Research for the

Riverine Plains 2019

A selection of research relevant to agriculture in the Riverine Plains

20 YEARS 1999–2019

Farmers inspiring farmers



Research for the
Riverine Plains 2019

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

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RiverinePlains 20 YEARS 1999–2019

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Welcome

Welcome to the 2019 edition of Research for the Riverine Plains.

During 2018 Riverine Plains Inc had a much smaller research program compared to previous years. Coming off the back of a record year of research in 2017, this year's edition is more compact, reflecting our greater involvement in extension projects over the past year, as well as the impact of the dry conditions and frost on regional trials.

With that said, the 2019 trial book contains articles from the Riverine Plains Inc and GRDC project *Optimising canola nutrition in the southern region of NSW*, several small plot trials hosted at the Riverine Research Centre (RRC), and the GRDC funded Subsoil acidity project. We have also continued our support of novel PhD student research from the Dookie Campus of The University of Melbourne.

We sincerely thank Michael Straight and Nick Poole, FAR Australia for their reports on the Riverine Plains Inc Rapid Results trial on winter wheat germplasm and the LaTrobe University led project *Development of crop management packages for early sown, slow-developing wheats in the Southern region* project.

On behalf of Riverine Plains Inc, I would like to thank all authors for sharing their results with our members. A special thank you to the Riverine Plains Inc staff for their contribution to this publication, especially Michelle Pardy for her work in pulling it together, and to sub-editor Catriona Nicholls and graphic designer Josephine Eynaud in preparing the trial book for print.

We hope you enjoy reading your copy of *Research for the Riverine Plains 2019* and wish you all the best for the remainder of the 2019 cropping season.

Dr Cassandra Schefe
Research Coordinator, Riverine Plains Inc.

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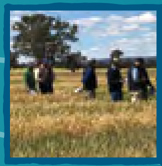

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Units of measurement

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

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

TABLE 1 Row spacing conversions

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

Standard units of measurement

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

centimetres — cm

gigahertz — GHz

hectares — ha

hectolitres — hL

kilograms — kg

kilojoules — kJ

litres — L

metres — m

millimetres — mm

tonnes — t

Cereal growth stages

Why are they important to cereal growers?

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

Zadoks cereal growth stage

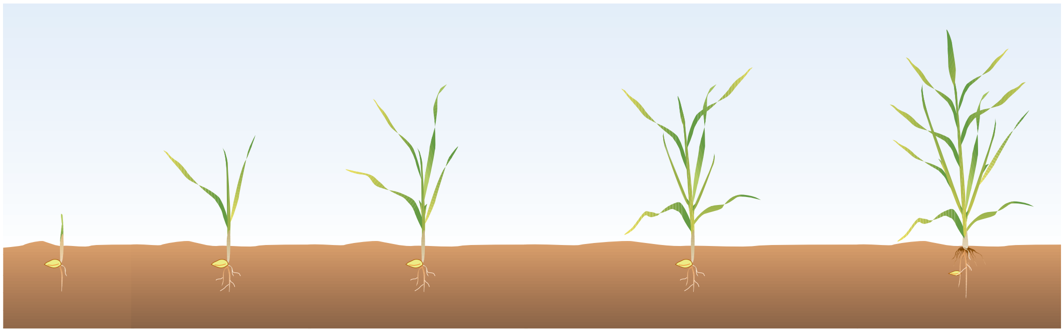
The most commonly used growth stage key for cereals is the:

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

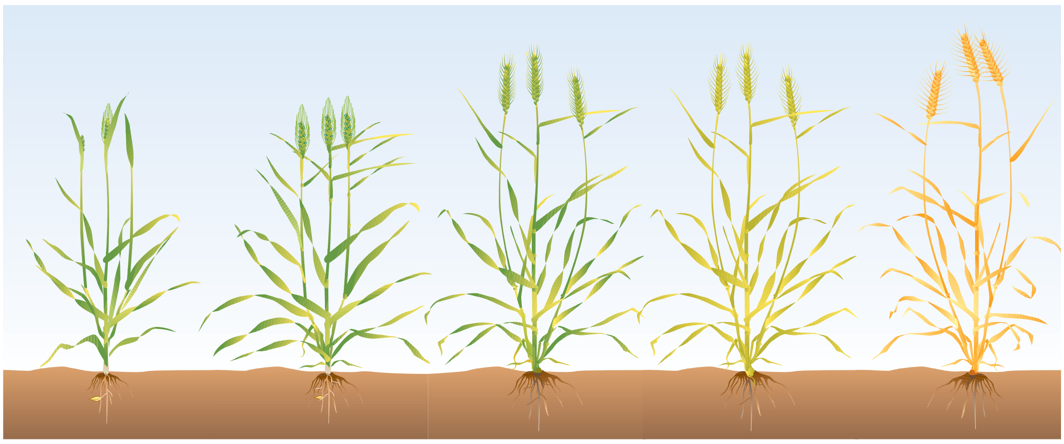
Within each of the 10 development phases there are 10 individual growth stages, for example, in the seedling stage:

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

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



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



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



Preface

Trials versus demonstrations — what the results mean

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

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

Statistical tests, for example, analysis of variance (ANOVA) and, least significant difference (LSD), are used to measure the difference between the averages. A statistically significant difference is one in which we can be confident that the differences observed are real and not a result of chance. The statistical difference is measured at the 5% level of probability, represented as 'P<0.05'.

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

TABLE 1 Example of a replicated trial with four treatments

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

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

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

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



A word from the Chairman

Ian Trevethan
Chairman, Riverine Plains Inc

Welcome to the 2019 edition of *Research for the Riverine Plains*.

The year in review 2018–19

I always find it difficult to summarise a season across such a wide geographic area. For some the 2018–19 season was an absolute disaster and one that our grandkids will hear about 40 years on. For others, who were fortunate enough to snag some timely rains, the strong commodity prices meant that the season served them very well financially. I think the 2018–19 season will be remembered for the stark contrast between the eastern and western regions and the relative financial performance of those businesses that got enough rain and those that didn't.

Luck plays a big part in determining the fortunes of farming business but so too does good management. Farming systems have evolved over the decades to adapt to the challenges of farming in the Australian climate. Practices like early sowing, stubble retention, the use of winter varieties and controlled traffic are now common-place, and all play their part in helping make the most of the season that mother nature dishes up. Australian farmers are amongst the most efficient in the world and will need to continue to evolve and adapt to prosper in an increasingly volatile climate.

Farming systems groups like Riverine Plains Inc play a vital role in validating cutting edge research at a local level, so that growers can continue to evolve and adapt their businesses with confidence. Our group prides itself on the quality of our research and extension programs, and I would especially like to thank members, sponsors and friends of the group for their continued support of our project activities as well as our stand-alone events.

2018 Extension summary

During 2018, Riverine Plains Inc delivered over 21 separate events as part of our extension program. Some of these events were run as part of our project work, some formed part of our regular event schedule, while others were delivered simply because we felt they were of value to our members. Delivering an extension program of this size requires lots of behind-the-scenes organisation and support. Special thanks to Executive Officer Fiona Hart, Extension sub-committee chair Adrian Clancy, our Research Coordinator, Cassandra Schefe, as well as all the sub-committee members for their efforts.

Sykesy's Buraja Meeting — 1 February

Over 100 people attended the annual *Sykesy's Buraja Meeting* at the Buraja Recreation Reserve Hall. This long-standing and highly valued community event saw the audience participate in a 2017 harvest debrief before hearing about the performance of wheat, barley and canola varieties in local trials and grain commodity markets.

Farmers inspiring farmers

GRDC Grains Research Update — 15 February

Hosted by Riverine Plains Inc, over 120 people attended the 2018 Corowa GRDC Grains Research Update. Presentations included; nitrogen dynamics in modern cropping systems, Riverine Plains Inc local research outcomes, productivity constraints in dryland systems, inoculant survival on acid soils and canola agronomy.

Soil Pit Days — February 2018

Riverine Plains Inc held 4 soil pit sessions during February, attended by 65 people in total. The sessions were facilitated by Cassandra Schefe, with soil pits being used to demonstrate local soil characteristics as well as the effects of water and nutrient movement last season.

- The **Miepoll and Bungeet Soil Pit** events were held on 6 February 2018 through the *Improving fertiliser and chemical use through local, real time weather and soil information for farmers of the productive plains* project. This project was supported by Goulburn Broken CMA, through funding from the Australian Government's National Landcare Program.
- The **Rand Soil Pit** event was held on 8 February 2018 through the *Linking nutrient movement to soil at weather stations in the Murray Region* project, supported by the Murray Local Land Services through funding from the Australian Government's National Landcare Program.
- The **Rutherglen Region Soil Pit and Weather Station** tour was held on 23 February 2018 and was a *Soil Moisture Probe Network Project* event (a partnership between Riverine Plains Inc and Boorhaman Landcare Group). This project was supported by North East CMA through funding from the Australian Government's National Landcare Program.

Agribusiness Dinner and Launch of the John Hanrahan Scholarship — 2 March, Corowa

An Agribusiness Dinner, hosted by Riverine Plains Inc at Corowa RSL, saw 165 people come together to help celebrate the families, communities and businesses involved in agriculture, as well as to participate in the official launch of the John Hanrahan Scholarship. Rural Bank Managing Director and CEO, Alexandra Gartmann, spoke about her own leadership journey as well as Rural Bank's Scholarship Program. The evening included a food and wine display which showcased the diverse range of produce originating from north east Victoria and southern NSW. Produce featured in the display was donated by local businesses, and then sold in hampers to raise monies in support of the continuation of the Scholarship Fund.

GRDC Southern Pulse Check Discussion Group Meeting — 7 March, Dookie

A pre-sowing Pulse Check Discussion Group meeting was held at Dookie, attended by 14 people. Phil Bowden, Pulse Australia, spoke on pulse marketing and production issues including paddock and variety selection, herbicide options, inoculant use and early nutrition.

Advanced Spray Course — 19 June, Oaklands

20 people attended the AgSkilled Advanced Spray Course at Oaklands, facilitated by Craig Day of Spray Safe and Save.

Stubble Project Paddock Walk — 21 June, Burramine

The final paddock walk for the GRDC *Stubble project* was held at the Riverine Research Centre at Burramine and was attended by around 35 people. Michael Straight (FAR Australia) and Dr Cassandra Schefe (Riverine Plains Inc) discussed the results from five years of trials comparing different stubble management strategies on crop growth and development, as well as key findings from small plot trials investigating the impact of stubble on row spacing, nitrogen application, yellow leaf spot and plant growth regulators.

GRDC Business Update — 27 June, Mulwala

Approximately 80 people attended the GRDC Farm Business Update at Mulwala. The audience heard from Brad Knight (GeoCommodities) on the benefits of on-farm storage while Phil O'Callaghan (ORM Pty Ltd) discussed potential ways to increase profitability on farms. Leo Delahunty (Templemore Partners) discussed succession planning and Paul Higgins (Emergent Futures) spoke on how to think about emerging technologies.

GRDC Southern Pulse Check Discussion Group — 16 July, Devenish

Around 15 farmers and advisors took part in the first pulse check discussion group paddock walk for the season. The paddock walk involved visits to chickpea and faba bean crops in the Devenish area, with good discussions had around establishment, weed control, pollination and marketing.

Spotlight on Canola Systems Field Day — 26 July

The event was attended by 46 people and included visits to the Riverine Plains Inc farmer scale Canola Systems Trial at Daysdale, as well as the GRDC and Riverine Plains Inc *Optimising crop nutrition in canola in the southern region of NSW* project sites at Coreen and Howlong.

In-Season Update — 9 August, Mulwala

Around 65 people attended the annual Riverine Plains Inc In-Season Update. Kate Coffey and Ian Trevethan (Riverine Plains Inc) presented local results from a GRDC project on



harvest weed seed control techniques before Mark Day spoke on his experiences with harvest weed seed control and incorporating stubble management into his program. Cassandra Schefe (Riverine Plains Inc) and Michael Straight (FAR Australia) gave a local research update and Dale Grey provided an update on the key climate indicators for the coming season. A panel session featuring Chris Minehan (Rural Management Strategies), Rob Inglis, (Elders) and Adam Inchbold (Yarrawonga), addressed dry season management options for failed crops as well as livestock considerations.

GRDC Southern Pulse Check Discussion Group — 3 September, Bungeet

Around 30 growers and advisors attended a Pulse Check canopy closure crop walk at Bungeet. Faba bean, chickpea and lentil paddocks were inspected, with discussions focussing on spring-time management. Guest speaker was Helen Burns, who along with Jason Condon (both NSW DPI), spoke on pH stratification and how this affects production potential.

Riverine Research Centre Open Day — 27 September, Burramine

Cereal Agronomy was the focus of the Riverine Plains Inc and FAR Australia Riverine Research Centre Open Day at Burramine, attended by around 70 people. A panel, comprising Michael Straight, Nick Poole (FAR Australia) and James Hunt (La Trobe University) spoke on the impact of the late-August frosts, which was then followed by Rachel Coombes (Agriculture Victoria) and Ian Trevethan (Riverine Plains Inc) who discussed the Riverine Plains Inc early-sown wheat trials. James Hunt then spoke on winter wheats while Michael Straight and Nick Poole discussed the potential for winter barley. Dr Maarten van Helden (SARDI) addressed concerns around Russian Wheat Aphid, while Eric Watson (Canterbury, New Zealand) described his farming systems and how he achieved his 16.79t/ha world record wheat crop.

GRDC Spray Technology Workshops — 13 & 14 September, Dookie and Rutherglen

Riverine Plains Inc hosted two GRDC Effective Spray Application Workshops, attended by a total of 44 people. The half-day workshops were presented by Bill Gordon (Bill Gordon Consulting) to assist farmers enhance the performance of their sprayers, improve their spray applications and get equipped with new information regarding 2,4-D label changes.

Inaugural Crop Competition — 19 October

Tony Chaston of Gerogery was announced as the winner of the Riverine Plains Inc inaugural crop competition at the Baker Seed Co Annual Field Day. His outstanding paddock of RGT Accroc wheat earned him 5 tonnes of new proprietary cereal seed valued at $5,000, kindly provided by crop competition sponsor, Baker Seed Co.

GRDC Northern Pulse Check Discussion Group — 26 October, Rand

38 people attended the inaugural meeting of the Riverine Plains Inc Northern GRDC Pulse Check Discussion Group. Roy Hamilton provided a farmer's perspective on pulses while James Madden (Madden Consulting) spoke on the positive and negatives of pulse production, as well as harvesting issues. Phil Bowden (Pulse Australia) spoke on pulse marketing and harvester fire safety, while Gary Drew (Lupins for Life) discussed value-adding. The meeting also involved visits to faba bean and lentil paddocks.

GRDC Southern Pulse Check Discussion Group — 25 October, St James

The final GRDC Southern Pulse Check paddock walk for the year was attended by 14 people. Chickpea and vetch crops were inspected, with discussions covering dessication, grazing pulses, pulses for soil health, harvesting and fire management. Guest speakers included Phil Bowden (Pulse Australia), Alison Frischke (BCG) and Cassandra Schefe (Riverine Plains Inc).

The Evan Moll Gerogery Field Day — 8 November, Gerogery

Around 55 people attended this highly regarded annual field day. Topics included grain markets, forage options and seed availability, dual purpose wheat, as well as the cereal and canola National Variety Trials.

Research summary

A number of Riverine Plains Inc research and extension projects were completed during 2018.

These included the GRDC investment *Maintaining profitable farming systems with retained stubble in the Riverine Plains region* project (we are currently working on a summary publication), the *Sustainable Agriculture Victoria: Fast-tracking Ag Innovation initiative*, made possible with the support of the Foundation for Rural and Regional Renewal (FRRR) together with the William Buckland Foundation, along with the GRDC investment *Harvest weed control in the southern region* project.

Other projects that finished during 2018 included *Improving fertiliser and chemical use through local, real time weather and soil information for farmers of the productive plains,* the *Refining deep soil nitrogen testing to reduce environmental losses* and *Soil moisture information for greater seasonal confidence in cropping*, supported by the Goulburn Broken Catchment Management Authority through funding from the Australian Government's National Landcare Program.

The *Linking nutrient movement to soil moisture at weather stations in the Murray and Riverina Region* projects, funded by Murray Local Land Services and Riverina Local Land Services through funding from the Australian Government's National Landcare Program, were also concluded.

While 2018 saw a number of projects conclude, it also saw a number of new research and extension projects begin. This included the commencement of trial work for the *Innovative approaches to managing subsoil acidity in the southern grain region* project, funded by NSW Department of Primary Industries with financial support from the GRDC, as well as our delivery of the *Australian Cool Farm Initiative* in partnership with the Sustainable Food Lab and Mars Petcare. We also commenced the GRDC investment *Increasing the effectiveness of nitrogen fixation in pulse crops through extension and communication of improved inoculation and crop management practices in the southern region* project, the *GRDC Pulse Check — local extension and communication for profitable pulse production in South East NSW* project and the Goulburn Broken CMA *From the Ground Up — Understanding subsoil acidity in cropping enterprises of the productive plains* project.

Our involvement in the GRDC investments *Optimising crop nutrition in canola in the southern region of NSW* and the *Southern pulse extension project* through the *Riverine Plains Inc Pulse Check Discussion Group,* also continued during 2018.

Excitingly, 2019 sees the beginning of a suite of new research projects as part of the Co-Operative Research Centre for High Performing Soils (Soil CRC) including; *Plant based solutions to improve soil performance through rhizosphere modification*, *Improving the representation of soil productivity/constraints in existing decision support systems and modelling platforms, Understanding adoptability of techniques and practices for improved soil management* and the *Mechanistic understanding of the mode to action of novel soil re-engineering methods for complex chemical and physical constraints* projects. We look forward to being able to report on these projects in next year's edition.

High-quality farmer-driven research remains at the core of what we do here at Riverine Plains Inc and I'd like to thank the Research sub-committee, chaired by John Bruce, along with our Research Coordinator, Cassandra Schefe, for their efforts in managing our research program and in submitting ideas for new projects. I'd also like to thank all of our farmer co-operators for their ongoing work and support of our research, as well as the Riverine Plains Inc staff members involved in writing and administering project applications and our reporting requirements.

Riverine Research Centre (RRC)

During 2019, the RRC features, for the second year, a Riverine Plains Inc variety by sowing date evaluation based on late March – early April and late April – early May sowing dates incorporating 10 wheat cultivars. These trials, funded by Riverine Plains Inc working in collaboration with FAR Australia, will form the basis of a rapid results service to Riverine Plains Inc members on variety performance in the region. The research builds on the 2017 and 2018 work completed as part of GRDC's Management of Early Sown Wheat project, with a wider range of cultivars, some drawn from the GRDC Hyper Yielding Cereal project.

Other trials sown at the RRC include the final year plots for the GRDC Management of Early Sown Wheat trials, SARDI Russian wheat aphid monitoring, a Melbourne University remote sensing trial and several commercial trials looking at nutrition and disease management in wheat, barley and canola.

The RRC held a number of events and hosted numerous groups during 2018. I would like to acknowledge the efforts of our centre collaborators FAR Australia, and in particular Michael Straight and Nick Poole, for the impeccable presentation of the site during these visits and events, as well the exceptionally high quality of trial results generated from the site (frost and drought not with-standing).



Funding partners

Riverine Plains Inc partners with a number of organisations in delivering our research and extension programs. We recognise the ongoing support and investment made by our funding partners; the Grains Research & Development Corporation (GRDC), NSW DPI, the Sustainable Food Lab/Mars Petcare, the Soil CRC and the Australian Government's National Landcare Program, as well as the support provided by Goulburn Broken Catchment Management Authority.

Sponsors

Through their financial support, the businesses that sponsor Riverine Plains Inc play an important role in allowing us to deliver additional services to members. Our sponsors and their representatives are also terrific supporters of our field days, seminars and other events and we sincerely value their presence and contributions. Many of our sponsors have been with us for many years and we thank them for their continued support.

Staff

On behalf of the committee and our members I would also like to recognise the contributions made by the staff of Riverine Plains Inc to the ongoing success of the group. Our Executive Officer Fiona Hart, Finance Officer Kate Coffey, Research Coordinator Dr Cassandra Schefe, Communications Officer Michelle Pardy and Project Officer Jane McInnes all work hard in their respective fields and their contributions to the organisation are greatly appreciated.

Committee

Riverine Plains Inc aims to promote excellence in farming systems by providing quality information, leading research and sharing ideas for the environmental, economic, and agricultural benefit of the Riverine Plains region. The committee, comprised entirely of volunteers, provides direction for the research and extension programs, oversees governance and financial management matters while also ensuring the needs and expectations of our members, sponsors and funders continue to be met. This is an important task and I would like to thank all committee members for their time, dedication and leadership.

Research for the Riverine Plains

You will notice that the 2019 edition of *Research for the Riverine Plains* is much less extensive that our record breaking 2018 edition, which contained a whopping fifteen articles on research undertaken in the Riverine Plains. In part, this reduction is due to the combination of drought and frost in 2018, which saw some trials abandoned or not reported on due to high levels of in-trial variation. However, this leaner look is also due to the conclusion of a number of projects during 2018, which have not yet been replaced with new research results. With a suite of new projects in development, we look forward to bringing you more locally relevant research findings in future editions.

Finally, I wish to thank Michelle Pardy, for her work in collating and editing these articles and also Cassandra Schefe for her technical and editorial contributions.

We trust you will enjoy the read and find value in the reports contained within. All the best for the remainder of the 2019 season.

Ian Trevethan
Chairman

2018 — the year in review

Monica Ley[1] and Adrian Smith[2]

[1] (former) Local Land Services Officer — Murray Local Land Services, Albury

[2] Senior Land Services Officer, Murray Local land Services, Deniliquin

Thankfully, 2018 has now been cast into the annals of time. It was a challenging year (particularly during the second half of the growing season) for growers across the Riverine Plains region and hopefully its trials and tribulations can be cast aside for better prospects during 2019.

Rainfall (or the lack thereof) was the dominant feature of 2018. Many areas received significant rainfall during December 2017 with between 80–100mm recorded in some areas (though whether it was well-timed or not depended on whether harvest had been completed). Where moisture conservation practices were implemented (through stubble retention, summer weed control etc) most growers were able to enter 2018 with relatively high levels of subsoil moisture and, perhaps, with some confidence for a productive year to come.

And then the 2018 season really hit.

Rainfall across the Riverine Plain region was generally around one-third to half of the annual long-term average.

For the calendar year, the rain gauges at Yabba South recorded 158mm, Rand 253mm and Culcairn 382mm. This compares with the long-term average rainfall at Corowa of 543mm (Figure 1).

While conditions were well below average, the 'good' news was that winter and early spring rainfall was reasonable. This, coupled with warmer-than-average temperatures, meant crops and pastures had plenty of early biomass and dry matter (DM) production and looked to be all set for a great spring.

However, the lack of spring rainfall, particularly across the western part of the Riverine Plains, combined with warmer-than-average daytime temperatures and a higher-than-normal number of frost events, resulted in poor spring growth for many. This caused crops and pastures to hay-off early and consequently limited DM production, which meant livestock producers had low reserves heading into what proved to be a hot, dry and particularly challenging 2018–19 summer.

The other challenge was the number and severity of late frosts recorded. Clear skies and drier-than-average soils, coupled with the prevailing weather conditions (i.e. above-average atmospheric pressure levels and a lack of cold front events), saw both August and September record a higher-than-average number of nights experiencing less than 2°C (Figure 2).

The long-term average number of frost days recorded at Rand for July is 16, while August is 12 and September is seven frost days. Figure 2 highlights the significant number of frost events experienced over the 2018 winter, particularly

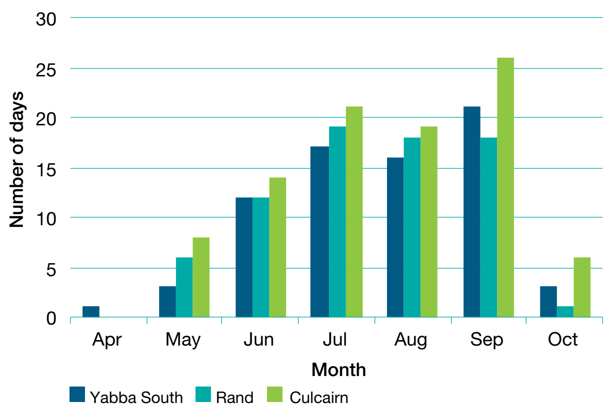


FIGURE 2 Number of frost days at Yabba South, Rand and Culcairn during the 2018 growing season (April–October)
Source: www.riverineplains.org.au

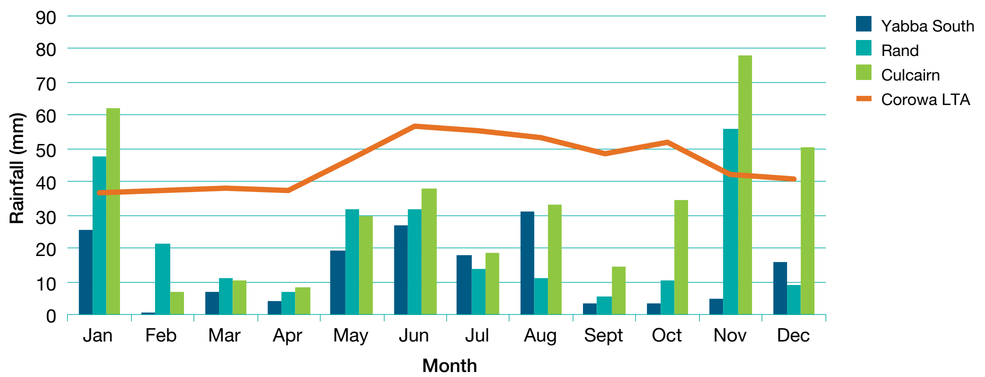


FIGURE 1 2018 monthly rainfall for Yabba South, Rand and Culcairn compared with the long-term average (LTA) for the Corowa Airport weather station (No. 74034)

during September when 2–3 times the long-term average number of frosts were experienced.

Frost damage, coupled with a lack of rainfall and soil moisture, forced the hand of many growers and saw numerous crops salvaged for hay or silage. Early decisions to cut affected crops resulted in impressive hay and silage yields, with quality (measured via protein levels and digestibility) being generally quite high. This was perhaps the only saving grace for those impacted by the frost and dry conditions.

Late frost events are becoming an all-too-common phenomena and growers should be factoring this into their decision making and planning strategies.

Overall, Australia experienced its ninth-warmest spring on record during 2018 and over the whole year 2018 was the third warmest on record (BoM, 2018).

Across New South Wales, the localised picture was worse still, with 2018 being the warmest year on record for both average temperature and average maximum temperature, while the average minimum temperature was the fourth-warmest on record. The year was dominated by dry conditions, with the third-driest January – September on record. While the months October – December saw some relief from the dry across some areas of NSW, with above-average rainfall recorded across parts of the state, overall NSW experienced its sixth-lowest annual rainfall on record (Figure 3) and its driest year since 2002.

Figure 4 shows how 2018 NSW annual rainfall fared against the long-term average. For much of NSW rainfall was at decile 1 (in the lowest 10% of rainfall recorded), while for some parts of the Riverine Plain area rainfall was slightly higher at decile 2–3. From a rainfall perspective, 2018 was very much a 'year out of the box'.

Summary

Subsoil moisture levels leading into 2018 were reasonable and rainfall during the first half of the year helped improve confidence. However, poor spring rain, coupled with above-average daytime temperatures and a high number of (late) frost events, left many growers facing difficult decisions about what to do with crops and livestock.

Growers that made early decisions, based around the best possible information at the time, were better placed to salvage some good results, despite the extenuating circumstances.

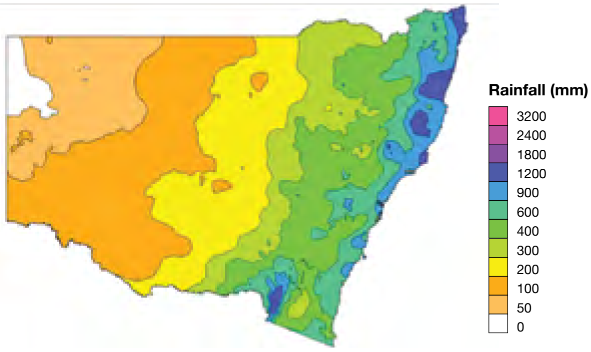


FIGURE 3 Total rainfall across NSW during 2018
Source: www.bom.gov.au, 2019

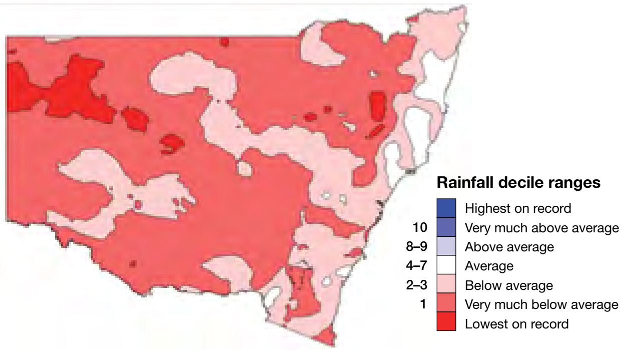


FIGURE 4 Rainfall deciles across NSW during 2018
Source: www.bom.gov.au

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Optimising crop nutrition in canola

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Key points

- The Coreen trial was not harvested due to dry conditions.
- While harvest results at Howlong were compromised due to dry conditions, early dry matter (DM) and tissue nitrogen (N) and sulphur (S) results indicate an interaction between nitrogen and sulphur.
- While early DM production increased with added nitrogen, there was a trend for further early biomass production when sulphur was also added.
- As tissue nitrogen concentrations increased, sulphur concentrations also increased, as measured at harvest.
- There were no differences in yield due to applied nitrogen or sulphur treatments, likely due to the dry conditions.
- Protein levels increased with added nitrogen, while oil levels decreased.

Background

Following the discovery of sulphur deficiency in canola in southern NSW during the late 1980s, the application of 20–30kg S/ha has been recommended when sowing canola (GRDC Canola guide, 2009). Since then, the wheat–canola rotation has become established, meaning growers are applying 20–30kg S/ha as frequently as every second year. With some sulphur moving to depth, growers are questioning whether they can reduce their sulphur application rates to their canola crops.

Furthermore, a variable response to sulphur has been observed, depending on background nutrition levels, (e.g. soil nitrogen status — where nitrogen supply is sub-optimal, plant uptake of sulphur can be inhibited, leading to a confounded yield response).

This Grains Research and Development Corporation (GRDC) investment, *Optimising crop nutrition in canola* is investigating the interactions between nitrogen supply and sulphur uptake, to ensure sulphur uptake is not limited by sub-optimal soil nitrogen levels.

Aims

This project aims to determine if nitrogen supply is limiting the uptake of sulphur in canola crops grown in the Riverine Plains region and whether sulphur uptake and yield are increased when nitrogen is available in non-limiting quantities.

The 2017 and 2018 trials assessed the response to nitrogen and sulphur in canola crops of the Riverine Plains by determining:

- the influence of nitrogen and sulphur application on canola tissue content, yield and oil
- the fluctuation in nitrogen and sulphur content and nitrogen:sulfur ratio in the plant from stem elongation (GS2.0) to harvest (GS6.9), and
- the optimum available soil nitrogen level for the region's canola crops at varying sulphur application rates.

Method

During 2018, two trial sites were established at Coreen and Howlong in southern NSW.

A randomised block design was used, with plots measuring 3m x 18m long, with four replicates. The Coreen site was sown on 18 April 2018 to canola cv Bonito. The Howlong site was sown on 29 April 2018 to canola cv Roundup Ready® 45Y25.

After sowing, combinations of nitrogen and sulphur treatments were applied to both trial sites. The Coreen site was severely affected by dry conditions and was not harvested. As a result, data from Coreen is not presented in this report.

Nitrogen (as urea) was applied in a split application at the 6 leaf stage (GS1.06) and greenbud (GS3.3) at five rates (0, 40, 80, 120, 160kg N/ha), with 40kg N/ha applied at the 6 leaf stage, and the remainder applied at green bud. Sulphur was applied as sulphate of ammonia (SOA) at four rates (0, 10, 20, 30kg S/ha), which was applied with the first application of in-crop nitrogen, with urea added to balance the nitrogen applied in the SOA. Sulphur treatments were applied across the suite of nitrogen treatments to determine the interaction between nitrogen and sulphur (Table 1).

The trial site was managed as part of the surrounding commercial crop, with the exception of the sulphur and nitrogen applications.

Tissue sulphur and nitrogen testing and DM sampling both occurred at early flowering (GS4.1–GS4.2), pod set (GS5.8) and harvest (GS6.9). Yield, oil and protein content was also measured.

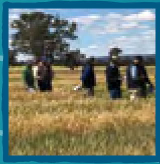

TABLE 1 Treatment list: Nitrogen applied as urea (46% N) and sulphur applied as ammonium sulphate (21% N and 24% S)

No.	6 leaf stage GS1.06	Green bud GS3.3	Total S (kg/ha S)	Total N (kg/ha N)
1	0	0	0	0
2	40N 0S	0	0	40
3	40N 10S	0	10	40
4	40N 20S	0	20	40
5	40N 30S	0	30	40
6	0	0	0	0
7	40N 0S	40N	0	80
8	40N 10S	40N	10	80
9	40N 20S	40N	20	80
10	40N 30S	40N	30	80
11	0	0	0	0
12	40N 0S	120N	0	160
13	40N 10S	120N	10	160
14	40N 20S	120N	20	160
15	40N 30S	120N	30	160
16	0	0	0	0
17	40N 0S	200N	0	240
18	40N 10S	200N	10	240
19	40N 20S	200N	20	240
20	40N 30S	200N	30	240

Treatments at six-leaf stage (GS1.06) applied as ammonium sulphate with residual nitrogen application applied as urea

The first 40kg N/ha of all nitrogen treatments was applied at the six-leaf stage, with the remainder applied at green bud (GS3.3).

Treatment list excludes MAP applied at sowing with the commercial crop

Trial 1: Howlong, NSW

Sowing date: 29 April 2018
Rotation: Canola after wheat
Variety: Canola, cv 45Y25
Rainfall:
GSR: 172.6mm (April – October):

i) Soil sampling results

Incremented soil samples (0–30cm, 30–60cm, 60–90cm) were collected on 28 May 2018 and analysed for nitrogen and sulphur content.

Field sites were selected based on previous cropping history and associated high levels of production and nutrient export. While the soil nitrogen values were high in the top 30cm, they decreased significantly at depth; this is as expected given the dry finish experienced during 2017 and the limited rainfall received during the 2017–18 summer before sowing the 2018 canola crop (Table 2). Low sulphur levels at depth suggest a sulphur response would be expected at this site.

ii) Dry matter (DM)

Due to the large number of treatments in this trial, only selected treatments (i.e. the nil-sulphur and high-sulphur treatments at each rate of nitrogen) received an in-crop assessment for DM production.

The DM measurement at 20% flowering (GS4.2) showed the 120N:30S treatment had the greatest biomass and this was 3.28t/ha higher than that measured in the untreated controls (UTC). However, no significant differences were observed in biomass production at either the 80% pods filled stage (GS5.8) or at harvest (GS6.9). This was likely due to the dry spring conditions contributing to both a limited nutrient response and the high variance observed in the trial (as seen by the 1.59t/ha difference in biomass between the two UTC treatments at harvest) (Table 3).

iii) Plant tissue nitrogen and sulphur content

The nitrogen content of the canola at 20% flowering (GS4.2) showed increased nitrogen uptake at higher application rates, which is expected. However, there was also trend

TABLE 2 Soil nitrogen and sulphur contents at the Howlong, NSW site, sampled 28 May 2018

Depth (cm)	Mineral N (kg/ha)	Mineral S values (kg/ha)
0–30	48.0	2.65
30–60	9.04	8.25
60–90	8.05	8.35
Total (0–90)	**65.1**	**19.3**

TABLE 3 Dry matter assessment at the Howlong, NSW site

	6 Sep 2018	18 Oct 2018	20 Nov 2018
	Dry matter (t/ha)		
	20% flower (GS4.2)	80% pods filled (GS5.8)	Harvest (GS6.9)
UTC	4.07^{d}	3.63	3.23
UTC	4.23^{cd}	4.46	4.82
40N:0S	6.49^{ab}	5.10	4.78
40N:30S	5.01^{bcd}	6.70	5.07
80N:0S	5.43$^{a\text{-}d}$	6.58	4.88
80N:30S	6.40^{abc}	5.37	6.31
120N:0S	6.53^{ab}	6.28	6.43
120N:30S	7.51^{a}	5.38	4.90
160N:0S	6.12$^{a\text{-}d}$	6.36	5.93
160N:30S	7.00^{ab}	5.61	4.58
Mean	**5.88**	**5.55**	**5.09**
LSD P=0.05	2.24	2.14	1.89
P value	0.05	n.s.	n.s.
CV	26.27	26.55	25.61
SD	1.54	1.47	1.30

UTC: Untreated control

Figures followed by different letters are regarded as statistically different.

for increased nitrogen uptake with sulphur addition, a trend which was statistically significant at the highest level of nitrogen addition (Table 4). Such a trend suggests a readily available supply of sulphur could facilitate increased nitrogen uptake early in the season.

There was less variance in canola nitrogen content at the 80% pods filled stage (GS5.8), with all treatments except 40N:0S having significantly more tissue nitrogen than the untreated controls. The significant increase in plant nitrogen content at 40N:30S compared with the equivalent nitrogen treatment with no sulphur (40N:0S) again indicates sulphur could aid nitrogen uptake, however, this trend was not evident at higher nitrogen application rates.

While differences in nitrogen uptake were even less evident at harvest (GS6.9), the highest nitrogen content was measured in the 80N:30S treatment, which was almost double the tissue nitrogen measured in the 160N:30S treatment.

While the 2017 results at Howlong showed an increase in nitrogen uptake over the season from an average of 129 to 181kg N/ha, the 2018 results show an overall depletion in plant tissue nitrogen from 20% flower (mean of 200kg N/ha) to harvest (mean of 54kg N/ha). As these results also correlate with a lack of increase in DM over the season, it is likely the dry conditions caused a large amount of leaf matter to die prematurely.

The range in tissue sulphur content at 20% flowering (GS4.2) significantly increased with additions, with strong interaction between additional sulphur and additional nitrogen (Table 4). As nitrogen addition increased, so did the tissue sulphur content, with a trend for higher sulphur contents when sulphur was added.

As the season progressed through to the 80% pods filled (GS5.8) and harvest (GS6.9) stages, there were no significant differences in sulphur content between treatments. This is likely due to the poor DM production caused by the dry seasonal conditions.

There was not a strong relationship between sulphur addition and DM production, which meant there was no clear connection between sulphur addition and plant growth (as water was the most limiting factor for growth). However there was a strong relationship between plant tissue nitrogen and sulphur content at harvest (Figure 1).

iv) Normalised difference vegetation index

Normalised difference vegetation index (NDVI) was measured in each plot 10 times throughout the season. While there were differences in plant greenness, as estimated by NDVI throughout the season, there were no statistically significant differences in NDVI between treatments (Figure 2). Hence, the average NDVI values are presented for each time period. Plant greenness peaked between green bud (GS3.3) and 20% flower (GS4.2).

TABLE 4 Plant tissue nitrogen and sulphur contents at Howlong, NSW

Treatment	Nitrogen content			Sulphur content		
	6 Sep 2018	18 Oct 2018	20 Nov 2018	6 Sep 2018	18 Oct 2018	20 Nov 2018
	kg N/ha			kg S/ha		
	20% flower (GS4.2)	80% pods filled (GS5.8)	Harvest (GS6.9)	20% flower (GS4.2)	80% pods filled (GS5.8)	Harvest (GS6.9)
UTC	81^{e}	45^{b}	22^{c}	10^{f}	18	19
UTC	95^{e}	62^{b}	32^{bc}	18^{def}	24	28
40N:0S	165^{cde}	59^{b}	34^{bc}	15^{ef}	22	25
40N:30S	109^{e}	138^{a}	47^{bc}	24^{def}	40	28
80N:0S	148de	130^{a}	37^{bc}	26^{c-f}	36	24
80N:30S	230^{bcd}	142^{a}	117^{a}	43^{abc}	40	37
120N:0S	264^{b}	140^{a}	93^{a}	35^{bcd}	33	32
120N:30S	302^{ab}	122^{a}	47^{bc}	57^{a}	30	25
160N:0S	246^{bc}	161^{a}	54^{bc}	28^{cde}	60	25
160N:30S	360^{a}	141^{a}	59^{b}	47^{ab}	36	24
Mean	**200**	**114**	**54**	**30**	**34**	**27**
LSD P=.05	86	52	33	18	30	10
P value	<0.001	<0.001	<0.001	<0.001	n.s.	n.s.
CV	29.5	31.7	41.6	40.9	60.9	26.3
SD	59	36	23	12	21	7

UTC: Untreated control

Figures followed by different letters are regarded as statistically different.

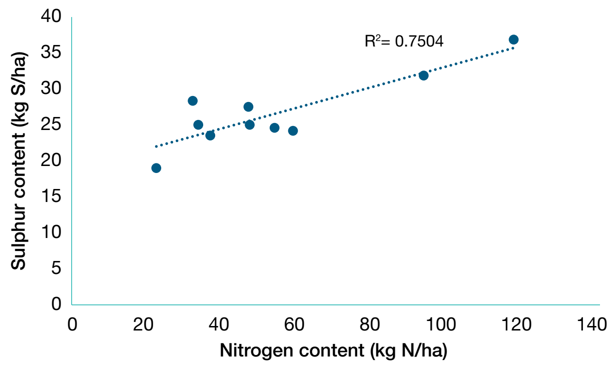

FIGURE 1 Relationship between tissue nitrogen and sulphur content at Howlong NSW, measured at harvest (GS6.9), 20 November 2018

v) Yield, oil and protein

During 2018, there were no significant differences in yield across the various treatments due to the dry conditions, with a total yield range of 0.89–1.51t/ha (Table 5). By comparison, the Howlong trial site yields ranged from 2.46–3.04t/ha during 2017.

While oil content decreased significantly as nitrogen application rates increased, protein content increased as nitrogen application rates increased. The rate of sulphur addition had minimal influence on oil and protein levels.

vi) Grain nitrogen and sulphur

The amount of nitrogen in the grain was not significantly increased with increased nitrogen addition (Table 6), ranging from 3.5% in the UTC to 4.2% when 160kg N/ha was added. The lack of difference in grain nitrogen percentage between the 120kg N/ha and 160kg N/ha treatments suggest grain nitrogen content may have reached its agronomic maximum.

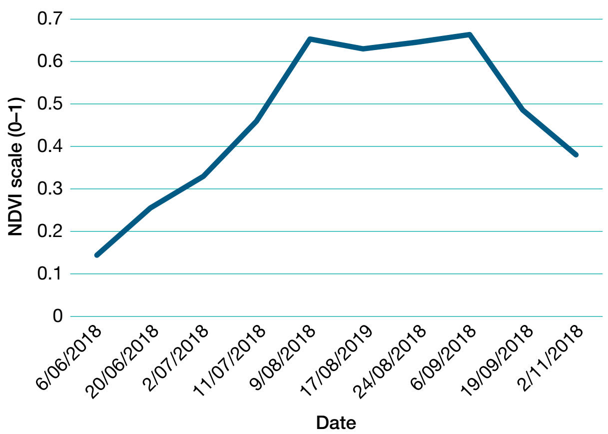

FIGURE 2 Average NDVI values across all treatments, measured from when cotyledons were unfolded (GS1.0) through to when most seeds were green-brown mottled (GS6.4), at Howlong, NSW

TABLE 5 Harvest yield and quality at Howlong, NSW

No.	Treatment	Yield* (t/ha)	Oil (%)	Protein (%)
1	UTC	0.89	44.3^{a}	20^{l}
2	40N:0S	1.14	43.3^{ab}	21.2^{jk}
3	40N:10S	1.15	43.8^{a}	20.8^{jkl}
4	40N:20S	1.21	43.6^{a}	21.4^{ijk}
5	40N:30S	1.20	43.1^{ab}	21.7^{hij}
6	0N:0S	0.93	43.5^{a}	20.6^{kl}
7	80N:0S	1.36	42.2^{bc}	22.2^{ghi}
8	80N:10S	1.25	41.4^{cd}	22.7^{gh}
9	80N:20S	1.36	39.8^{ef}	23.7^{ef}
10	80N:30S	1.31	40.5^{de}	22.8^{fg}
11	0N:0S	1.05	43.9^{a}	20.4^{kl}
12	120N:0S	1.41	40.7^{de}	24de
13	120N:10S	1.51	41.3^{cd}	23.9^{de}
14	120N:20S	1.44	40.6^{de}	24.1^{de}
15	120N:30S	1.26	40.5^{de}	24.6^{cde}
16	0N:0S	0.94	43.6^{a}	20.5^{kl}
17	160N:0S	1.26	38.3^{g}	25.8^{a}
18	160N:10S	1.29	39.1^{fg}	24.8^{bcd}
19	160N:20S	1.22	38.7^{fg}	25.7^{ab}
20	160N:30S	1.33	38.6^{g}	25.2^{abc}
Mean		**1.23**	**41.5**	**22.8**
LSD P=.05		0.22	1.24	1.0
P value		n.s.	<0.001	<0.001
CV		12.83	2.11	3.07
SD		0.157	0.87	0.70

*Trial harvested 28 November 2018

Increasing the rate of sulphur or nitrogen application did not significantly change the sulphur content of the grain.

vii) Post-season soil sampling

Soil sampling across the whole site was carried out during February 2019. There were no significant differences in either nitrogen or sulphur content in the soil post treatment.

viii) Gross margin

Gross margin (GM) analyses were undertaken to ascertain the optimum application rate of sulphur and nitrogen in canola. There was an error in the GM analysis of the 2017 data, which was reported to the GRDC during April 2018. This error is detailed in Appendix A and has been corrected in this report.

Costs were based on growers' input costs and included contract rates for machinery operations. Fertiliser rates were converted to combinations of urea and sulphate of ammonia, using values of $400/t for urea (2017 and 2018) and $350/t and $400/t (2017 and 2018 respectively) for sulphate of ammonia.

TABLE 6 Grain nitrogen and sulphur at Howlong, NSW at harvest (GS6.9), 28 November 2018

No.	Treatment	Grain nitrogen (%)	Grain sulphur (%)
1	0N:0S	3.5	0.3
2	40N:0S	3.3	0.3
3	40N:10S	3.5	0.3
4	40N:20S	3.2	0.3
5	40N:30S	3.3	0.3
6	0N:0S	3.3	0.3
7	80N:0S	3.4	0.3
8	80N:10S	3.7	0.3
9	80N:20S	3.8	0.3
10	80N:30S	3.9	0.3
11	0N:0S	3.4	0.4
12	120N:0S	3.3	0.3
13	120N:10S	3.9	0.4
14	120N:20S	3.5	0.3
15	120N:30S	3.4	0.3
16	0N:0S	3.6	0.3
17	160N:0S	4.2	0.3
18	160N:10S	4	0.3
19	160N:20S	4.4	0.3
20	160N:30S	4.2	0.4
Mean		**3.64**	**0.32**
LSD P=.05		0.52	0.08
P value		n.s.	n.s.
CV		10.03	17.66
SD		0.36	0.06

Grain value for the 2017–18 harvest was calculated using prices of $515/t for canola delivered Howlong and $470/t for Roundup Ready® canola delivered Yarrawonga. For the 2018–19 harvest the price was $570/t for Roundup Ready® canola delivered Howlong.

There was no statistical analysis of the GM results.

2017 results Yarrawonga

During 2017 (a decile 3 rainfall year), there was a significant canola yield response to the addition of 20kg of sulphur in combination with 160kg N/ha at the Yarrawonga site. The highest returning GM treatment was 160kg N/ha and 20kg S/ha, which was $319/ha more profitable than applying 160kgN/ha with no sulphur (Table 7; for full results see Appendix B, Yarrawonga results 2017).

The benefit:cost ratio of the application of 20kg S/ha (when nitrogen was applied at 160kg/ha) was $23.70:1, which means every additional dollar spent on sulphur up to 20kg/ha generated an additional $23.70 in gross income. When the amount of sulphur increased to 30kg/ha, there was no significant increase in yield from the nil sulphur treatment and minimal increase in GM.

TABLE 7 Gross margin analysis of applying nitrogen and sulphur fertiliser at Yarrawonga, 2017

Treatment	Yield (t/ha)	Fertiliser cost ($/ha)	Gross margin ($/ha)	Gross margin compared with 160N:0S ($/ha)
160N:0S	2.42[e]	139	690	-
160N:10S	2.63[cde]	146	783	93
160N:20S	3.11[a]	153	1009	319
160N:30S	2.54[de]	160	700	10

Figures followed by different letters are regarded as statistically different

2017 results Howlong

During 2017 (a decile 4 rainfall year) there were no significant canola yield responses to applying sulphur at the Howlong site (Table 8; for full results see Appendix B). Note that this site was shown to have high starting nitrogen levels compared with the Yarrawonga site. The highest returning GM treatment was 80kg N/ha and 20kg S/ha, which was $53/ha more profitable than applying 80kgN/ha with no sulphur.

The benefit:cost ratio of applying 20kg S/ha (when nitrogen was applied at 80kg/ha) was $4.78:1, which means every additional dollar spent on sulphur up to 20kg/ha generated an additional $4.78 in gross income. When the amount of sulphur increased to 30kg/ha, there was no significant increase in yield from the nil sulphur treatment and the GM decreased.

Sensitivity analysis 2017 data

A sensitivity analysis tested the impact of a change in key variables (canola price and fertiliser cost) on the economic optimum of nitrogen and sulphur at the Yarrawonga site during 2017. When the price of canola was reduced by 10% (from $470/t to $423/t), the most profitable option remained 160kg N/ha and 20kg S/ha (Table 9). Similarly, a 10% increase in the cost of fertiliser (urea from $400/t to $440/t and sulphate of ammonia from $350/t to $385/t) did not change the order of the most profitable application rate (Table 10).

A sensitivity analysis tested the impact of a change in key variables (canola price and fertiliser cost) on the economic optimum of nitrogen and sulphur at the Howlong site during 2017. When the price of canola was reduced by 10% (from $515 to $463.50), or the price of fertiliser increased by 10% (urea from $400/t to $440/t and sulphate of ammonia from $350/t to $385/t), the most profitable option remained 80kg N/ha and 20kg S/ha (Tables 11 and 12).

TABLE 8 Gross margin analysis of applying nitrogen and sulphur fertiliser at Howlong, 2017

Treatment	Yield (t/ha)	Fertiliser cost ($/ha)	Gross margin ($/ha)	Gross margin compared with 80N:0S
80N:0S	2.91^{abc}	70	1237	-
80N:10S	2.84^{abc}	76	1182	-55
80N:20S	3.04^{a}	83	1290	53
80N:30S	2.84^{abc}	90	1162	-75

Figures followed by different letters are regarded as statistically different

TABLE 9 Impact of a 10% reduction in the price of canola on the profitability of applying nitrogen and sulphur at Yarrawonga, 2017

Treatment	Gross margin (canola price reduced by 10%) ($/ha)	Gross margin (compared with 160N:0S) ($/ha)
160N:0S	575	-
160N:10S	658	83
160N:20S	860	285
160N:30S	582	7

TABLE 10 Impact of a 10% increase in the price of fertiliser on the profitability of applying nitrogen and sulphur at Yarrawonga, 2017

Treatment	Gross margin (fertiliser price increased by 10%) ($/ha)	Gross margin (compared with 160N:0S) ($/ha)
160N:0S	676	-
160N:10S	768	92
160N:20S	994	318
160N:30S	684	8

TABLE 11 Impact of a 10% reduction in the price of canola on the profitability of applying nitrogen and sulphur at Howlong, 2017

Treatment	Gross margin (canola price reduced by 10%) ($/ha)	Gross margin compared with 80N:0S ($/ha)
80N:0S	1073	-
80N:10S	1024	-49
80N:20S	1120	47
80N:30S	1004	-69

TABLE 12 Impact of a 10% increase in the price of fertiliser on the profitability of applying nitrogen and sulphur at the Howlong site, 2017

Treatment	Gross margin (fertiliser price increased by 10%) ($/ha)	Gross margin compared with 80N:0S ($/ha)
80N:0S	1230	-
80N:10S	1175	-55
80N:20S	1281	51
80N:30S	1153	-77

2018 results

There were two sites during 2018: Coreen and Howlong. A decision was made during October 2018 not to harvest the Coreen site, which was extremely drought affected. Therefore, no economic analysis was undertaken for this site. Even though the Howlong site was also drought affected (decile 1 GSR), the site had enough yield potential to be harvested.

The most economic treatment at Howlong was the application of 120kg N/ha, 10kg S/ha, which yielded 1.5t/ha with a gross margin of $353/ha (Table 13; for full list of treatment results, see Appendix C).

The second most profitable treatment (80kg N/ha and 0kg S/ha) had a GM of $329/ha. The third most profitable treatment was 120kg N/ha, 0kg S/ha. The three highest gross margin treatments were at least $100/ha more profitable than the average of the untreated control, suggesting it was economic to apply nitrogen and sulphur fertiliser in the low yielding conditions. However, as the yield of these treatments were not statistically different from the untreated controls, these gross margin results are not definitive.

Decreasing the canola price by 10% (from $570/t to $513/t) or increasing the fertiliser cost by 10% (urea and sulphate of ammonia from $400/t to $440/t) did not change the order of the most profitable options (Appendix C).

Discussion

The 2017 results from this trial were confounded due to the dry finish. Likewise, the 2018 results were confounded due to dry conditions throughout the season, with the Howlong site only recording decile 1 GSR. While the Coreen site had to be abandoned due to plant death, the Howlong site achieved a measurable yield.

While the yield results from Howlong do not show clear treatment influences due to the dry conditions, the early-season results suggest there was an effect from the nutrient treatments applied. A nitrogen response was seen with DM production at 20% flower, while plant tissue nitrogen also increased with additional nitrogen.

Interestingly, additional sulphur appeared to facilitate nitrogen uptake, with a strong relationship between tissue nitrogen and sulphur levels, which continued through to harvest. The increase in tissue sulphur content with increasing nitrogen was likely due to the increased DM production associated with nitrogen addition, with more roots and biomass resulting in greater uptake of sulphur from soil. If the seasonal conditions had been more favourable, it could be speculated this interaction could have followed through to an effect on yield.

TABLE 13 Gross margin analysis of applying nitrogen and sulphur fertiliser at Howlong, 2018

Treatment	Yield (t/ha)	Gross margin ($/ha)	Gross margin# ($/ha)	Gross margin^ ($/ha)
Average of untreated control	0.95n.s.	187	131	187
120N:0S	1.41n.s.	304	226	294
80N:0S	1.36n.s.	329	251	322
120N:10S	1.51n.s.	353	268	341

Canola price reduced by 10%

^ Fertiliser price increased by 10%)

This project was undertaken over two years, one of which (2017) experienced a dry finish, and the other (2018) experiencing drought conditions. This means the general knowledge to be derived from this project is limited.

Although recommendations on application rates and soil sulphur thresholds cannot be determined, this work does reinforce that basic sulphur nutrition is needed to ensure nitrogen supply is not limited. Rather than relying on standard application rates of sulphur with every canola crop, a focus on understanding fluctuations in soil sulphur levels at a paddock level needs to be valued in the same way as deep soil nitrogen (DSN) levels provide a measure of confidence in urea application rates.

The most economic combination of sulphur and nitrogen was specific to site and year and given both years were dry, no definitive conclusions can be drawn. There was a strong statistical and economic response to sulphur and nitrogen at Yarrawonga during 2017 (decile 3 year), while at Howlong in 2017 (decile 4 year), there was an economic response to sulphur but not a statistical yield response, suggesting the economic response was marginal. The 2018 results from the Howlong site were constrained by extremely low rainfall (decile 1) and therefore the economic optimum treatment was not representative of a typical year.

Acknowledgements

Riverine Plains acknowledges the investment made by the GRDC to the *Optimising crop nutrition in canola in the southern region of NSW (RPI00013)* project.

We also thank trial contractors FAR Australia and our 2018 farmer co-operators, Trevethan Family Farms and Tomlinson Ag, as well as our 2017 co-operators the Cummins Family and Trevethan Family Farms.

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Appendix A

Error in the 2018 GRDC report for *Optimising sulphur and nitrogen nutrition in canola*

The error was a result of an incorrect price for sulphate of ammonia and an incorrect calculation for the rates of urea, which resulted in lower amounts of urea used for gross margin (GM) calculations (Table A1). The original and corrected rates of urea for both the Howlong and Yarrawonga sites are the shaded treatments listed in Table A1. The original price used for sulphate of ammonia was $750/t and the corrected price was $350/t. There was no change to the sulphate of ammonia rate (Table A1).

To correct this error and to obtain some key economic take-home messages, a summary of the 2017 results was rewritten for this report and the amended GM of all treatments for 2017 have been included in Appendix B. The error did not change the most economic option for both sites, however the corrected GM was $11/ha lower for the Yarrawonga site and $19/ha higher for the Howlong site than reported during 2018.

TABLE A1 Urea rates used in gross margin analyses of 2017 data for Howlong and Yarrawonga

No.	Treatment	Incorrect urea rate (kg/ha)	Corrected urea rate (kg/ha)	Sulphate of ammonia rate (unchanged) (kg/ha)
1	UTC	0	0	0
2	UTC	0	0	0
3	UTC	0	0	0
4	UTC	0	0	0
5	40N:0S	87	87	0
6	40N:10S	67	67	42
7	40N:20S	50	50	83
8	40N:30S	30	30	125
9	80N:0S	174	174	0
10	80N:10S	134	154	42
11	80N:20S	100	136	83
12	80N:30S	60	116	125
13	160N:0S	348	348	0
14	160N:10S	268	328	42
15	160N:20S	200	309	83
16	160N:30S	120	290	125
17	240N:0S	521	521	0
18	240N:10S	402	502	42
19	240N:20S	300	483	83
20	240N:30S	180	465	125

Appendix B

Revised gross margin analysis for 2017 Yarrawonga (Table A2) and Howlong (Table A3).

TABLE A2 Yarrawonga 2017: Fertiliser application rate, gross margin and sensitivity analysis for treatments

Treatment	Urea application rate (kg/ha)	SOA application rate (kg/ha)	Gross margin ($/ha)	Gross margin# (canola price less 10%) ($/ha)	Gross margin# (fertiliser price plus 10%) ($/ha)
UTC	0	0	462*	386*	462*
40N:0S	87	0	647	548	644
40N:10S	67	42	635	536	631
40N:20S	50	83	713	605	708
40N:30S	30	125	706	598	701
80N:0S	174	0	818	697	811
80N:10S	154	42	964	827	956
80N:20S	136	83	875	746	866
80N:30S	116	125	874	745	865
160N:0S	348	0	690	575	676
160N:10S	328	42	783	658	768
160N:20S	309	83	1009	860	994
160N:30S	290	125	700	582	684
240N:0S	521	0	852	713	831
240N:10S	502	42	804	669	782
240N:20S	483	83	838	699	816
240N:30S	465	125	728	600	705

* Average of gross margin results from four untreated control treatments; # Gross margins not statistically analysed

Highlighted treatment has the highest gross margin

TABLE A3 Howlong 2017: Fertiliser application rate, gross margin and sensitivity analysis for treatments

Treatment	Urea application rate (kg/ha)	SOA application rate (kg/ha)	Gross margin ($/ha)	Gross margin# (canola price less 10%) ($/ha)	Gross margin# (fertiliser price plus 10%) ($/ha)
UTC	0	0	1110*	968*	1110*
40N:0S	87	0	1147	997	1143
40N:10S	67	42	1253	1091	1249
40N:20S	50	83	1210	1052	1205
40N:30S	30	125	1111	963	1106
80N:0S	174	0	1237	1073	1230
80N:10S	154	42	1182	1024	1175
80N:20S	136	83	1290	1120	1281
80N:30S	116	125	1162	1004	1153
160N:0S	348	0	1112	954	1098
160N:10S	328	42	1201	1034	1187
160N:20S	309	83	1097	940	1082
160N:30S	290	125	1059	904	1043
240N:0S	521	0	1006	852	985
240N:10S	502	42	1072	910	1050
240N:20S	483	83	1107	941	1085
240N:30S	465	125	973	821	950

* Average of gross margin results from four untreated control treatments; # Gross margins not statistically analysed. The difference between the gross margins of 80N:20S and 80N:0S is therefore likely to be minimal as the yields of these treatments were not statistically different.

Highlighted treatment has the highest gross margin

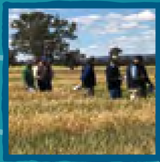
Appendix C

Full gross margin analysis Howlong 2018 (Table A4).

Table A4 Full gross margin analysis Howlong 2018

Treatment	Yield (t/ha)	Urea application (kg/ha)	SOA application (kg/ha)	Gross margin ($/ha)	Gross margin# (canola price less 10%) $/ha	Gross margin# (fertiliser price plus 10%) $/ha
0N:0S	0.89	0	0	155	103	155
40N:0S	1.14	87	0	251	184	247
40N:10S	1.15	67	42	248	180	243
40N:20S	1.21	50	83	270	200	265
40N:30S	1.20	30	125	251	181	245
0N:0S	0.93	0	0	172	118	172
80N:0S	1.36	174	0	329	251	322
80N:10S	1.25	154	42	245	174	237
80N:20S	1.36	136	83	278	203	269
80N:30S	1.31	116	125	250	177	240
0N:0S	1.05	0	0	245	183	245
120N:0S	1.41	260	0	304	226	294
120N:10S	1.51	241	42	353	268	341
120N:20S	1.44	222	83	297	216	284
120N:30S	1.26	203	125	188	117	175
0N:0S	0.94	0	0	179	124	179
160N:0S	1.26	348	0	161	93	147
160N:10S	1.29	328	42	172	102	157
160N:20S	1.22	309	83	121	55	106
160N:30S	1.33	290	125	170	98	153

Gross margins not statistically analysed
Highlighted treatment has the highest gross margin- note gross margins of four untreated controls averaged $187.



Wheat germplasm — April sowing performance

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

Key points

- Two small plot trials at the Riverine Research Centre, Burramine, compared the relative performance of 10 winter-type or spring-type wheat cultivars sown at two sowing dates; 3 April and 30 April 2018. Varieties included commercial cultivars and novel varieties not previously tested across the region.
- Both time-of-sowing trials were affected by drought stress and extreme frost events during the season.
- In both trials, winter cultivars produced more tillers than spring cultivars, however this did not always relate to winter cultivars having more heads/m^2.
- Dry matter (DM) differences at the first node stage (GS31) suggested that winter wheats produced more biomass than spring wheats up until stem elongation (GS30). As plots became more water stressed, the earlier-maturing spring cultivars then produced more DM than the winter wheats.
- The trial sown 3 April showed a correlation between varietal growth stage at the time of the frost event (August 28 and 29), and floret sterility. More advanced cultivars (i.e. those at a growth stage between flag leaf and head emergence) generally showed more damage.
- Normalised difference vegetation index (NDVI) assessments concluded a clear distinction in growth habits between most winter and spring cultivars for both times of sowing, with winter cultivars having a more prostrate growth habit and greater ground cover than the spring cultivars.
- The winter feed wheat, Annapurna (not yet commercially available), achieved the highest grain yield while also having lower tiller mortality and floret sterility (42%) when sown on 3 April.
- The winter feed wheat, RGT Accroc, had the highest yield when sown on 30 April (0.60t/ha). RGT Accroc was still in the vegetative stage when the frost event occurred and carried the greatest number of heads through to maturity.

Method

Two small plot trials were established during 2018 at the Riverine Research Centre (RRC), Burramine (near Yarrawonga), Victoria as part of a collaboration between FAR Australia and Riverine Plains Inc.

Each trial assessed the performance of 10 wheat cultivars sown either on 3 April (time of sowing 1) or 30 April (time of sowing 2). The earlier sown trial was primarily focused on evaluating winter wheat germplasm, while the later-sown trial had focussed more on spring wheat germplasm. The trial design was a randomised complete block, replicated four times.

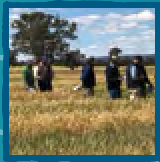
Due to the dry start to the season, the trial sown on 3 April was irrigated with 10mm of water after sowing to support emergence. This trial also received a further irrigation on 20 April to ensure trial survival. The trial sown on 30 April was not irrigated as there was sufficient rainfall after sowing to ensure emergence during early May. Overall, management applications were made as per the seasonal conditions to maximise yield potential.

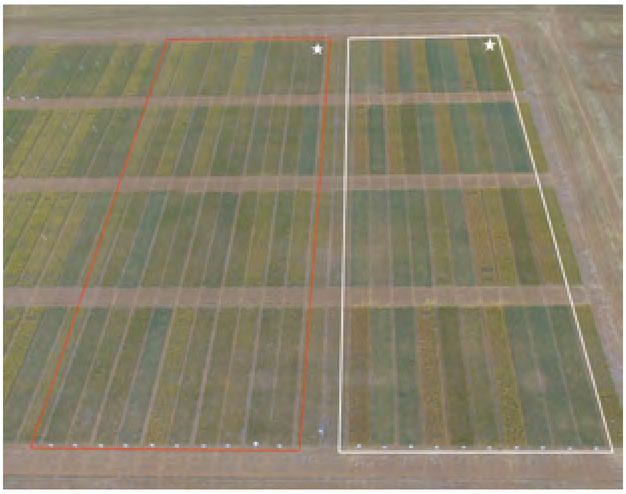
The yield results were presented and distributed as *Riverine Plains Express Results* in December 2018 for Riverine Plains Inc members.

Trial 1.

Sowing date: 3 April, 2018 (irrigated with 10mm on 4 April, emerged 7 April)
Irrigated: 10mm, 20 April (to ensure trial survival)
Harvested: 4 December 2018
Rotation position: First cereal after canola
Rainfall:
GSR: 166mm (April – October)
Soil mineral nitrogen: (Sampled 10 April 2017 from buffer areas of trial site)
0–10cm: 23.7kg N/ha
10–20cm: 6.1kg N/ha
20–30cm: 3.9kg N/ha
30–60cm: 7.8kg N/ha
Total (0–60cm): 41.5kg N/ha

The time of sowing 1 trial included a range of winter and spring wheat cultivars (Table 1) and focussed more on winter wheat varieties compared with the time of sowing trial 2.





Outline of trials: White outline sown 3 April 2018, Red outline sown 30 April 2018. White stars denote first plot in each trial.

TABLE 1 Cultivar, type and maturity of wheat sown 3 April 2018, as part of the time of sowing 2 trial, near Yarrawonga, Victoria

Cultivar/Line	Type	Maturity
Oakley	Winter	Long-season
RGT Calabro	Winter	Long-season
Manning	Winter	Long-season
RGT Accroc	Winter	Intermediate – long
Annapurna	Winter	Intermediate – long
EGA Wedgetail	Winter	Intermediate
AGT W002	Winter	Intermediate
RGT Zanzibar	Spring	Intermediate – long
Beaufort	Spring	Intermediate
DS Pascal	Spring	Intermediate – long

Results

i) Establishment and crop structure

The trial site had an average plant establishment of 146 plants/m^2, with EGA Wedgetail having the highest establishment (180 plants/m^2) at the two-leaf stage (GS12) while the European winter variety RGT Calabro had the lowest establishment (120 plants/m^2).

At early first node (GS31) there was a significant difference between winter and spring cultivars in terms of tillering. EGA Wedgetail produced the highest number of tillers (449 tillers/m^2), while the spring variety Beaufort, produced the fewest tillers (271 tillers/m^2). The winter variety AGT W002 produced the fewest tillers (353 tillers/m^2) of all the winter wheats and was the only winter variety that did not produce significantly more tillers than the spring varieties (271–301 tillers/m^2).

Head counts at harvest revealed that tiller mortality was much higher in the winter wheats than the spring wheats. The spring wheat, DS Pascal, produced significantly more heads (56 heads/m^2) than the other spring varieties, while the winter-type varieties, Manning and AGT W002, produced significantly fewer tillers (46 heads/m^2) than the other winter types (Table 2). These trends in head numbers were not correlated to yield.

ii) Phenology and floret sterility

Phenology data from the trial was collected at least once a week for the life of the trial. Of the winter wheat types, EGA Wedgetail and AGT W002 reached first node stage (GS31) the earliest, on 6 August and 23 July respectively. The other winter wheat types reached GS31 in the eight days between 20 – 28 August. Extreme frost events during late August affected the development of the trial, with temperatures at the RRC reaching -10°C for an hour on August 29. Growth stages were assessed and frost damage to the embryo ear of the cultivar directly corresponded to the stage of development of the crop on 29 August.

The winter wheats, RGT Calabro and Manning, were both at GS31 when the frost event occurred and had significantly more floret sterility (when assessed at early grain fill) than Oakley, which was at GS30 when the frost occurred (Table 3 and Figure 1). The spring wheat DS Pascal was the most advanced (being at head emergence) on 29 August and had significantly more floret sterility than any of the winter wheats.

There was a trend for the spring wheats to have a longer period from first node (GS31) until flowering (GS65) than the winter wheats (Figure 2), although the frost event would have destroyed many of the earliest flowering heads.

TABLE 2 Plant counts assessed at the two leaf stage (GS12), 19 April 2018; tiller counts assessed at first node stage (GS31)* and head counts assessed when grain was at physical maturity (GS92), 28 November 2018

	Plants/m²	Tillers/m²	Heads/m²
Cultivar/Line	**GS12**	**GS31**	**GS92**
Oakley	142^{b-e}	463^{a}	202^{a}
RGT Calabro	120^{e}	407^{abc}	203^{a}
Manning	134^{cde}	388^{bc}	139^{b}
RGT Accroc	160^{a-d}	465^{a}	223^{a}
Annapurna	124^{e}	399^{abc}	211^{a}
EGA Wedgetail	180^{a}	449^{ab}	202^{a}
AGT W002	133^{cde}	353^{cd}	156^{b}
RGT Zanzibar	164^{abc}	276^{e}	151^{b}
Beaufort	171^{ab}	271^{e}	167^{b}
DS Pascal	127^{de}	301^{de}	223^{a}
Mean	**146**	**377**	**188**
LSD	35	68	33

* Tiller counts were taken when each cultivar reached first node stage (GS31)
Figures followed by different letters are regarded as statistically significant

TABLE 3 Time of sowing 1 trial (sown April 3); varietal growth stage on 29 August and dates when crop reached first node (GS31) and flowering (GS65)

Cultivar/Line	Type	29 August	Date reached	
		Growth stage	GS31	GS65
Oakley	Winter	GS30	28 August	29 October
RGT Calabro	Winter	GS31	27 August	22 October
Manning	Winter	GS31	27 August	22 October
RGT Accroc	Winter	GS32	20 August	17 October
Annapurna	Winter	GS32	20 August	12 October
EGA Wedgetail	Winter	GS37	6 August	6 October
AGT W002	Winter	GS37	23 July	15 October
RGT Zanzibar	Spring	GS47	25 June	25 September
Beaufort	Spring	GS55	12 June	2 October
DS Pascal	Spring	GS57	12 June	25 September

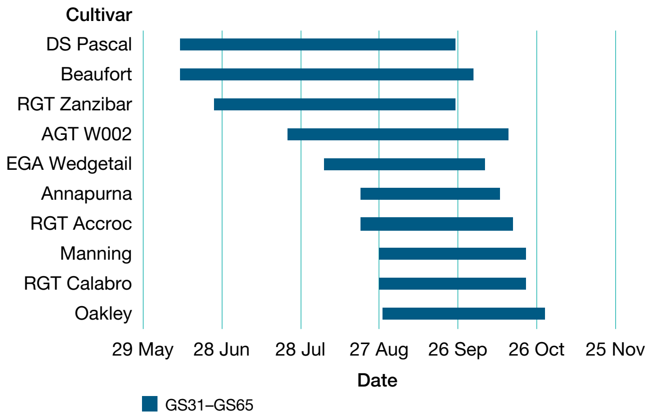


FIGURE 2 Duration (calendar days) between the development stages of first node (GS31) and flowering (GS65)

N.B. The flowering period of the spring wheats was likely extended as a result of the destruction of the primary tillers, which caused flowering to be delayed

The earliest cultivars to reach flowering were RGT Zanzibar and DS Pascal, on 25 September. The slowest cultivar to reach flowering was Oakley, on 29 October (Oakley currently holds the world record for the highest wheat yield of 16.79t/ha, grown in Canterbury, New Zealand).

iii) Dry matter (DM) production

Dry matter assessments were carried out for four of the 10 cultivars (Oakley, RGT Accroc, EGA Wedgetail and DS Pascal) at first node (GS31), early grain fill (GS71) and at physiological maturity (GS89) (Table 4). Dry matter production was very low in all cultivars due to the decile 1 rainfall conditions. The European winter cultivar Oakley, which was one of the last of the cultivars to reach first node (GS31), produced significantly more DM (2.61t/ha) than any other cultivar. The spring cultivar, DS Pascal (1.02t/ha), produced 0.65t/ha less DM than the winter type EGA Wedgetail (1.67t/ha). At flowering (GS65) DS Pascal produced significantly more DM (4.73t/ha) than

TABLE 4 Dry matter production at first node (GS31), mid-flowering (GS65) and grain over-ripe (GS92)

Cultivar	Dry matter (t/ha)		
	GS31	GS65	GS92
Oakley	2.61^{a}	3.59^{b}	3.77^{b}
RGT Accroc	2.26^{b}	3.66^{ab}	3.97^{ab}
EGA Wedgetail	1.67^{c}	3.58^{b}	4.18^{ab}
DS Pascal	1.02^{d}	4.73^{a}	4.44^{a}
Mean	**1.89**	**3.89**	**4.09**
LSD	0.33	1.10	0.62

*DM at GS31 and GS65 were taken when each cultivar was at the appropriate growth stage.
Figures followed by different letters are regarded as statistically significant

Oakley (3.59t/ha) or EGA Wedgetail (3.58t/ha). The earlier stem elongation achieved by DS Pascal resulted in good dry matter accumulation up until head emergence (when it was frosted). At harvest the winter cultivars showed a slight increase in DM accumulation over that recorded at flowering, however that was not the case with DS Pascal.

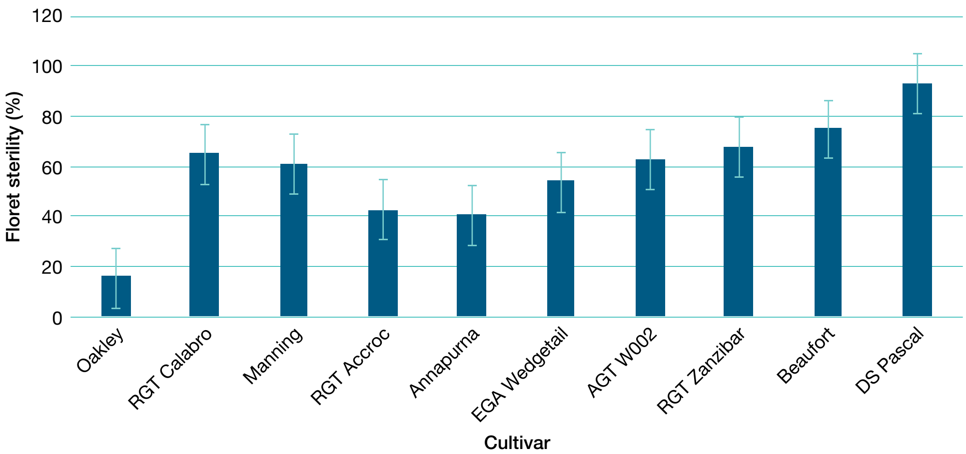


FIGURE 1 Floret sterility for each cultivar assessed at early grain fill (GS71) at the Riverine Research Centre, 2018

iv) Normalised difference vegetative index (NDVI)

Crop reflectance measurements taken with the Greenseeker™ and recorded as NDVI showed differences in the crop canopy due growth habit (Figure 3). For the spring cultivars, NDVI readings peaked on 26 July, while the winter-type NDVI readings peaked on August 9. When the spring cultivars were assessed on 26 July, RGT Zanzibar was significantly greener than the other two spring types. RGT Zanzibar also had significantly greener canopy compared with DS Pascal and Beaufort, and this continued through to the November assessment. The significantly greener canopy of RGT Zanibar was probably linked to its more prostrate growth habit and increased ground coverage. From September through to November the varieties Oakley, RGT Calabro, Manning and RGT Accroc were all significantly greener compared with the other varieties.

v) Grain yield and quality

The time of sowing 1 trial was harvested on 4 December. The trial had an average yield of only 0.44t/ha (Table 5) due to the dry conditions and frost, which impacted on yield and grain quality quite markedly. The variability in the yields between cultivar was large, with the lowest-yielding cultivar, Manning, yielding 0.17t/ha while the highest-yielding cultivar, Annapurna, yielding 0.93t/ha. Annapurna yielded significantly more (0.37t/ha) than all other cultivars, while Manning, RGT Zanzibar and DS Pascal yielded significantly less (0.17–0.19t/ha) than the other cultivars.

As with yield, grain protein varied between cultivars. Beaufort and EGA Wedgetail had the highest protein (16.4%) and Oakley had the lowest (12.9%). Test weights and thousand seed weights were generally low and variable, ranging from 66.9–76.0kg/hL for test weights and 19.5–35.9g for thousand seed weight, due to grain being frost affected. Screening percentages also varied and ranged from 7.3–30.7%, with Oakley having the highest screenings and RGT Calabro having the lowest screenings for this sowing date.

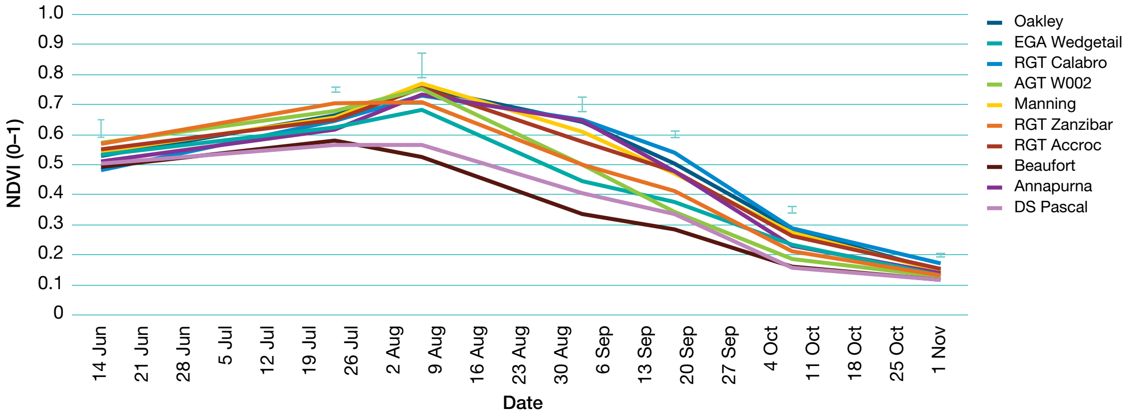


FIGURE 3 NDVI readings for the time of sowing 1 trial (0 – 1 scale) on 18 June, 26 July, 9 August, 4 September, 19 September, 8 October and 1 November 2018

TABLE 5 Yield, protein, test weight and screenings at harvest (GS99), 4 December 2018

Cultivar/Line	Yield (t/ha)	Protein (%)	Test weight (kg/hL)	Screenings (%)	TSW* (g)
Oakley	0.56b	12.9f	75.2abc	30.7a	19.5e
RGT Calabro	0.46b	15.8abc	72.9cde	7.3b	30.9bc
Manning	0.17c	14.2e	66.9f	8.8b	24.2d
RGT Accroc	0.55b	13.0f	74.0abc	13.2b	25.4d
Annapurna	0.93a	14.6de	76.0a	10.2b	29.8c
EGA Wedgetail	0.41b	16.4a	70.5e	13.1b	34.0ab
AGT W002	0.52b	15.1cd	73.3bcd	7.9b	34.0ab
RGT Zanzibar	0.23c	15.6bc	71.3de	21.9ab	35.9a
Beaufort	0.42b	16.4a	70.6e	10.0b	30.0c
DS Pascal	0.19c	16.3ab	75.6ab	7.6b	31.0bc
Mean	**0.44**	**15**	**72.6**	**13.1**	**29.5**
LSD	0.15	0.8	2.7	16.7	4.0

*Thousand seed weight

Figures followed by different letters are regarded as statistically significant

Trial 2.

Sowing date: 30 April 2018 (emerged 4 May without irrigation)
Harvested: 4 December 2018
Rotation position: First cereal after canola
Rainfall:
GSR: 166mm (April – October)
Soil mineral nitrogen: (Sampled: 10 April 2017, from buffer areas of trial site)
0–10cm: 23.7kg N/ha
10–20cm: 6.1kg N/ha
20–30cm: 3.9kg N/ha
30–60cm: 7.8kg N/ha
Total (0–60cm): 41.5kg N/ha

The second time of sowing trial (sown on April 30, 2018) included a range of winter and spring wheat cultivars as presented in Table 6. This trial had a greater focus on spring wheat cultivars compared with the first trial.

TABLE 6 Cultivar, type and maturity for cultivars sown 30 April as part of the time of sowing 2 trial near Yarrawonga, Victoria

Cultivar/Line	Type	Maturity
RGT Accroc	Winter	Intermediate – long
EGA Wedgetail	Winter	Intermediate
Longsword	Winter	Short
DS Pascal	Spring	Intermediate – long
RGT Zanzibar	Spring	Intermediate – long
Cobra	Spring	Intermediate
Coolah	Spring	Intermediate – long
Beckom	Spring	Intermediate
Trojan	Spring	Intermediate
Corack	Spring	Short-Intermediate

Results

i) Establishment and crop structure

Establishment rates for the later sowing date were low and averaged only 93 plants/m^2. EGA Wedgetail had the highest emergence counts at the two-leaf stage (GS12) (107 plants/m^2) while the spring wheat cultivars DS Pascal and Coolah had the lowest emergence counts (both 79 plants/m^2) (Table 7). At first node (GS31) there was a significant split between winter and spring cultivars. All three winter cultivars (RGT Accroc, EGA Wedgetail and Longsword) produced significantly more tillers (51 tillers/m^2) than the spring cultivars, with the exception of RGT Zanzibar, which had the most tillers of all the spring wheats. DS Pascal produced the most tillers per plant (3.8) while the shorter-season spring cultivar, Corack, produced the least tillers per plant (2.6).

TABLE 7 Plant counts assessed at the two-leaf stage (GS12) on 21 May 2018; tiller counts when crop was at first node (GS31) and head counts assessed at physiological maturity (GS92) on 28 November 2018

	Plants/m^2	Tillers/m^2	Heads/m^2
Cultivar/Line	GS12	GS31*	GS92
RGT Accroc	95^{abc}	359^{a}	169^{a}
EGA Wedgetail	107^{a}	371^{a}	167^{ab}
Longsword	101^{ab}	374^{a}	141^{def}
DS Pascal	79^{c}	308^{bc}	145^{c-f}
RGT Zanzibar	94^{abc}	348^{ab}	126^{f}
Cobra	86^{bc}	300^{c}	147^{b-e}
Coolah	79^{c}	244^{d}	159^{a-d}
Beckom	86^{bc}	294^{c}	172^{a}
Trojan	99^{ab}	263^{cd}	163^{abc}
Corack	101^{ab}	268^{cd}	131^{ef}
Mean	**93**	**313**	**152**
LSD	20	47	20

* Tiller counts were taken when each cultivar was at GS31
Figures followed by different letters are regarded as statistically significant

Head counts were low across the trial, with an average of 152 heads/m^2 due to the combined effects of drought and frost. When assessed at maturity (GS92) the winter wheat RGT Accroc had produced 169 heads/m^2, whereas the spring wheat RGT Zanzibar had produced 126 heads/m^2. The highest tiller mortality rates were in RGT Zanzibar and Longsword, which lost more than 62% of the tillers assessed at first node (GS31).

ii) Phenology and floret sterility

Phenology data was collected on a weekly basis over the life of the trial. Spring cultivars reached first node (GS31) over a wide range of dates, with Corack reaching first node (GS31) on 10 July while DS Pascal reached first node (GS31) on 6 August. Of the winter wheats, Longsword reached first node (GS31) on 10 August, while RGT Accroc was the slowest developer, reaching first node (GS31) on 3 September (Table 8).

The same extreme frost events that affected the time of sowing 1 trial during late August also influenced the development of the varieties in the time of sowing 2 trial. Growth stages and frost damage were assessed following the frost event and damage to the embryo ear of the cultivar was not linked to development stage. In this trial, the spring wheat Coolah had the flag leaf fully emerged (GS39) during the frost, but had the lowest levels of floret sterility (26%) when assessed at the start of grain fill. The spring wheats, RGT Zanzibar and Cobra, both had their flag leaves emerging (GS37) at the time of the frost events and both presented significantly more damage (74.5% and 75.7% floret sterility respectively) than the other cultivars (Figure 4). Cultivars sown on April 30 developed at a more similar rate than those sown 3 April, with the flowering window extending for around three

TABLE 8 Time of sowing 2 trial growth stages on 29 August 2019 and dates when individual varieties reached first node (GS31) and flowering (GS65)

Cultivar/Line	Type	Growth stage		
		29 August	GS31	GS65
RGT Accroc	Winter	GS30	3 September	17 October
EGA Wedgetail	Winter	GS32	20 August	11 October
Longsword	Winter	GS33	13 August	11 October
DS Pascal	Spring	GS32	6 August	9 October
RGT Zanzibar	Spring	GS37	1 August	11 October
Cobra	Spring	GS37	30 July	11 October
Coolah	Spring	GS39	26 July	2 October
Beckom	Spring	GS39	26 July	2 October
Trojan	Spring	GS39	23 July	4 October
Corack	Spring	GS43	10 July	28 September

(Left) Dissected Cobra (sown 30 April) stem, showing high floret sterility in embryo ear, 2 weeks after frost event, 12 September 2018. (Right) Dissected RGT Accroc (sown 30 April) stem, showing low floret sterility in embryo ear, 2 weeks after frost event 12 September, 2019.

weeks compared with the five-week flowering window for the first time of sowing. Corack reached flowering first on 28 September and RGT Accroc was the last to reach flowering (GS65) on 17 October. There was a continued trend for spring wheats to spend a longer period developing from first node (GS31) until flowering (GS65). This can be largely, but not completely, attributed to the spring wheats reaching first node (GS31) sooner (Figure 5) than the winter wheats.

iii) Dry matter (DM) production

Dry matter assessments were carried out at first node (GS31), at mid-flowering (GS65) and at physiological maturity (GS92) (Table 9) using four varieties considered representative of the different maturity classes in the trial (RGT Accroc, EGA Wedgetail, DS Pascal and Trojan). Dry matter production was low overall due to the dry conditions, with total DM production of the selected treatments not exceeding 3.18t/ha. At the first node (GS31) assessment, the winter feed cultivar, RGT Accroc (1.20t/ha) produced significantly more DM (0.32t/ha) than any other cultivar, principally as a result of having a longer period of growth to this development stage compared with the other varieties. By flowering the spring cultivars, Trojan and DS Pascal, had produced significantly

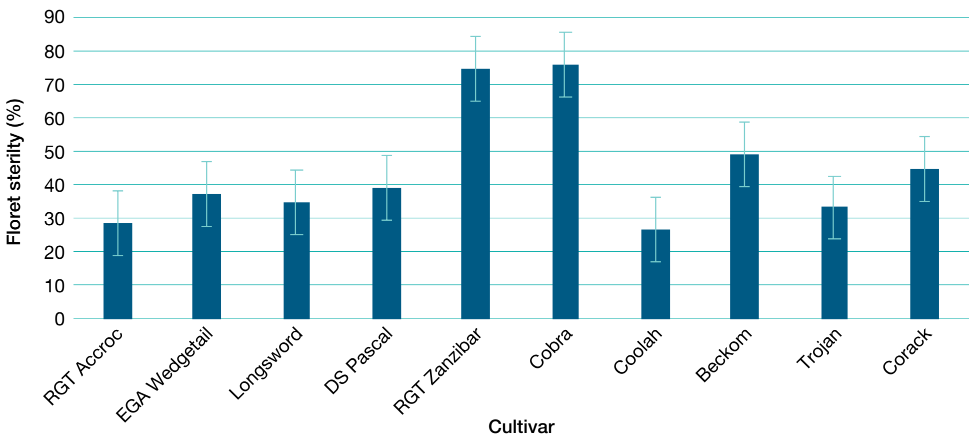


FIGURE 4 Floret sterility of cultivar assessed at early dough – hard dough stage (GS82–87), 5 November 2018

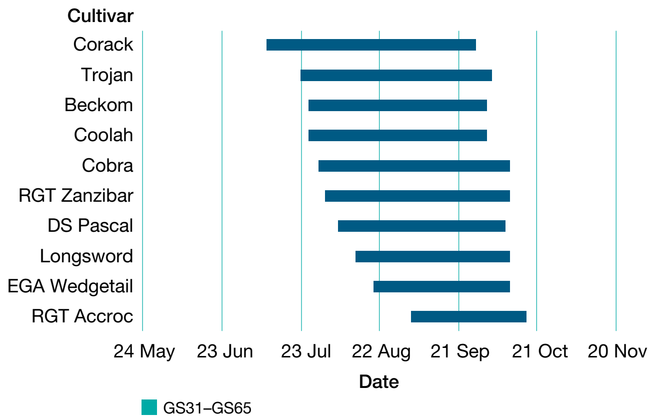


FIGURE 5 Duration (calendar days) between the development stages of first node (GS31) and flowering (GS65)

TABLE 9 Dry matter production at first node (GS31), mid-flowering (GS65) and physiological maturity (GS92)

Cultivar/Line	Dry matter (t/ha)		
	GS31	GS65	GS92
RGT Accroc	1.20^{a}	2.02^{b}	2.53^{b}
EGA Wedgetail	0.82^{b}	2.62^{ab}	2.22^{b}
DS Pascal	0.60^{b}	2.76^{a}	2.70^{ab}
Trojan	0.71^{b}	3.19^{a}	3.18^{a}
Mean	**0.83**	**2.65**	**2.66**
LSD	0.26	0.68	0.60

*DM at GS31 and GS65 were taken when each cultivar was at the appropriate growth stage.
Figures followed by different letters are regarded as statistically significant

more DM than the winter cultivar EGA Wedgetail. Dry matter benefits were also evident in earlier-maturing cultivars at the assessment undertaken at physiological maturity (GS92). Trojan produced at least 0.65t/ha more DM by maturity than either of the winter wheats, RGT Accroc and EGA Wedgetail, however RGT Accroc was still higher yielding (Table 10).

iv) Normalised difference vegetative index (NDVI)

Crop reflectance measurements taken with the Greenseeker™ and recorded as NDVI showed differences in the crop canopy due to growth habit (Figure 6). On 26 July the spring cultivars, Trojan and Beckom, recorded significantly lower NDVI readings than the other spring cultivars. The winter types, RGT Accroc, EGA Wegdgetail, and the spring type, RGT Zanzibar, were the greenest cultivars from 26 July until harvest. The growth pattern of EGA Wedgetail and RGT Accroc was more prostrate compared with the spring cultivars, which created more ground cover and led to higher NDVI readings.

v) Grain yield and quality

The trial was harvested on 4 December and had an average yield of 0.39t/ha (Table 10). The decile 1 rainfall conditions and frost impacted on yield and grain quality, as was also the case with the 3 April sowing. There were significant differences in grain yields across the trial, with RGT Accroc giving the highest yields (0.6t/ha). RGT Accroc had a yield 0.15t/ha greater than the next best spring cultivar DS Pascal (0.45t/ha). Cobra (0.16t/ha) had the lowest yield, a result that related to higher levels of floret sterility.

Grain protein levels were very high, with Cobra having significantly higher grain protein (by 1.7%) than the other cultivars, principally as an artefact of its low yield. RGT Accroc had the lowest grain protein of 14.8%, which was linked to its higher yield relative to the other varieties.

Test weights and screenings varied, ranging from 74.3–80.9kg/hL and 1.5–16.1% respectively, due to grain being frost affected.

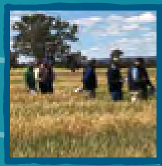
Conclusion

The dry conditions and extreme frost events of 2018 significantly reduced the yield potential from both times

TABLE 10 Yield, protein, test weight and screenings at harvest (GS99), 4 December 2018

Cultivar/Line	Yield (t/ha)	Protein (%)	Test weight (kg/hL)	Screenings (%)	TSW* (g)
RGT Accroc	0.60^{a}	14.8^{g}	76.8^{de}	8.8^{b}	33.6^{de}
EGA Wedgetail	0.34^{de}	16.3^{b}	76.6^{de}	3.0^{f}	38.8^{b}
Longsword	0.44^{bc}	16.5^{b}	78.2^{bc}	1.5^{g}	38.2b^{c}
DS Pascal	0.45^{bc}	15.7^{de}	77.4^{cd}	5.7^{c}	32.4^{e}
RGT Zanzibar	0.28^{e}	15.5^{ef}	76.0^{e}	5.9^{c}	37.9^{bc}
Cobra	0.16^{f}	18.2^{a}	74.3^{f}	3.6^{ef}	35.6^{cd}
Coolah	0.50^{b}	15.1^{fg}	76.8^{de}	16.1^{a}	31.8^{e}
Beckom	0.38^{cd}	16.3^{bc}	79.0^{b}	4.9^{cd}	31.6^{e}
Trojan	0.44^{bc}	15.9^{cd}	80.9^{a}	3.5^{ef}	36.2^{bcd}
Corack	0.33^{de}	15.5^{de}	78.9^{b}	4.3^{de}	41.7^{a}
Mean	**0.39**	**16.0**	**75.8**	**5.7**	**35.8**
LSD	0.08	0.4	1.3	1.1	2.7

*Thousand seed weight
Figures followed by different letters are regarded as statistically significant



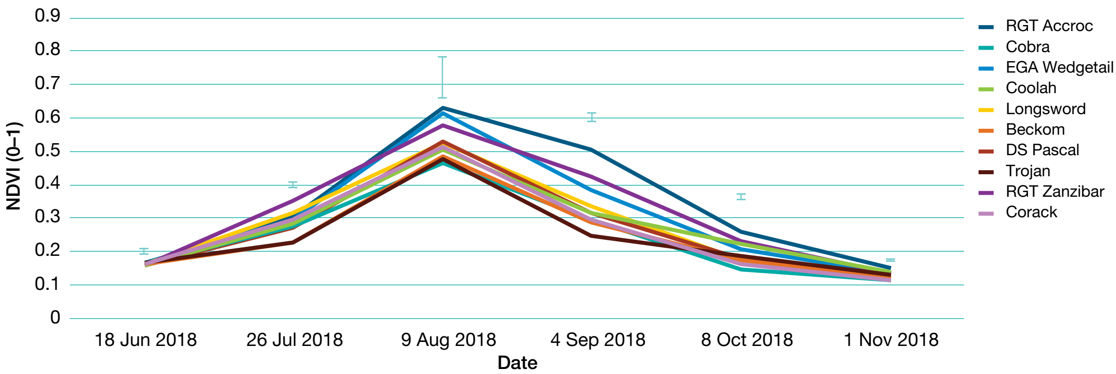


FIGURE 6 NDVI readings for the second time of sowing trial taken 18 June, 26 July, 9 August, 4 September, 8 October and 1 November 2018

of sowing. However, the results demonstrate that incorporating several wheat varieties of variable flowering time into a cropping program may spread the risk of frost in a dry season. Moreover, a number of winter wheats had equivalent yields at an early sowing time, which may be of value in seasons with an early break.

Acknowledgements

This trial was funded by Riverine Plains Inc on behalf of its members and carried out at the Riverine Research Centre (RRC), at Burramine, near Yarrawonga, Victoria. The RRC is a collaboration between Riverine Plains Inc and FAR Australia. We would also like to thank FAR Australia for managing the trial. Thank you also to Riverine Research Centre hosts, Telewonga Pty Ltd.

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Management of early-sown wheat

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

The following report has been based on a single year's data from a research project. Please exercise caution when interpreting the results.

Key points

- Ten wheat cultivars sown across four sowing dates (18 March, 3 April, 16 April and 30 April) yielded between 0.19–1.20t/ha.
- There was a significant interaction between sowing date and cultivar yield performance, with yields increasing when the sowing date was delayed from 18 March to 16 April.
- Due to seasonal conditions, wheat yields were low and unstable across the trial.
- Floret sterility (mainly due to frost damage) was recorded at high levels (trial average of 48%) across all wheat cultivars across all times of sowing.
- The winter wheat varieties Longsword, DS Bennett and Nemo had the lowest levels of floret sterility across the trial.

Background

During the past 10 years there has been a major shift to sow broadacre crops earlier across south eastern Australia. This early-sowing regime has been underpinned by increased grain yields, particularly in the low-rainfall and medium-rainfall zones. However, the move to early sowing has also exposed shortcomings in wheat germplasm, with earlier sowing resulting in earlier flowering and a subsequent increase in the risk of frost damage. Consequently, there has been increasing interest in new shorter-season winter wheat cultivars, which are better adapted to early sowing.

Method

Two trials were established during 2018 as part of a LaTrobe University research project for the Grains Research and Development Corporation (GRDC) investment *Development of crop management packages for early-sown, slow-developing wheats in the Southern region* (MESW) (Project code ULA9175069).

The first trial investigated the performance of new winter wheat germplasm at four times of sowing from 18 March to 30 April. The second trial sought to understand how changing the canopy structure (through sowing rate, nitrogen timing and grazing) affected the management and yield of winter wheats. The trials were carried out at the Riverine Research Centre (RRC) at Yarrawonga, Victoria.

Seasonal conditions

Both trials were seriously affected by extreme frost events during late August in combination with a very dry spring. Growing season rainfall (GSR) for the site was 166mm (decile 1), with 33mm of GSR falling during late October. Canopy temperatures fell below -11°C on 28 August 2018.

Trial 1.

Time of sowing x cultivar

Sowing date: See Table 1
Rotation: Wheat following canola
Stubble: Canola unburnt
Rainfall:
GSR: 166mm (April – October)
Summer rainfall: 47mm
Soil mineral nitrogen:
0–10cm: 23kg N/ha
10–30cm: 10kg N/ha
30–60cm: 9kg N/ha

The research carried out at the RRC involved 10 developmentally different cultivars sown across four sowing dates (Table 1 and 2). Two spring wheat cultivars were also included as controls for each time of sowing.

Trickle tape irrigation was used to mimic an autumn break if there was not enough natural rainfall for establishment, applied as 10mm for time of sowing 1 and 2 (Table 1). In-crop assessments were made to increase the understanding of early-sown wheat phenology and provide insights as to how new winter wheats can be best managed in broadacre systems.

Treatment list

See Table 1.

TABLE 1 Time of sowing treatment details, for MESW trial 1, Yarrawonga, Victoria, 2018

	Times of sowing (TOS) 2017		
TOS	Targeted time of sowing	Actual time of sowing	Date of emergence
1	15 March	18 March	22 March
2	1 April	3 April	7 April
3	15 April	16 April	20 April
4	1 May	30 April	7 May

TABLE 2 Cultivar and season length details for MESW trial 1, Yarrawonga, Victoria, 2018

	Cultivar	Type
1	Scepter	Fast spring
2	Cutlass	Mid spring
3	LPB14-0392	Intermediate; fast winter–slow spring
4	Longsword	Fast winter
5	Illabo (V09150-01)	Mid–fast winter
6	Kittyhawk	Mid-winter
7	ADV13.1292	Mid-winter
8	DS Bennett (ADV11.9419)	Slow winter
9	Descartes	Slow winter (European)
10	Nemo	Slow winter (European)

Results

i) Establishment and crop structure

All plots were sown at 120 seeds/m^2, resulting in establishment of 80–106 plants/m^2 (Table 3).

Based on weather station data, the two spring wheat cultivars, Scepter (fast spring) and Cutlass (intermediate spring), required less thermal time to reach first node (GS31) than the eight winter wheat cultivars (Figure 1). The accumulated thermal time to reach first node (GS31) was greater in the winter wheat cultivars when they were sown earlier, however this was not as prevalent with the spring wheat cultivars.

ii) Floret sterility

Floret sterility (principally due to frost) was recorded at high levels across all cultivars, but was generally higher in the first two times of sowing (18 March and 3 April) (Figure 2). Several extreme frost events at the end of August, where canopy temperatures reached -11°C, had a profound effect across all varieties. There was less floret sterility in some later-maturing varieties at the first two times of sowing when compared with the spring varieties, Scepter and Cutlass. There was also evidence of Descartes, Kittyhawk and ADV13.1292 having sterility above 50%, whereas the similar-maturing type, DS Bennett, had around 35% sterility.

TABLE 3 Plant counts 9 April 2018, 19 April 2018, on 4 May 2018 and 21 May 2018 from MESW trial 1, Yarrawonga, Victoria, 2018

Time of sowing (TOS)	Date of plant count	Plants/m^2
TOS 1 (18 March)	9 April	80^{c}
TOS 2 (3 April)	19 April	82^{c}
TOS 3 (16 April)	4 May	89^{b}
TOS 4 (30 April)	21 May	110^{a}
Mean		**90**
LSD		5
Cultivar		
Scepter		87^{c}
Cutlass		95^{b}
LPB14-0392		96^{b}
Longsword		87^{c}
Illabo (V09150-01)		108^{a}
Kittyhawk		103^{a}
ADV13.1292		92^{bc}
DS Bennett (ADV11.9419)		82^{d}
Descartes		90^{c}
Nemo		63^{e}
LSD		5

Note: Mean is average plants/m^2 for all times of sowing
Figures followed by different letters are regarded as statistically significant.

iii) Grain yield and quality

Wheat yields were very low due to severe frosts and decile 1 growing season rainfall for the region. DS Bennett

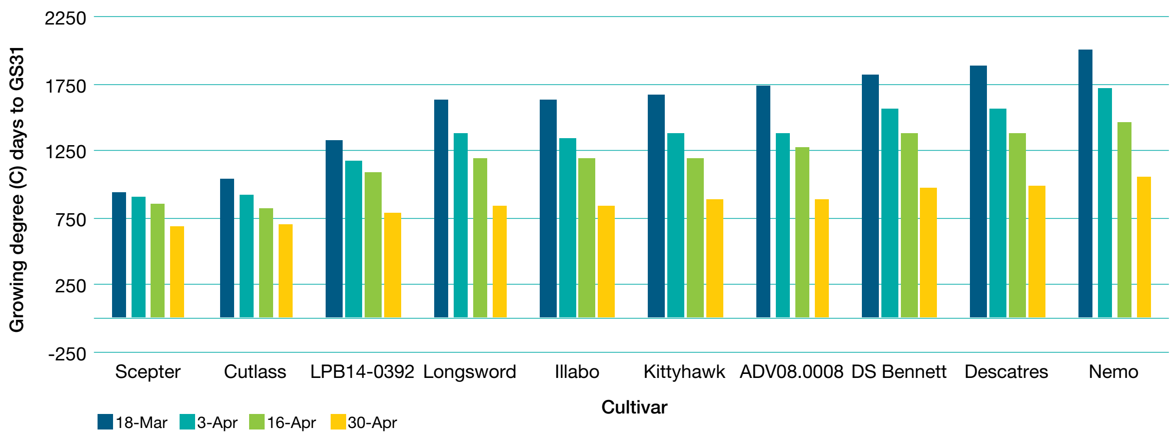

FIGURE 1 Growing degree (C°) days for each cultivar at each time of sowing to reach first node (GS31) from MESW Trial 1, Yarrawonga, Victoria, 2018

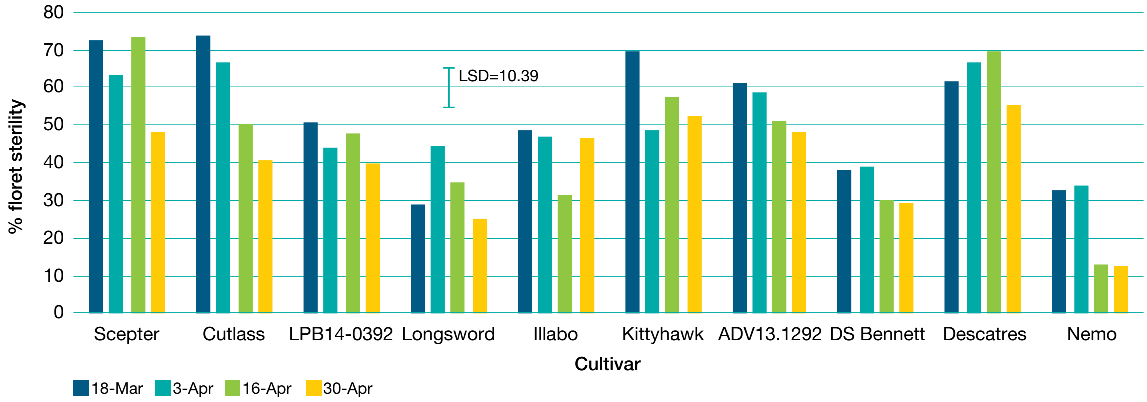

FIGURE 2 Percentage of floret sterility for each cultivar at each time of sowing in MESW Trial 1, Yarrawonga, Victoria, 2018
Error bar is a measure of LSD

produced the highest average yield across all times of sowing of 0.96t/ha, but fellow winter wheat ADV13.1292 (0.31t/ha) had the lowest yield across all times of sowing.

TABLE 4 Yield, protein, test weight and screenings of time of sowing at harvest (GS99) for MESW trial 1, at Yarrawonga, Victoria, 4 December 2018*

Time of sowing	Yield (t/ha)	Protein (%)	Test weight (kg/hL)	Screenings (%)
18 March	0.42[c]	15.04[a]	72.6[b]	11.0[a]
3 April	0.54[b]	14.76[bc]	73.5[b]	10.0[ab]
16 April	0.60[a]	14.55[c]	74.8[a]	8.4[b]
30 April	0.59[a]	14.84[ab]	74.6[a]	8.8[ab]
Mean	**0.54**	**14.80**	**73.9**	**9.6**
LSD	0.04	0.23	1.0	2.2

*Mean of eight cultivars
Figures followed by different letters are regarded as statistically significant.

There was a significant interaction between sowing date and cultivar yield performance, with yield of the spring wheat cultivars increasing from the 18 March sowing date to 16 April (Tables 4 and 5).

Sowing DS Bennett on 16 April produced the highest yield of the trial at 1.20t/ha. All varieties had high grain protein levels at harvest (average across all plots of 14.8%) due to the low-yielding conditions, except for DS Bennett and Nemo, which ranged from 12–13.5%. In general, sowing later was a better strategy for 2018, though frost affected every cultivar and the yield from both spring and winter varieties was seriously penalised by frost damage. DS Bennett was the highest-yielding variety at each time of sowing (Figure 3).

TABLE 5 Yield, protein, test weight and screenings for cultivars at harvest (GS99) for MESW trial 1, Yarrawonga, Victoria, 4 December 2018*

Cultivar	Yield (t/ha)	Protein (%)	Test weight (kg/hl)	Screenings (%)
Scepter	0.52[c]	14.4[c]	74.7[b]	5.3[de]
Cutlass	0.53[c]	15.0[bc]	76.4[b]	6.4[cd]
LPB14-0392	0.47[d]	15.6[ab]	72.8[c]	14.2[b]
Longsword	0.61[bc]	15.6[a]	74.6[b]	3.8[e]
Illabo (V09150-01)	0.56[c]	15.0[bc]	71.8[d]	5.5[de]
Kittyhawk	0.41[e]	15.4[ab]	75.5[ab]	3.8[e]
ADV13.1292	0.31[f]	15.9[a]	73.0[c]	9.6[c]
DS Bennett (ADV11.9419)	0.96[a]	13.2[d]	75.7[a]	6.4[cde]
Descartes	0.39[e]	15.7[a]	72.9[c]	8.6[cd]
Nemo	0.64[b]	12.2[e]	71.1[d]	32.1[a]
Mean	**0.54**	**14.8**	**73.9**	**9.6**
LSD	0.05	0.6	0.9	3.3

*Mean of four sowing dates
Figures followed by different letters are regarded as statistically significant.

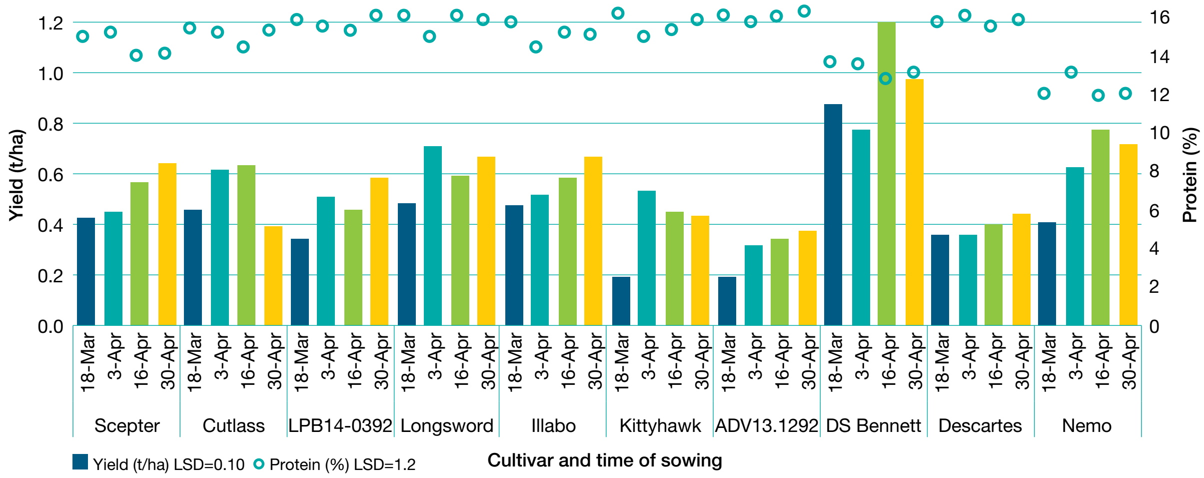

FIGURE 3 Interaction between time of sowing and cultivar on yield and protein for MESW Trial 1, Yarrawonga, Victoria, 2018

Visual differences in canopy colour caused by frost damage between DS Bennett (left) and Sceptre (right) on October 2, sown 18 March 2018.

Trial 2

Cultivar x sowing rate x nitrogen timing x grazing

Key points

- Three cultivars sown on 16 April yielded between 0.21–1.64t/ha.
- When all parameters were considered together (cultivar, nitrogen treatment and sowing rate), there was significant interaction between grazing and yield; ungrazed crops incurred a yield penalty.
- Floret sterility (mainly due to frost damage) was recorded at higher levels in certain ungrazed cultivars.
- Larger amounts of biomass were removed from plots with a higher sowing rate and nitrogen applied at sowing.

Sowing date: 16 April 2018
Rotation: Wheat following canola
Stubble: Canola unburnt
Rainfall:
GSR: 166mm (April–October)
Summer rainfall: 47mm
Soil mineral nitrogen:
0–10cm: 23kg N/ha
10–30cm: 10kg N/ha
30–60cm: 9kg N/ha

Cultivar x sowing rate x nitrogen timing x grazing trial on 16 June 2018 after first grazing

The aim of the trial was to manipulate the canopy of early-sown wheat and understand how these interventions can affect crop management.

Manipulation of the crop canopy was achieved by cultivar selection, sowing rate, nitrogen fertiliser application and grazing. The trial studied three winter wheat cultivars ADV11.9419, Kittyhawk and Longsword, sown at two target plant populations (50 and 150 plants/m^2) on 16 April 2018 (Table 6). Plots were fertilised with nitrogen as urea at sowing (GS00) or at the start of stem elongation (GS30). Each treatment combination was either grazed mechanically or left ungrazed.

Treatment list

See Table 6.

Results

i) Establishment and crop structure

Establishment was below target, with the low density (target 50 plants/m^2) establishing at 30 plants/m^2 and the high

TABLE 6 Target population treatment details for MESW trial 2, Yarrawonga, Victoria, 2018

Cultivar	Target plant density (plants/m^2)	Nitrogen timing (200kg urea)	Grazing*
DS Bennett	50	GS00	Nil
	50	GS00	Grazed
	50	GS30	Nil
	50	GS30	Grazed
	150	GS00	Nil
	150	GS00	Grazed
	150	GS30	Nil
	150	GS30	Grazed
Kittyhawk	50	GS00	Nil
	50	GS00	Grazed
	50	GS30	Nil
	50	GS30	Grazed
	150	GS00	Nil
	150	GS00	Grazed
	150	GS30	Nil
	150	GS30	Grazed
Longsword	50	GS00	Nil
	50	GS00	Grazed
	50	GS30	Nil
	50	GS30	Grazed
	150	GS00	Nil
	150	GS00	Grazed
	150	GS30	Nil
	150	GS30	Grazed

*Grazing was undertaken on each plot by mechanical defoliation at the four-tiller stage (GS24) and start of stem elongation (GS30)



density (target 150 plants/m2) establishing at 70 plants/m^2 (Table 7). There was a small cultivar effect, with Longsword establishing at lower average plant density (44 plants/m^2) compared with Kittyhawk (56 plants/m^2) and DS Bennett (51 plants/^{2}).

ii) Dry matter offtake at grazing

Dry matter (DM) availability at the first grazing (GS15) was driven by plant density, with high density treatments having 0.9 t DM/ha and low density 0.5 t DM/ha. There was also a significant effect of cultivar, but this was confounded by the different cultivar densities described above.

At the time of the second grazing (GS30) the effect of density was reduced (0.7t/ha vs. 0.6t/ha) and nitrogen timing became the most important factor, with nitrogen applied at sowing increasing dry matter from 0.5 to 0.8t/ha (Table 8).

iii) Infertile tillers and floret sterility

Differences in yield between cultivars and grazing were largely driven by stem frost damage and the stage of crop development. Longsword was the most advanced when the frost hit and 61% of its tillers were infertile in comparison to Kittyhawk at 45% and DS Bennett at 30% (Table 9). Grazing reduced infertile tillers from 49% to 41%, but there was no effect of density or nitrogen timing. Grazing also reduced floret sterility from 46% to 24% as a main effect, and there was an interaction with cultivar (Table 10). Grazing did not reduce sterility in DS Bennett, but did to a very large extent in Kittyhawk and to a lesser extent in Longsword.

TABLE 7 Target and actual plant emergence 3 May for MESW trial 2, Yarrawonga, Victoria, 2018

Target plant population (plants/m^2)	Actual plant population (plants/m^2)
50	30
150	70

TABLE 8 Effect of plant density and nitrogen timing on dry matter offtake when all cultivars were combined, at the start of stem elongation (GS30) 27 July for MESW Trial 2, Yarrawonga, Victoria, 2018

Plant density	DM (t/ha)
30 plants/m^2	0.34^{b}
70 plants/m^2	0.55^{a}
Mean	**0.51**
LSD	0.17
Nitrogen timing	
GS00	0.57^{a}
GS30	0.32^{b}
LSD	0.17

Figures followed by different letters are regarded as statistically significant

TABLE 9 Effect of cultivar and grazing on infertile tillers at flowering (GS65) 15 October for MESW trial 2, Yarrawonga, Victoria, 2018

Cultivar	Infertile tillers (%)
DS Bennett	30^{c}
Kittyhawk	45^{b}
Longsword	61^{a}
Mean	**45**
LSD	3.4
Grazing	
Grazed	41^{b}
Nil	49^{a}
Mean	**45**
LSD	3

Figures followed by different letters are regarded as statistically significant

TABLE 10 Interaction of cultivar and grazing on floret sterility at early dough stage (GS83), 12 November 2018 for MESW trial 2, Yarrawonga, Victoria, 2018

Cultivar and treatment	Floret sterility (%)
DS Bennett ungrazed	34^{b}
DS Bennett grazed	27^{bc}
Kittyhawk ungrazed	67^{a}
Kittyhawk grazed	24^{c}
Longsword ungrazed	37^{b}
Longsword grazed	22^{c}
Mean	**35**
LSD	11

Figures followed by different letters are regarded as statistically significant.

iv) Yield and quality

Plant density had no main effect on yield, while both grazing and deferring nitrogen increased yield by 0.2t/ha. DS Bennet (1.1t/ha) yielded more than Kittyhawk (0.7t/ha) and Longsword (0.6t/ha). There was a significant interaction between cultivar, grazing and nitrogen rate (Table 11), with the highest-yielding treatment being DS Bennett, ungrazed

TABLE 11 Effect of cultivar, nitrogen timing and grazing on grain yield 11 December for MESW Trial 2, Yarrawonga, Victoria, 2018

	Grazed		Ungrazed	
	Nitrogen application		Nitrogen application	
Cultivar	Early stem	Sowing	Early stem	Sowing
DS Bennett	1.13	1.09	1.48	0.87
Kittyhawk	0.92	0.67	0.39	0.29
Longsword	0.93	0.89	0.52	0.55
Mean		**0.8**		
LSD		0.24		

Figures followed by different letters are regarded as statistically significant

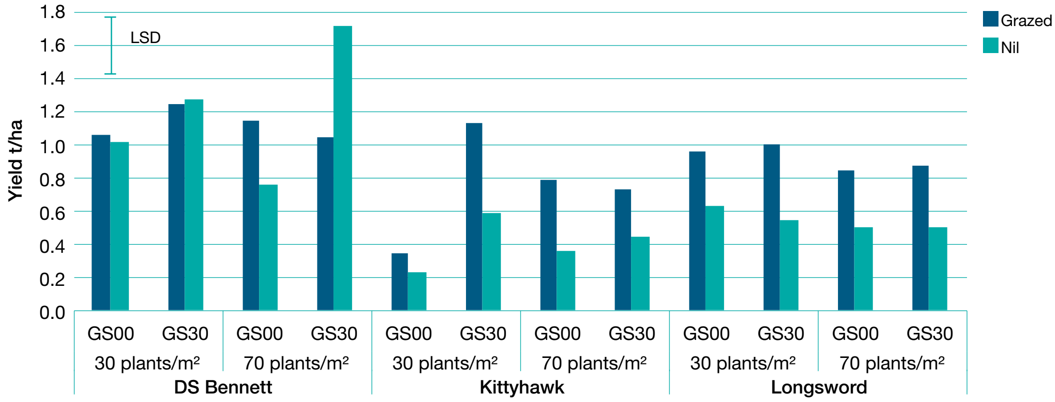

FIGURE 4 The interaction of cultivar, plant density, nitrogen timing (GS00 or GS30) and grazing on yield at harvest (GS99), 11 December for MESW trial 2 Yarrawonga, Victoria, 2018

Error bar is a measure of LSD

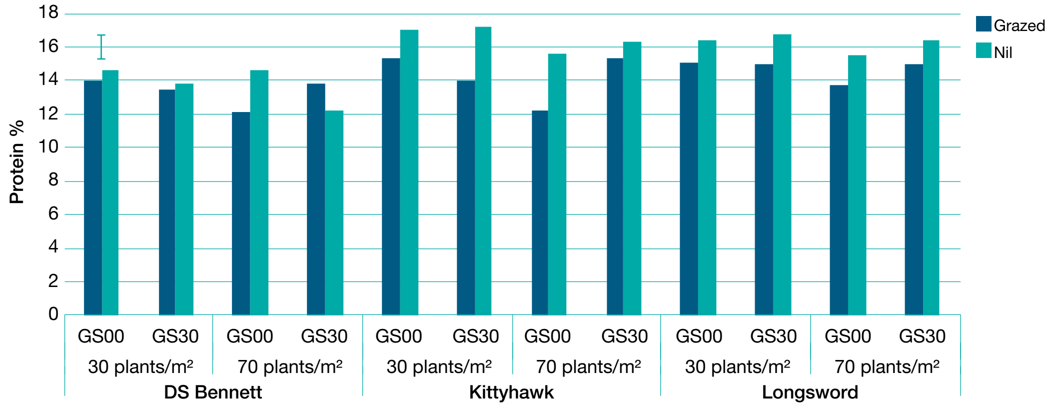

FIGURE 5 The interaction of cultivar, plant density, nitrogen timing (GS00 or GS30) and grazing on protein at harvest (GS99), 11 December for MESW trial 2, Yarrawonga, Victoria, 2018

Error bar is a measure of LSD

with nitrogen deferred until early stem elongation (GS30) (Figure 4). Grain protein was generally high across the trial, with ungrazed Kittyhawk, sown at 30 plants/m^2 (17%) the highest and grazed DS Bennett, sown at 70 plants/m^2, had the lowest protein in the trial (12%) (Figure 5).

Acknowledgements

This work was carried out as part of the GRDC investment *Development of crop management packages for early-sown, slow-developing wheats in the Southern region* (ULA9175069), led by LaTrobe University. Thank you also to our farmer co-operator at the Riverine Research Centre, Telewonga Pty Ltd.

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Addressing soil acidity: subsurface soil amendments increasing pH and crop yield at Rutherglen

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Graham Centre for Agricultural Innovation (alliance between Charles Sturt University and New South Wales Department of Primary Industries)

Key points

- Deep placement of soil ameliorants improved soil pH and decreased aluminium (Al) concentrations in the subsurface soil layer.
- The benefits of soil amendments to soil pH and aluminium concentration remain for future seasons.
- No yield improvement was recorded during 2018 due to low growing season rainfall (GSR) and frost events.

Introduction

Acidity of subsurface soil (below 10cm from the soil surface) is a major constraint to crop production in the high-rainfall (500–800mm) cropping zone. While acidic surface soil (0–10cm) can be easily and effectively addressed by incorporating lime at the soil surface, amelioration of the subsurface (below 10cm) soil has not been practical.

The current GRDC-funded project *Innovative approaches to managing subsoil acidity in the southern grain region* (DAN00206) aims to identify and evaluate a range of products, which may be used to overcome adverse effects of subsurface soil acidity. These products include alkaline materials, such as lime and dolomite, and novel products, such as magnesium silicate (which reacts to create alkali) or reactive phosphate rock (which can increase pH and release plant available phosphorus (P) as it dissolves in acidic soil).

Organic amendments, such as lucerne pellets, are known to increase soil pH either by being an alkali source or by enabling alkaline reactions to occur during the decomposition of organics. The influence of these products on the conditions of subsurface acidity (soil pH and toxic aluminium) and crop yield were investigated.

Aim

To quantify the yield limitation caused by subsoil acidity and evaluate innovative soil amendments that act to ameliorate subsurface acidity.

Method

A three-year, replicated field experiment was established at Rutherglen, Victoria, on a site located adjacent to the Rutherglen–Wahgunyah Road. The site has a history of more than 20 years of clover pasture, which was grazed and cut for hay. The absence of any lime applications to the site during this time, has resulted in highly acidic soil and high aluminium (Al) concentrations in both the surface (0–10cm) and subsurface soil (10–30cm) (Table 1).

Existing pasture was sprayed out and 14 amendment treatments were applied during March 2017 in a randomised block design with three replicates, with plots measuring 5m x 20m (Table 2). Canola was grown during 2017, wheat during 2018 and canola was sown again in 2019.

There were 14 treatments, including 11 deep amendment treatments to contrast with a nil control (no additions), lime control and surface lime treatments. Apart from the nil control, all other treatments received surface application of superfine lime (neutralising value = 98%) at 1.7t/ha to achieve a soil pH in the 0–10cm of pH 5.0 in order to ameliorate surface acidity. The surface lime treatment received a higher rate (2.7t/ha) of surface applied lime to achieve a target pH of 5.5 in the surface layer.

Deep amendment treatments included: lime, dolomite, magnesium silicate (MgSi), lucerne pellets, reactive phosphate rock (RPR) and liquid phosphorus (P). The deep amendments were placed approximately 10–30cm deep in the profile at a 50cm row spacing using the 3D Ripper machine engineered by NSW DPI. A deep-ripped control, which had surface lime (pH 5.0) but was deep ripped with no amendment added (deep ripping only), was included to contrast the deep amendment treatments. Deep amendments were applied at rates to achieve a target pH 5.0 based on short-term laboratory incubation studies conducted at Charles Sturt University. Amendments

TABLE 1 Initial pH and exchangeable aluminium (Al) percentage* of the Rutherglen field trial, January 2017

Soil depth (cm)	Soil pH ($CaCl_2$)	Al%
0–10	4.55	12
10–20	4.22	30
20–30	4.32	10
30–40	5.05	3

* Exchangeable aluminium percentage is determined as the percentage of the measured cation exchange capacity (CEC), which is comprised of aluminium. A value greater than 6% generally indicates aluminium to be likely to cause plant phytotoxicity.



TABLE 2 Surface and deep amendment treatments applied to the Rutherglen, Victoria trial site during 2017

Treatment	Surface lime application rate (t/ha)	Target surface pH ($CaCl_2$)	Deep amendment (placed about 10–30cm deep)	Deep amendment application rate (t/ha)
Nil control	0	-	n/a	n/a
Limed control	1.7	5.0	n/a	n/a
Surface lime	2.7	5.5	n/a	n/a
Deep ripping only	1.7	5.0	Deep ripping only	n/a
Deep lime	1.7	5.0	Lime	2.5
Deep dolomite	1.7	5.0	Dolomite	2.3
Deep MgSi (low)	1.7	5.0	Magnesium silicate	4
Deep MgSi (high)	1.7	5.0	Magnesium silicate	8
Deep lucerne (low)	1.7	5.0	Lucerne pellets	7.5
Deep lucerne (high)	1.7	5.0	Lucerne pellets	15
Deep RPR (low)	1.7	5.0	Reactive phosphate rock	4
Deep RPR (high)	1.7	5.0	Reactive phosphate rock	8
Deep P	1.7	5.0	Liquid phosphorus	15kg P/ha
Deep P + deep lime	1.7	5.0	Liquid phosphorus + lime	15kg P/ha + 2.5t/ha Lime

applied at two rates (MgSi, RPR and lucerne pellets) were labelled high and low, for the targeted pH 5.0 rate and half that rate, respectively.

Lancer wheat was sown on 14 May 2018 at 80kg/ha, with 75kg DAP/ha placed with the seed using an air seeder on a 25cm row spacing. Urea was top-dressed at 50kg N/ha to all plots on 25 July 2018. Crop growth was monitored through the season and standard agronomic metrics (establishment counts, biomass, tiller numbers) were recorded (data not presented).

The site was harvested on 7 December 2018 using a plot harvester. Yield data were statistically analysed using ANOVA and a Student-Newman-Keuls test to determine treatment differences.

The soil from each plot was sampled after harvest by taking two 44mm diameter cores on the rip-line and two cores between rip lines to a depth of 140cm. Core samples were divided into depth increments of 0–10, 10–20, 20–30, 30–40, 40–60, 60–80, 80–100, 100–120, 120–140cm with depth increments from duplicate cores bulked to produce representative soil samples for each sampling depth, on and off the rip-line.

Each soil sample was air-dried and analysed for soil water content, soil pH ($CaCl_2$), and other chemical properties, such as mineral nitrogen (N), aluminium, and available phosphorus.

Results

The experimental site received 170mm rainfall during the growing season (long-term average rainfall during that period is 400mm) and the site experienced 16 nights of negative temperatures.

Following harvest during December 2018, the soil pH in the surface (0–10cm) soil ranged pH 4.6 to 5.4 (Figure 1) as a result of the surface lime application during 2017. In the 10–20cm layer, large increases in soil pH were recorded, relative to the control, in the lime and dolomite treatments resulting in soil pH of approximately 6. All other treatments containing liming agents resulted in soil pH of approximately 5 in that layer. Changes in pH below 20cm were not significantly different between treatments. The exchangeable aluminium percentage for most treatments receiving liming agents was less than 5% of effective cation exchange capacity (ECEC) (Figure 1). Aluminium toxicity would have had the potential to limit yield in the nil control, deep ripping only, and surface lime only treatments as their 10–20cm layers exhibited an aluminium percentage greater than 15%.

However, there were no significant differences between treatments for any plant production measures taken during the experiment in 2018 (Table 3). A combination of drought and frost appeared to be the greatest limitation to plant growth in that year.

Observations and comments

Treatment differences were observed visually during the first four weeks of growth. The nil control and surface lime treatments only had small, spindly growth, while deep amended treatments appeared healthier. However, due to the harsh conditions experienced during the growing season, the early visual symptoms did not carry through to result in significant differences between treatments at harvest. Despite the poor agronomic result achieved during 2018, data from soil sampling indicated that, in general, liming agents applied at the start of the 2017

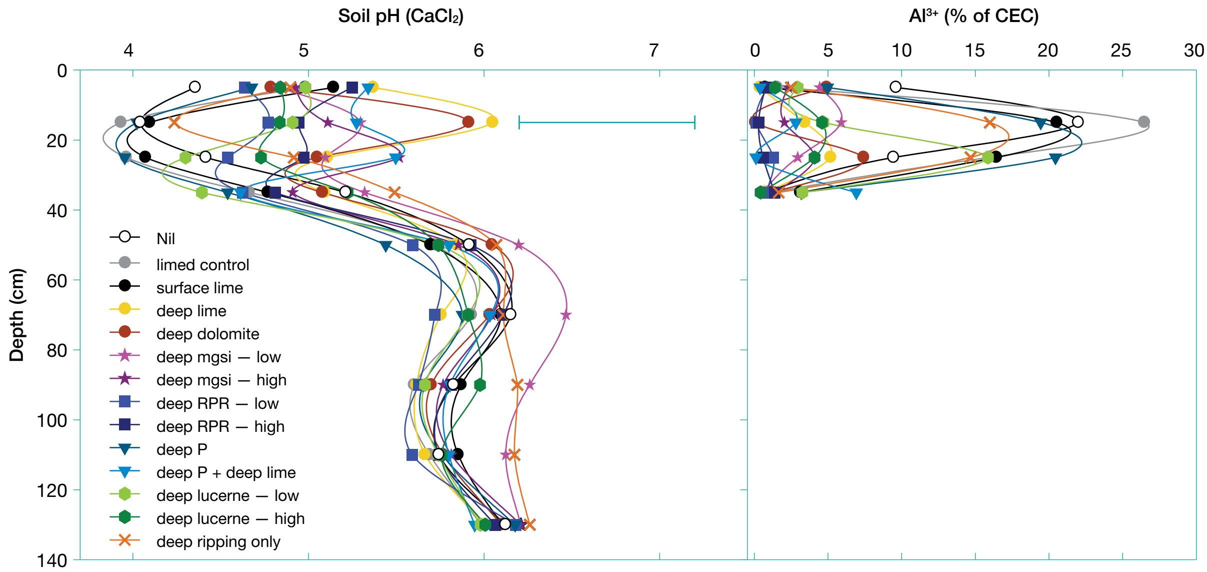

FIGURE 1 Profile soil pH ($CaCl_2$) and exchangeable aluminium percentage (% of ECEC) of amendment treatments at Rutherglen site measured after wheat harvest, December 2018

Data are means of three replicates of each treatment. Bar represents LSD for pH data at *P*=0.05 at the only depth increment where significant differences occurred (10–20cm)

TABLE 3 Establishment counts, flowering head counts, flowering and harvest biomass and grain yield of Lancer wheat, 2018

Treatment	Establishment (plants/m²)	Head counts at flowering (heads/m²)	Biomass at flowering (t/ha)	Biomass at harvest (t/ha)	Grain yield (t/ha)
Nil control	154 (6.5)	343 (25.7)	5.0 (0.6)	5.2 (0.7)	1.5 (0.4)
Limed control	139 (4.2)	321 (7.3)	4.5 (0.0)	4.5 (0.2)	1.2 (0.2)
Surface lime	157 (2.1)	341 (12.5)	5.0 (0.2)	5.1 (0.4)	1.4 (0.4)
Deep ripping only	140 (5.4)	332 (23.3)	5.2 (0.2)	5.3 (0.1)	1.4 (0.1)
Deep lime	141 (1.4)	334 (27.1)	5.5 (0.4)	5.5 (0.7)	1.5 (0.7)
Deep dolomite	154 (4.8)	379 (25.4)	6.2 (0.4)	6.4 (0.2)	2.1 (0.2)
Deep MgSi (low)	147 (3.5)	349 (23.9)	5.6 (0.6)	5.9 (0.6)	1.7 (0.3)
Deep MgSi (high)	143 (4.3)	350 (25.1)	5.3 (0.4)	5.9 (0)	1.7 (0.2)
Deep lucerne (low)	136 (0.4)	344 (5.0)	5.2 (0.0)	5.1 (0)	1.4 (0.2)
Deep lucerne (high)	151 (7.3)	341 (72.5)	6.3 (0.7)	5.9 (1)	1.3 (0.6)
Deep RPR (low)	139 (2.7)	342 (29.4)	5.4 (0.5)	6.1 (0.9)	1.7 (0.2)
Deep RPR (high)	139 (4.4)	370 (14.8)	5.5 (0.5)	5.4 (0.5)	1.4 (0.2)
Deep P	134 (5.5)	340 (31.6)	5.1 (0.5)	4.6 (0.5)	1.2 (0.4)
Deep P + deep lime	143 (5.8)	326 (20.7)	5.0 (0.4)	5.4 (0.2)	1.5 (0.0)

Note: There was no significant difference between treatments and values in parentheses are standard error of means.

season still maintained positive effects on soil pH and exchangeable aluminium concentrations when measured during December 2018. This should act to improve plant growth if better seasonal conditions are experienced in future years. This also indicates the potential benefit from amendments spans more than the year of application, reducing the risk of loss of investment from inputs applied to the field.

Acknowledgements

This project is funded by NSW DPI with financial support from the GRDC through the *Innovative approaches to managing subsoil acidity in the southern grain region (DAN00206) project*. The project is supported by Riverine Plains Inc, Farmlink Research, Southern Farming Systems and the Holbrook Landcare Network. Thanks to farmer co-operator Stephen Chambers. Technical staff: Richard Lowrie, Alek Zander, Adam Lowrie and Andrew Price.

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Barley germplasm and fungicide interaction

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

Key points

- Severe frost events on 28 and 29 August 2018, combined with dry conditions during spring (GSR of 166mm with 32mm of the total falling during mid – late October), caused trial variability and significantly impacted yield results.
- Applying a foliar fungicide gave variable yield responses, depending on cultivar in the absence of significant disease levels.
- La Trobe was significantly higher yielding than other barley cultivars tested, with retention and screenings among the best in the trial.
- Maltster and RGT Planet gave slightly inferior yields under the extreme environmental conditions experienced during 2018, but had statistically similar grain retention and screenings to La Trobe and superior test weights.
- Winter barley cultivars that developed later during spring were more severely affected by the dry conditions than the earlier-developing spring barley cultivars.

Method

A barley trial was established during late April 2018 at the Riverine Research Centre (RRC), Burramine, Victoria, with funding assistance from Elders Limited.

The trial assessed the performance of nine individual barley cultivars sown on 27 April and focused on winter vs spring barley types and their interaction with fungicides. Each cultivar was subjected to either a full fungicide program of Prosaro at first node (GS31) and Amistar Xtra at first awns visible (GS49) or no fungicide at all. The late sowing date aimed to mitigate the dry start and make best use of early May rainfall for emergence.

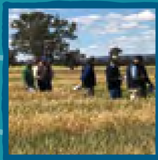
The trial had a split plot design, with fungicide being the main plot, replicated four times. Overall management applications were made as per the seasonal conditions to maximise yield potential.

The yield results were presented as express results during December 2018 for Elders and Riverine Plains Inc members.

Sown: 27 April 2018 (emerged 5 – 7 May)
Harvested: 19 November 2018
Rotation position: First cereal after canola
Rainfall:
GSR: 166mm (April – October)
Soil mineral nitrogen: (Sampled 10 April 2017, from buffer areas of trial site.)
0–10cm: 22.4kg N/ha
10–20cm: 5.2kg N/ha
20–30cm: 3.9kg N/ha
30–60cm: 9.4kg N/ha
Total (0–60cm): 40.8kg N/ha
Treatment list: see Table 1

TABLE 1 Treatment list

Cultivar/Line	Type	No fungicide	Full fungicide (product and timing)	
			GS31	GS49
Alestar	Spring	-	Prosaro 150mL/ha	Amistar Xtra 200mL/ha
Maltstar	Spring	-	Prosaro 150mL/ha	Amistar Xtra 200mL/ha
Cassiopée	Winter	-	Prosaro 150mL/ha	Amistar Xtra 200mL/ha
Salamandre	Winter	-	Prosaro 150mL/ha	Amistar Xtra 200mL/ha
Maltesse	Winter	-	Prosaro 150mL/ha	Amistar Xtra 200mL/ha
RGT Planet	Winter	-	Prosaro 150mL/ha	Amistar Xtra 200mL/ha
RGT Conquest	Winter	-	Prosaro 150mL/ha	Amistar Xtra 200mL/ha
La Trobe	Spring	-	Prosaro 150mL/ha	Amistar Xtra 200mL/ha
Rosalind	Spring	-	Prosaro 150mL/ha	Amistar Xtra 200mL/ha
Alestar	Spring	-	Prosaro 150mL/ha	Amistar Xtra 200mL/ha



Results

i) Establishment and crop structure

The trial site averaged an establishment of 102 plants/m^2, with RGT Planet having the highest emergence counts (137 plants/m^2) and RGT Conquest the lowest emergence (76 plants/m^2) at the three-leaf stage (GS13) (Table 2).

When tillers were counted on 6 August, individual cultivar development ranged from early stem elongation (GS30) to third-node stage (GS33). The European winter cultivar Maltesse had low plant establishment numbers but high tiller numbers (10.5 tillers/plant), producing at least 168 tillers/m^2 more than any other cultivar in the trial, which was significantly more than the other winter barley cultivars Cassiopee and Salamandre. Of the spring cultivars, RGT Conquest had low plant numbers, but compensated by producing 8.6 tillers/plant.

ii) Phenology

Phenology data was assessed throughout the season. Of the winter wheat types Maltese was the slowest to develop, reaching first node (GS31) the latest (3 September) and then flowering (GS65) on 9 October (Table 3). However, Maltese spent the second shortest time (36 days) in the phase from first node (GS31) through to flowering (Figure 1). The spring cultivars, La Trobe and Rosalind, were the earliest to reach first node (GS31) on 16 July and Rosalind was the first to reach flowering on 20 August. Alestar had the longest period of time from first node to flowering (56 days), while Salamandre had the shortest period (29 days).

iii) Normalised difference vegetation index (NDVI)

Crop reflectance measurements taken with the Greenseeker™ and recorded as NDVI measurements,

TABLE 2 Plant counts 31 May 2018, three leaf stage (GS13), tiller counts and tillers per plants 6 August, late tillering – third node (GS30–33) for barley varieties sown 27 April at Burramine, Victoria

Cultivar/Line	Plants/m^2	Tillers/m^2	Tillers/plant
Alestar	98.1^{bc}	542.2^{e}	6.7^{c}
Maltstar	98.6^{bc}	555.6^{e}	5.7^{cd}
Cassiopée	108.6^{b}	724.4^{b}	7.2^{bc}
Salamandre	95.8^{bc}	675.6^{bcd}	7.2^{bc}
Maltesse	91.1^{c}	892.2^{a}	10.5^{a}
RGT Planet	137.2^{a}	688.9^{bc}	4.9^{d}
RGT Conquest	72.5^{d}	631.1^{cd}	8.6^{b}
La Trobe	106.4^{bc}	642.2^{cd}	6.0^{cd}
Rosalind	108.9^{b}	624.4^{d}	5.8^{cd}
Mean	**101.9**	**664.1**	**7.0**
LSD	16.0	64.1	1.7

Note: When tiller counts were taken on 6 August, individual cultivars ranged from GS29–GS33.
Figures followed by different letters are regarded as statistically significant.

TABLE 3 Dates when barley cultivars reached first node (GS31) and flowering (GS65) for a trial sown 27 April 2018 at Burramine, Victoria

Cultivar/Line	Type	GS31 (2018)	GS65 (2018)
Alestar	Spring	23 July	17 September
Maltstar	Spring	6 August	17 September
Cassiopée	Winter	20 August	25 September
Salamandre	Winter	27 August	25 September
Maltesse	Winter	3 September	9 October
RGT Planet	Winter	23 July	10 September
RGT Conquest	Winter	23 July	10 September
La Trobe	Spring	16 July	27 August
Rosalind	Spring	16 July	20 August

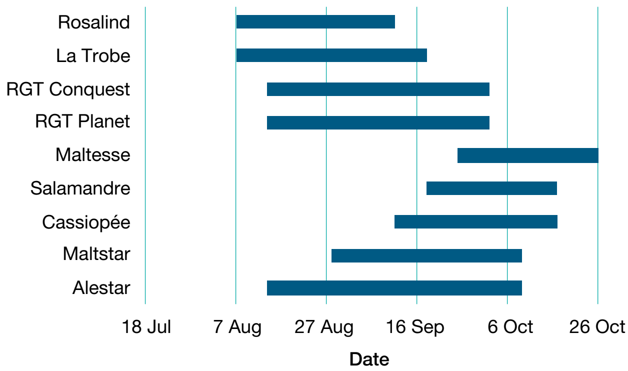


FIGURE 1 Duration of the development period between first node (GS31) and flowering (GS65) for individual cultivars sown 27 April 2018 at Burramine, Victoria

showed significant differences in the crop canopy due to growth habit (Figure 2). The quickest-maturing cultivars, Rosalind and La Trobe, consistently recorded lower NDVI measurements than the longer-season cultivars, with their lower NDVI figures corresponding to a more erect growth habit and less ground cover. Planet had significantly higher NDVI measurements compared with any other cultivar early in the season. Longer-season cultivars presented higher NDVI readings for longer, emphasising a more prostrate growth habit and higher tiller numbers.

iv) Grain yield and quality

The trial was harvested on 4 December 2018 with an average yield of 1.06t/ha. Drought conditions and frost incidence had a marked impact on grain yield and quality. European winter cultivars that developed later in the season suffered significant yield penalties.

In what was a low-yielding season across the board, the best-performing winter cultivar, Salamandre, yielded significantly less (0.87t/ha) than the lowest-yielding spring type Alestar (1.03t/ha). The faster-maturing spring type,

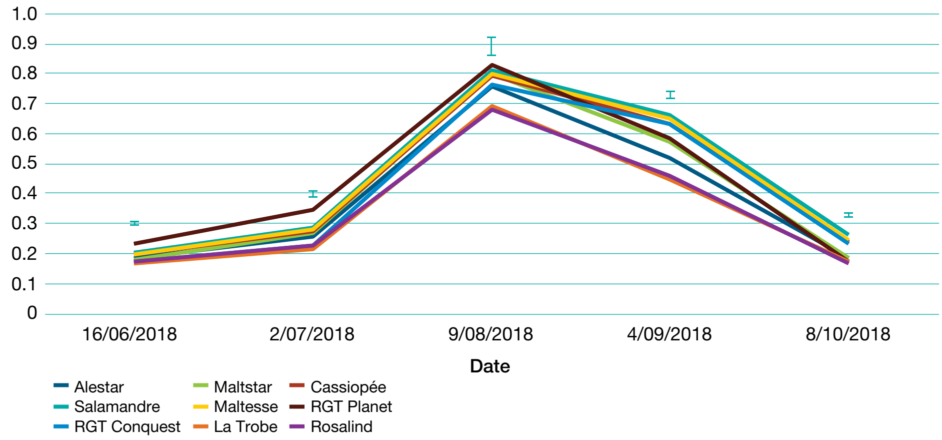


FIGURE 2 NDVI readings on 16 June, 2 July, 9 August, 4 September and 8 October 2018 for barley cultivars sown 27 April 2018 at Burramine, Yarrawonga

La Trobe, proved to yield significantly higher (1.66t/ha) than other cultivars in the trial.

In the absence of significant disease, foliar fungicide applications gave variable yield responses. The yield of several cultivars was significantly less where fungicide was applied, which would not be expected in a season with sustained disease pressure (Table 4).

Winter barley cultivar, Cassiopée, and spring type, RGA Conquest, both had significantly higher grain protein (by at least 1 per cent) than other cultivars in the trial (Table 5), while the grain protein levels of Maltstar (14.3 per cent) were significantly less than other cultivars. Test weights varied, with the winter types generally being lower than the spring type barley cultivars. Although La Trobe yielded significantly higher, RGT Planet and Maltstar proved to have significantly better test weights. The frost-affected winter cultivars Cassiopée, Salamandre and Maltesse all had significantly higher screenings and lower retention than the other trial cultivars.

Conclusions

In a difficult growing season, applying fungicide gave variable responses in the absence of any significant disease stress. Winter cultivars flowered later than spring cultivars sown on the same date and also had a shorter period from the start of stem elongation to flowering. The winter barley cultivars that developed later in the season

TABLE 4 Mean grain yield and percentage, 19 November 2018 for barley sown 27 April 2018 at Burramine, Victoria

	Management Level			
	No fungicide	Full fungicide	Mean yield	(Percentage of site mean)
Cultivar/Line	Yield (t/ha)	Yield (t/ha)	(t/ha)	(%)
Alestar	1.01^{ef}	1.05^{def}	1.03^{d}	97
Maltstar	1.42^{bc}	1.23^{cd}	1.33^{b}	125
Cassiopée	0.94^{fg}	0.56^{h}	0.75^{e}	70
Salamandre	0.93^{fg}	0.81^{g}	0.87^{e}	82
Maltesse	0.35^{i}	0.38^{hi}	0.36^{f}	34
RGT Planet	1.17^{de}	1.24^{cd}	1.20^{bc}	113
RGT Conquest	1.23^{cd}	1.11^{def}	1.17^{cd}	110
La Trobe	1.78^{a}	1.54^{b}	1.66^{a}	156
Rosalind	1.23^{cd}	1.18^{de}	1.21^{bc}	113
Mean	**1.12**	**1.01**		
LSD cultivar p = 0.05	0.14			
LSD management p = 0.05	0.07			
LSD cultivar x management p = 0.05	0.20			

Figures followed by different letters are regarded as statistically significant.

TABLE 5 Grain protein, retention, screenings and test weight for barley sown 27 April 2018 at Burramine, Victoria

Cultivar/Line	Grain yield and quality			
	Protein (%)	Test weight (kg/hL)	Retention (%)	Screenings (%)
Alestar	15.8^{bc}	62.6^{bc}	71.8^{abc}	5.0^{cd}
Maltstar	14.3^{e}	65.0^{ab}	71.2^{bc}	3.8^{cde}
Cassiopée (winter barley)	17.2^{a}	61.1^{cd}	40.2^{d}	9.4^{ab}
Salamandre (winter barley)	15.0^{d}	60.0^{d}	37.7^{d}	10.9^{a}
Maltesse (winter barley)	16.0^{b}	54.6^{e}	63.8^{c}	7.9^{b}
RGT Planet	15.2^{cd}	63.8^{b}	77.3^{ab}	4.0^{cde}
RGT Conquest	17.4^{a}	66.4^{a}	79.9^{a}	2.7^{de}
La Trobe	15.5^{bcd}	60.8^{cd}	75.2^{ab}	2.3^{e}
Rosalind	15.6^{bcd}	56.5^{e}	72.4^{abc}	5.3^{c}
Mean	**15.8**	**61.2**	**65.5**	**5.7**
LSD	0.6	2.5	8.7	2.5

Figures followed by different letters are regarded as statistically significant.

were more severely affected by the dry conditions than the cultivars that developed earlier. In a low-yielding season, the winter cultivars yielded between 0.35t/ha and 0.94t/ha, while spring barley cultivars fared better (as they developed earliest and managed to escape frost damage). La Trobe and Maltstar were the best performing cultivars, yielding 1.66t/ha and 1.33t/ha respectively.

While seasonal effects have to be considered when assessing these results, there are clear trends showing the slower-developing winter barley cultivars are not as effective as the spring types in dryer areas or in a dry season.

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Grid soil mapping to manage variability across multiple soil properties

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Precision Agriculture Pty Ltd

Key points

- Soil sampling to understand in-paddock variations of pH, exchangeable cations and phosphorus (P) provides growers with an understanding of key soil constraints and their distribution, supporting more targeted amelioration strategies.
- For a case study property near Tocumwal, Victoria the variable-rate application (VRA) of lime, gypsum, phosphorus and potentially magnesium (Mg) was well supported by soil test results.
- Measurement of pH, exchangeable cations and phosphorus parameters across 280 paddocks showed a generally poor correlation between these components suggesting different management zones are required to address different soil constraints.

Background

Soil constraints, such as acidity, sodicity and nutrient availability, are a significant challenge across the Riverine Plains area. While ameliorating these constraints by applying lime, gypsum and fertiliser accounts for a significant portion of annual on-farm expenditure, a strong evidence base, combined with the capability for variable rate applications (VRA), can improve the return on investment (ROI).

Grower knowledge, historic yield and satellite data can all provide a valuable insight into in-paddock variation for both crop and pasture production. However, this variation is driven by multiple factors including, soil type, available water, available nutrients, the effects of soil constraints and previous yields and management. Grid soil sampling is a proven sampling strategy to identify and allow for targeted amelioration of soil constraints across a paddock.

Aim

This project investigated the use of grid soil mapping to measure a variety of soil chemistry properties, specifically soil pH, exchangeable cations and soil phosphorus (P), and explored the potential relationships between different soil characteristics across individual paddocks.

Method

Grid soil mapping is the process of collecting soil samples on a standard grid to quantify the spatial variability across a paddock. The process of grid soil mapping used in this study involved:

- digitising the paddock boundary and developing a sampling grid of 1–2ha in size
- collecting GPS-referenced surface soil (0–10cm) samples
- submitting soil samples to an accredited laboratory for analysis, including pH_{CaCl_2}, exchangeable cations and phosphorus (Colwell P).

Data was collected and analysed from an irrigated mixed farming enterprise near Tocumwal, NSW along with 12 months of commercial soil grid mapping data collected from 280 paddocks (10–200ha in size) by Precision Agriculture Pty Ltd during 2018. This data was collected from paddocks across SA, Vic, Tas and NSW, with approximately 60 of the paddocks located within the Riverine Plains area.

Figure 1 outlines the 320ha property near Tocumwal, which was mapped on a 2ha grid.

Results

i) Soil pH

Soil acidity affects 50% of Australia's agricultural land and can significantly limit both crop and pasture production, restrict crop choice, and, when untreated can reduce the health of the soil resource. During 2018 Precision Agriculture collected almost 10,000 soil samples across the Riverine Plains region. Of these samples, 40% had a pH <4.8 (moderately to highly acidic) and 47% had a pH of between 4.8 and 5.4 (slightly acidic), which indicates the scale of the problem across the region.

The average soil pH was 5.2 across the Tocumwal case study paddock (Figure 2), with 190ha having a pH <5.2, which places these soils into the slightly — highly acidic categories.

Calculating the variable rate strategy for this property involved setting a target pH of 5.8 in order to increase crop choice (including pulses and a move to potential summer crops such as maize). To achieve a target of pH 5.8, an average lime rate of 2.0t/ha was required, with a VRA ranging from 0–4.5t/ha across the paddock.

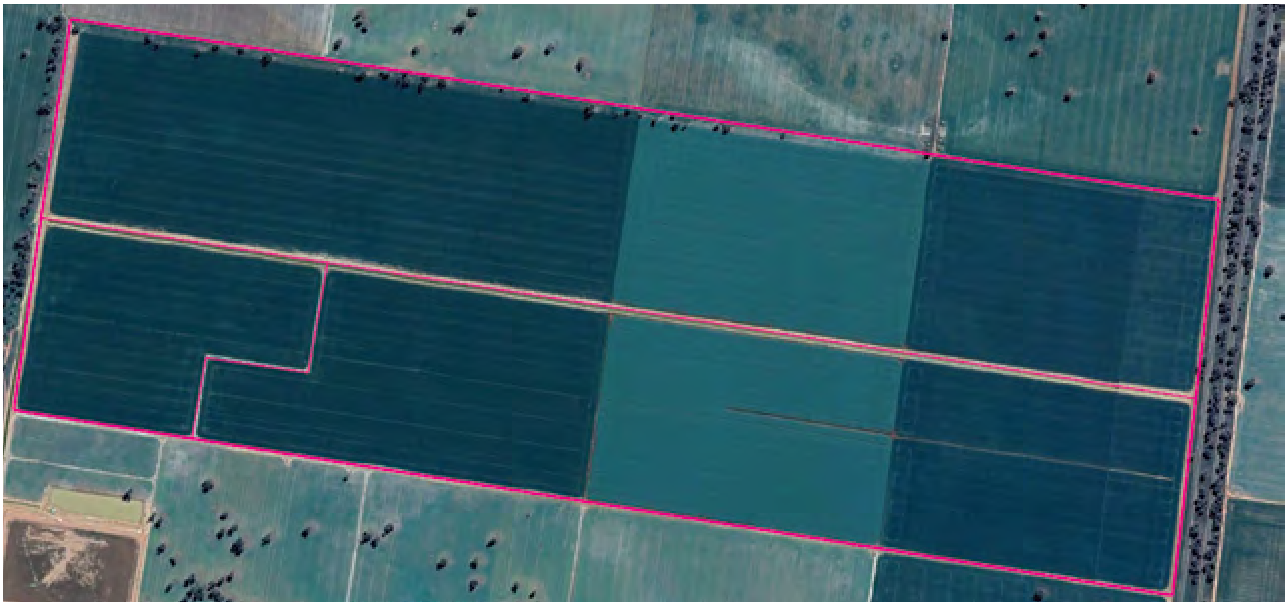

FIGURE 1 Satellite image of the Precision Agriculture case study property near Tocumwal, NSW (August 2018)

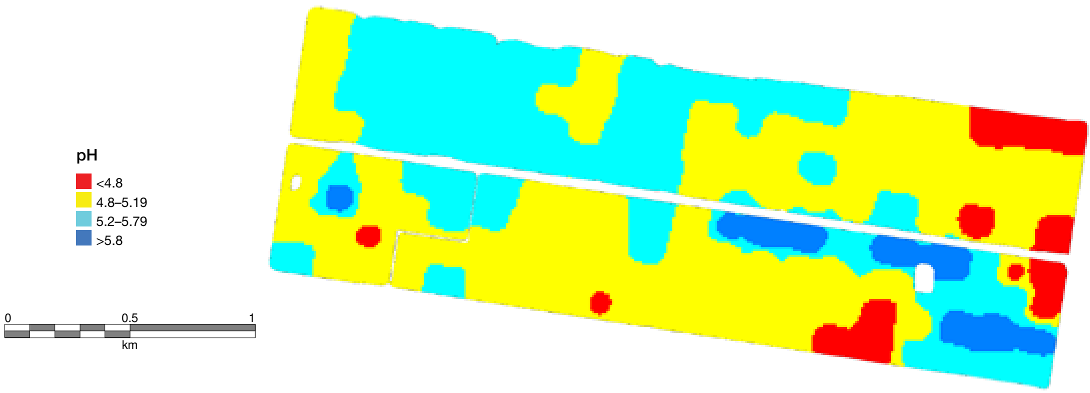

FIGURE 2 Grid-mapped soil pH_{CaCl2} data (0–10cm)

A blanket application of 2.0t/ha lime across the paddock was estimated to result in a range of soil pH from 5.1–7.3.

ii) Phosphorus

Soil phosphorus levels depend on a range of factors including previous management history and natural variation. Soil phosphorus (Colwell P) was measured on the case study property and the grid soil sampling results (Figure 3a) reveal the variation in phosphorus soil test values, with an average Colwell P of 77 mg/kg, and a range of 38–140mg/kg.

Even with a low-to-moderate phosphorus buffering index (PBI) (<280), the entire paddock had a Colwell P above the critical value of 38mg/kg for wheat, suggesting base phosphorus levels were adequate, so no capital rates of phosphorus were applied. However, a VRA replacement strategy would ensure the areas close to critical values are not run down to marginal levels, while also ensuring that phosphorus levels across the majority of the paddock are not increased.

iii) Exchangeable cations

Cation exchange capacity (CEC) provides a measure of the soil's ability to supply and hold important plant nutrients, including calcium (C), magnesium (Mg) and potassium (K) and also provides an indication of the soil's ability to buffer changes in soil pH. The CEC of the Tocumwal paddock was measured, with the area averaging 8.4cmol/kg, with a range of 4.5–19cmol/kg (Figure 3b).

Exchangeable potassium was 256mg/kg, with a range of 120–470mg/kg, exchangeable calcium was 1045mg/kg, with a range of 640–2090mg/kg and exchangeable magnesium was 231mg/kg ranging from

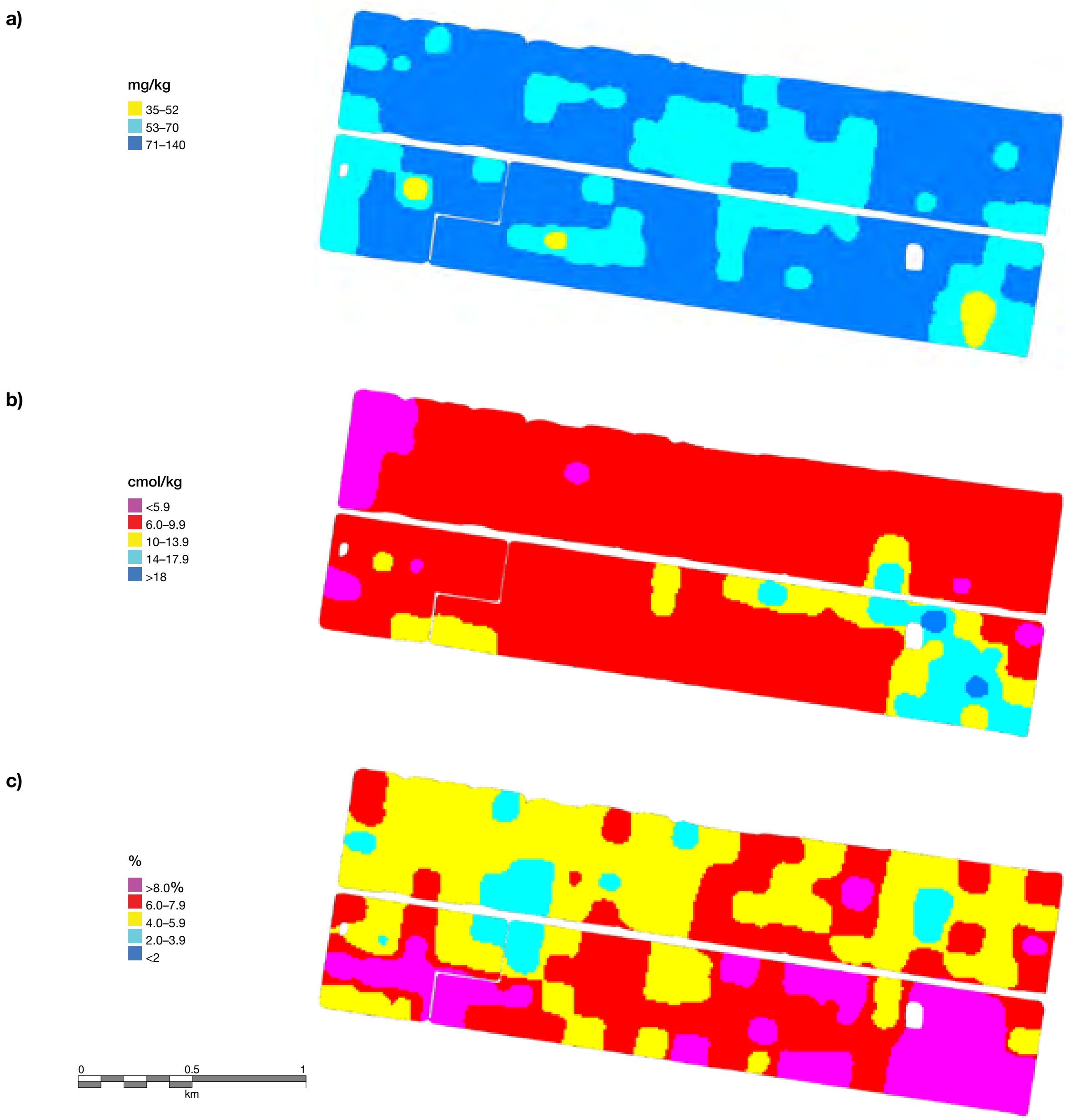

FIGURE 3 Grid mapped soil (a) phosphorus (mg/kg); (b) cation exchange capacity (CEC) (cmol/kg) and (c) exchangeable sodium percentage (ESP) (%) for a Precision Agriculture Pty Ltd 2018 case study paddock near Tocumwal, NSW

40–900mg/kg. In the context of wheat, the calcium and potassium levels were generally within or above the desired ranges. However, there were areas of the paddock where magnesium levels were low (<175mg/kg), suggesting the potential for VRA of magnesium to target these areas.

Exchangeable cations can also be used to calculate the exchangeable sodium percentage (ESP), with an ESP above 6% considered sodic. Sodicity impacts soil structure and can affect seedling emergence, root penetration, water infiltration, nutrient availability and soil aeration. For the case study property, the ESP averaged 6.6% and ranged from 2–18%, with just on half the paddock considered sodic (Figure 3c). VRA Gypsum would allow for the targeted amelioration of sodicity across the paddock, with gypsum concentrated on the most sodic areas of the paddock.

iv) Variation in multiple soil characteristics observed across 280 paddocks

The 2018 grid soil mapping results for the 280 paddocks sampled across south eastern Australia, including the Riverine Plains region, demonstrated a high level of variability for pH, phosphorus, CEC and ESP. The average paddock pH ranged from 4.3–6.9, with 65% of the paddocks having an average pH of less than 5.2. Soil pH varied within paddocks by an average of 1.0 pH units (maximum –



minimum pH), with the greatest observed paddock variation being 3.2 pH units (pH 4.3–7.5). Assuming a target pH of 5.2, 90% of sampled paddocks had a measured minimum pH below 5.2 and therefore required lime in parts of the paddock. Conversely, 70% of paddocks had a maximum pH greater than 5.2, meaning no lime was required in these areas. These results show that pH variation occurs frequently within paddocks and highlights the potential for VRA lime in these paddocks. Similar variability was seen across the 280 paddocks for phosphorus, CEC and ESP, which also indicates that the potential for VRA phosphorus, magnesium, potassium and gypsum was significant.

Across the 280 paddocks mapped during 2018, the variability between the different soil properties was not correlated (consistent with the case study property), suggesting that variable rate management zones for acidity, sodicity and nutrient availability will differ. The major exception to this is the strong positive correlation (>0.7) across 70% of paddocks between pH and CEC, which reflects the role of exchangeable cations in buffering changes to soil pH, as well as the effect of pH on variable charge exchange sites in the soils.

Observations and comments

Understanding the variation in soil chemistry parameters across a paddock through grid sampling, as demonstrated by the results from the case study property, provides an understanding of the key soil constraints and their distribution, which can allow for more targeted amelioration strategies.

Results from the case study property, and the 2018 combined set of grid soil mapping data, show little to no correlation between the different soil attributes, with the exception of soil pH and CEC. This means different management zones are required to address different soil constraints.

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Silicon supplementation — a sustainable drought stress management strategy in lentils

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Key points

- Drought stress increased the infrared thermal canopy temperature (IRTc) for all lentil cultivars, while the addition of silicon significantly decreased the IRTc under drought stress.
- The lower IRTc in the silicon-treated plots may have been due to a silicon-mediated increase in plant water uptake under drought stress.

Background

Drought is a major physical stress, which negatively impacts the growth and productivity of lentils. Lentils are an important legume food crop, grown in semi-arid Mediterranean climatic regions worldwide.

Silicon is an essential plant nutrient and its beneficial effects on physical stress tolerance have been reported across several plant species. Moreover, laboratory experiments at The University of Melbourne, Parkville campus, have shown that silicon supplements across a range of lentil cultivars grown in a growth chamber under drought conditions, have proven to be beneficial in improving drought stress tolerance.

Aim

The field trial aimed to investigate the role of silicon in mitigating drought stress in lentils by assessing the variations in infrared thermal canopy temperature (IRTc) and yield traits.

Methods

Experiments were carried out under field conditions with selected lentil cultivars:

- ILL 6002 — drought-tolerant
- PBA Jumbo 2 — moderately tolerant
- ILL 7537 — drought susceptible.

Each cultivar was subjected to severe drought stress at the onset of flowering (GSR1).

The treatments were control (C), which was well irrigated, drought stress (D), drought stress with supplemented silicon (DSi), and silicon alone (Si). The experiment was laid out in a randomised block design, with three cultivars and three replicates, using a split plot arrangement across three blocks.

Plants were spaced at 25cm apart in each row. Buffer zones (0.5m) were established to minimise potential silicon contamination via lateral movements in soil.

Silicon was applied to the treatment plots in granular form (source: sodium metasilicate) and was mixed manually with soil one week before sowing. Plots were managed in line with standard growing practices (including seed and fertiliser rates). Seeds were inoculated with Group F rhizobia (*Rhizobium leguminosarum*) and were hand sown at a sowing depth of 2.5cm, at a sowing rate of 120 plants/m^2 during May 2018.

Drought-stress treatment plots (D and DSi) were subjected to drought stress by withholding water at flowering (GSR1) for 14 days during mid-October 2018.

The volumetric soil moisture content in each plot was measured using a soil moisture sensor (Theta probe, ML2) on a fortnightly basis throughout the growing season, to ensure the severity of drought stress.

Infrared thermal canopy temperature (IRTc) is considered as a meaningful parameter to identify the severity of drought stress, with higher IRTc readings indicative of plant stress. IRTc was measured from thermal images captured using infrared camera FLIR T-series (Model B360) after 14 days of drought stress treatment. The thermal images were processed and analysed using a customised code written in MATLAB R2018b and the Image Analysis Toolbox to estimate IRTc.

All plots were harvested during December 2018. Above-ground biomass and yield traits (pod number, pod weight, seed number, seed yield) were measured after drying at 40ºC for 72 hours. Statistical analysis of the data (not presented) was carried out using analysis of variance (ANOVA), followed by a Tukey pairwise comparison test between cultivars and treatments using Minitab®v18

Results

In this trial, drought stress increased the IRTc for all lentil cultivars, while the addition of silicon significantly decreased the IRTc under drought stress (see Figure 1). This provided evidence the addition of silicon augmented drought

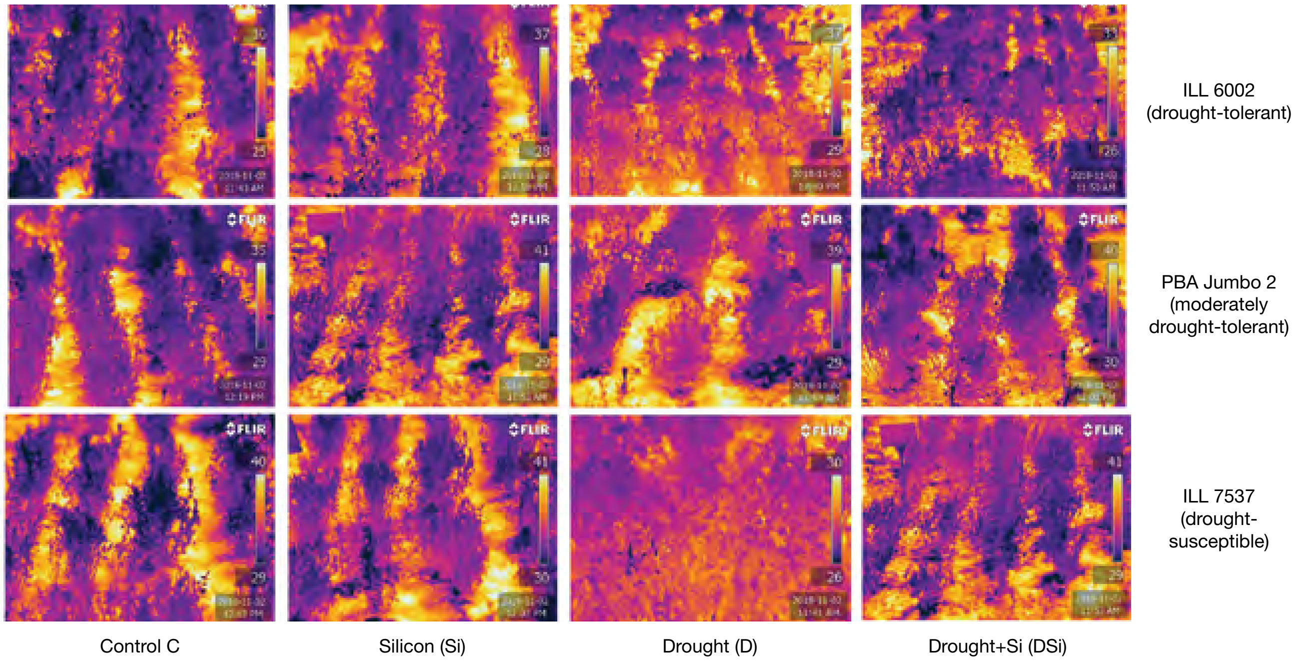

FIGURE 1 Infrared thermal images from different treatment plots in the field. Purple coloured regions indicate low canopy temperature (non-drought-stressed) and yellow-coloured regions indicate high canopy temperature (drought-stressed)

tolerance in the lentil plots. The lower IRTc in the silicon-treated plots may have been due to an increased capacity for extraction of plant available water when plots were placed under drought stress, compared to the untreated plots.

The above-ground biomass of all the lentil cultivars was enhanced by adding silicon under both drought and non-drought conditions (Note: data not presented as statistically analysed data is soon to be published in a peer reviewed journal). This is consistent with previous findings in lentil seedling research which show an increased capacity for silicon-treated plants to extract water compared to untreated plants.

Grain yield from the plots of the drought susceptible cultivar (control plot) was 0.09t/ha compared with the yield of the drought-susceptible cultivar in the drought-stressed plots (D) (0.03t/ha). The moderately drought-tolerant cultivar yielded 0.26t/ha in the drought-stressed plots supplemented with silicon (DSi) treatment compared with 0.15t/ha from the drought-stressed plots with no silicon (D). A similar pattern was observed for the drought-tolerant cultivar (0.26t/ha from the drought-stressed plots supplemented with silicon (DSi) and 0.17t/ha from the drought stressed plots (D)). Silicon supplementation resulted in 0.33 to 0.55-fold increase in the grain yield values of all the lentil cultivars studied.

These results show the impact of silicon supplementation on enhancing the yield in lentil cultivars under drought stress, with increased biomass and decreased IRTc observed in the lentil plots supplemented with silicon. The higher yield in these plots can be attributed to the increased ability of the silicon-supplemented plants to extract more available soil water.

Outcomes and implications

Supplementing lentil crops with silicon before sowing improved plant growth and development, and boosted grain yields in drought-stressed lentils in this trial. Silicon supplementation to crops may be a sustainable management strategy to enhance yield and productivity in environments likely to experience drought stress. Further research is underway to extend these findings to determine the potential for silicon supplements to different lentil-growing areas across Australia.

Acknowledgements

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Optimising dual-purpose wheat management practices for grazing and grain production in drier environments

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Key points

- During 2018, applying foliar micronutrient to a dual-purpose wheat crop after grazing helped aid crop recovery and maintained grain yield potential.

Background

High-value dual-purpose wheat for grazing and grain production is becoming an increasingly popular option in mixed farming systems. Dual-purpose wheat provides diversity within the system, generating income from both forage and grain in the production system.

Within a mixed farming enterprise, dual-purpose crops can fill an important winter feed gap when pasture growth rates are unable to meet livestock requirements. Mixed farming systems that incorporate dual-purpose wheats are also better placed to generate some income from livestock production (through grazing) if the crop fails due to climatic stresses, such as those experienced in many areas during 2018.

However, the impact on grain yield of grazing a wheat crop, particularly during a drier season, has always been a major concern for growers. In dry seasons, water availability becomes the most limiting factor to obtaining optimum crop yields because moisture stress impedes biomass production. This affects the ability of the crop to support recommended stocking rates without incurring grain yield penalties from grazing.

Plants also require macronutrients and micronutrients for optimal growth and development. Although micronutrients are only required in small amounts, they play an important role in various plant processes and are an important factor in crop growth and grain yield. Changing climatic conditions and limited options for crop rotations have affected soil health, especially beneficial macro and microflora, and the availability of adequate levels of macronutrients and micronutrients. Supporting the grazing and grain yield potential of a dual-purpose wheat crop requires an adequate supply of both micronutrients along with macronutrients.

Objectives

The project objectives were to

a) evaluate the performance of a dual-purpose wheat variety grazed during one of two different windows (the recommended grazing window and a later-than-recommended grazing window)

b) to evaluate the effect of micronutrient foliar application on crop recovery (grain yield) after grazing.

Materials and methods

The Australian Hard quality (South Australia and Victoria) dual-purpose wheat variety LRBP Kittyhawk, was used in this study. The trial site was located at The University of Melbourne, Dookie Campus farm (36.395°S, 145.703°E) in a paddock with a history of wheat and canola crop production. The trial site experiences a temperate climate, receiving an average annual rainfall of 575mm. The soil type is classified as Currawa Loam.

Kittyhawk wheat was sown into moisture at a rate of 85kg/ha on 27 April 2018. The crop was raised according to standard growing practices. The experiment was laid out in randomised complete block design with three replicates. Each replicate had six treatments;

1. Control (no grazing and no micronutrients)
2. Control with micronutrients (no grazing with micronutrients)
3. First grazing window (no micronutrients)
4. Second grazing window (no micronutrients)
5. First grazing window (with micronutrients)
6. Second grazing window (with micronutrients)

In total, there were 18 plots and each plot measured 33.3m × 50m in size.

Grazing windows, stocking rate and sampling data

A stocking rate of 21 sheep per hectare (calculated based on biomass available for grazing) was tested for two grazing windows; a) the recommended grazing window, 95–100 days after sowing at the 3–4 leaf stage and b) a second



grazing window, 110-115 days after sowing at the 5–6 leaf stage. Regular monitoring ensured sheep were removed before the crop was grazed below a certain height and this meant the grazing duration was different for each sowing window.

Due to there being less moisture in the paddock, the crop did not gain the expected biomass for the recommended grazing start time and stock were introduced only when the crop had accumulated enough biomass. Due to the drier start to the season, this was later than planned and also required a reduced stocking rate to ensure there was enough biomass for sheep to graze. These options were tested to see if late grazing (both windows) and a lower stocking rate would minimise grain yield penalties.

The first grazing window treatment saw sheep introduced at the 3–4 leaf stage (GS13–14) for 18 days and removed when the crop reached early tillering (GS23–24). The second sowing window treatment involved introducing sheep at the 5–6 leaf stage (GS 15–GS16) for 16 days, with sheep being removed at late tillering (GS28).

Foliar application of the micronutrients, at the rate of 1.0L/ha for the treated plots, was carried out after the completion of grazing for each of the two grazing windows and before flowering.

The micronutrient formulation used (not specified in this report) has had a proven effect on yield, irrespective of micronutrients available in the soil (paddock soil test results not presented). Sometimes these micronutrients are not available in plant usable form or there may be other interactions occurring in soil, which affect their availability to the plant. Therefore, foliar application of a specific micronutrient formulation can boost crop growth after grazing, particularly when water is a major limitation (because it can indirectly affect micronutrient uptake from soil in the time of need).

Results and discussion

The data were recorded for biomass production and grain yield as higher biomass production is generally linked to higher grain production in cereals when plants are not under stress. There were no significant differences between the two grazing windows in terms of the actual amount of dry matter (DM) removed due to grazing (Table 1).

Within the first grazing window, micronutrient application showed an improved, though non-significant yield increase of 0.066t/ha over the treatment that didn't receive a micronutrient application. For the second grazing window there was a similar, non-significant, trend towards a marginal yield increase with micronutrient application. Across all the treatments, the control (ungrazed) treatment with micronutrient application had the highest yield (0.935t/ha) (Figure 1, Table 2), which was significantly greater than the yield of the grazing window treatments that did not receive micronutrients. However, when yields from the first and second grazing windows were compared, micronutrient application led to a non-significant trend for higher grain yield from the first grazing window compared with the second window. The yield from the first grazing window with the micronutrient treatment was not significantly different from the grain yield of the ungrazed control with micronutrient treatment. The similarity in yield between these treatments suggests micronutrient application provided the crop with a boost which aided crop recovery after grazing and meant that there was no grain yield penalty from grazing in the first window compared to the control treatment.

Conclusion

Grazing duration, plant growth stage and stocking rate are critical factors affecting the success of dual-purpose crops during drier seasons. In a dry year, like 2018, grazing at the 3–4 leaf stage (when there is sufficient biomass), followed by a micronutrient foliar application, may be an option to maximise recovery and yield after grazing.

TABLE 1 Comparison of dry biomass after each grazing window

Treatment	Dry matter before grazing (t/ha)	Dry matter after grazing (t/ha)	Total dry matter removed due to grazing (t/ha)
First grazing window (T1)	0.64	0.70	0.52
Control*	0.60	1.22	
LSD	0.139	0.225	
Second grazing Window (T2)	0.99	1.08	0.54
Control*	1.22	1.62	
LSD	0.137	0.290	

* Respective control plot values of DM for each grazing window

Note: Stock were removed at early tillering (GS 23–24) for the first grazing window and at late-tillering (GS28) for the second grazing window.

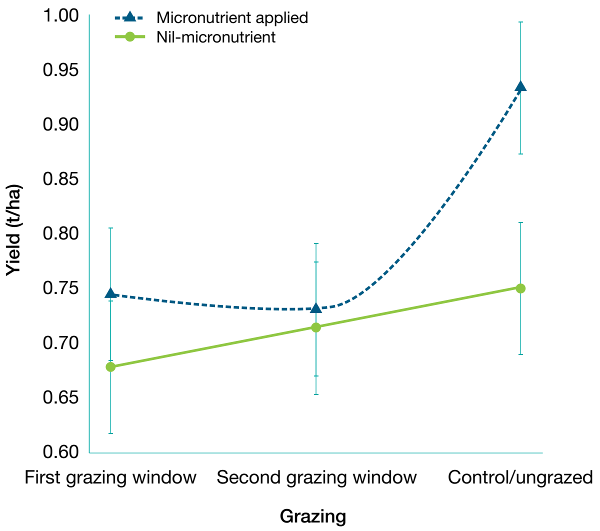

FIGURE 1 Grain yield comparison among various treatments

Wheat grazed after the first node stage (GS31–32) requires close attention to prevent the growing point being removed or damaged by livestock. Removal or damage to the growing point can lead to delayed plant recovery and low biomass production, which can ultimately affect grain yield.

TABLE 2 Comparisons of average grain yield according to treatment

	Without micronutrient	With micronutrient
	Grain yield (t/ha)	Grain yield (t/ha)
Grazing window 1	0.680[a]	0.746[ab]
Grazing window 2	0.716[a]	0.732[ab]
Control	0.752[ab]	0.935[b]
LSD (Interaction)	0.1916	

Note: Means for each grazing treatment with the same letter in common are not significantly different from one another.

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