seasons, particularly with the establishment of crops such as canola. Establishment of these small-seeded crops into a thick mulch is particularly difficult in autumns with full soil moisture profiles. The farm rotation has been moving to more frequent break crops and more first wheat trying to avoid second wheat in the rotation. John is happy with canola as the main break crop and faba beans on the heavier ground, however is trying to find a reliable break crop for the lighter country. Peas have performed well but can be hard on machinery at harvest according to John. John uses an oaten hay crop to combat any grass weed issues in problem paddocks and seasons.

Farming philosophy

John is a firm believer in not chasing markets but instead concentrating on making sure the rotation and the agronomy are working optimally to maximise productivity. He believes you cannot predict what the markets will do so it is best to concentrate on getting things right on farm and make the best of any professional advice to bring all the pieces of the farming system together. Part of John's philosophy is also to try out new techniques and new crops whenever the opportunity arises.

Sowing equipment

- **Seed drill type**
  11m Conserva Pak with the standard knife points designed to move less soil. The tine openers are mounted in three rows and there are standard v shaped press wheels.
- **Row spacing**
  30cm row spacing

Establishment system

John recognises he could be sowing on a narrower spacing following the Riverine Plains project results but sees the limitation of reducing the current 30cm row spacing being the speed and accuracy with which they can inter-row sow the following season. Even with low disturbance tine openers and GPS autosteer inter-row spacing on 30cm is not always easy and to move to 25cm would be even more problematic in terms of speed of drilling and accuracy, unless he moved to discs. While in the past John might have tried to pursue full stubble retention in every paddock every season, he is more pragmatic now accepting that occasionally he has to burn previous crop stubbles in order to retain a no-till system.

Crop agronomy

Reflecting on agronomy changes over the years John remembers discussions about herbicide-resistant weeds some 15 years ago, he says the difference now is that every decision you make on farm comes back to preventing resistant weed numbers building up. He feels focusing on resistant weeds early can make a difference, particularly if you address the cultural control measures in addition to rotating the herbicides.

2.0 Background

This publication marks the completion of the Riverine Plains Inc Grains Research and Development Corporation (GRDC) funded project *Improved water use efficiency (WUE) in no-till cropping and stubble retention systems in spatially and temporally variable conditions in the Riverine Plains* (RP100007). The project was initiated to investigate the influence of row spacing on WUE in the cropping systems typical of the Riverine Plains.

Although results of this project have been reported annually since 2010 in the Riverine Plains Inc *Research for the Riverine Plains* compendium, this report compiles the results from all project years enabling readers to evaluate the overall results in light of seasonal conditions and crop sequence position.

The *Improved water use efficiency (WUE) in no-till cropping and stubble retention systems in spatially and temporally variable conditions in the Riverine Plains* project ran from 2009–14 with the principal objective of:

- Assessing the impact of row spacing on grain yield and WUE in a rotational trial that included cropping sequences of canola and wheat; both of which are important crops in the Riverine Plains region.

Within this overarching objective the underlying aims of the project were to:

- determine whether a drill opener, either tine or disc, has any influence on optimum row spacing,
- assess the impact of growing season rainfall (GSR) on the performance of crops grown at different row spacings,
- determine whether the rotation position of wheat influences the optimum row spacing, and
- determine whether there is an interaction between crop row spacing and subsequent in-crop agronomy.

A combination of contractors and Riverine Plains Inc grower members carried out the research work according to protocols produced by the Foundation for Arable Research (FAR). All trial work was carried out using no-till full stubble retention (NTSR) at trial sites in Coreen and Barooga, NSW, and Bungeet and Yarrawonga, Victoria. This spread of trial sites generated research results based on different potential grain yields and soil types.

This report also contains a series of case studies featuring individual members of Riverine Plains Inc, which focus on current grower practices with regard to row spacing in the Riverine Plains region.

In compiling these results into one publication we would like to place on record our grateful thanks to the growers who hosted these research trials on behalf of Riverine Plains Inc: the Hanrahan family at Coreen, John and Peter Alexander at Bungeet, the Inchbold family and the Cummins family at Yarrawonga, and John Bruce at Barooga. We would also like to thank John Seidel, Peter Baines, Russell Ford and staff from Rice Research Australia, and staff from Peracto and Agrisearch for all their hard work on the project trials. In order to bring such projects to fruition it is important to recognise the hard work and input of the Riverine Plains committee and staff, in particular Adam Inchbold, Fiona Hart and Cassie Schefe. We would also like to thank our colleagues Michael Straight and Tabitha Armour from FAR for their input.

Finally, we would like to thank James Hunt and the team at CSIRO for their overarching support in running the national GRDC Water Use Efficiency Initiative.

Nick Poole and Tracey Wylie
FAR Australia

3.0
Row spacing as part of the farming system

During the past two decades, as Australian grain growers have increasingly adopted a no-till crop establishment system as part of a conservation farming approach, there has been an increasing trend towards sowing equipment with wider row spacings. Historically, when ground was cultivated more frequently, the common row spacing for crops was 17.8cm (7 inches). Growers have since moved crop row spacings out to 22.9cm (9 inches), 25.4cm (10 inches), 30.5cm (12 inches) and wider.

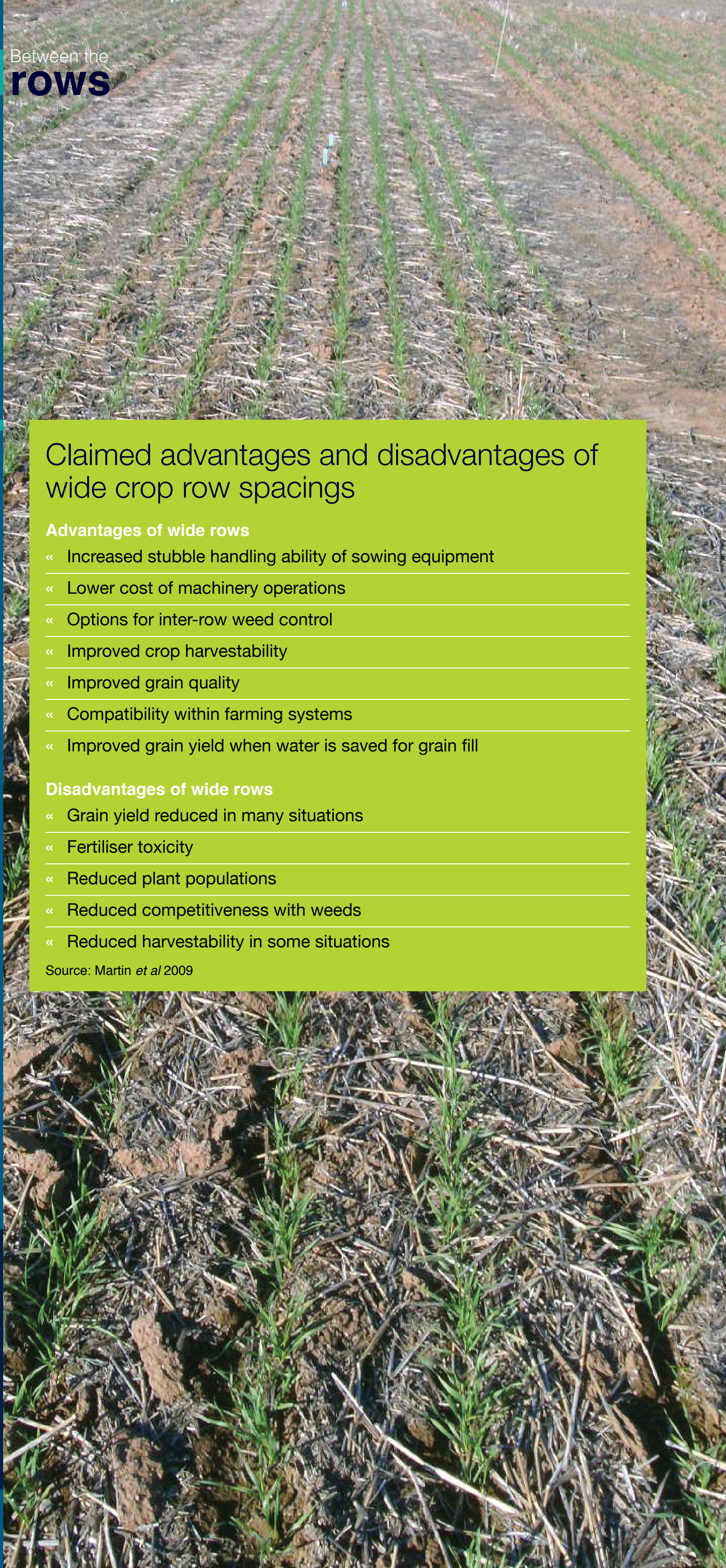
There are many reasons for this move to wider row spacings. With narrower row spacings, fully-retained chopped straw and stubble from the previous crop becomes more difficult to sow through, as the drill coulters impede the flow of residue through the machine causing residue blockages and uneven coverage of the newly-established seedbed. Moving to a wider row spacing and extending the overall length of the seed drill by mounting drill openers in several rows has ensured better residue flow, particularly where all residues are retained. This system is commonly referred to as a no-till full-stubble-retention (NTSR) system.

Wider row spacings have been enhanced by introducing accurate global positioning system (GPS) equipment. This technology has delivered relatively accurate inter-row sowing, where the following crop is sown between the stubble rows of the previous crop. For example, if a grower uses a 37.5cm row spacing, accurate GPS-based auto-steer can enable the next two years' crops to be inter-row sown. In the first year the rows are moved across by 12.5cm, then another 12.5cm the following year. This approach has had benefits in terms of both residue flow at sowing and disease control.

Even with wider row spacings, growers experience more difficulty with NTSR in seasons with heavy crop residues from the previous harvest. This was the case during 2010 when GSR exceeded 500mm across the Riverine Plains region. Autumn sowing during 2011 was hampered by heavy stubble loads, with a number of growers resorting to some form of residue removal, such as stubble burning or incorporation. The effect of this practical intervention, which some growers employ on a rotational basis (particularly between first and second wheat), is the subject of a new Riverine Plains Inc research project funded by the GRDC *Maintaining profitable farming systems with retained stubble in the Riverine Plains region* (RPI00009).

Other reasons put forward as claimed advantages and disadvantages of wider row spacings were featured in a thorough review of row spacing conducted by Scott *et al* (2013). One claimed advantage is the lower cost of machinery operations; not only based on fewer drill openers per metre width of drill machine, but also the tractor horsepower required to pull the seed drill. Obviously the more drill openers pulled, particularly if they are working at depth, then the more power it takes to pull them. In many cases increased row widths have been the result of seeding bar extensions where growers have increased the width of the drill without increasing the number of drill openers.

The principal disadvantages experienced by growers implementing wider row spacings tend to be reduced yields in some cropping scenarios and a lack of competition with resistant weeds, such as annual ryegrass.



Project rationale

The *Improved water use efficiency (WUE) in no-till cropping and stubble retention systems in spatially and temporally variable conditions in the Riverine Plains* project was initiated as a response to Riverine Plains Inc members' interest in the influence of row spacing and drill openers within their region. Members were asking important questions such as:

- What are the yield effects of row spacing in our region?
- How does row spacing influence nitrogen and WUE?
- Is there different optimum row spacing with crops of different yield potential and in different parts of the rotation?

These important questions are addressed in the next section of this report.

Claimed advantages and disadvantages of wide crop row spacings

Advantages of wide rows

- Increased stubble handling ability of sowing equipment
- Lower cost of machinery operations
- Options for inter-row weed control
- Improved crop harvestability
- Improved grain quality
- Compatibility within farming systems
- Improved grain yield when water is saved for grain fill

Disadvantages of wide rows

- Grain yield reduced in many situations
- Fertiliser toxicity
- Reduced plant populations
- Reduced competitiveness with weeds
- Reduced harvestability in some situations

Source: Martin *et al* 2009

4.0 Project outline — what we did

To address the objectives of the project (outlined on page 6), the project team ran four field trials over four years (2009–12) in the Riverine Plains region.

Two trial sites were established at Coreen, NSW and two at Bungeet, Victoria (see site details below) with the aim of improving WUE by 10% during the trial period and reducing the risk associated with NTSR systems. The NSW site historically, and through the course of the project, experienced lower GSR than the Victorian site.

The trials were established using plot seed drills and grown according to best management practice, using a combination of inputs applied by the trials contractor and host farmer. Each trial was established on the same site each year, with residues retained from the year before. Row spacing treatments were maintained in the same plots for the four years of the project, with crop plots sown in between the rows of the previous year's stubble.

In order to eliminate at least some of the seasonal effects influencing the performance of any one crop, each row spacing trial was repeated twice at each trial site. This second (repeat) trial was referred to as a **time replicate**, since the same sequence of crops was repeated, but starting at a different crop in the rotation in order to ensure the same sequence was exposed to different weather patterns. Both trials were positioned in the same paddock on the same soil type, 30m apart.

Results generated from the trials provided the opportunity to compare the same rotation position across different years, GSR and temperatures. For example, first wheat crops after canola at Coreen can be compared in the time replicate trials from 2010 and 2012. Wheat-on-wheat performance at the same site can be compared using data from 2010 and 2011. Similarly canola performance following two wheat crops can be compared using 2011 and 2012 data from the same site.

Trial site background information

Trial site growing season rainfall (GSR) for 2009–12

Trial site	Coreen, NSW	Bungeet, Victoria
GPS co-ordinates	-35°43'32.77"S, 146°20'36.34"E	-36°18'59.91"S, 146°0'34.72"E
Soil type	Clay loam	Loam over clay Wattville number 205
pH	pH (H_20): 5.9 pH ($CaCl_2$): 4.9	pH (H_20): 6.74 pH ($CaCl_2$): 5.5
GSR		
2009	234mm	286mm
2010	570mm	537mm
2011	187mm	301mm
2012	196mm	232mm
Total GSR 2009–12	1187mm	1356mm

Establishment of row spacing trials at Bungeet, Victoria.

Trial crop rotations 2009–12

Site 1 Coreen, NSW					
Year	**2008**	**2009**	**2010**	**2011**	**2012**
Time replicate 1 (Established autumn 2009)					
Sowing date	Farm crop	1 June	27 May	3 May	16 May
Crop	Triticale	Canola	Wheat	Wheat	Canola
Time replicate 2 (Established autumn 2009)					
Sowing date	Farm crop	29 May	27 May	3 May	17 May
Crop	Canola	Wheat	Wheat	Canola	Wheat

Site 2 Bungeet, Victoria					
Year	**2008**	**2009**	**2010**	**2011**	**2012**
Time replicate 1 (Established autumn 2009)					
Sowing date	Farm crop	4 June	8 June	1 June	22 May
Crop	Wheat	Wheat	Canola	Wheat	Wheat
Time replicate 2 (Established autumn 2010)					
Sowing date	Farm crop	Farm crop	8 June	1 June	22 May
Crop	Wheat	Faba	Wheat	Wheat	Canola

Note that at Bungeet the time replicate 2 only ran for three seasons

Row spacing and drill opener treatments used in each trial

The same row spacing and drill opener combinations were used in the same plot position of the trial for the life of the project. There were six row spacing — drill opener combinations, based on three row spacing treatments, with a tine or disc opener.

The treatments were as follows:

Row spacing	Drill opener
22.5cm (approximately 9 inches)	Janke single disc
30cm (approximately 12 inches)	or
37.5cm (approximately 15 inches)	Tine

Each treatment combination of row spacing and drill opener was replicated four times with plots configured in a randomised complete block design. Each plot was approximately 2.5 x 44m, though precise plot widths depended on the exact row spacing. There were 10 crop rows with 22.5cm row-spaced plots, eight rows with 30cm plots and six rows with 37.5cm plots. Edge rows of plots were removed at harvest and plot areas adjusted accordingly before calculating grain yields.

Janke single disc drill opener used in trial work.

Tine openers used in trial work.

Case study — John Bruce

Farm detail

- Business: J & S Bruce
- Location: Barooga, NSW
- Farm size: 1800ha (including 600ha leased)
- Soil types: Red sandy clay loams through to grey clays
- Enterprise mix: 75% crop (5–7 years) and 25% stock (3–5 years) (Merino first-cross lambs)

Cropping enterprise

The Bruce enterprise is a mixed farming system based on 75% cropping and 25% livestock. The livestock component is a Merino flock based on first-cross lambs. The current pasture phase is a five-year lucerne phase, but John is looking at the potential for arrowleaf clover to deliver similar benefits in a shorter pasture phase. The cropping rotation after the five-year lucerne pasture phase starts with wheat followed by canola then three cereals: two wheats followed by barley. Depending on annual ryegrass weed populations after the barley, the crop returns to pasture or is put back into canola and then first wheat. Therefore the cropping phase either goes for five or seven years before going back to pasture. Likewise depending on pasture conditions these may be broken early or late.

Farming philosophy

Flexibility and diversity are key to John's farming system philosophy. He believes both flexibility and diversity allow him to successfully manage risk. John sees the livestock system as being one of the key components in managing this risk and giving the farming business resilience. As much as he enjoys farming he recognises that for future generations to farm the land the farming enterprise has to be profitable.

Sowing equipment

- **Seed drill type**
  Horwood Bagshaw 7.5m tine based drill with openers spread over four rows for trash flow.
- **Opener**
  12.5cm drill openers are followed by individual press wheels for each coulter (used to be based as banks of press wheels which was not as effective). The depth placement uses a parallelogram system.
- **Row spacing**
  25cm row spacing

Establishment system

John operates a no-till system whenever he can within the rotation but isn't afraid to cultivate (principally following the pasture phase, but also following summer rain in order to incorporate crop residues into the soil). This practice is on a paddock-by-paddock basis depending on summer rainfall patterns. John will burn stubbles when he needs, which in 2014 was all stubbles. Liquid in-furrow fungicide is a key part of the establishment system and John is considering using UAN (urea ammonium nitrate).

Reason for current row spacing

Row spacing on the farm changed from 30cm to 25cm spacing since the farm was growing a proportion of grazing wheat where dry matter productivity was being lost. John feels this move has helped with weed competition in the farming system.

If he was to try to reduce row spacing and still inter-row sow, John acknowledges he would have to go to a controlled traffic scenario, which would only be something to consider if the farm went 100% cropping.

Crop agronomy

John doesn't believe he has had to make any changes to his agronomy approach since he went from a 30cm to 25cm row spacing.

5.0 Project findings

5.1 How do crop row spacing and seed drill openers influence crop performance in different positions of the rotation?

i. Overall influence of row spacing

Yield data from the two trials at each trial site (time replicate 1 and 2) showed differences in crop performance due to season, row spacing and rotation position (Tables 1 and 2).

Attributing a nominal value for grain outputs of $280/tonne for wheat and $500/tonne for canola revealed an average $79/ha output advantage to the narrowest row spacing (22.5cm) over the widest row spacing (37.5cm) at Coreen and $114/ha at Bungeet (when averaged across the two time replicates).

At both the Coreen and Bungeet trial sites the highest grain yields (6.27t/ha and 5.44t/ha respectively) were achieved during 2010, which coincided with the highest GSR. Overall, higher yields were achieved with the narrower row spacing (22.5cm) but differences varied depending on the season and crop type (wheat vs canola). With wheat crops there was a general trend for the narrow row spacing to out-yield the wider row spacings. This wasn't seen in canola, with wide rows performing similarly to narrow rows.

The differences in crop yield and other parameters, such as WUE, have been statistically analysed and are presented in the following sections.

TABLE 1 Average crop yields and returns across three row spacings for Coreen, NSW (2009–12)

Year	Crop	Yield (t/ha)		
		Row spacing (cm)		
		22.5	30.0	37.5
Time replicate 1				
2009	Canola	1.56	1.69	1.49
2010	Wheat	6.27	5.98	5.82
2011	Wheat	3.23	3.10	2.92
2012	Canola	2.32	1.94	2.04
Average return ($/ha)		1150	1089	1053
Time replicate 2				
2009	Wheat	2.63	2.62	2.28
2010	Wheat	5.01	4.90	4.81
2011	Canola	2.20	1.84	2.20
2012	Wheat	3.12	2.86	2.79
Average return ($/ha)		1028	957	967
Average return across both time replicates ($/ha)		1089*	1023	1010

*Average advantage of $79/ha for narrow row spacing compared with the widest row spacing
N.B. – Average returns calculated using $280/t for wheat and $500/t for canola

TABLE 2 Average crop yields and returns across three row spacings for Bungeet, Victoria (2009–12)

Year	Crop	Yield (t/ha) Row spacing (cm) 22.5	30.0	37.5
Time replicate 1				
2009	Wheat	3.03	2.99	2.54
2010	Canola	n/a	n/a	n/a
2011	Wheat	4.03	3.54	3.45
2012	Wheat	4.44	3.87	3.95
Average return ($/ha)		1073	971	928
Time replicate 2				
2010	Wheat	5.44	4.96	4.80
2011	Wheat	4.04	3.88	3.65
2012	Canola	2.67	2.35	2.75
Average return ($/ha)		1330	1217	1247
Average return across both time replicates ($/ha)		1202*	1094	1088

*Average advantage of $114/ha for narrow row spacing compared with the widest row spacing
N.B. – Average returns calculated using $280/t for wheat and $500/t for canola — note 2010 canola trial was lost in a hail storm before harvest (n/a – not available)

Wheat at the 22.5cm row spacing at the (from left to right): start of stem elongation (GS30–31), flag leaf emergence (GS39), flowering (GS65) and crop maturity (GS99).

Disc establishment of wheat into canola stubble (top) and wheat stubble (bottom) on a 30cm row spacing at Bungeet, Victoria.

ii. Influence of row spacing in first wheat crops, second wheat crops and canola

Combining the yield data from the two time replicate trials provides an average yield for the three crops at each site (first wheat, second wheat and canola), which has been statistically analysed in Tables 3, 4 and 5.

At the Coreen site, first and second wheat yielded approximately 4.0 t/ha with no statistical difference in yield between the 22.5 and 30cm row spacings, despite a trend for the narrow row spacing to be higher yielding in both rotation positions. Moving row spacing wider to 37.5cm resulted in significant yield reductions compared to the 22.5cm row spacing, with a 0.38t/ha reduction in yield in first wheat and 0.25t/ha in second wheat. Row spacing had no significant influence on the yield of canola at the Coreen site (Table 3).

TABLE 3 Influence of row spacing on the yield of different crops in the rotation at Coreen, NSW (2009–12)

Row spacing (cm)	First wheat 2009, 2010 & 2012	Second wheat 2010 & 2011	Canola 2009, 2011 & 2012
	Yield (t/ha)		
22.5	4.01	4.12	2.03
30.0	3.82	4.00	1.82
37.5	3.63	3.87	1.91
Mean	**3.82**	**4.00**	**1.92**
LSD	0.20	0.15	0.40
P value	0.016	0.034	0.438

TABLE 4 Influence of row spacing on the yield of different crops in the rotation — Bungeet, Victoria (2009–12)

	First wheat	Second wheat	Canola
	2010 & 2011	2009, 2011 & 2012	2012
Row spacing (cm)	Yield (t/ha)		
22.5	4.74	3.84	2.67
30.0	4.25	3.58	2.35
37.5	4.13	3.38	2.75
Mean	**4.37**	**3.60**	**2.59**
LSD	0.09	0.36	* only 1 rep
P value	0.002	0.059	

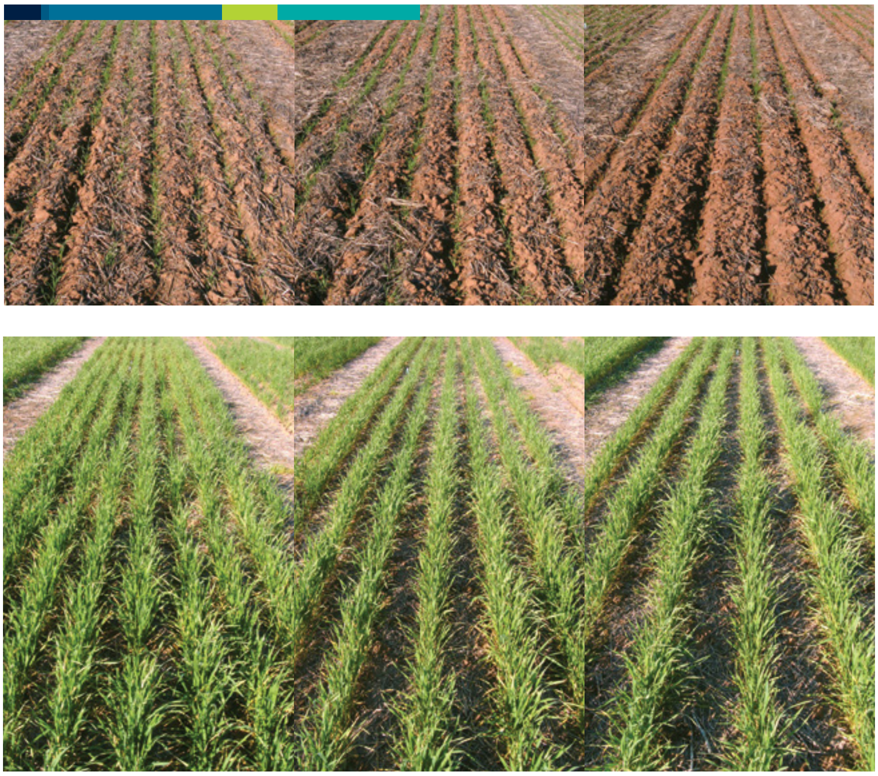
TABLE 5 Influence of row spacing on the yield of different crops in the rotation combined from both trial sites — Bungeet, Victoria and Coreen NSW (2009–12)

	First wheat	Second wheat	Canola
	2009–2012	2009–2012	2009, 2011 & 2012
Row spacing (cm)	Yield (t/ha)		
22.5	4.30	3.95	2.19
30.0	3.99	3.75	1.96
37.5	3.83	3.57	2.12
Mean	**4.04**	**3.76**	**2.09**
LSD	0.16	0.19	0.28
P value	<.001	0.005	0.198

Canola sown on a 22.5cm row spacing at two true leaves (GS12) (top), green bud (GS51) (middle) and flowering (GS65) (bottom).

At the Victorian site at Bungeet (Table 4) results were similar to Coreen, though in the first wheat rotation position the 22.5cm row spacing was significantly superior to both the 30cm and 37.5cm row spacings.

When data from both sites was combined, wheat crops grown at the 22.5cm row spacing were significantly higher yielding than crops sown at the 30cm and 37.5cm row spacings, irrespective of whether it was first or second wheat (Table 5). There was no statistical difference in wheat yield between the 30cm and 37.5cm row spacings. Row spacing had no significant influence on canola yields when all data was taken into account.



Wheat at the three-leaves-unfolded stage (GS13) growth stage (top) and start of stem elongation (GS30–31) (bottom) sown on 22.5cm (left), 30cm (middle) and 37.5cm (right) row spacings.

First wheat after the break crop

The grain yields of all first wheat crops grown after a break crop (of canola or faba beans) harvested from 2009–12) were analysed and revealed a significant trend for increasing row width to decrease crop yield (Figure 1). Assuming this was a linear relationship, the yield reduction associated with increasing row width every centimetre above 22.5cm ranged from 22–43kg/ha/cm.

Influence of yield potential in first wheat

In the first wheat crop there was some evidence the yield loss associated with wider rows was greater in crops with higher yield potential (Figures 2 and 3).

The lowest yields over the years of the project were recorded during 2009; the year that had low GSR and no stored soil moisture. In 2009 at lower yield potential (3.0t/ha and below) the effect of widening crop row spacing on wheat yield was neutral between 22.5cm and 30cm. There was however a significant drop off in yield when row spacing was increased from 30cm to 37.5cm (Figure 2).

The low yields recorded during 2009 contrasted sharply with those recorded the following year from the same plots. During 2010 the GSR doubled (Coreen: 570mm and Bungeet: 537mm) and resultant first wheat yields ranged from 5t/ha to 6.5t/ha. Under these conditions there was a significant yield loss associated with the 30cm row spacing of 0.29t/ha at Coreen and 0.48t/ha compared with 22.5cm (Figure 3).

Top left to bottom right: Wheat sown on a 30cm row spacing at the three-leaves-unfolded stage (GS13) up close and plot scale, start of stem elongation (GS30–31), flag leaf emergence (GS39), flowering (GS65), and crop maturity (GS99).

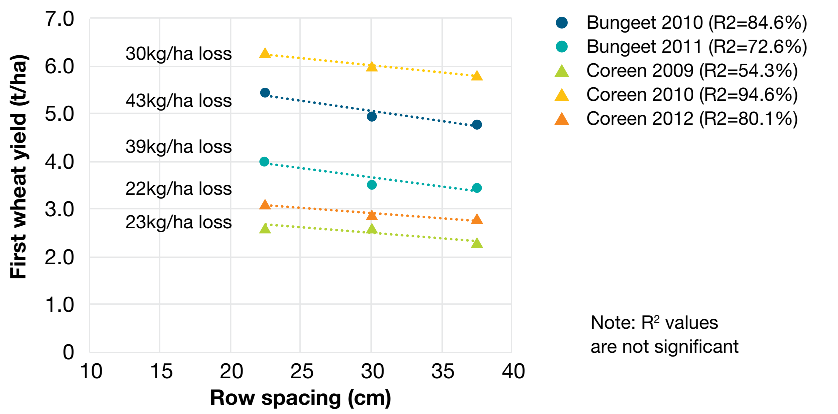


FIGURE 1 Influence of row spacing on the yield of first wheat — all trials (2009–12)

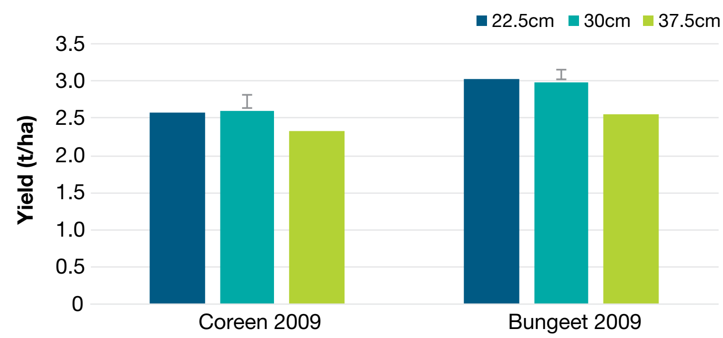


FIGURE 2 Influence of row spacing on wheat yield (comparison of first and second wheat in a low-yielding year) at Coreen, NSW and Bungeet VIC (2009)*

* Error bars represent LSD

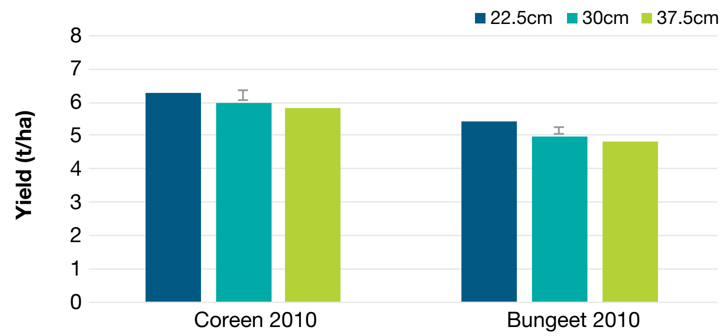


FIGURE 3 Influence of row spacing on first wheat yield at Coreen, NSW and Bungeet VIC (2010)*
* Error bars represent LSD

From left to right: Wheat sown on 22.5cm, 30cm and 37.5cm row spacings at the three-leaves-unfolded stage (GS13).

Second wheat after the break crop

Comparing first wheat with second wheat (wheat-on-wheat) revealed less of a yield penalty from increasing row widths in the second wheat crop (Figure 4). In this case the yield loss associated with increasing row width above 22.5cm ranged from 13–33kg/ha/cm. With second wheat crops there was no clear trend to suggest crops with higher yields generated relatively higher losses from increasing row width.

It is unclear why increasing row width might have had a greater effect on first wheat than second wheat. At first it was thought that closer row spacing in wheat-on-wheat situations might have increased root disease pressure. However Predicta B disease testing of soil samples did not generate any data to substantiate this explanation. Trial design may be a factor in explaining these results, as following establishment all plots were treated with the same overall management.

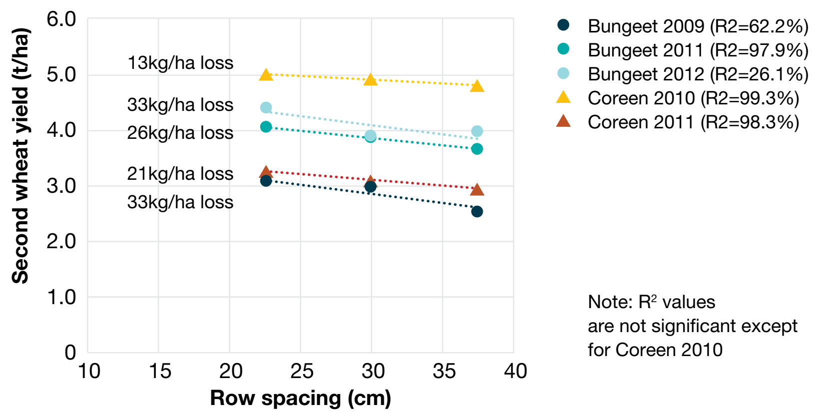


FIGURE 4 Influence of row spacing on the second wheat yield across all trials (2009–12)

If first wheat crops yielded more with narrow row spacing it could mean second wheat crops placed on these plots the following year were disadvantaged due to less residual fertiliser carryover or soil moisture to sustain crop growth.

While neither of these explanations can be proven, second wheat crops grown on narrow row spacings still recorded higher biomass per unit area than crops grown on wide rows. However, unlike first wheat, where this higher biomass led to more grain, in second wheat this increase in yield was not as evident.

So why did wheat crops sown on wider rows incur a yield penalty?

Lower dry matter production per unit area appears to be the most likely cause of the yield reduction encountered with wider row spacings, with crops sown on narrow rows producing significantly more dry matter per hectare.

One of the reasons for lower dry matter production at a wider row spacing was lower levels of plant establishment following sowing, despite plots being sown at the same sowing rates per unit area. Therefore it is difficult to accurately conclude how much of the reduction in dry matter production was a result of lower plant numbers and how much was due to row spacing.

However, in the canopy management trials reported in section 5.2 it is clear the influence of lower plant population on decreasing dry matter is usually observed in early growth stages, but by flowering and harvest the crop has compensated and the differences are no longer present.

Case study — The Davis Family, Geoff, Jan and Adam

Farm detail

- Business: GK & JM Davis
- Location: Rennie, NSW
- Farm size: 1700ha
- Soil types: Clay loam red brown earths (slightly acidic)
- Enterprise mix: Six years cropping followed by a four-year lucerne – clover pasture

Cropping enterprise

The Davis' enterprise is 70% cropping and 30% livestock featuring a self-replacing Merino flock. The cropping rotation after the four-year pasture phase starts with wheat followed by canola then two cereals: first wheat followed by second wheat or second barley (depending on annual ryegrass control). The two years of cereals are followed by lupins on lighter country, or canola on heavier country, then back into wheat followed by triticale undersown with lucerne and clover for the pasture phase. Second wheat crops are grown following burning and are higher yielding than the first wheat crops following pasture or canola.

Farming philosophy

Pastures lie at the heart of the Davis' farming system. In Geoff's words pastures give the system a "free kick" in terms of weed control options and soil fertility. Geoff believes the sustainability of their farming system is tied in with the benefits of these pastures. He admits they looked hard at going to a total cropping system but have resisted the temptation even though he acknowledges the free kicks from the pasture come with extra labour input.

Sowing equipment

- **Seed drill type**
  Purchased in shares with another farmer in the district the 12.3m Flexicoil seeder is fitted with tine openers (small wings fitted to the openers for extra shatter). Openers are followed by individual press wheels for each coulter (used to be based as banks of press wheels, which were not as effective). Openers are spread across four banks.
- **Opener**
  Super seeder knife points fitted with small wings. There is a double-shoot delivery system allowing seed and fertiliser delivery.
- **Row spacing**
  26.3cm row spacing

Establishment system

Geoff describes their establishment system as minimal till breaking the pasture phase using the seed drill as the cultivator (one pass at right angles to the sowing pass). After this, the first crop is established directly. The Davis's use sub 2cm GPS auto-steer to allow inter-row sowing, moving over 12.5cm in the following crop. Geoff's preferred option would be to retain stubble and chopped straw after the header, except when moving from first to second wheat, where burning is a key tool, for stubble, weed, disease management and yield, employed by the Davis family.

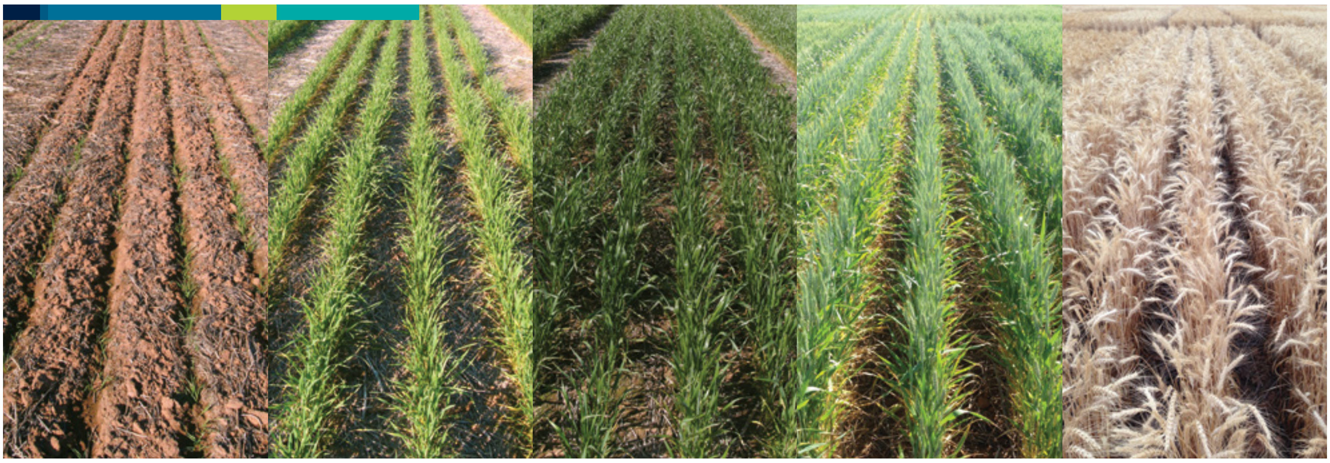
Reason for current row spacing

The Davis family adopted a 26.3cm rowing spacing in 2010 after the drill was modified. The original bar was widened and the same number of openers was then employed on the wider bar, hence row spacing moved from 22.5cm to 26.3cm.

The Davis family wouldn't rule out going back to 22.5cm spacing but acknowledge they would need to look at a different way of inter-row sowing. One reason for this would be to secure better crop — ryegrass competition. Disc machines might allow inter-row sowing on 22.5cm provided the machine was not excessively wide.

Crop agronomy

Geoff does not think the current row spacing has specifically led to any modifications to their agronomy program, however he acknowledges that since crops on the wider rows might be less competitive with weeds he is committed to higher rates of pre-emergent herbicides, particularly with the lack of effective post-emergent options with resistant ryegrass.



Wheat established at the 37.5cm row spacing at: three-leaves-unfolded stage (GS13), stem elongation (GS30–31), flag leaf emergence (GS39), flowering (GS65) and crop maturity (GS99).

Influence of row spacing on crop structure and dry matter production — first wheat

Despite the same sowing rates per unit area, row spacing significantly influenced the number of plants established, with higher populations establishing on the narrower row spacing, producing more tillers and significantly more grain heads at harvest.

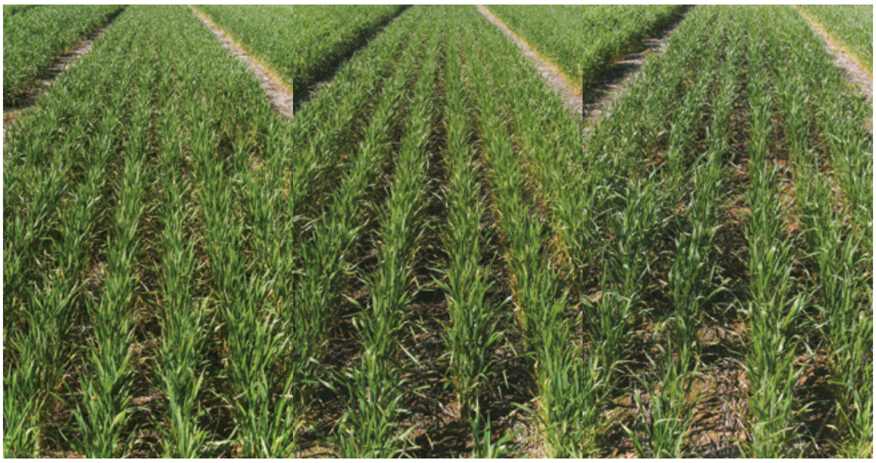
Greater canopy size associated with this increased plant population in narrow-row-spaced crops produced significantly more dry matter throughout the season (Table 6).

Influence of row spacing on crop structure and dry matter production — second wheat

The canopy structure and dry matter production of second wheat crops was influenced by row spacing in the same manner as first wheat (Table 7).

Though they cannot be compared statistically, harvest dry matters were almost identical in the two different rotation positions although grain yields were higher with first wheat, indicating that harvest indices (proportion of dry matter harvested as grain) were higher in first wheat rotation positions.

Comparing dry matter production earlier in the season at the start of stem elongation (GS31) there is a trend to suggest dry matter production was generally higher in first wheat than second wheat, but thereafter there appeared little difference between the two rotation positions.



From left to right: Wheat sown on 22.5cm, 30cm and 37.5cm row spacings at flag leaf emergence (GS39).

TABLE 6 Influence of row spacing on canopy composition* and dry matter production** for first wheat across five trials (2009–12)

Row spacing (cm)	Canopy composition/m²			Dry matter production (t/ha)			
	Plants	Tillers	Heads	GS30	GS39	GS61	GS99
22.5	202.2	499.6	371.0	2.58	5.63	8.28	12.1
30.0	152.1	395.3	318.9	2.16	4.90	7.27	11.2
37.5	117.7	326.5	285.0	1.62	4.10	6.71	10.4
Mean	**157.3**	**407.1**	**324.9**	**2.12**	**4.88**	**7.42**	**11.2**
LSD (5%)	14.3	35.9	22.1	0.28	0.52	0.49	0.46
P value	<.001	<.001	<.001	0.002	0.001	<.001	<.001

* Canopy composition: plant establishment assessed at the three-leaf stage (GS13), tiller production assessed at the start of stem elongation (GS31) and heads produced per square metre

** Dry matter production assessed from the start of stem elongation (GS30) to crop maturity (GS99)

TABLE 7 Influence of row spacing on canopy composition* and dry matter production** for second wheat across five trials (2009–12)

Row spacing (cm)	Canopy composition			Dry matter production (t/ha)			
	Plants/m^2	Tillers/m^2	Heads/m^2	GS30	GS39	GS61	GS99
22.5	183.4	505.2	316.2	2.15	6.17	8.15	12.6
30.0	138.6	384.8	278.6	1.56	5.36	7.41	11.3
37.5	111.5	312.1	242.6	1.26	4.61	6.48	10.3
Mean	**144.5**	**400.7**	**279.1**	**1.6**	**5.38**	**7.35**	**11.4**
LSD (5%)	14.5	38.2	17.7	0.27	0.50	0.71	1.9
P value	<.001	<.001	<.001	<.001	<.001	0.002	0.073

* Canopy composition: plant establishment assessed at the three-leaf stage (GS13), tiller production assessed at the start of stem elongation (GS31) and heads produced per square metre
** Dry matter production assessed at the start of stem elongation (GS30) to crop maturity (GS99)

From left to right: Wheat sown on 22.5cm, 30cm and 37.5cm row spacings at flowering (GS65).

Key points

Grain yields

- Increasing row spacing in both first and second wheat crops decreased grain yields.
- The yield reductions observed as row spacing was increased from 22.5cm (9 inches) to 37.5cm (15 inches) were: 11% (0.47t/ha) in first wheat crops after the break crop and 9.5% (0.38t/ha) in second wheat (based on data from both trial sites).
- In first wheat crops there was some evidence the yield loss associated with wider rows was greater in trials where yields were higher.
- In 2009 at yields of 3t/ha and lower there was no difference in yield between row widths of 22.5cm (9 inches) and 30cm (12 inches). In contrast in 2010 at yields of 5–6t/ha first wheat sown on 30cm (12 inch) rows significantly reduced yields by 0.29t/ha at Coreen and 0.48t/ha at Bungeet compared with the 22.5cm (9 inch) row spacing.
- In second wheat crops the influence of row spacing on yield was smaller and not always significant.
- Unlike first wheat crops, results from second wheat crops did not always show an increased yield penalty with increasing row widths.
- There was limited evidence to suggest the relationship between row spacing and grain yield might not be linear as there was no difference in yield between crops on 22.5cm and 30cm row spacings when yields were 3t/ha or lower (2009 data).

Dry matter production

- Wider row spacings produced less dry matter per unit area than narrow row spacings; a difference that was observed throughout the season.
- Decreased dry matter with wider row spacings was partly caused by lower plant establishment at sowing, however differences in plant population (110–200plants/m^2) are unlikely to be the primary cause of decreased dry matter at harvest with wider rows.
- It is more probable that the inability to capture all the sunlight with wider rows (reduced ground cover) decreased productivity over the season, as plots did not achieve row/canopy closure at the widest row spacing in many trials.
- When comparing first and second wheat data (not statistically) despite similar dry matter production at harvest, second wheat crops produced thinner crop canopies (tiller and head production) and lower yields.

Row spacing in canola

The results for canola were less consistent than for the wheat trials. Losses associated with increasing row spacing from 22.5cm ranged from 0–18kg/ha/cm. The dataset for canola grown at the Bungeet trial site showed there to be a 5kg/ha/cm gain by increasing row spacing (Figure 5).

Influence of row spacing on yield potential of canola

There was little evidence to show that increasing the row spacing (from 22.5cm to 37.5cm) would decrease the yield of canola. The performance of crops sown on a 30cm row spacing was highly variable compared with those sown on 22.5cm and 37.5cm spacings.

In 2009 at Coreen, canola crops sown on a 30cm row spacing were significantly higher yielding, but in other datasets, yields were lower than both the narrower 22.5cm and wider 37.5cm row spacings.

Canola at the 30cm row spacing (from left to right): two true leaves (GS12), green bud (GS51), mid flower (GS65).

From left to right: Canola sown at the 22.5cm, 30cm and 37.5cm row spacings at the green bud stage (GS51).

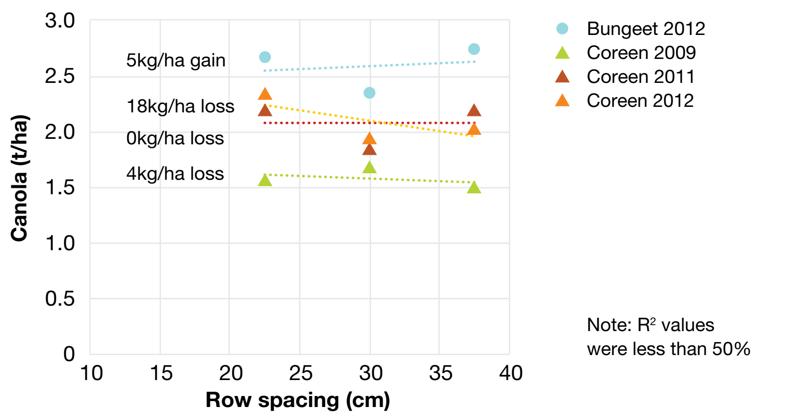


FIGURE 5 Influence of row spacing on canola yield across all trials (2009–12).
As the yield results were highly variable, R^2 values are not presented on this graph. However, the dotted lines still assist in demonstrating trends within each dataset.

Influence of row spacing on plant population and dry matter production in canola

Despite a uniform sowing rate across the three row widths, significantly more canola plants established at the narrowest row spacing (22.5cm). This supported the production of greater canopy biomass throughout the season at all assessment timings (Table 8). Unfortunately due to errors at sowing plant populations were sown higher than planned, which meant all plots had abnormally high plant populations during 2011 and 2012.

TABLE 8 Influence of row spacing on canola plant establishment and dry matter production as assessed throughout the season, across four trial sites (Coreen — three trials and Bungeet — one trial)

Row spacing (cm)	Plants/m²	Dry matter production (t/ha)				
		Green bud	Yellow bud	Mid flower	Pod set	Ripening
22.5	150.4	1.57	4.21	4.79	7.44	7.80
30.0	113.6	1.40	3.86	4.51	6.72	7.04
37.5	90.7	1.20	3.77	4.25	6.20	7.18
Mean	**118.2**	**1.39**	**3.95**	**4.52**	**6.79**	**7.34**
LSD (5%)	51.4	0.29	0.41	0.56	0.67	0.85
P value	0.075	0.053	0.078	0.14	0.011	0.14

Key points

- The effect of row spacing on canola yield was highly variable in this project.
- When results from the four datasets were analysed together there were no significant yield differences in canola seed yields due to row spacing.
- However there were significant effects in individual years; in 2009 at Coreen the canola grown on 30cm (12 inch) rows was significantly higher yielding than crops grown on 22.5cm (9 inch) and 37.5cm (15 inch) rows.
- In the three other datasets the 30cm (12 inch) row spacing was significantly lower yielding than the 22.5cm (9 inch) row spacing and in two of the three trials also significantly lower yielding than the 37.5cm (15 inch) spacing.
- The results indicate that different row spacings in canola produce different harvest indices (proportion of plant biomass harvested as seed), as wider row spacings produced less biomass but yielded the same as narrow row spacings.

iii. Influence of row spacing on water use efficiency (WUE)

In first and second wheat, WUE was calculated from the final harvest biomass and grain yield.

In first wheat crops the 22.5cm row spacing gave significantly better WUE than the 30cm and 37.5cm row spacings (6.8% and 14.6% respectively). There was no significant difference in transpiration efficiency (TE) or harvest index (HI). Wider row spacings showed greater losses through soil evaporation and unused water. Significantly more water was used (as transpiration) to grow crop canopies in narrower rows. In the dry year of 2009, when first wheat crops yielded 3t/ha or less, the WUE of the 22.5cm and 30cm row-spaced crops was identical, but water losses were made up differently. When crops were grown on 30cm row spacings, more water was lost through soil evaporation (and unused water), while the wheat on the 22.5cm row spacing used more water through transpiration (Table 9).

In second wheat crops, the 22.5cm row spacing yielded significantly better WUE than the 30cm and 37.5cm row spacings (6.8% and 9.3% respectively). There was no significant difference in TE or HI. Wider row spacings showed greater losses through soil evaporation and unused water, but the differences were not statistically different. There was a non-significant trend for narrower rows to use more water through transpiration (Table 10).

There were no differences in WUE in canola crops due to row spacing (Table 11).

The WUE calculations are based on the following measurements and assumptions:

1. All biomass and grain yield calculations are based on dry matter content (i.e. 0% moisture, rather than 12.5% moisture for grain yield as in previous sections of this report).
2. Harvest index (HI) is calculated by dividing the final harvest yield by the final harvest biomass.
3. Water use efficiency (WUE) is calculated by dividing grain yield by the available soil water (mm).
4. Transpiration through the plant was based on a maximum 55kg biomass/ha.mm transpired for wheat and 50kg biomass/ha.mm transpired for canola.
5. Soil evaporation, drainage, or unused water is calculated as the water that remains unaccounted for after transpiration water has been subtracted from available soil water (stored in the fallow plus GSR).
6. Transpiration efficiency (TE) is calculated by dividing the final harvest yield (kg/ha) by water transpired through the plant.
7. Soil water for the growing season (April – October, except 2010 April – mid November when the growing season was extended by abnormally high spring rainfall) was calculated by adding the rainfall for this period (GSR) to soil water present on April 1.
8. Soil water on April 1 was calculated by adding up the rainfall for January, February and March and assuming 35% was available to the crop at the start of the growing season (April 1).

TABLE 9 Average biomass at harvest, yield, harvest index (HI), water use efficiency (WUE), transpiration, evaporation/drainage and transpiration efficiency (TE), across first wheat trials at Bungeet and Coreen 2009–12*

Row spacing (cm)	Biomass[1] (t/ha)	Yield[1] (t/ha)	HI[2] (%)	WUE[3] (kg/mm)	Transpiration[4] (mm)	Evaporation[5] (mm)	TE[6] (kg/mm)
22.5	12.07	3.50	29.5	9.4	219.5	155.6	15.6
30.0	11.20	3.24	29.7	8.8	203.6	171.4	15.7
37.5	10.41	3.07	30.0	8.2	189.2	185.9	15.8
Mean	**11.23**	**3.27**	**29.7**	**8.8**	**204.1**	**171.0**	**15.7**
LSD (5%)	0.46	0.20	2.2	0.5	8.4	8.4	1.2
P value	<.001	0.005	0.862	0.002	<.001	<.001	0.861

* Average of both openers
[1] – Numbering relates to the list of assumptions outlined above

Available soil water calculated for first wheat trials

Year	Site	GSR (mm)	Calculated soil water available on April 1 (mm)	Total soil water available (mm)
2009	Coreen	234	0	234
2010	Coreen	570	160	730
2011	Bungeet	301	115	416
2012	Coreen	196	85	281

TABLE 10 Average biomass at harvest, yield, harvest index (HI), water use efficiency (WUE), transpiration, evaporation/drainage and transpiration efficiency, across second wheat trials at Bungeet and Coreen 2010–12*

Row spacing (cm)	Biomass[1] (t/ha)	Yield[1] (t/ha)	HI[2] (%)	WUE[3] (kg/mm)	Transpiration[4] (mm)	Evaporation[5] (mm)	TE[6] (kg/mm)
22.5	12.60	3.67	31.0	9.4	229.1	173.1	16.45
30.0	11.30	3.45	31.9	8.8	205.4	196.7	16.94
37.5	10.35	3.36	34.0	8.6	188.1	214	18.07
Mean	**11.41**	**3.49**	**32.3**	**9.0**	**207.5**	**194.6**	**17.15**
LSD (5%)	1.92	0.17	3.9	0.5	34.8	34.8	2.18
P value	0.073	0.01	0.235	0.018	0.073	0.073	0.256

* Average of both openers
[1] – Numbering relates to the list of assumptions outlined on page 22

Available soil water calculated for second wheat trials

Year	Site	GSR (mm)	Calculated soil water available on April 1 (mm)	Total soil water available (mm)
2010	Coreen	570	160	730
2011	Bungeet	301	115	416
2011	Coreen	187	87	274
2012	Bungeet	232	118	350

TABLE 11 Average biomass at harvest, yield, harvest index (HI), water use efficiency (WUE), transpiration, evaporation/drainage and transpiration efficiency, across canola trials at Bungeet and Coreen 2009–12*

Row spacing (cm)	Biomass[1] (t/ha)	Yield[1] (t/ha)	HI[2] (%)	WUE[3] (kg/mm)	Transpiration[4] (mm)	Evaporation[5] (mm)	TE[6] (kg/mm)
22.5	7.80	1.99	25.8	6.8	156.0	136.8	12.91
30.0	7.04	1.78	25.5	6.1	140.7	152.2	12.74
37.5	7.18	1.93	26.9	6.5	143.5	149.4	13.46
Mean	**7.34**	**1.90**	**26.1**	**6.5**	**146.7**	**146.1**	**13.04**
LSD	0.85	0.26	3.4	0.9	17.0	17.0	1.68
P value	0.14	0.206	0.582	0.283	0.14	0.14	0.582

* Average of both openers
[1] — Numbering relates to the list of assumptions outlined on page 22

Available soil water calculated for canola trials

Year	Site	GSR (mm)	Calculated soil water available on April 1 (mm)	Total soil water available (mm)
2009	Coreen	234	0	234
2011	Coreen	187	87	274
2012	Bungeet	232	118	350
2012	Coreen	196	85	281

From left to right: Wheat sown on 22.5cm, 30cm and 37.5cm row spacings at crop maturity (GS99).

Wheat sown with the disc opener at the 37.5cm row spacing.

Wheat sown with the tine opener at the 37.5cm row spacing.

iv. Influence of drill opener on crop performance across rotation positions

The different drill openers, although visually creating differences at establishment in terms of stubble and soil movement, had little effect on crop growth and the resulting yield (Table 12).

The second wheat rotation position showed a significant advantage with the disc opener in terms of the canopy composition assessments, however this did not result in increased yield (Table 13).

Although there were no differences in canola establishment due to the drill opener, at harvest there was a significant yield advantage with the disc opener when four datasets were considered (Table 14).

Top: Disc opener at 37.5cm.
Bottom: Tine opener at 37.5cm.

TABLE 12 Influence of drill opener in the first wheat rotation position on plant establishment at the three-leaf stage (GS13), tiller production (start of stem elongation — GS31), heads per metre square and yield across five trials (2009–12)

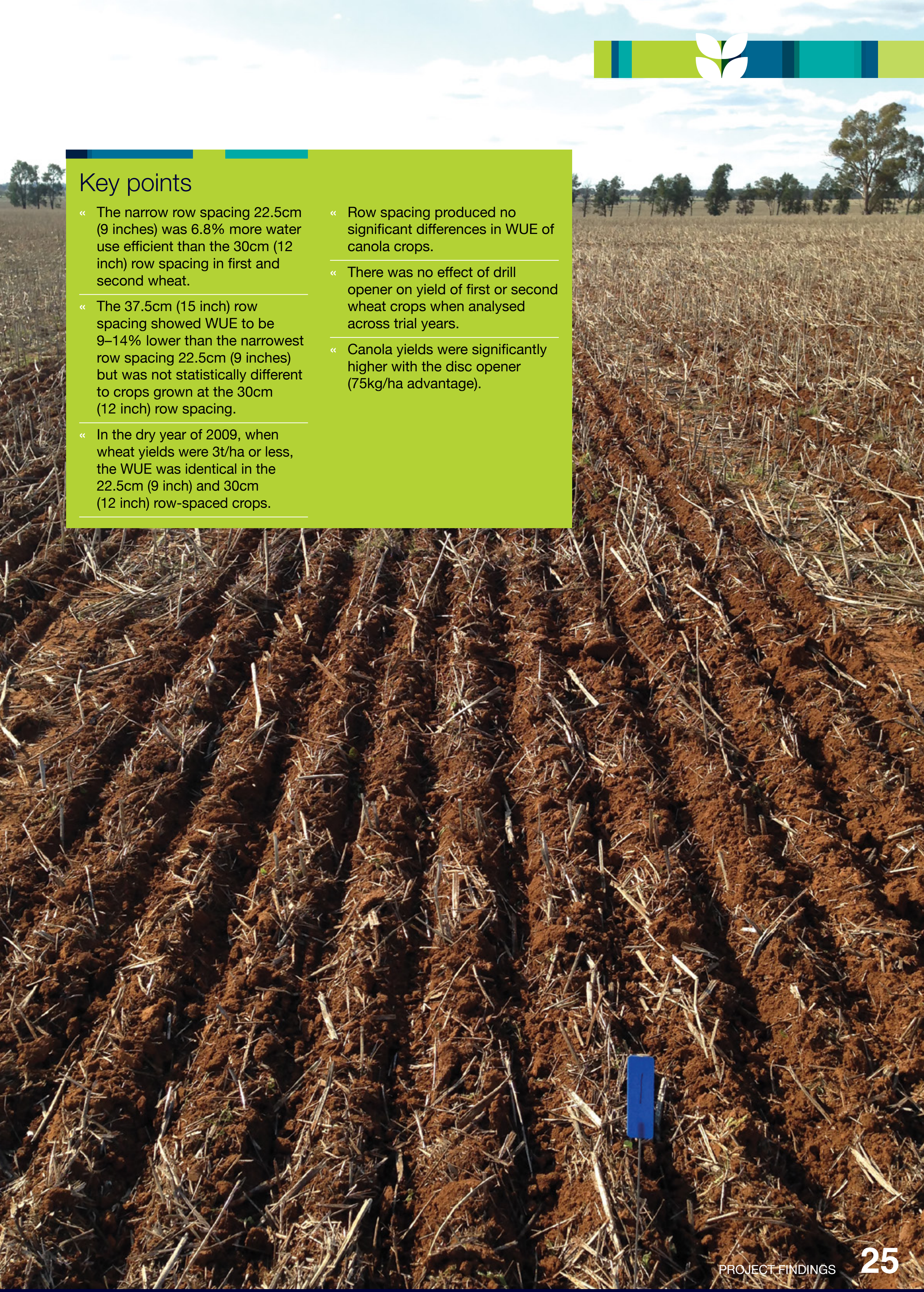
Drill opener	Canopy composition			Yield (t/ha)
	Plants/m²	Tillers/m²	Heads/m²	
Disc	160	430	329	4.03
Tine	155	385	316	4.06
Mean	**157**	**407**	**322**	**4.05**
LSD (5%)	13	55	16	0.28
P value	0.34	0.09	0.08	0.80

TABLE 13 Influence of drill opener in the second wheat rotation position on plant establishment at the three-leaf stage (GS13), tiller production (start of stem elongation — GS31), heads per metre square and yield across five trials (2009–12)

Drill opener	Canopy composition			Yield (t/ha)
	Plants/m²	Tillers/m²	Heads/m²	
Disc	147	409	305	3.81
Tine	140	370	282	3.71
Mean	**144**	**389**	**293**	**3.76**
LSD (5%)	8	36	22	0.20
P value	0.05	0.04	0.04	0.26

TABLE 14 Influence of drill opener on the establishment of canola at the three-leaf stage and yield across four trials

Drill opener	Plants/m²	Yield (t/ha)
Disc	111	2.13
Tine	126	2.05
Mean	**119**	**2.09**
LSD (5%)	39	0.06
P value	0.28	0.03



Key points

- The narrow row spacing 22.5cm (9 inches) was 6.8% more water use efficient than the 30cm (12 inch) row spacing in first and second wheat.
- The 37.5cm (15 inch) row spacing showed WUE to be 9–14% lower than the narrowest row spacing 22.5cm (9 inches) but was not statistically different to crops grown at the 30cm (12 inch) row spacing.
- In the dry year of 2009, when wheat yields were 3t/ha or less, the WUE was identical in the 22.5cm (9 inch) and 30cm (12 inch) row-spaced crops.
- Row spacing produced no significant differences in WUE of canola crops.
- There was no effect of drill opener on yield of first or second wheat crops when analysed across trial years.
- Canola yields were significantly higher with the disc opener (75kg/ha advantage).

Case study — Adam Inchbold

Farm detail

- Business: Inchbold family
- Location: Yarrawonga, Victoria and Mulwala, NSW
- Farm size: 3550ha
- Soil types: Red brown earth ranging to grey sodic clays
- Enterprise mix: 7–8 years cropping followed by five years of lucerne pasture

Cropping enterprise

The Inchbold family run a mixed farming enterprise based on a 7–8-year cropping rotation followed by a pasture phase. The cropping sequence is based on oaten hay followed by canola (or faba beans on heavier wetter soils or irrigated ground). These break crops are followed by two cereal crops: wheat followed by barley. This sequence is repeated starting with an oaten hay crop on the land with annual ryegrass resistance or by skipping the oaten hay and going straight to canola or faba beans. GM canola is being introduced to the rotation for improved annual ryegrass control for a better two-year break option. The cropping phase is followed by a five-year lucerne pasture phase for Adam's beef cattle enterprise.

The Inchbolds aim to add value to existing enterprises, for example, by running a beef feedlot.

Farming philosophy

The Inchbold's philosophy is to maintain diversity within a mixed farming system in order to ensure a farming enterprise that is both robust and sustainable. This philosophy extends to crop husbandry, marketing and business management. Inevitably it means accepting that profitability will not be as great as a pure cropping enterprise in a high-yielding year. In terms of agronomy Adam's philosophy is to maximise the use of the rotation in order to manage ryegrass resistance.

Sowing equipment

- **Seed drill type**
  Janke Universal 13.72m bar. It has the strength of effective residue flow, however depth control can be an issue as the drill does not have a parallelogram system for seed placement.
- **Opener**
  The Janke tine has been modified with an Agmaster seeding boot, which allows split fertiliser:seed application and deep banding. Janke coulters are positioned in front of five ranks of seeding openers in order to cut through long canola stubbles and deliver effective residue flow. Manutec press wheels are fitted at the rear of the bar.
- **Row spacing**
  25cm row spacing

Establishment system

Adam describes his establishment system as "direct drilling" rather than "no-till". He rarely burns his paddocks, but Adam bales about 60% of his straw behind the header, which makes direct drilling easier in the cropping phase. Cultivation (one pass of one-way discs) is only done when the lucerne pasture phase returns to the cropping phase.

Reason for current row spacing

When the drill was modified some years ago, row spacing was increased from 22.5cm to 25cm as a result of the bar being extended from 12.19m to 13.72m while using the same number of openers.

To improve seed placement, in the future Adam plans to increase bar width to 16.76m and reduce crop row spacing to 17.5cm based on a parallelogram. Adam is moving to narrower row spacing based on his observations with oaten hay and recent trial results from Riverine Plains Inc.

Crop agronomy

With a 25cm row spacing Adam has been increasing the proportion of nitrogen applied before stem elongation, unless soil testing indicates fertility is high. With canola Adam applies this earlier nitrogen at sowing, while with cereals he applies it at tillering. If he reduces sowing row widths further Adam plans to hold back on early nitrogen unless there is very low fertility.

5.2 Do different crop row spacings require different in-crop agronomy — plant populations and nitrogen management?

Previous sections of this report have concentrated on results from the row spacing trials where subsequent in-crop agronomy was the same for all row spacing and drill opener treatments. In addition, all the starting points in terms of sowing rates and base-rate fertiliser were identical.

Another important aspect of the project was to investigate whether the performance of particular crop row spacing could be enhanced by adjusting the sowing rates or adjusting the timing of nitrogen (N) applications.

For example, growers were asking:

- Do wider row spacings require higher sowing rates to overcome the lower levels of establishment experienced in project trials?
- Do wider row spacings require greater emphasis on nitrogen at sowing in order to create greater dry matter production earlier?

To answer these questions, canopy management trials were established in first and second wheat crops. Trials were only run for one year, with trial treatment variables established at two row spacings: 22.5cm and 37.5cm.

The variables were:

- two plant population targets:
  1. low (based on establishing 100–150 plants/m²)
  2. high (based on 200–250 plants/m²)
- four nitrogen timings (of 50kg N/ha):
  1. no nitrogen
  2. all nitrogen applied in the seedbed at sowing
  3. all nitrogen applied at early stem elongation (GS30–31)
  4. nitrogen split 50:50 between sowing and early stem elongation (GS30–31)

Five datasets were generated over the project and are analysed as one in the following section. The results represent four first wheat datasets and one second wheat dataset. These factorial trials have been presented showing the effect of each single variable (row spacing, plant population and nitrogen timing), then the combination of those variables.

Plant population target of 200–250 plants/m² at the 22.5cm row spacing (top) and 37.5cm row spacing (bottom).

TABLE 15 Influence of row spacing on plants, tillers and heads, yield and protein, for five sets of trial data*

Row spacing (cm)	Canopy composition			Harvest data	
	Plants/m²	Tillers/m²	Heads/m²	Yield (t/ha)	Protein (%)
22.5	194.6	387.0	270.9	3.66	8.7
37.5	122.9	257.3	209.1	3.38	9.1
Mean	**158.8**	**322.2**	**240.0**	**3.52**	**8.9**
LSD (5%)	9.9	14.4	7.4	0.14	0.3
P value	<.001	<.001	<.001	<.001	0.008

* Mean of two plant populations and four nitrogen treatments

Left to right: 22.5cm row spacing target 100 plants/m², 22.5cm target 200 plants/m², 37.5cm target 100 plants/m², 37.5cm target 200 plants/m².

Results on row spacing mirrored those produced in the rotational trials reported in section 5.1, though the yield advantage of crops sown on the narrow spacing over the wide rows was only 0.28t/ha (Table 15, page 27) compared with a yield advantage of 0.38–0.47t/ha in the other trial series (Table 5, page 14).

Though higher plant populations significantly increased tiller production and final head numbers, the yield difference (0.09t/ha) was not statistically significant, although there was a trend for increased plant populations to generate a higher yield. The reduction in grain protein content with higher plant populations was significant (Table 16).

When nitrogen timing was considered as a single variable, it did not influence plant population. Tiller numbers were significantly greater where nitrogen was applied in the seedbed at the full rate of 50kg N/ha and head numbers were significantly higher than the nil-nitrogen treatment, regardless of the rate applied in the seedbed (full 50kg N/ha or the split rate).

Top: Targeted 200 plants at 22.5cm.
Bottom: Targeted 200 plants at 37.5cm.

Top: Targeted 100 plants at 37.5cm.
Bottom: Targeted 200 plants at 37.5cm.

TABLE 16 Influence of targeted plant population on plants, tillers and ears, yield and protein for five sets of trial data*

Target plant population	Canopy composition			Harvest data	
	Plants/m²	Tillers/m²	Heads/m²	Yield (t/ha)	Protein (%)
100 plants	121.4	287.3	222.6	3.48	9.0
200 plants	196.1	357.0	257.4	3.57	8.7
Mean	**158.8**	**322.2**	**240.0**	**3.52**	**8.9**
LSD (5%)	9.9	14.4	7.4	0.14	0.3
P value	<.001	<.001	<.001	0.209	0.047

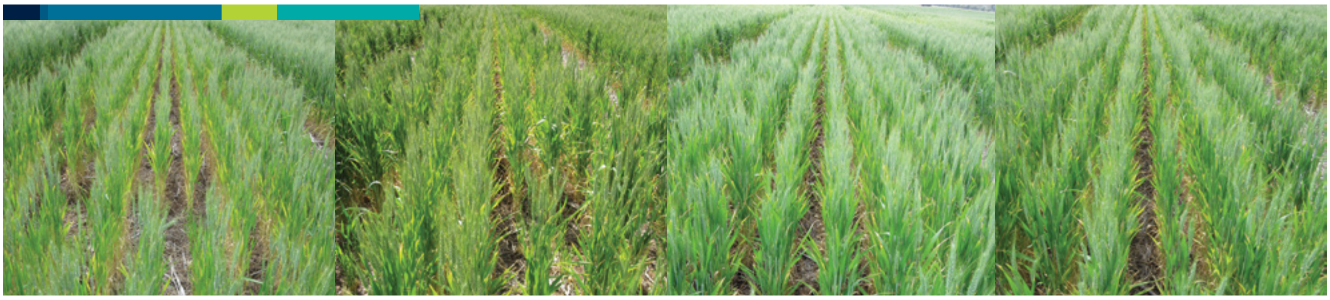
* Mean of two row spacings and four nitrogen treatments

All nitrogen applications produced significant yield and protein gains over the nil-nitrogen plots (Table 17). Nitrogen use efficiency (NUE) was significantly higher when nitrogen was applied at stem elongation, giving the same yields but at higher levels of protein than other timings. This increase in NUE was achieved with significantly fewer tillers/m² than the earlier nitrogen timings.

TABLE 17 Influence of the timing of nitrogen application on plants, tillers and heads, yield and protein for five sets of trial data*

Nitrogen treatment	Canopy composition			Harvest data	
	Plants/m²	Tillers/m²	Heads/m²	Yield (t/ha)	Protein (%)
Nil nitrogen	157.5	304.9	223.7	2.91	8.1
50kg N/ha seedbed	160.2	361.9	250.1	3.74	8.7
50kg N/ha GS30–31	159.5	299.0	239.5	3.78	9.5
50:50 seedbed: GS30–31 split	157.8	322.9	246.6	3.78	9.1
Mean	**158.8**	**322.2**	**240.0**	**3.55**	**8.9**
LSD (5%)	14.1	20.3	10.5	0.2	0.4
P value	0.974	<.001	<.001	<.001	<.001

* Mean of two row spacings and two plant populations



From left to right: Nil nitrogen, 50kg N/ha seedbed, 50kg N/ha GS30–31, 50kg N/ha split 50:50 (seedbed:GS30–31) (target 200 plants/m^2 at the 22.5cm row spacing).

One of the confounding factors in the rotational trials reported in section 5.1 was that the wider row spacing resulted in reduced crop establishment despite similar sowing rates being used in the trial work. This resulted in wider rows having lower plant populations, a factor that influences dry matter production, particularly during the early stages of growth.

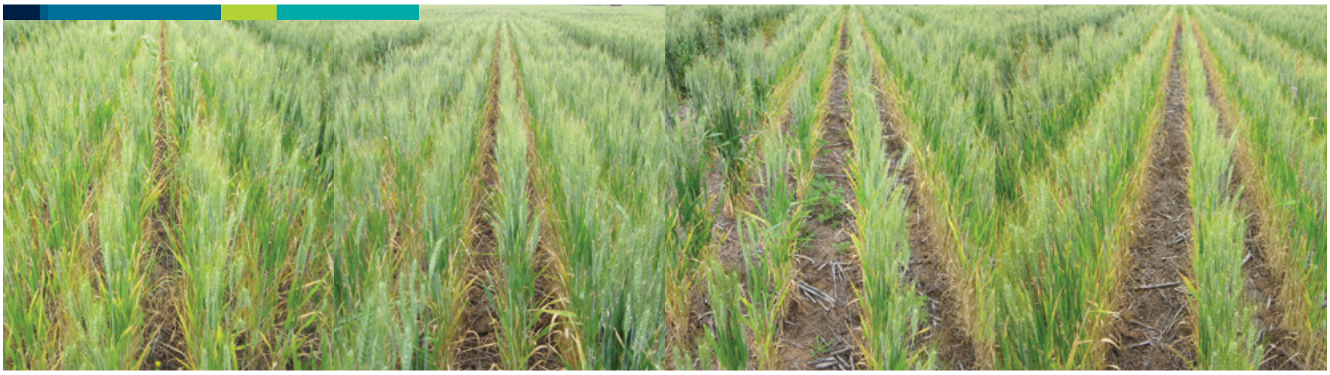
In these canopy management trials the plant population was manipulated, resulting in crops with the same plant populations in the wide and narrow spacings. Table 18 averages indicate that the lower plant population achieved with narrow-row-spaced wheat crops was almost identical to the high plant population achieved with the wider row spacing (average 145 plants/m^2 – 100 target @ 22.5cm vs 148 plants/m^2 200 target @ 37.5cm). With the same plant populations crops sown on wide rows produced significantly fewer tillers and significantly fewer heads at harvest compared with crops sown on the narrow row spacing. These reductions in final ear numbers led to a 0.19t/ha reduction in yield (although not statistically significant).

When lower plant populations (target 100 plants/m^2) were established on the wider row spacing, the yield disadvantage compared with the narrow row spacing at 145 plant/m^2 increased from 0.19t/ha to 0.42t/ha, illustrating that a proportion of the disadvantage of the wider row spacings in the rotational trials (see section 5.1) was the effect of lower plant establishment at sowing.

Increasing plant populations with a narrow row spacing resulted in average plant populations of about 250 plants/m^2. While this resulted in increased tiller and head numbers compared with other row spacing – plant population combinations, it did not increase yield above that achieved with narrow-row-spaced crops established at 145 plants/m^2. The interaction of row spacing and plant population was statistically significant, as the yield response of

TABLE 18 Interaction of plant population, row spacing and the timing of nitrogen application on plants, tillers and ears for five sets of trial data

Target plant population	Nitrogen timing	Canopy composition					
		Established plants/m^2		Tillers/m^2		Heads/m^2	
		Row spacing					
		22.5cm	37.5cm	22.5cm	37.5cm	22.5cm	37.5cm
100 plants/m^2 (low target)	Nil nitrogen	142.8	97.7	328.3	210.1	227.8	181.9
	50kg N/ha seedbed	146.9	98.6	379.1	257.8	255.0	199.0
	50kg N/ha GS30–31	148.3	96.8	337.9	214.4	256.4	196.7
	50:50 seedbed: GS30–31 split	144.2	96.1	340.5	230.5	254.8	209.2
	Mean	**145.6**	**97.3**	**346.5**	**228.2**	**248.5**	**196.7**
200 plants/m^2 (high target)	Nil nitrogen	242.4	147.0	413.8	267.4	279.0	206.1
	50kg N/ha seedbed	248.1	147.3	485.2	325.4	313.0	233.2
	50kg N/ha GS30–31	243.9	149.1	379.4	264.2	289.5	215.4
	50:50 seedbed: GS30–31 split	240.2	150.7	431.6	289.0	291.2	231.4
	Mean	**243.7**	**148.5**	**427.5**	**286.5**	**293.2**	**221.5**
	Mean across both target plant populations	**194.6**	**122.9**	**387.0**	**257.3**	**270.9**	**209.1**
	LSD (row spacing x plant pop^n x nitrogen timing)	28.1		40.6		10.5	
	P value	0.974		0.65		0.01	



Left to right: 22.5cm row spacing target 100 plants/m², 22.5cm target 200 plants/m², 37.5cm target 100 plants/m², 37.5cm target 200 plants/m².

crops sown on wide rows was positive to increasing plant population, while crops sown in narrow rows did not show a yield increase as population increased. The relationship between row spacing and plant population is likely to have been strongly influenced by the very high plant population range established in the narrow-row-spaced crops (145–244 plants/m² compared with 97–148 plants/m² with wide-row-spaced crops).

There were no other significant yield interactions recorded, which indicates that wheat crops sown on wider rows responded similarly to nitrogen application and timing as those sown on narrow rows (Table 19). Overall, the split approach to nitrogen application gave less variable yield results than when all the nitrogen was delayed until stem elongation (GS30–31), even though when averaged across all combinations of row spacing and plant population, the yield of split and all nitrogen at GS30–31 was identical. However, higher grain protein was measured when all the nitrogen was applied at GS30–31. Nitrogen applied at GS30–31 also gave higher NUE than the split application.

TABLE 19 Interaction of plant population, row spacing and the timing of nitrogen application on yield and protein for five sets of trial data

Target pant population	Nitrogen timing	Harvest data			
		Yield (t/ha)		Protein (%)	
		Row spacing			
		22.5cm	37.5cm	22.5cm	37.5cm
100 plants/m² (target)	Nil nitrogen	3.09	2.68	7.9	8.5
	50kg N/ha seedbed	3.79	3.39	8.4	9.2
	50kg N/ha GS30–31	3.96	3.52	9.7	10.0
	50:50 seedbed: GS30–31 split	3.91	3.49	9.0	9.5
	Mean	**3.69**	**3.27**	**8.8**	**9.3**
200 plants/m² (target)	Nil nitrogen	3.08	2.80	7.8	8.3
	50kg N/ha seedbed	3.80	3.97	8.4	8.8
	50kg N/ha GS30–31	3.75	3.40	9.0	9.4
	50:50 seedbed: GS30–31 split	3.91	3.82	9.0	8.9
	Mean	**3.64**	**3.50**	**8.5**	**8.9**
	Mean across the two plant pop^n	3.66	3.38	8.7	9.1
	LSD (row spacing x pop^n)	0.20		0.4	
	P value	0.048		0.555	
	LSD (row spacing x pop^n x nitrogen timing	0.39		0.8	
	P value	0.613		0.837	

Pop^n — plant population

Key points

Grain yields

- The yield disadvantage associated with wider rows — 37.5cm (15 inches) — could be partially overcome by ensuring that reduced plant establishment (a common feature of sowing in wider rows) is compensated for with higher seed rates.
- Plant populations of 125–150 plants/m^2 with wheat provided optimum yields. Yields in wide rows will be reduced if plant populations fall back to 80–100 plants/m^2.
- Even with plant populations in the optimum range, crops sown on 37.5cm (15 inch) rows have restricted ability to tiller and produce viable heads in comparison to wheat crops sown in 22.5cm (9 inch) rows.
- Wider rows reduce the ability of the crop to intercept maximum sunlight per unit area. This reduces dry matter production, which is reflected in decreased tillering and head numbers.
- There was no evidence that the grain yield of wider-row-spaced crops could be improved with specific nitrogen timings in relation to narrow-row-spaced crops.

Grain protein content

- The optimum NUE was achieved when all the nitrogen (50kg/ha) was applied at the start of stem elongation (GS30–31) where crops achieved equal highest yields with significantly higher grain protein.
- There was evidence that despite better NUE when all the nitrogen was applied at GS30–31, yields with the 50:50 split of nitrogen between sowing and GS30–31 were less variable. This result is likely to have been influenced by dry conditions during spring when it is difficult to ensure sufficient rainfall for crop nitrogen uptake.

Top, from left to right: 100 plants/m^2 at 22.5cm row spacing at three-leaves-unfolded stage (GS13), two tillers and the main stem (GS22, start of stem elongation (GS31). Bottom from left to right: Start of booting (GS40), start of flowering (GS61) and start of flowering plus 14 days (GS61+14days).

Case study — Peter White

Farm detail

- Business: P & M White
- Location: Yarrawonga, Victoria
- Farm size: 2000ha
- Soil types: Yarrawonga red clays through to sodic grey clays
- Enterprise mix: 90% crop (six-year rotation) and 10% stock based on self-replacing Bond flock

Cropping enterprise

The White enterprise is a mixed cropping livestock system with 300ha of permanent pastures: some located on the poorer swamp country. This pasture phase has been in for 10–15 years. Peter is now looking to rotate the pasture phase with the cropping phase in order to derive greater benefits from the whole rotation. Until two years ago canola represented 50% of the cropping area. This has now been reduced to 35% as Peter has introduced a second cereal crop. The second cereal is either wheat or barley; the barley allowing a spread of frost risk and the ability to crop top. Farm scale and a return to more typical growing seasons has allowed Peter to go back into pasture after six seasons of cropping (in effect two rounds of canola followed by two cereal crops). Peter has tried peas and lupins but is not growing these crops now. He is interested in the performance of arrowleaf clover as a break crop and likes the weed control opportunities making hay offers.

Farming philosophy

The Whites have farmed at Whites Road Yarrawonga since 1873 and Peter's philosophy is that he would like to ensure his children have the opportunity to farm the land on Whites Road into the future if they would like to do so. He acknowledges it is only through recent injection of capital for land and machinery that this might be possible, due to increased farm size. With regard to his cropping system Peter is concerned about having to buy every input for the system, hence his belief in returning to integrating more pasture.

Sowing equipment

- **Seed drill type**
  Simplicity 9.2m tine-based seed drill with openers spread across four rows for trash flow.
- **Opener**
  Agmaster 12.5cm blade knifepoint drill openers followed by individual press wheels for each coulter. The drill does not use a parallelogram system but speed is the key to getting the best out of the drill openers. Can also apply liquid through the drill openers.
- **Row spacing**
  30cm row spacing

Establishment system

Peter describes himself as a no-till farmer who relies heavily on trifluralin for annual ryegrass control and is therefore open to both burning and cultivation when he has to use these tools to create the conditions for this pre-emergence herbicide to work. This is particularly the case when stubble loads are high. Peter aims to establish canola with 40kg N/ha at sowing and to apply similar amounts to wheat shortly after establishment.

Reason for current row spacing

During 2007, after 15 years of minimal tillage, Peter moved from 17cm row spacing to 30cm row spacing. Strengths of the current row spacing are seen as residue handling and an ability to plant on time. Though the seed drill is not based on a parallelogram system Peter believes slower forward speeds have improved establishment and seed placement. He accepts that the 30cm row spacing is too wide for dry-matter-based crops, such as oaten hay, but when they have been sown they have been sown twice.

Having purchased GPS auto-steer, Peter is looking to move to inter-row sowing, moving over 15cm to establish the next crop.

Crop agronomy

Peter doesn't believe he has had to make any significant changes to his agronomy approach since he went to 30cm row spacing.

5.3 Do crops sown on wider rows perform better when sown earlier?

If crops sown on wider rows intercept less sunlight, due to later canopy closure, which inevitably reduces dry matter production relative to crops with full ground cover, ***what would happen if crops were sown earlier?***

One of the criticisms of the project outlined so far is that all field trials were sown during the mid-May to early-June sowing window. A number of Riverine Plains Inc growers are using very wide rows (up to 45cm) combined with much earlier sowing (mid-April). ***Would this sowing window give different results?***

Since earlier-sown crops produce relatively more growth during autumn it could be argued that earlier-sown crops might create full ground cover much earlier in the season, nullifying any yield disadvantage of wider row spacings.

The Riverine Plains Inc *Maintaining profitable farming systems with retained stubble in the Riverine Plains region* (2013–18) project has enabled questions around early sowing and row spacing to be explored in more detail in two trials: one carried out in Yarrawonga, Victoria and the other at Barooga, NSW.

The trials evaluated four wheat cultivars (Eaglehawk⌽, Lancer⌽, EGA Wedgetail⌽, Bolac⌽) sown at three row spacings (22.5cm, 30cm and 37.5cm). Trials were established during mid-April 2014 (sown 14–15 April) and represented the sowing window used by growers in the region. The sowing window of the two trials detailed in this section were about 4–6 weeks ahead of trials carried out as part of the *Improved water use efficiency* (WUE) project outlined in earlier sections of this report.

Wheat cultivar snapshot

Wedgetail⌽

- 20-year-old true winter wheat cultivar, popular with growers wanting to start sowing programs during late March and April.

Eaglehawk⌽

- Spring wheat with a longer stem elongation development period (GS30–61) when sown earlier.

Lancer⌽ and Bolac⌽

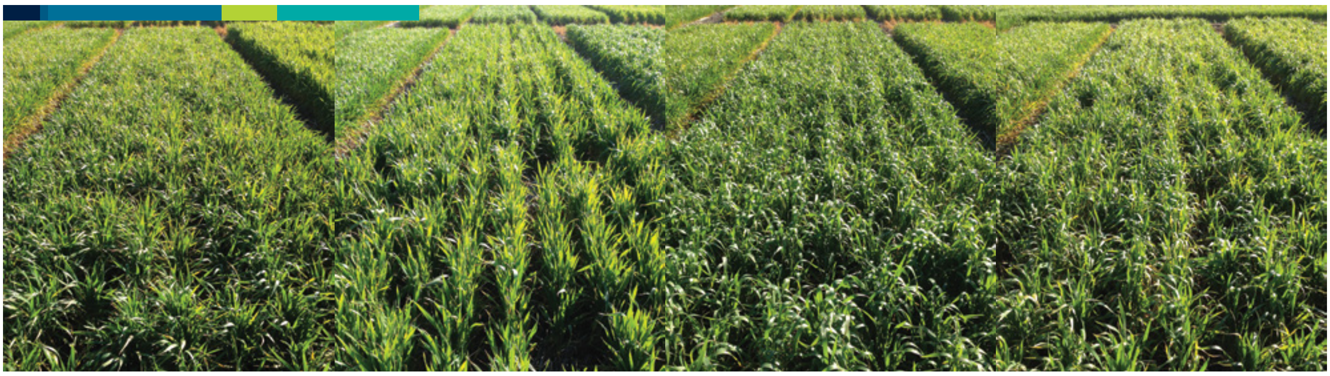
- Longer-season spring wheat cultivars.

Yarrawonga, Vic

At the Yarrawonga site similar plant populations (100–112 plants/m^2) were established across the different row spacings (Table 20 page 34). Different numbers of tillers were produced, with narrow-row-spaced crops producing significantly more tillers than those sown on the wider row spacing. The reduced tillering associated with the wider row spacing was observed with the later sowing window as previously described (see section 5.1).

The four wheat cultivars also produced significantly different tiller populations with Wedgetail⌽ producing the highest tiller numbers at early stem elongation (GS31–32). Eaglehawk⌽ and Lancer⌽ produced the lowest tiller populations, which followed through to the head counts at harvest. There was no difference in the head numbers as a result of row spacing.

Dry matter production at the Yarrawonga trial site showed no difference at the start of stem elongation (GS31–32) as a result of row spacing, however by flowering (GS60–69) and at harvest there was a significant advantage with the 22.5cm narrow row spacing over the 30cm and 37.5cm spacings (Figure 6).



Left to right: 22.5cm row spacing in Wedgetail⌽, Bolac⌽, Lancer⌽ and Eaglehawk⌽ at second node detectable (GS32).

TABLE 20 Influence of row spacing and cultivar on plant establishment assessed 13 May at three-leaf stage (GS13), tillers assessed at the start of stem elongation (GS31–32) and heads at harvest, Yarrawonga, Victoria.

Row spacing (cm)	Cultivar	Canopy composition		
		Plants/m^2	Tillers/m^2	Heads/m^2
22.5		101.3	358.8	359.5
30.0		112.8	319.4	321.1
37.5		105.9	287.7	317.9
Mean		**106.7**	**321.9**	**332.8**
LSD (5%)		5.0	19.0	59.3
P value		0.004	<0.001	0.240
	Bolac$^{\phi}$	110.0	337.3	352.2
	Eaglehawk$^{\phi}$	94.9	299.3	305.6
	Lancer$^{\phi}$	107.0	281.2	300.8
	Wedgetail$^{\phi}$	114.7	369.9	372.7
	LSD (5%)	14.5	25.8	32.3
	P value	0.055	<0.001	<0.001

Note: actual growth stages at tiller assessment to account for varietal differences; Bolac$^{\phi}$ and Lancer$^{\phi}$ GS39, Wedgetail$^{\phi}$ and Eaglehawk$^{\phi}$ GS33

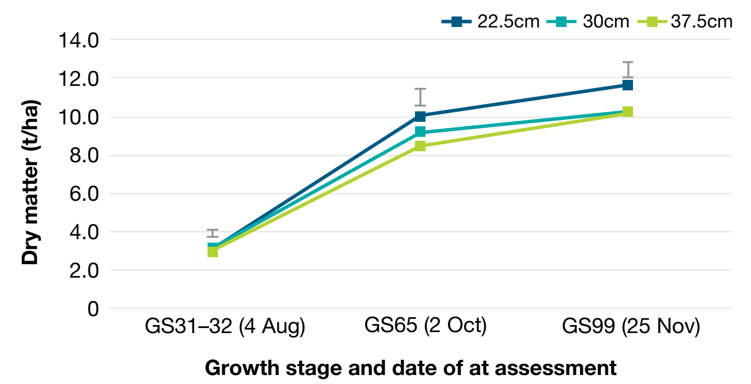


FIGURE 6 Influence of row spacing on dry matter production*
* Mean of four cultivars
Error bars represent LSD

the 22.5cm and 30cm row spacings was less than 0.1t/ha and again was not significant.

There is some suggestion from the screenings results that Bolac$^{\phi}$ and Eaglehawk$^{\phi}$ may have been affected by frost (Table 21).

There was no significant yield interaction between cultivar and row spacing. Other than the effect on screenings and test weight, there were no significant effects of row spacing or cultivar on grain quality.

Effect on water use efficiency (WUE)

When crop canopies were compared for their WUE, the most noticeable features were that significantly higher dry matter produced on the narrow row spacing led to significantly more water being used by the crop (calculated transpiration use) than on wider row spacings (Table 22). However, the higher biomass of the crops grown on the narrow row spacing did not translate into higher grain yields, leading to significantly lower HI and calculated TE. Despite the advantages of the wider row spacing in terms of HI and calculated TE there were no significant differences in calculated WUE due to row spacing since wider rows were calculated to have lost significantly more water through soil evaporation (and other unused water).

The cultivar effect on dry matter (mean of three row spacings) was significant early on with Bolac$^{\phi}$ (more advanced development at GS32) showing the highest dry matter. No differences were evident among any of the cultivars by harvest (see Figure 7).

Yield effect of row spacing and cultivar when the crop was sown early

There was no difference in yield due to row spacing, however there was a trend for crops grown on the 30cm row spacing to be higher yielding than those on the 37.5cm spacing, although the 0.3t/ha difference was not significant. The difference between

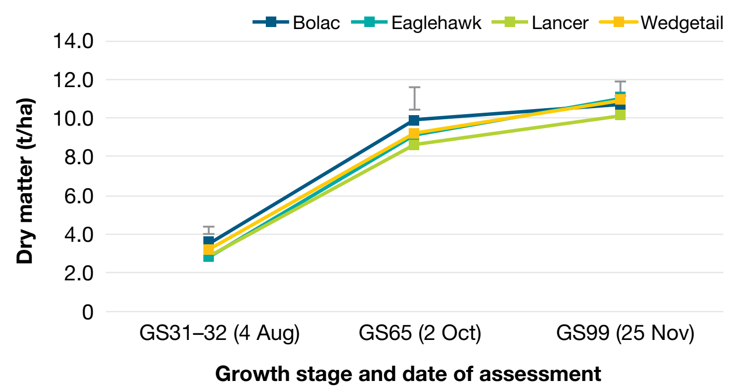


FIGURE 7 Influence of cultivar on dry matter production*
* Mean of three row spacings
Error bars represent LSD
Note: small differences in development on the day of assessment at stem elongation and flowering may have meant slightly more advanced cultivars gave higher dry matter

Left to right: 30cm row spacing in Wedgetail[PBR], Bolac[PBR], Lancer[PBR] and Eaglehawk[PBR] at flowering (GS65).

TABLE 21 Influence of row spacing and cultivar on yield and grain quality

Row spacing (cm)	Cultivar	Yield and grain quality			
		Yield (t/ha)	Protein (%)	Screenings (%)	Test weight (kg/hl)
22.5		4.49	12.1	6.8	74.6
30.0		4.55	12.2	7.0	75.9
37.5		4.27	12.4	7.1	75.9
Mean		**4.44**	**12.2**	**7.0**	**75.5**
LSD (5%)		0.29	0.3	2.1	2.4
P value		0.109	0.382	0.947	0.400
	Bolac[PBR]	4.01	12.4	11.5	72.6
	Eaglehawk[PBR]	4.23	12.1	10.8	76.4
	Lancer[PBR]	4.73	12.4	2.6	79.5
	Wedgetail[PBR]	4.79	12.2	3.0	73.3
	LSD (5%)	0.28	0.3	2.4	2.3
	P value	<.0001	0.35	<.0001	<.0001
Interaction		0.588	0.758	0.609	0.643

TABLE 22 Average biomass at harvest, yield, harvest index (HI), water use efficiency (WUE), transpiration, evaporation/drainage and transpiration efficiency (TE)

Row spacing (cm)	Biomass (t/ha)	Yield[5] (t/ha)	HI (%)	WUE[1] (kg/mm)	Transpiration[2] (mm)	Evaporation[3] (mm)	TE[4] (kg/mm)
22.5	11.64	3.93	34.2	10.9	211.7	148.1	18.8
30.0	10.28	3.98	38.9	11.1	186.9	172.8	21.4
37.5	10.14	3.73	37.0	10.4	184.3	175.5	20.4
Mean	**10.69**	**3.88**	**36.7**	**10.8**	**194.3**	**165.5**	**20.2**
LSD (5%)	5.36	0.50	0.7	0.7	4.6	4.6	0.0
P value	0.007	0.109	0.053	0.109	0.007	0.007	0.053

[1] — Numbering relates to the list of assumptions outlined prior to Table 9 (page 22)

Available soil water calculated for Yarrawonga trial site

Year	Site	GSR (mm)	Calculated soil water available on April 1 (mm)	Total soil water available (mm)
2014	Yarrawonga	320.1	39.7	359.8

Barooga, NSW

In the second trial at Barooga, NSW the results were similar, with row spacing effects being relatively small in terms of established plant populations (117–130 plants/m²), with significantly higher tiller numbers where narrow rows were established (Table 23). The differences in tiller numbers did not lead to higher head numbers with crops grown on the narrow row spacing. These differences in canopy composition were reflected in dry matter production, with a non-significant trend for the narrow row spacing to produce more dry matter (Figure 8).

Canopy composition differences between cultivars were the same as in the Yarrawonga trial, with Bolac⁽ᴾ⁾ and Wedgetail⁽ᴾ⁾ having significantly greater plant populations than Eaglehawk⁽ᴾ⁾ and Lancer⁽ᴾ⁾, which followed through to increased tillers and head numbers (Table 23). Significant differences in dry matter as a result of cultivar were evident at harvest, with more than a tonne per hectare difference in dry matter production between the highest (Wedgetail⁽ᴾ⁾) and the lowest (Eaglehawk⁽ᴾ⁾) (Figure 9).

Yield effect of row spacing and cultivar when crop was sown early

Row spacing had no significant effect on yield in this trial when the wheat was sown early (mid-April), despite the higher dry matter recorded at harvest with the narrowest 22.5cm rows (Table 24). The 37.5cm row spacing yielded 0.2t/ha less than the 30cm row spacing but the difference was not significant. Eaglehawk⁽ᴾ⁾ was significantly lower yielding than the other cultivars. There was no interaction between row spacing and cultivar, indicating in this trial that the effect of altering row spacing was the same for all four cultivars.

TABLE 23 Influence of row spacing and cultivar on plant establishment assessed 13 May at three-leaf stage (GS13), tillers assessed at the start of stem elongation (GS31–32) and heads at harvest, Barooga, NSW

Row spacing (cm)	Cultivar	Canopy composition		
		Plants/m²	Tillers/m²	Heads/m²
22.5		130	421	349
30.0		130	410	325
37.5		117	351	324
Mean		**126**	**395**	**333**
LSD (5%)		12	33	32
P value		0.056	0.005	0.175
	Bolac⁽ᴾ⁾	138	411	376
	Eaglehawk⁽ᴾ⁾	118	338	284
	Lancer⁽ᴾ⁾	106	343	313
	Wedgetail⁽ᴾ⁾	142	485	358
	LSD	12	46	39
	P value	<0.000	0.000	0.000

Note: actual growth stages at tiller assessment to account for varietal differences; Bolac⁽ᴾ⁾ and Eaglehawk⁽ᴾ⁾ GS32, Wedgetail⁽ᴾ⁾ GS31 and Lancer⁽ᴾ⁾ GS32

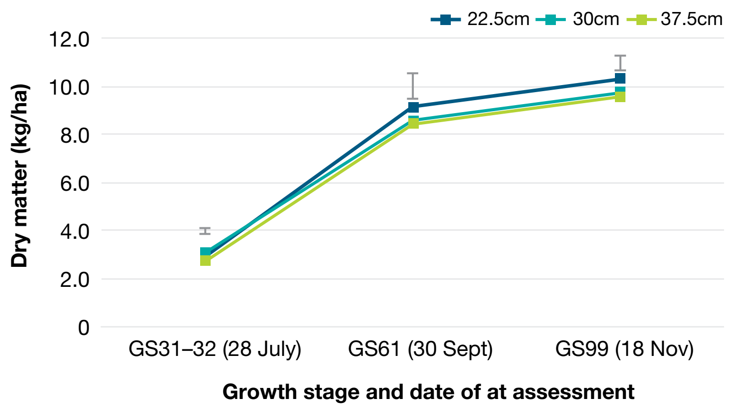


FIGURE 8 Influence of row spacing on dry matter production*
* Mean of four cultivars
Error bars represent LSD

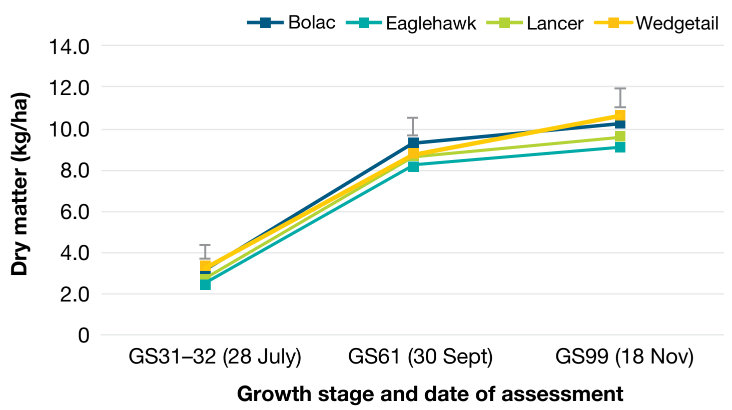


FIGURE 9 Influence of cultivar on dry matter production*
* Mean of three row spacings
Error bars represent LSD

TABLE 24 Influence of row spacing and cultivar on yield and grain quality

Row spacing (cm)	Cultivar	Yield and grain quality Yield (t/ha)	Protein (%)	Screenings (%)	Test weight (kg/hl)
22.5		3.85	11.8	2.8	77.5
30.0		3.98	11.9	2.7	78.9
37.5		3.78	11.8	2.6	79.2
Mean		**3.87**	**11.9**	**2.7**	**78.5**
LSD (5%)		0.20	0.7	0.2	1.8
P value		0.107	0.967	0.253	0.133
	Bolac⦹	4.14	11.2	3.4	79.9
	Eaglehawk⦹	3.28	12.4	3.2	78.5
	Lancer⦹	4.02	12.0	2.2	80.2
	Wedgetail⦹	4.05	11.9	2.0	75.5
	LSD (5%)	0.17	0.6	0.4	2.0
	P value	<0.001	0.004	<0.001	0.000
Interaction		0.282	0.967	0.575	0.420

Left to right: 37.5cm row spacing in Wedgetail⦹, Bolac⦹, Lancer⦹ and Eaglehawk⦹ at crop maturity (GS99).

There were no significant effects of row spacing on the grain quality parameters of protein, test weight or screenings in this early-sown wheat trial, however Bolac⊕ recorded significantly lower protein, Bolac⊕ and Eaglehawk⊕ recorded significantly higher screenings and Wedgetail⊕ recorded the lowest test weights.

Effect on water use efficiency (WUE)

There were no differences in WUE due to row spacing when yield and crop canopy dry matter was considered (Table 25). The comparisons of HI and other calculated parameters of transpiration, evaporation and TE showed similar trends (non-significant) to the rotational trials at Coreen and Bungeet, with the crops grown on the narrow row spacing exhibiting higher dry matter production, however it did not translate into higher grain yields with the earlier sowing window.

Key points*

Grain yields

- The yield disadvantage associated with wider rows (30–37.5cm or 12–15 inches) compared with the narrow rows (22.5cm or 9 inches) in wheat crops sown during late May – early June was not observed with wheat sown during mid-April.
- Though the yield differences were not statistically significant, there was still a trend for crops grown on the 37.5cm (15 inch) row spacing to yield less than those on the 30cm (12 inch) spacing (0.2–0.3t/ha less).
- Crops grown on the 30cm (12 inch) row spacing yielded the highest at both sites, despite significantly less dry matter at harvest, however the yield advantage over 22.5cm (9 inches) averaged less than 0.1t/ha and was not significant.

Grain protein content

- There were no significant effects of row spacing on grain quality.

Water use efficiency

- There were no significant differences in WUE due to row spacing.
- Significantly higher dry matter production with crops grown on the narrow row spacing did not translate to more yield compared with those on the wider row spacing, due to lower HI.
- Although crops grown on the wider row spacing appeared to result in more efficient grain production per millimetre of water transpired through the plant (TE), this effect was negated by calculations indicating greater water losses though soil evaporation or unused water in crops on the wider rows.

*Caution: only one year of results

TABLE 25 Average biomass at harvest, yield, harvest index (HI), water use efficiency (WUE), transpiration, evaporation/drainage and transpiration efficiency (TE)

Row spacing (cm)	Biomass[1] (t/ha)	Yield[1] (t/ha)	HI[2] (%)	WUE[3] (kg/mm)	Transpiration[4] (mm)	Evaporation[5] (mm)	TE[6] (kg/mm)
22.5	10.32	3.37	33.0	9.8	187.7	156.8	18.1
30.0	9.71	3.49	36.4	10.1	176.6	167.9	20.0
37.5	9.60	3.31	34.6	9.6	174.5	170.0	19.0
Mean	**9.88**	**3.39**	**34.7**	**9.8**	**179.6**	**164.9**	**19.1**
LSD (5%)	0.64	0.17	2.8	0.5	11.6	11.6	1.5
P value	0.065	0.106	0.067	0.108	0.065	0.065	0.067

[1] — numbering relates to assumptions outlined after Table 9 (page 22)

Available soil water calculated for Barooga trial site

Year	Site	GSR (mm)	Calculated soil water available on April 1 (mm)	Total soil water available (mm)
2014	Barooga	315.1	29.4	344.5

Case study — Denis Tomlinson

Farm detail

- Business: Tomlinson Ag
- Location: Daysdale, NSW
- Farm size: 3000ha
- Soil types: Clay loams ranging to sodic clays, generally acidic top soil
- Enterprise mix: 100% cropping with no livestock component

Cropping enterprise

Tomlinson Ag is a 100% cropping-based operation on no-till full stubble retention (NTSR). The rotation is based on canola or faba beans as the primary break crop followed by three cereal crops: wheat, wheat and then barley. The farming system is designed to return crop residues to the soil, preserve soil moisture and protect soils from erosion and compaction.

Farming philosophy

With little margin for error in farming, Denis' philosophy is to endeavour to make sure that whatever you do you try to do it well. The business' profitability is based on looking after soil health, so no-till establishment and stubble retention is central to the farming system, maximising soil organic matter levels. Denis' farm philosophy is to maximise annual ryegrass control wherever possible using diverse herbicide chemical groups and crop competition. With the farm having capital infrastructure based on 100% cropping Denis recognises there is not the opportunity for employing livestock or a pasture phase to control herbicide-resistant ryegrass.

Sowing equipment

- **Seed drill type**
  15.3m Auseeder knifepoint DBS system based on three ranks of drill openers.
- **Opener**
  Standard 15cm DBS tine openers based on a parallelogram seed placement system with press wheels.
- **Row spacing**
  30cm row spacing

Establishment system

Denis describes the farm establishment system as no-till rather than zero-till, since it is based on a tine opener as opposed to disc. Full stubble retention is the standard farm practice. Occasionally Denis burns paddocks when stubble levels are extremely heavy or there are problems with the drill autosteer system preventing inter-row sowing the following crop. Achieving even distribution of crop residues off the header is difficult with the 13.5m cutting width. In order to minimise the quantity of crop residue chopped and spread, crop stubble heights are set at 25cm.

Reason for current row spacing

Denis finds that a 30cm row spacing maximises his opportunity to retain crop stubbles while allowing residue to flow through the sowing equipment. It allows the two subsequent crops to be sown 10cm from the stubble of the previous crop. The wider row spacing also allows faster forward speeds when incorporating trifluralin herbicide, without damaging levels of the herbicide getting into the neighbouring drill row. When Denis adopted the 30cm row spacing, trial information suggested that wider rows yielded no differently to narrower spacing (17.5cm).

Denis plans to move to a 25cm row spacing in order to improve yield and to allow crops to outcompete the ryegrass. He recognises this will require a more accurate method of inter-row sowing, possibly with the use of discs.

Crop agronomy

Denis sees early nitrogen as an essential element of his farming system, using 30cm row spacing, particularly under low soil fertility. Canola receives 30–40kg N/ha at sowing while cereals receive nitrogen during tillering.

6.0
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