ONLINE DELIVERY
BORDERTOWN
SOUTH AUSTRALIA
20TH AUGUST 2020

GRAINS RESEARCH UPDATE

GRDC™
GRAINS RESEARCH & DEVELOPMENT CORPORATION

grdc.com.au

Connect with us

Keep in touch with us to find out about the latest RD&E, news and events.

Newsletter subscription	Twitter @GRDC	Facebook @GRDC	Instagram thegrdc	LinkedIn GRDC

GRDC PODCAST

GET THE LATEST INFO ON THE GO

The GRDC's podcast series features some of the grain sector's most pre-eminent researchers, growers, advisers and industry stakeholders sharing everything from the latest seasonal issues, to ground-breaking research and trial results with on-farm application.

https://grdc.com.au/news-and-media/audio

To subscribe to receive newsletters and publications and keep your details up-to-date visit the GRDC subscription centre:
www.grdc.com.au/subscribe

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

P Level 4 | 4 National Circuit, Barton ACT 2600 | PO Box 5367, Kingston ACT 2604 **T** +61 2 6166 4500 **F** +61 2 6166 4599
E grdc@grdc.com.au @theGRDC

GRAINS RESEARCH UPDATE

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

ONLINE DELIVERY

Bordertown, South Australia

20th August 2020

#GRDCUpdates

GRDC Grains Research & Development Corporation

GRDC Grains Research Update online
proudly convened by ORM Pty Ltd.

ORM

46 Edward Street
PO Box 189
Bendigo VIC 3552

T 03 5441 6176
E admin@orm.com.au
W orm.com.au

Contents

On Twitter? Follow **@GRDCSouth** and use the hashtag **#GRDCUpdates** to share key messages

SOUTHERN/WESTERN REGION*

PREDICTA B
DNA Soilborne disease tests

PREDICTA® B
KNOW BEFORE YOU SOW

*CENTRAL NSW, SOUTHERN NSW, VICTORIA, TASMANIA, SOUTH AUSTRALIA, WESTERN AUSTRALIA

Cereal root diseases cost grain growers in excess of $200 million annually in lost production. Much of this loss can be prevented.

Using PREDICTA® B soil tests and advice from your local accredited agronomist, these diseases can be detected and managed before losses occur. PREDICTA® B is a DNA-based soil-testing service to assist growers in identifying soil borne diseases that pose a significant risk, before sowing the crop.

Enquire with your local agronomist or visit
http://pir.sa.gov.au/research/services/molecular_diagnostics/predicta_b

Potential high-risk paddocks:

- Bare patches, uneven growth, white heads in previous crop
- Paddocks with unexplained poor yield from the previous year
- High frequency of root lesion nematode-susceptible crops, such as chickpeas
- Intolerant cereal varieties grown on stored moisture
- Newly purchased or leased land
- Cereals on cereals
- Cereal following grassy pastures
- Durum crops (crown rot)

There are PREDICTA® B tests for most of the soil-borne diseases of cereals and some pulse crops:

- Crown rot (cereals)
- Rhizoctonia root rot
- Take-all (including oat strain)
- Root lesion nematodes
- Cereal cyst nematode
- Stem nematode
- Blackspot (field peas)
- Yellow leaf spot
- Common root rot
- Pythium clade f
- Charcoal rot
- Ascochyta blight of chickpea
- White grain disorder
- Sclerotinia stem rot

Government of South Australia
Primary Industries and Regions SA

SARDI
SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

GRDC™
GRAINS RESEARCH & DEVELOPMENT CORPORATION

CONTACT:
Russell Burns
russell.burns@sa.gov.au
0401 122 115

Assessment and treatment of subsurface acidity

Melissa Fraser.

PIRSA Rural Solutions SA.

GRDC project code: DAS1905-011RTX

Keywords

- acidity, subsurface, stratification, lime, incorporation.

Take home messages

- Subsurface acidity and stratification are emerging as serious constraints to crop production across SA, NSW, Victoria, and WA.
- Traditional soil sampling strategies can lead to misdiagnosis of subsurface issues; strategic sampling at specific depth intervals is required.
- Lime rates need to be adjusted to account for subsurface pH, changes in soil texture and organic carbon content down the profile.
- Strategic incorporation/tillage can aid the efficacy of lime application for treating subsurface issues; other subsoil constraints (e.g. compaction) should be taken into consideration to maximise treatment impact, along with the risks associated with soil disturbance.
- Options for treating subsurface and stratification issues are being examined in the new GRDC Acid Soils SA Project.

Background

Soil pH is largely a function of soil type, rainfall and farming system, and can be inherently variable both horizontally and vertically in the profile. A soil pHCa between 5.2 and 7.5 provides optimum conditions for most agricultural crops, though plant species differ in their tolerance to acidity (low pH) and alkalinity (high pH).

Acidity can be a severe soil degradation problem that greatly reduces the productive potential of crops and pastures. Acidification is a natural process however, it is often accelerated under productive farming practices, primarily driven by the leaching of nutrients (especially nitrates) from topsoil, and the removal of alkaline farm products. Where no lime is applied, the topsoil becomes acidified and the acidic layer spreads down the soil profile into subsurface layers (Fleming et al. 2020).

The development of acidity can induce nutrient deficiencies and/or toxicities, limit crop responses to fertiliser application and adversely affect root growth and water uptake as toxic amounts of aluminium are released into the soil solution. Additionally, for acid-sensitive crops like pulse legumes, rhizobia survival and nodulation are compromised at pH_{Ca} below 5.0, reducing plant vigour and N fixation (Burns et al. 2017a). Acidic conditions also contribute to the suppression of organic matter breakdown and cycling of organic N within the subsurface layer (Paul et al. 2003).

Subsurface acidity is the acidification of the soil below the top 10cm; the delineation between surface and subsurface acidity is important as monitoring and treatment options will vary, becoming increasingly complex at depth. Remedial action is required to curb its development; when it comes to subsurface acidity, prevention is better than cure.

Key Question 1 - How wide-spread is the problem of subsurface acidity and why is it suddenly on our radar?

Much of SA's 4.4 million hectares of productive farmland has a topsoil pH_{Ca} below 5.5 or has the potential to develop acidity (Figure 1). The potential for subsurface acidity to develop across these areas is high, particularly where lighter textured A horizons are thicker than 20cm.

Acidic layers at 5 to 15cm are becoming increasingly common under no-till systems in the high and medium rainfall regions of southern Australia, even where topsoils have been limed (Angus et al. 2019, Burns et al. 2017b, Paul et al. 2003, Scott et al. 2017). The development of these discrete acidic bands is often referred to as 'stratification', and commonly occurs at the depth where N fertiliser is applied.

In 2019 there were various reports of subsurface acidity and stratification across the State, including in unexpected regions, such as the Murray Mallee and Yorke Peninsula. Across the Limestone Coast, acidity is prevalent both in deep sands and on duplex soils in the north and south, and in the red loams of the eastern border, particularly where the intensity of cropping has increased over the past two decades.

Soil type plays a large part in determining the susceptibility for subsurface acidity to develop. In duplex soils the changing soil clay content, which drives pH buffering capacity, can have an impact on the speed of development of acidic subsoil layers (Paul et al. 2003). The higher soil organic matter content in surface layers may also buffer against pH changes, maintaining a higher pH than the underlying soil. Conversely, the lack of organic matter in light textured sandy subsoils can mean that severe acidity can develop quickly. Given the high spatial variability in soil properties in the region, even at the paddock scale, subsurface acidity is often widespread, but not uniform.

Key Question 2 - How do growers assess whether it's a problem on their farm or not?

The presence of subsurface acidity is often masked by conventional topsoil sampling methods (0-10cm), with an often alkaline 0 to 3-5 cm layer diluting acidic bands below, resulting in an overall pH value that doesn't cause alarm (Figure 2). Where stratification and/or subsurface acidity is present, strategic soil sampling methods are required to accurately detect pH variability and its severity in the profile; targeted sampling to depths at suitable increments is required.

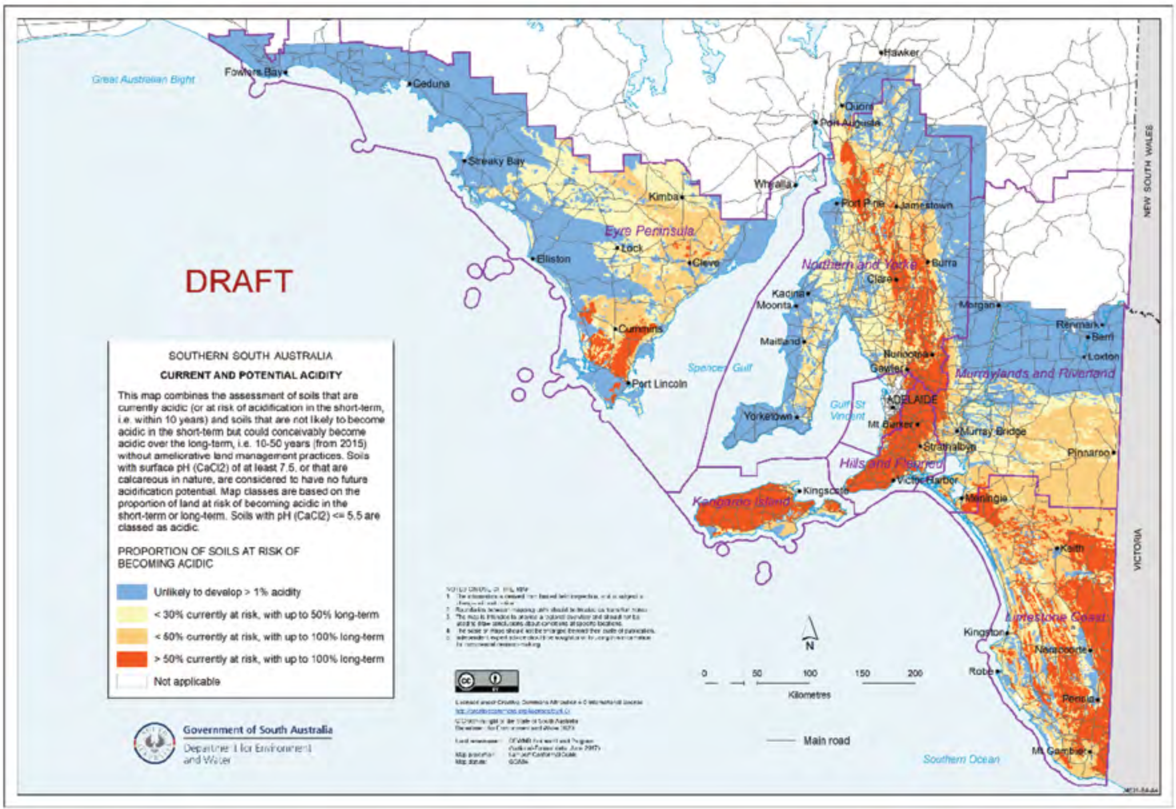


Figure 1. Map of South Australia showing the proportion of soils at risk of becoming acidic (including currently acidic soils). (Source: Department for Environment and Water, Government of South Australia).

Figure 2. Example soil pit face with pH indicator dye applied. An alkaline surface layer can be seen (purple), overlying acidic soil (bright green) below 3cm.

In the paddock, pH indicator dye can be used to quickly and cheaply determine whether acidity is contributing to poor plant growth.

In the lab, a soil pH test measures the amount of hydrogen ions in a 1:5 solution of soil to water (pH_W), or soil to calcium chloride (pH_{Ca}). As pH can be affected by soil moisture status and seasonal conditions, it is recommended to measure pH_{Ca}. This test is offered by all commercial laboratories and enables test results from different seasons to be more reliably compared.

The pH_{Ca} is often 0.5 to 1 unit lower than pH_W. To achieve optimum plant growth, the soil pH_{Ca} should be maintained above 5.5 in the top 10cm, and above 4.8 in the subsurface (below 10cm), but these threshold values are currently under review and being tested in SA.

Diagnosis

Late winter is a great time to look for acidity issues (along with other subsoil constraints), with patches of poor crop growth often being observed visually and from satellite (NDVI) images, particularly in faba bean and canola crops (chickpea, lentil and barley are also sensitive crop types). Previous yield maps can also often point to areas of 'good' and 'poor' production in a paddock, assisting with the identification of diagnostic sampling zones.

Summary of process to diagnose acidity issues:

- Access NDVI and/or old yield maps to detect variable plant growth in each paddock. Take these to the paddock to identify diagnostic zones that reflect areas of good and poor production. These areas often align with changes in soil type and topography.
- Within each diagnostic zone, dig 3 to 5 holes to 40cm, creating a flat vertical soil profile face.
- Apply pH indicator liquid dye down the profile and then apply the powder and let the colour develop (Figure 2). Alternatively, you can use a Dig Stick soil probe (spurr probe) to remove an intact soil core and apply the same procedure to assess the change in pH.

- Once the colour reaction is complete, use the diagnostic colour card to determine the pH down the profile. Any acid layers will be visible as bright green or yellow colours. The pH measured with this dye is equivalent to pH_w, so the ideal pH is between 6.5 and 8 on the card (Table 1).
- Use a tape measure to identify the positions of any pH changes and take a photo, including the tape measure for future reference.
- N.B. As the indicator solution can deteriorate over time and the observations are visual (subjective), care should be taken with interpreting results.

Table 1. Severity of acidity as determined using a pH indicator kit, which is equivalent to the pH in water (pHW).

Rating	pH
Neutral	7
Mild	6.5
Moderate	6
Strong	5.5
Severe	5 and below

If acidic areas have been identified using pH indicator dye, additional soil sampling and more accurate laboratory pH measurement and other analyses are recommended:

- Within each diagnostic zone, collect 20 to 30 cores, combining the soil from each relevant layer depth in a clearly labelled bucket.
- Depending on the position of the acid layer in the profile, soil depths for sampling might include: 0-5, 5-10, 10-20 and possibly 20-30 cm. If acidity is more common in the 5-15 cm layer, then depths of 0-5, 5-15 and 15-25 cm are more appropriate.
- Thoroughly mix the samples for each layer depth for each zone and bag a sub-sample; send to an accredited laboratory for pH_{Ca} analysis, organic carbon % and a soil texture assessment (this information is needed to calculate a lime rate). Aluminium (measured in $CaCl_2$) is also warranted.

Alternatively, precision soil sampling approaches, such as grid-based or on-the-go Veris® pH mapping can provide more detailed data on the variability in surface pH and possible stratification. These maps should still be ground-truthed to assist interpretation, diagnose subsurface issues and generate variable rate lime prescriptions.

Key Question 3 - What are the options to treat subsurface acidity and how important is it to identify other constraints before treatment?

Acidic soils must be limed– lime it or lose it!

Lime treats acidity by neutralising the acid reaction in soils. The carbonate component of lime consumes hydrogen ions in the soil solution and in doing so raises the pH. Lime should be applied at rates to keep the surface pH_{Ca} at 5.5 or more in the top 10cm (Burns et al. 2017a, Conyers and Scott 1989, Scott and Conyers 1995).

The rough rules of thumb to change the pH by one unit for each 10cm depth of soil are: 2t/ha of good quality lime for a sandy soil; 3t/ha for a sandy loam; and 4t/ha for a loam/clay loam. Where organic matter is low (common in subsurface layers and/or lower rainfall areas), rates can be substantially reduced and will have the same effect.

However, as lime can come from a variety of sources with different qualities and effectiveness, application rates need to be adjusted to reflect lime quality. If soil magnesium levels are low, consider using dolomitic lime instead to prevent grass tetany in livestock.

Calculators are available to assist with lime rate decisions and assessment of lime quality from different sources on the Acid Soils SA website (https://acidsoilssa.com.au/). N.B. these decision support packages were developed to target surface acidity only (0 to 10cm) and will be reviewed as part of the new SA project to calculate lime rates that account for subsurface acidity.

As lime usually moves very slowly in soils, about 1cm a year at best, incorporating lime through strategic cultivation is recommended when treating subsurface acidity. The more vigorous the soil disturbance after lime application, the faster the soil will be neutralised (Angus et al. 2019). Effective forms of deep cultivation include soil mixing (spading, large offset discs) and soil inversion (mouldboard plough, modified one-way disc plough), with deep ripping (with and without inclusion plates) and delving offering less mixing of applied lime. Cultivation and deep tillage assessments are included in several current trials across the state in the GRDC Acid Soils SA project.

As most soils in the south east region contain a combination of chemical and physical constraints, such as acidity and water repellence and/or compaction, strategic deep tillage and/or soil mixing that extends beyond the top 10cm can be used to alleviate multiple constraints in a single pass. Implementing strategic cultivation/tillage to treat multiple constraints effectively spreads the cost and risk of incorporating lime and maximises the potential gains in production (Davies et al. 2019).

A complete set of methods to diagnose sandy soil constraints in SE SA, along with suitable lime incorporation methods can be found on the MacKillop Farm Management Group website (https://mackillopgroup.com.au/project/current-projects/sandy-soil-constraints-in-south-east-south-australia-a-guide-to-their-diagnosis-and-treatment/).

Conclusion

Subsurface acidity is becoming increasingly prevalent across SA's cropping land, leading to patchy plant growth and reduced grain yields, especially in pulses. Its presence often goes unnoticed until it is well developed, due to limited or inaccurate subsurface soil sampling and assessment. A strategic soil sampling approach is proposed to adequately identify stratified and subsurface bands of acidity, particularly in no-till systems. Lime application rates need to be developed that take into consideration the degree and depth of acidity, soil type and organic matter content, and lime quality. Growers should consider methods to incorporate applied lime to increase its efficacy in treating subsurface issues. PIRSA is working on developing new calculators to assist lime rate decisions to treat subsurface acidity and will assess incorporation methods suited to South Australian soils.

Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, the authors would like to thank them for their continued support.

Useful resources

https://acidsoilssa.com.au/

References

Angus J, Bell M, McBeath T and Scanlan C (2019) Nutrient-management challenges and opportunities in conservation agriculture. In (Eds J Pratley and J Kirkegaard) "Australian Agriculture in 2020: From Conservation to Automation" pp 221-236 (Agronomy Australia and Charles Sturt University: Wagga Wagga).

Burns H, Norton M and Tyndall P (2017a). Topsoil pH stratification impacts on pulse production in SE Australia. GRDC update 2017 Wagga.

Burns H, Norton M and Tyndall P (2017b). Topsoil pH stratification impacts on pulse production in SE Australia. GRDC update 2017 Bendigo.

Conyers MK and Scott BJ (1989). The influence of surface incorporated lime on subsurface soil acidity. Australian Journal of Experimental Agriculture 29:201-207.

Davies S, Armstrong R, Macdonald L, Condon J and Petersen E (2019). Soil Constraints: A Role for Strategic Deep Tillage. Chapter 8 In (Eds J Pratley and J Kirkegaard) "Australian Agriculture in 2020: From Conservation to Automation" pp 117-135 (Agronomy Australia and Charles Sturt University: Wagga Wagga).

Fleming N, Fraser M, Dohle L and Hughes B (2020). Subsurface acidity: how far has the research advanced? GRDC update 2020 Adelaide.

Paul KI, Black SA and Conyers MK (2003). Development of acidic subsurface layers of soil under various management systems. Advances in Agronomy 78:187-214.

Scott BJ and Conyers MK (1995). Magnesium nutrition and lime movement down the profile. Making better fertiliser, lime & gypsum recommendations. Proceedings of a workshop. Agricultural Research Institute, Wagga Wagga, Australia, August 15 and 16, 1995.

Scott BJ, Conyers MK, Burns HM, Evans CM and Fettell NA (2017). Stratification of acidity in the shallow soil surface - experiences in the cropping areas of southern and central NSW. In: Proceedings of the 18th Australian Agronomy Conference, Ballarat, Australia.

Contact details

Dr Melissa Fraser
Rural Solutions SA, PIRSA
74 Struan House Rd, Struan via Naracoorte, SA 5271
0427 084 569
Melissa.fraser@sa.gov.au
@Mel_Fraser1

Return to contents

Notes

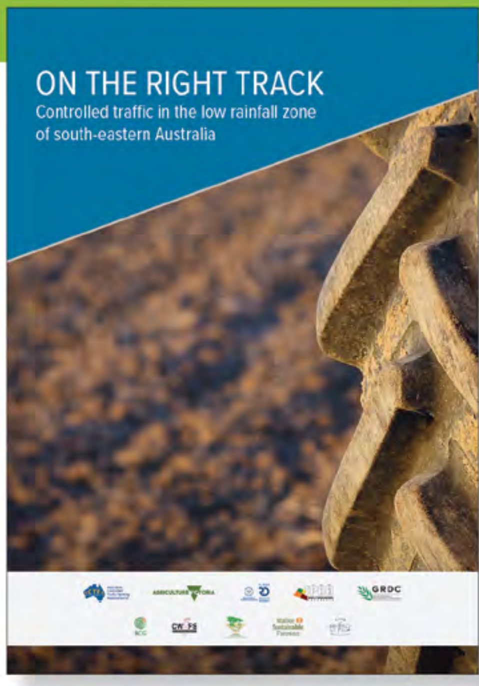
Notes

NEW BOOK FOR LOW RAINFALL GROWERS IN AUSTRALIA

IS CTF WORTHWHILE IN THE LRZ?

This new publication addresses common questions about CTF in the LRZ, such as:

- » DO LRZ SOILS SELF-REPAIR OR IS AMELIORATION WORK NEEDED?
- » IS CTF FEASIBLE IN LOW INTENSITY SYSTEMS WITH VERY WIDE MACHINES?
- » DOES CTF REDUCE POWER AND FUEL USE IN LIGHT LRZ SOILS?
- » IS CTF COMPATIBLE WITH LIVESTOCK IN THE SYSTEM?



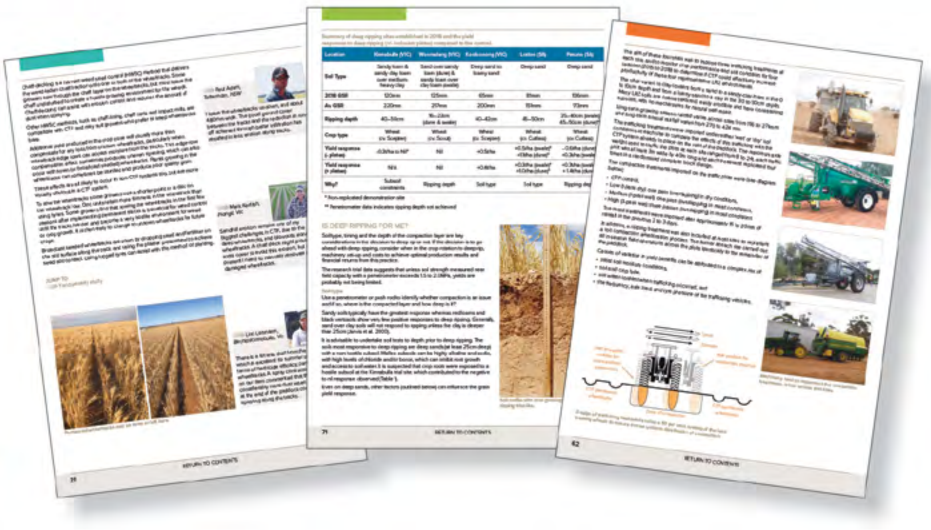
DOWNLOAD YOUR COPY OF THIS NEW RESOURCE FROM grdc.com.au or actfa.net

http://bit.ly/LRZ-CTF

YOU'LL FIND:

- » Practical guides
- » Grower experience
- » Research findings
- » Study investigations

all relevant to the implementation of Controlled Traffic Farming in Low Rainfall Zones



LOOK AROUND YOU.

1 in 5 people in rural Australia are currently experiencing mental health issues.

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

The GRDC supports the mental wellbeing of Australian grain growers and their communities. Are you ok? If you or someone you know is experiencing mental health issues call *beyondblue* or Lifeline for 24/7 crisis support.

beyondblue
1300 22 46 36
www.beyondblue.org.au

beyondblue
Depression. Anxiety.

Lifeline
13 11 14
www.lifeline.org.au

Lifeline
13 11 14

Looking for information on mental wellbeing? Information and support resources are available through:

www.ifarmwell.com.au An online toolkit specifically tailored to help growers cope with challenges, particularly things beyond their control (such as weather), and get the most out of every day.

www.blackdoginstitute.org.au The Black Dog Institute is a medical research institute that focuses on the identification, prevention and treatment of mental illness. Its website aims to lead you through the logical steps in seeking help for mood disorders, such as depression and bipolar disorder, and to provide you with information, resources and assessment tools.

www.crrmh.com.au The Centre for Rural & Remote Mental Health (CRRMH) provides leadership in rural and remote mental-health research, working closely with rural communities and partners to provide evidence-based service design, delivery and education.

Glove Box Guide to Mental Health
The *Glove Box Guide to Mental Health* includes stories, tips, and information about services to help connect rural communities and encourage conversations about mental health. Available online from CRRMH.

www.rrmh.com.au Rural & Remote Mental Health run workshops and training through its Rural Minds program, which is designed to raise mental health awareness and confidence, grow understanding and ensure information is embedded into agricultural and farming communities.

www.cores.org.au CORES™ (Community Response to Eliminating Suicide) is a community-based program that educates members of a local community on how to intervene when they encounter a person they believe may be suicidal.

www.headsup.org.au Heads Up is all about giving individuals and businesses tools to create more mentally healthy workplaces. Heads Up provides a wide range of resources, information and advice for individuals and organisations – designed to offer simple, practical and, importantly, achievable guidance. You can also create an action plan that is tailored for your business.

www.farmerhealth.org.au The National Centre for Farmer Health provides leadership to improve the health, wellbeing and safety of farm workers, their families and communities across Australia and serves to increase knowledge transfer between farmers, medical professionals, academics and students.

www.ruralhealth.org.au The National Rural Health Alliance produces a range of communication materials, including fact sheets and infographics, media releases and its flagship magazine *Partyline*.

ifarmwell growing farmers' wellbeing | Black Dog Institute | Centre for Rural & Remote Mental Health | CORES™
Rural & Remote Mental Health | Heads up Better mental health in the workplace | National Centre for Farmer Health | National Rural Health Alliance Ltd

P Level 4 | 4 National Circuit, Barton ACT 2600 | PO Box 5367, Kingston ACT 2604 **T** +61 2 6166 4500 **F** +61 2 6166 4599 **E** grdc@grdc.com.au

Heat and frost impact on lentil and how remote sensing can benefit growers

Audrey Delahunty[1], Eileen Perry[1], Ashley Wallace[1], Brendan Christy[1], Jason Brand[1] and James Nuttall[1].

[1]*Agriculture Victoria.*

GRDC project code: DAV00143

Keywords

- frost, high temperature, flowering, pulses.

Take home messages

- Knowledge on the impact of frost on yield and quality of lentil, depending on its timing during the flowering and grain filling phase, allows growers to limit production risk through sowing time and cultivar choice.
- For lentil crops surveyed within the Victorian Mallee in 2018, varieties with group B tolerance (e.g. PBA HurricaneXT⁽ᵈ⁾) were not linked with increased frost susceptibility.
- Linking remote sensing tools to frost damage in pulse crops provides new opportunities for spatially zoning paddocks for informing management decisions, such as maximising grain quality.

Background

Pulse production in southern Australia is limited by the occurrence of heat waves and frost during the growing season. The major pulse crops in the southern region are lentil, chickpea, faba bean and field pea where the suitability of these crops varies across agroecological zones, for example significant production of lentil in the Wimmera, and faba bean in the high rainfall zone. Typically, for lentil, temperatures that exceed 30°C during the flowering and pod filling phase cause yield losses, where the effects are amplified under dry (low rainfall and stored soil water) and windy conditions. During a frost event, temperatures of 0°C or below at the crop canopy also translate to yield loss and grain quality penalties in pulse crops. For both high temperature and frost, the growth stage of the crop, duration and intensity of exposure are critical in defining the extent of damage, where cumulative time (load) above or below a critical threshold are used to classify expected yield loss.

The principles applied for lentil in this paper broadly apply to other pulse crops in terms of risk management and susceptibility to extreme events.

Definition: cold and heat load

To account for the varying severity in frost (temperature × duration) imposed on lentil, we calculated the cold load as the sum of degrees Celsius (°C) below 0°C, with time (°C.hr) for temperature measured at the canopy. The same approach is used for heat when temperature exceeds 30°C.

Key Question 1 - What affect does high temperature and frost have on lentil?

Pulse crops, including lentil, are most sensitive to frost and high temperature during the reproductive phase which extends from first flowering to filled pod.

Crop damage of lentil caused by frost and heat at different growth stages, looks similar:

- Vegetative – premature death of leaves and tendrils.
- Flowering – dropping of flowers and buds.
- Flat pod – dropping of pods, generally translates to yield losses (reduced grain number) and formation of underdeveloped dark grain.
- Filled pod – deterioration in grain quality, generally shrivelling of grain and some darkening of seed coat.

If a frost (<0°C at canopy) or heat wave (>30°C) is forecast, knowing the growth stage will provide insight into the damage you can expect and importantly inform, if your crop may recover. The indeterminant nature of pulse crops provides a partial recovery mechanism to maintain yield potential, by continuing to set pods following extreme events, although the extent of recovery will be influenced by timing (the earlier in the season the greater recovery) and water availability.

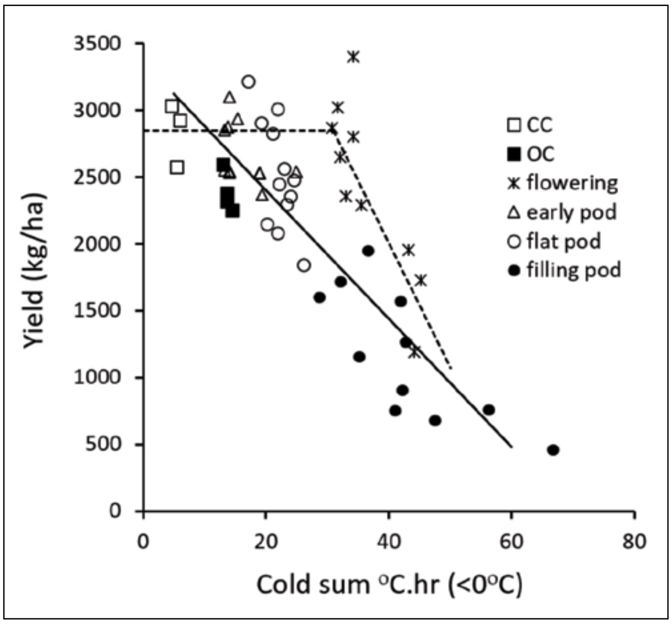


Figure 1. Relationship between lentil (cv. Jumbo 2$^{(\phi)}$) grain yield and cold load (°C.hr <0°C) associated with frost treatments applied at five different growth stages; late vegetative, flowering, early pod, flat pod and filling pod in 2017. CC, chamber control; OC, open control data set (black) is for data < 70 °C.hr <0°C). Segmented regression model is for CC and flowering data and linear models are for CC, OC, and pod filling stages (black solid line) (Delahunty et al. 2019a).

Lentil response to heat

As a rule of thumb, for every degree-hour (>30°C) during the podding stage, there is a 0.13% reduction in yield. Further research is required to determine how this rate varies for different growth stages.

Lentil response to frost

A relationship between lentil yield response and frost (cold load) was defined using field data during 2017 at Horsham, Victoria, where no natural frost was recorded during the reproductive window. At flowering, damage occurs when a threshold of 31°C. hr (<0°C) is reached, here after yield decline was 3.8% per °C.hr (<0°C) (Figure 1). At pod filling, for every degree below zero there was a 2% reduction in grain yield indicating that this is the most sensitive phase for lentil to frost. The difference in response to frost at flowering and pod filling indicates that timing, intensity and duration has an effect the extent to which lentil will recover from frost.

Key question 2 - Does the lentil variety influence the response of lentil to heat/frost?

High temperature

Genetic variation to high temperatures exists for lentil across commercial cultivars and landraces. This variation in plant response was demonstrated through a field trial which screened a combination of landraces and commercial varieties for yield stability under high temperature in the Wimmera, Victoria, 2014. For the commercial varieties tested, cv. PBA Bolt$^{(\phi)}$ was the most stable variety, but had lower absolute yield potential, whereas cv. Nipper$^{(\phi)}$, a small-seeded variety, had both moderate yield stability and high yielding potential (Figure 2). Importantly this research indicates that further opportunity to increase the tolerance of lentil to high temperature exists through utilising high temperature tolerant landraces within current pulse breeding programs (Figure 2).

Frost

For current commercial lentil varieties, there is little difference in capacity to tolerate frost. It is likely that genetic variation does exist across landraces, where a range in tolerance has been observed in other pulses including field peas (Davies & Pham, 2017).

Following the release of PBA HurricaneXT$^{(\phi)}$, there was concern that varieties with Group B herbicide tolerance were more susceptible to frost compared

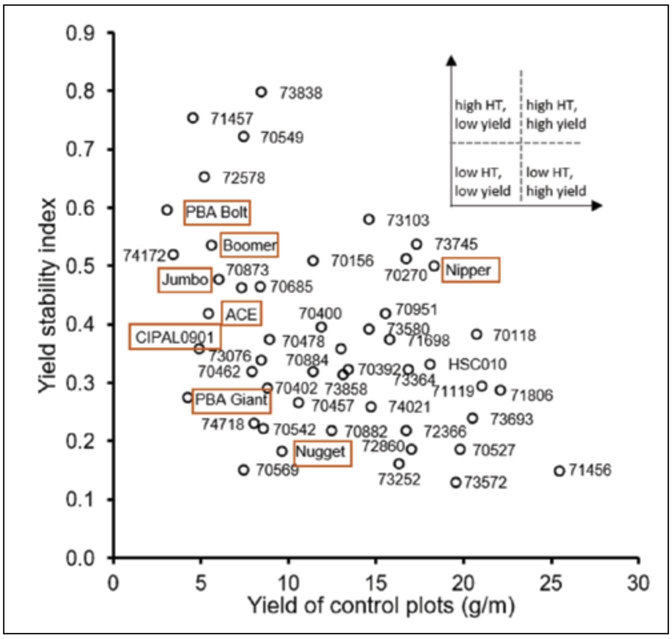


Figure 2. Screening of lentil varieties and landraces for high temperature tolerance. The relationship between the absolute yield of 'control' plants (protected from sun/ high temperature) and yield stability index (yield of plants grown under high temperature compared to the control). Commercial and breeding lines are highlighted in orange (Delahunty et al. 2020, unpublished).

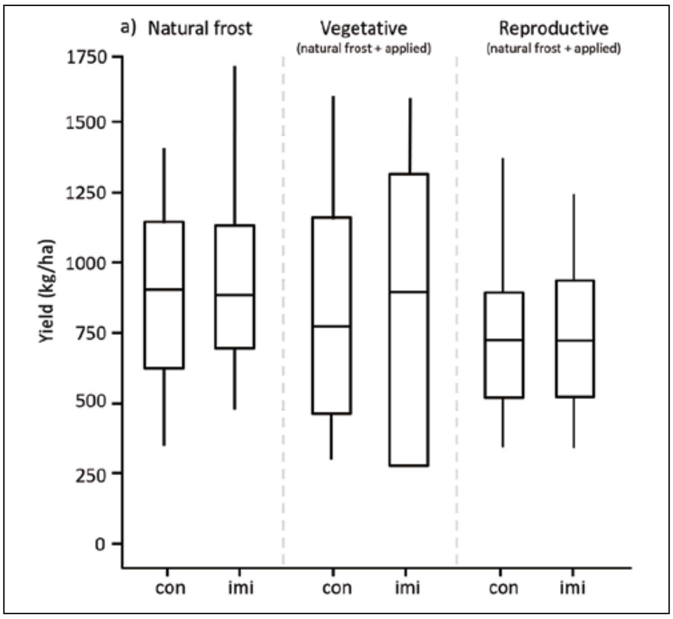


Figure 3. Comparison of grain yield of conventional (con) to imi-tolerant (imi) varieties tested in 2018 field trial at Ouyen. Frost treatments are natural frost, applied at vegetative and natural frost, applied at reproductive and natural frost.

with conventional lentil varieties. In 2018, a field experiment at Ouyen, Victoria assessed lentil yield for natural and artificial frost effects which occurred during the late vegetative and late podding stage, across four imi-tolerant lentil varieties (PBA Herald$^{\phi}$, PBA HurricaneXT$^{\phi}$, PBA HallmarkXT$^{\phi}$, CIPAL1721) and two conventional varieties (PBA Jumbo 2A and PBA Flash$^{\phi}$) (Delahunty et al. 2019b).

For the natural frost conditions which occurred in 2018, all varieties were equally susceptible to frost, indicating that imi-tolerance was not linked to increased frost sensitivity under these conditions (Figure 3). Furthermore, under applied frost conditions (severe), conventional and imi-tolerant lines were equally affected by frost during the late vegetative and reproductive period (Figure 3). This result suggests that the increased visual symptoms of frost damage in imi-tolerant lines (e.g. PBA HurricaneXT$^{\phi}$), did not translate to greater yield loss due to frost, in this study. Future work is required to verify this pattern of response to frost under wetter growing conditions where yield potential is greater than in 2018, and for alternative frost stress patterns.

Key question 3 - When does heat/frost have greatest impact on lentil yield and quality and how does this influence growers' decisions?

Pulse crops, including lentil, are most sensitive to extreme temperature (heat waves and frost) during the reproductive period. This period spans from flowering to when grain is formed in the pods. Current management strategies to mitigate frost and high temperature damage are largely through avoidance; manipulating variables such as sowing date, crop and cultivar selections. However, these strategies possess the dilemma of weighing up avoidance of either the frost or heat wave window (depending on what risk you are trying to manage) (Figure 4). This challenge is significant and limiting the impact of frost and high temperature effects will be informed by understanding the region-specific historic occurrence of frost and high temperature and their probability of occurrence (Figure 4a versus Figure 4b). Pulse crops also range in their susceptibility to frost damage, where faba bean are more tolerant and field pea the most sensitive. These differences are primarily due to plant architecture (e.g. faba bean thick pod wall and field pea thin pod wall) and flowering time of each crop (e.g. chickpea and lentil flower later and avoid some frost).

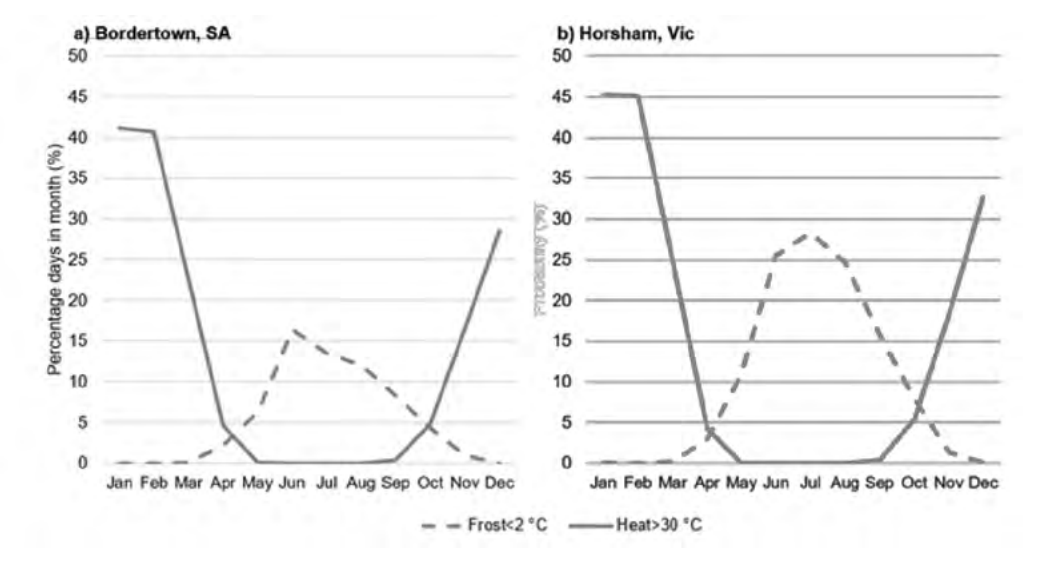


Figure 4. Comparison of the risk profile of frost and high temperature for a) Bordertown and b) Horsham. Measure of occurrence is percentage of days in month for either frost (< 2°C at 1.8m) or high temperature (> 30°C) which has been calculated from the past 100 years of weather data (Source: Bureau of Meteorology).

When sowing time is used to manipulate flowering time and related frost and high temperature risk windows, the impact of time of sowing (TOS) on yield potential must also be considered. Generally, sowing at the optimal time based on region and cultivar choice translates to highest yield potential (Table 1). For example, for lentil crops at Curyo in 2014, delaying sowing by three weeks caused yield reductions of between 53 and 63% across a range of varieties (Table 1). These reductions in yield were due to the combined effects of mis-matching cultivar phenology with season, and high temperature and water stress associated with late maturing crops in this region.

In some years, delayed sowing can be beneficial due to the occurrence of other abiotic and biotic constraints, such as high incidence of disease (correlated to wet conditions). An example of this was in 2016 when there was a high infection rate of Botrytis Grey Mould (BGM) for crops sown on the recommended sowing date at both Curyo and Rupanyup which caused yield losses for susceptible varieties (PBA Bolt$^{\phi}$, PBA HurricaneXT$^{\phi}$ and PBA Jumbo$^{\phi}$), where PBA Jumbo 2$^{\phi}$ which is rated resistant – moderately resistant (RMR) was not affected by the disease. This response highlights the value of selecting the variety best suited to your region, e.g. wetter areas should consider disease rating.

Table 1. Percentage change in yield (negative is reduction) due to delayed sowing compared to recommended sowing time for lentil varieties in the Wimmera (Rupanyup, Pimpinio and Kalkee) and Southern Mallee (Curyo).

	2012		2013		2014		2016		Average
	Curyo	Rupanyup	Curyo	Kalkee	Curyo	Pimpinio	Curyo	Rupanyup	
Boomer$^{\phi}$	-14	48	4	-19	-53	32			0
Nipper$^{\phi}$	-14	14	-11	-10	-56	1			-13
Nugget	-18	-14	-3	-19	-58	41			-12
PBA Ace$^{\phi}$	-21	23	-26	-9	-63	3	10	-4	-11
PBA Bolt$^{\phi}$	-22	14	-3	-11	-61	-19	29	19	-7
PBA HurricaneXT$^{\phi}$	-23		-19	-7	-40	-28	6	25	-12
PBA Jumbo$^{\phi}$	-10	-6	-13	-21	-59	16	48	22	-3
PBA Jumbo2$^{\phi}$					-60	-24	-16	-11	-17

NB: Recommended sowing for the Wimmera is around the 10th of May and the last week of April/ early May at Curyo, delayed sowing is approximately three weeks. (Source: Jason Brand, Southern Pulse Agronomy).

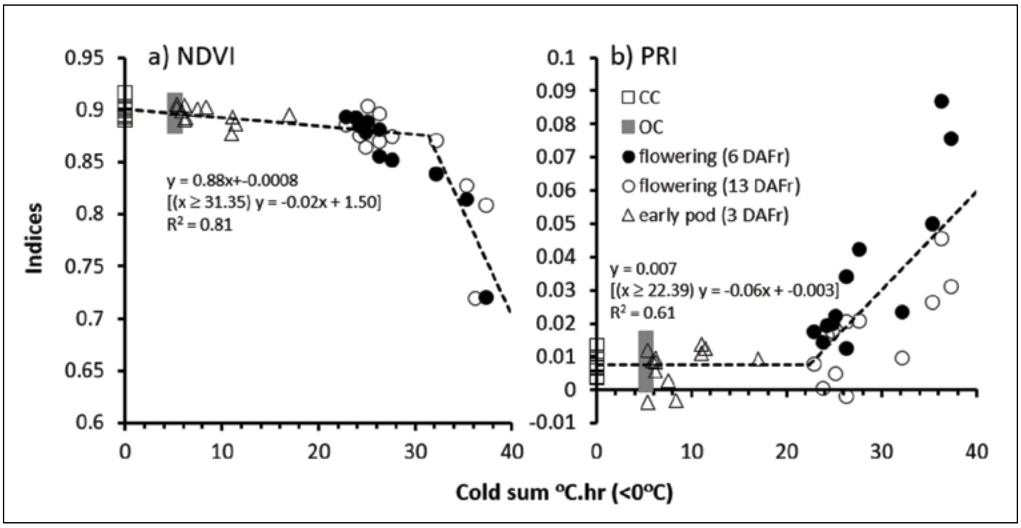


Figure 5. Reflectance indices for lentil cv. Jumbo 2(d) exposed to frost at varying intensities expressed as cold loads. Reflectance indices a) NDVI and b) PRI were measured using a portable spectrometer 10cm above the canopy at 6 days after frost (DAFr)and 13 DAFr (following flowering application) and 3 DAFr (following podding treatment). Segmented regression models are for CC (protected from frost events), OC (exposed to natural frost events), flowering and early podding data. 0 DAFr is the day following the night of frost application (Delahunty et al. 2019b).

Key Question 4 - Remote sensing for frost damage in lentil – can it be done and how does it assist growers' decisions

While not a solution, rapid estimation of damage, using remote and proximal sensing, would allow for tactical decision making for limiting financial losses through cutting for hay, precision harvesting and quality segregation opportunities.

To determine the utility of remote sensing for ultimately informing management decisions, the impact of frost to lentil was measured using proximal sensing following the application of artificial frost treatments. Several reflectance indices were strongly correlated with cold load, including Normalised Difference Vegetative Index (NDVI) and Photochemical Response Index (PRI). NDVI and PRI are surrogates for chlorophyll content/ greenness, biomass and photosynthetic efficiency/ plant stress, respectively.

There was a strong negative correlation between cold load and NDVI (Figure 5a), where PRI was more sensitive to frost damage compared to NDVI (Figure 5b). The good agreement of remote sensing indices; NDVI and PRI to frost affected crop, supports the potential to utilise non-destructive measurements taken from vehicle, airborne or satellite platforms for making in-season management decisions on-farm which limit losses due to abiotic constraints.

Conclusion

Frost and high temperature during the reproductive phase of pulse crops, such as lentil, pose a significant challenge for growers to manage. Generally, the best management option to maximise yield is to sow crops in the optimal window recommended for the cultivar and district, where some reduction in yield and quality may occur due to frost and heat. In this case, selecting cultivars that flower in the period where region-specific chances of frost and heat severity are least will provide maximum chance for avoidance. Genetic variation to high temperature exists in lentil and provides future opportunity to increase lentil adaptation through breeding. Under severe frost conditions there is no difference between imi tolerant and conventional varieties. Finally, this work indicates that there is potential to spatially manage frost damage at the paddock scale using remote sensing technologies. Ongoing work is required to validate the use of remote sensing for detection of abiotic stresses and extend the use of such diagnostics to other pulse crops.

Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, the author would like to thank them for their continued support. This work was delivered through the 'Improving practices and adoption through strengthening D&E capability and delivery in the southern region', Regional Research Agronomist program (DAV00143) and funded by Agriculture Victoria and the GRDC. The authors also wish to acknowledge the assistance of Agriculture Victoria staff Ashley Purdue, Kate Finger, Mitchell Fromm and Alexander Clancy and Frontier Farming Systems.

Useful resources

https://www.agric.wa.gov.au/frost/managing-frost-risk?page=0%2C1

http://www.bom.gov.au/climate/climate-guides/

https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2020/02/rapid-detection-of-frost-damage-in-wheat-using-remote-sensing

https://grdc.com.au/__data/assets/pdf_file/0027/366165/GrowNote-Lentil-West-6-Plant-Growth-Physiology.pdf

References

Davies P, Pham T (2017) A method to select for reproductive tolerance in field pea (Pisum sativum L.), Journal of Agronomy and Crop Science, 203(4), 332-337

Delahunty A, Perry E, Wallace A, Nuttall J (2019a) Frost response in lentil. Part 1. Measuring the impact on yield and quality, 19thAustralian Agronomy Conference, Wagga Wagga, Australia

Delahunty A, Perry E, Wallace A, Nuttall J (2019b) Frost response in lentils, GRDC Grains Research Update, Bendigo, Australia

Contact details

Audrey Delahunty
Cnr Eleventh St & Koorlong Ave, Irymple, Victoria, 3498
0427 580 131
audrey.j.delahunty@agriculture.vic.gov.au
@AudreyDelahunty

Return to contents

Notes

Notes

GRDC™
GROWNOTES

SPRAY APPLICATION GROWNOTES™ MANUAL

SPRAY APPLICATION MANUAL FOR GRAIN GROWERS

The Spray Application GrowNotes™ Manual is a comprehensive digital publication containing all the information a spray operator needs to know when it comes to using spray application technology.

It explains how various spraying systems and components work, along with those factors that the operator should consider to ensure the sprayer is operating to its full potential.

This new manual focuses on issues that will assist in maintaining the accuracy of the sprayer output while improving the efficiency and safety of spraying operations. It contains many useful tips for growers and spray operators and includes practical information – backed by science – on sprayer set-up, including self-propelled sprayers, new tools for determining sprayer outputs, advice for assessing spray coverage in the field, improving droplet capture by the target, drift-reducing equipment and techniques, the effects of adjuvant and nozzle type on drift potential, and surface temperature inversion research.

It comprises 23 modules accompanied by a series of videos which deliver 'how-to' advice to growers and spray operators in a visual easy-to-digest manner. Lead author and editor is Bill Gordon and other contributors include key industry players from Australia and overseas.

Spray Application GrowNotes™ Manual – go to:
https://grdc.com.au/Resources/GrowNotes-technical
Also go to https://grdc.com.au/Resources/GrowNotes
and check out the latest versions of the Regional Agronomy Crop GrowNotes™ titles.

GRDC™
GRAINS RESEARCH & DEVELOPMENT CORPORATION

Break crop options in cropping rotations

Amanda Pearce..

South Australian and Research Development Institute.

GRDC project code: 9175938BA

Keywords

- cropping, sequences, break crops, grain, annual pasture legume phase, annual ryegrass, gross margin

Take home messages

- Pastures can be a productive and profitable break crop option for mixed farming systems in the Upper South East of South Australia.
- Up to a 26% increase in wheat yields has been achieved following a pasture phase compared to a wheat on wheat rotation.
- A pasture phase can be used in a rotation to decrease annual ryegrass populations.
- Initial gross margins are responsive to a legume in the rotation.

Background

As part of the GRDC-SARDI Strategic Research Agreement (Program 5, Regional Agronomy Capacity) the project 'Integrated Farming Systems in the Medium Rainfall Zone' commenced in the Upper South East (USE) of South Australia (SA) in 2017.

The expected outcome of the project is that by 2021, growers in the Medium Rainfall Zone (MRZ) of the South East (SE) and their advisers will have access to new relevant information on diverse crop rotations and integrated farming systems, particularly the incorporation of a pasture phase. This will allow for better crop sequencing decision making, with the aim of increasing farm sustainability, diversity and ultimately profitability, through the adoption of improved rotations and break crop management options.

Two rotation trials were established as part of this project at Bordertown and Sherwood in 2017.

The rotation trials are evaluating the following:

(i) What is the magnitude of impact of an annual pasture legume in the integrated farming system rotation in the MRZ of the USE on subsequent crops?

(ii) Is the break effect (environmental, agronomic, economic and risk) of an annual pasture legume phase comparable to that of pulse and canola break crops?

(iii) Do double breaks increase subsequent wheat yields compared to single breaks?

(iv) Does the break effect impact on the second wheat crop and beyond?

This paper addresses three key questions relating to the rotation trials:

(i) What is the best rotation of crops/pastures for growers in this area?

(ii) What are the agronomic benefits of using a pasture as a break crop option?

(iii) How do the economics of an annual pasture break crop compare to that of other break crop options?

The Bordertown and Sherwood trials have been statistically designed for a four-year rotation. The first year of sequences were sown in 2017 and the final sequences were sown in May 2020. The sequences are phased throughout the four years, to minimise the bias of seasonal conditions and commodity fluctuations. Therefore, data presented prior to the completion of the rotations is only a snapshot, providing an insight into the full results.

Key Question 1 - What is the best rotation of crops/pastures for growers in this area?

The inclusion of an annual pasture legume into the cropping rotation can provide integrated farming systems with a diverse and flexible break crop option. Understanding the value of pastures as a break crop is complex and incorporates agronomic, environment and economic components.

The rotation trials are evaluating nine crop types (cereals (wheat, barley and oats), canola, faba bean, lentil at Bordertown and lupin at Sherwood, and three different annual pasture legumes, subterranean clover, balansa clover and burr medic) across 16 different rotations. The rotations include continuous wheat, continuous pastures, and single and double break crop options.

Data generated from the rotation trials at Bordertown and Sherwood suggest that the inclusion of a pasture legume break crop phase can be a profitable and productive option, not only in the break crop year, but in the subsequent years.

A simple way of looking at the data generated from the rotation trials is to review wheat yields following different break crop options over several years. Discussed in the following sections are preliminary results of single and double break crops and subsequent wheat yields.

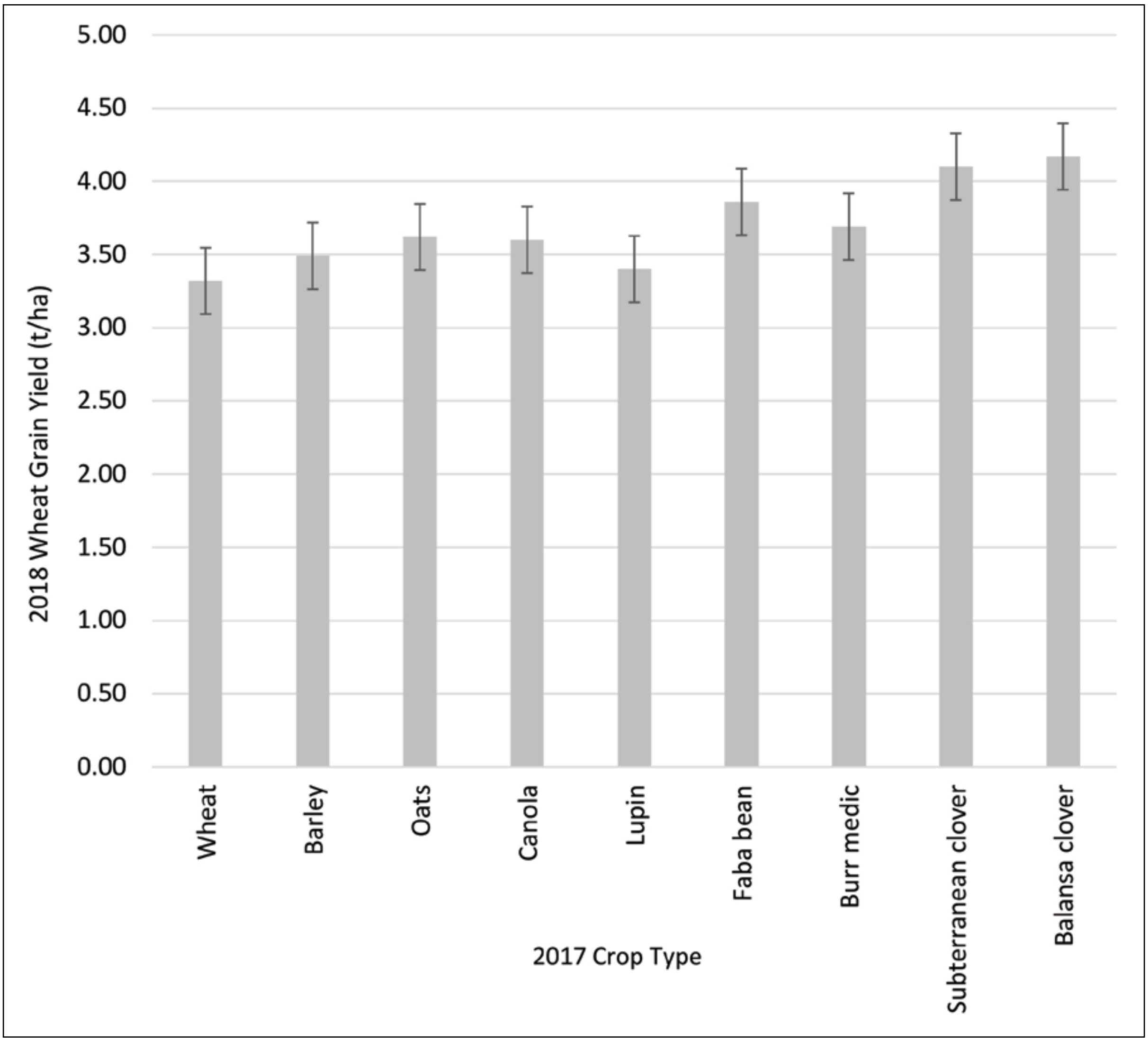


Figure 1. Sherwood 2018 wheat grain yields (t/ha), following different crop types sown in 2017. Error bars indicate standard error (P value (<0.001), LSD 0.454).

An annual pasture legume as a single break crop option

In 2018 at Sherwood wheat grain yields were responsive to a legume break crop (Figure 1). Wheat yields averaged 3.69t/ha and as shown in Figure 1 were greater following balansa clover and subterranean clover, compared to a canola and cereal break crop. There was up to a 26% increase in wheat yields following balansa clover compared to a wheat on wheat rotation.

In 2019 at Sherwood wheat yields averaged 4.61t/ha (Table 1). In 2019 there was a 12% increase in wheat yields following a subterranean clover (4.88t/ha), compared to a wheat on wheat rotation (4.36t/ha) (Table 1). The break crop faba bean also increased wheat yields significantly compared to a wheat on wheat rotation.

Wheat yields averaged 5.35t/ha at Bordertown in 2018 (Table 2). As shown in Table 2, wheat yields were not significantly greater following a legume break crop compared to a cereal break crop.

In 2019 Bordertown wheat averaged 4.82t/ha. In contrast to 2018 a significant difference was measured between the single break crop options (Figure 2). A break crop of subterranean clover increased yields by 24% compared to a wheat on wheat rotation. The use of lentil and burr medic as break crops also significantly increased wheat grain yields compared to a wheat on wheat rotation.

The benefits of a single pasture legume break crop on subsequent wheat yields has been realised in years with lower wheat production. At Sherwood a response was measured in 2018 when wheat yields averaged 3.69t/ha, compared to no significant response in 2019 when wheat yields averaged 4.61t/ha. At Bordertown no significant response was measured when wheat yields averaged 5.35t/ha, but in 2019 when wheat yields had a lower yield average of 4.82t/ha a response was measured.

Pastures as a double break crop option

The rotation trials have evaluated the use of a double break crop and the impact on subsequent wheat yields. To-date there is only one-year of data to review. At Bordertown the value of a double break of pasture or a canola X pasture double break increased subsequent wheat yields by over 15% compared to a grower rotation of oat X faba bean X wheat rotation (Table 3). Double breaks that include a pasture increased subsequent wheat yields by up to 1.45t/ha, compared to a continuous wheat rotation. After initial analysis at Sherwood the value of a double break crop option has not been realised (data not presented).

Key Question 2 - What are the agronomic benefits of using a pasture as a break crop option?

The agronomic benefits of pastures as a break crop option include reductions in weeds, pests and diseases; improved soil water supply, extraction, retention and water use efficiency; and increased soil mineral nitrogen, organic carbon and soil fertility.

Of particular interest in the rotation trials is the benefit experienced from the reduction in annual ryegrass (ARG) populations with the inclusion of a pasture in the rotation. Sequencing can impact on

Table 1. Sherwood 2019 wheat grain yields (t/ha) following different crop types sown in 2018.

2018 Crop	2019 Wheat Grain Yield (t/ha)	
Burr medic	4.04	a
Wheat	4.36	ab
Barley	4.36	abc
Canola	4.51	abcd
Balansa clover	4.61	bcd
Lupin	4.65	abcd
Oat	4.82	bcd
Subterranean clover	4.88	cd
Faba bean	5.00	d
Site Mean	4.61	
P Value	0.001	
LSD (05)	0.56	

Means with the same letter are not significantly different (P =0.05)

Table 2. Bordertown 2018 wheat grain yields (t/ha), following different crop types sown in 2017.

2017 Crop	2018 Wheat Grain Yield (t/ha)	
Wheat	5.15	
Barley	5.89	
Oats	5.19	
Canola	4.90	
Lentil	5.80	
Faba bean	5.23	
Burr medic	5.20	
Subterranean clover	5.42	
Balansa clover	5.39	
Site Mean	5.35	
P value	0.831	Not significant

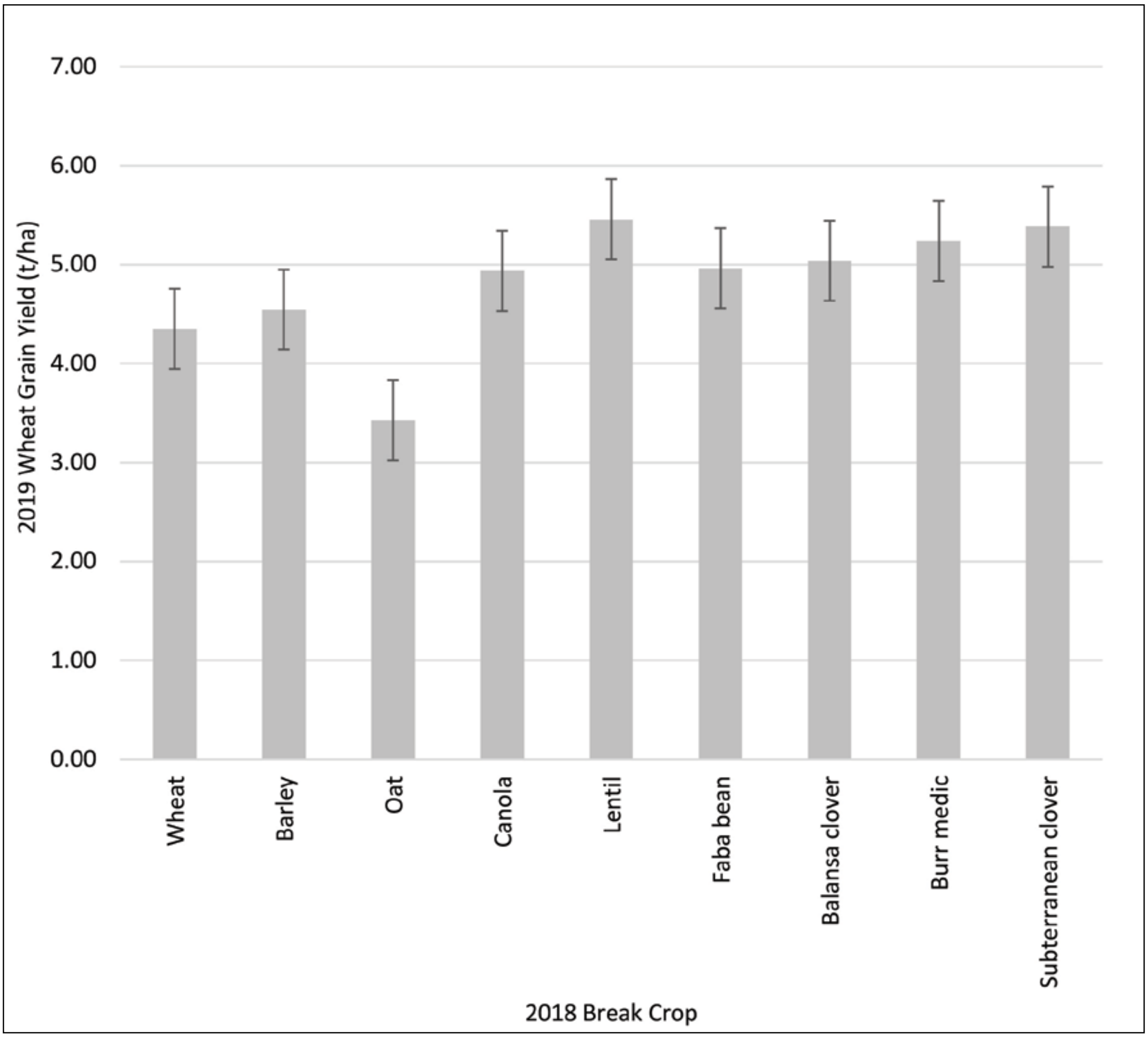


Figure 2. Bordertown 2019 wheat grain yields (t/ha), following different crop types sown in 2018. Error bars indicate standard error (P value (<0.001), LSD 0.81).

Table 3. Bordertown 2019 wheat grain yields (t/ha), following different rotations, 2017 crop type X 2018 crop type.

Rotation	2017	2018	2019 Wheat Grain Yield (t/ha)	
Single break Oat	Wheat	Oat	3.43	a
Continuous Wheat	Wheat	Wheat	4.25	b
Single break Barley	Wheat	Barley	4.55	bc
Grower rotation	Oat	Faba bean	4.62	bc
Single break Balansa clover	Wheat	Balansa clover	4.69	bcd
Single break Canola	Wheat	Canola	4.94	bcd
Single break Subterranean clover	Wheat	Subterranean clover	5.13	cd
Single break Burr medic	Wheat	Burr medic	5.14	cd
Single break Faba bean	Wheat	Faba bean	5.31	cd
Double break Subterranean clover	Subterranean clover	Subterranean clover	5.33	cd
Double break Burr medic	Burr medic	Burr medic	5.35	cd
Double break Balansa clover	Balansa clover	Balansa clover	5.39	cd
Single break Lentil	Wheat	Lentil	5.46	cd
Double break	Canola	Subterranean clover	5.70	d
		Site Mean	4.94	
		P Value (05)	<.001	
		LSD	1.0281	

Means with the same letter are not significantly different (P =0.05)

Table 4. Annual ryegrass (ARG) plants/m^2 in wheat in 2019 and 2020, following different rotations, average of a single break of either canola/faba bean/lentil or lupin, a single break or double break of subterranean clover and continuous wheat.

Rotation	2019 ARG plants/m^2		2020 ARG plants/m^2	
	Bordertown	Sherwood	Bordertown	Sherwood
Single break canola/faba bean/lentil/lupin	63	128	47	81
Single break subterranean clover	0	117	7	50
Double break subterranean clover	3	14	0	24
Continuous wheat	72	209	35	69

ARG populations, but often it is in conjunction with other factors. Factors contributing to ARG population reductions can include, but is not limited to, seeding conditions and success of pre-emergent herbicides, subsequent herbicide options and timing of applications, time of sowing and seeding rates, crop establishment, crop competition and management of crop for either grazing, hay or grain.

In 2017 ARG populations were lower at Bordertown (site average three plants/m^2), compared to Sherwood (site average 56 plants/m^2), with populations generally greater in cereal plots compared to the other crop types.

In 2018 at both sites, crops following cereals had higher ARG plant numbers, 34 ARG plants/m^2 at Bordertown and 225 ARG plants/m^2 at Sherwood, compared to plots following a pasture break crop, 23 ARG plants/m^2 at Bordertown and 47 ARG plants/m^2 at Sherwood.

This result was replicated in 2019 at both sites. As shown in Table 4, a continuous wheat rotation had 72 plants/m^2 at Bordertown and 209 plants/m^2 at Sherwood. A double break of subterranean clover had 3 plants/m^2 ARG numbers at Bordertown and 14 plants/m^2 at Sherwood, compared to the average of a single break of canola, faba bean or lentil/lupin which averaged 63 plants/m^2 at Bordertown and 128 plants/m^2 at Sherwood. At Sherwood the double break of subterranean clover had lower ARG plants/m^2 compared to a single break, this was not replicated at Bordertown, where ARG numbers were low in both single and double break options of subterranean clover.

In 2020 a continuous wheat rotation had 35 ARG plants/m^2 at Bordertown and 69 ARG plants/m^2 at Sherwood (Table 4). A double break of subterranean clover had 0 ARG plants/m^2 at Bordertown and 24 plants/m^2 at Sherwood. As shown in Table 4 and similar to 2019 there was little difference in ARG plant numbers following a double break or a single break of subterranean clover at Bordertown, and at Sherwood the double break of subterranean clover had lower ARG plant numbers compared to the single break. The subterranean break crop rotations had fewer ARG plants compared to the average of a single break of canola, faba bean or lentil/lupin.

Key Question 3 - How do the economics of an annual pasture break crop compare to that of other break crop options?

An initial gross margin (GM) ($/ha) has been completed for the three years; 2017, 2018 and 2019 of the rotation. When all rotations have been phased (2020 harvest), a full economic and sensitivity analysis will be completed. This will accommodate commodity price fluctuations and seasonal differences.

Figure 3 presents a snapshot of five different rotations at Sherwood and their calculated GM. The rotations presented are continuous wheat, continuous subterranean clover, grower rotation (faba bean, wheat and canola), a single break of subterranean clover and a double break of subterranean clover. The GM ($/ha) has been calculated based on cropping inputs ($/ha) (seed, herbicide, insecticide, fungicide and fertiliser. It does not include labour, machinery costs, levies, insurances, or EPR (full inputs are available on request)), subtracted from the income ($/ha) (commodity price ($/t) X production (grain/hay harvested t/ha)).

At Sherwood wheat is being managed to achieve a 4.5t/ha crop and canola a 2.0t/ha crop. Importantly, the pasture GM has been calculated as if it was a hay crop. It is recognised that this undervalues the pasture as a commodity and in the final analysis the value of pasture as a grazing option will be calculated.

In 2017 wheat at Sherwood averaged 2.9t/ha, it was FED 1 quality, with a commodity price of $215.00/t and a GM of $114/ha was achieved. Faba bean achieved a GM of $842/ha, based on a 3.8t/ha yield and a commodity price of $315.00/ha. Subterranean clover, as a hay option produced 3.0t/ha, with the lowest input cost of $200.00/ha (compared to $510/ha for wheat and $355/ha for faba bean). A commodity price of $190/ha resulted in a GM of $370/ha.

In 2018 wheat following a subterranean clover yielded 4.1t/ha compared to a continuous wheat rotation yield of 3.3t/ha, representing in a 26% wheat yield increase. The input costs were lower following a subterranean clover and faba bean compared to following a wheat. This is because less N was required to achieve a 4.5t/ha crop, due to higher residual soil N following a legume compared to a continuous wheat rotation. Wheat on wheat plots achieved FED 1 quality ($320/ha commodity price), whereas wheat following the legumes achieved APW1 quality ($370/ha commodity price). The continuous pasture hay produced 5.6t/ha and had a commodity price of $190/ha.

In the third year of the rotation; 2019, a double break of subterranean clover had a subsequent wheat yield of 4.9t/ha, compared to the continuous wheat rotation of 4.2t/ha. Both rotations achieved H2 for quality with a commodity price of $315/ha. Wheat input costs were higher in the continuous wheat treatment, a result of lower soil N compared to the rotations which included a legume phase. Canola produced 2.0t/ha, with an input cost of $480/ha and a commodity price of $570/ha. The continuous pasture phase again had the lowest input costs, yielded 4.3t/ha and had a higher commodity price compared to the two previous years of $250/ha.

Over the three years the combined GM is responsive to a legume phase. In this simplistic review of five rotations at Sherwood, over the three years (2017, 2018 and 2019) the continuous wheat rotation had the lowest combined GM of $1513/ha, compared to the grower rotation (FB-W-C) of $2480/ha, the single break of subterranean clover $2390/ha and the double break of subterranean clover $2328/ha. The continuous pasture had a three-year GM of $2124/ha.

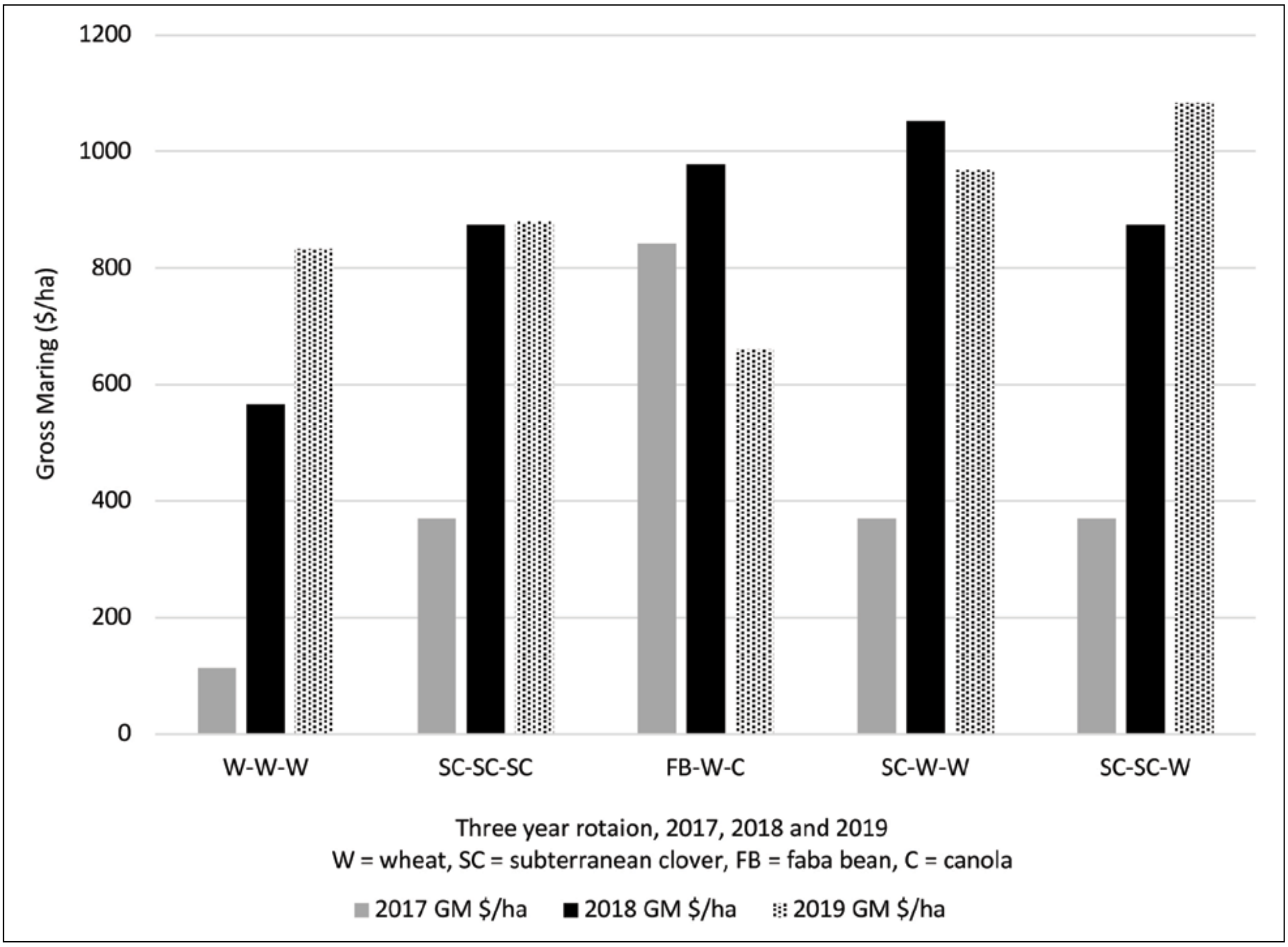


Figure 3. Sherwood rotation trial gross margin (GM) ($/ha) for 2017, 2018 and 2019. The GM ($/ha) has been calculated based on cropping inputs ($/ha) (seed, herbicide, insecticide, fungicide and fertiliser. It does not include labour, machinery costs, levies, insurances, or EPR (full inputs are available on request)), subtracted from the income ($/ha) (commodity price ($/t) X production (grain/hay harvested t/ha)).

Conclusion

The inclusion of a pasture legume break crop phase in the rotation can be a profitable and productive option, not only in the break crop year, but in the subsequent years.

Wheat yield increases of up to 26% have been achieved following a pasture break crop compared to a wheat on wheat rotation. The benefits of single pasture break crop on subsequent wheat yields has been realised in years with lower wheat yields. The use of a pasture phase can reduce annual ryegrass populations. The snapshot GM presented in this paper has shown that an annual pasture legume can be a profitable break crop option and that the GM has been responsive to the inclusion of a legume in the rotation.

Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, the author would like to thank them for their continued support. This research has been funded through the GRDC-SARDI Strategic Research Agreement (Program 5, Regional Agronomy Capacity). The ongoing cooperation of the Johnson family at Bordertown and the Menz Family at Sherwood is greatly appreciated.

Useful resources

Angus JF, Kirkegaard JA, Hunt JR, Ryan MH, Ohlander L, Peoples MB (2015) Break crops and rotations for wheat. *Crop & Pasture Science* **66**, 523-552.

Ewing MA, Flugge F (2004) The benefits and challenges of crop-livestock integration in Australian agriculture. In 'Proceedings 4th International Crop Science Congress', Brisbane, Australia.

GRDC (Grains Research & Development Corporation) (2009) Good rotations – when do you need a break. Online: www.grdc.com.au

Kirkegaard JA, Christen O, Krupinsky J, Layzell D (2008) Break crop benefits in temperate wheat production. *Field Crop Research* **107**, 185-195.

Pearce AL, Turner F (2015) Final Report Crop Sequencing Project (CSP00146) – South East of South Australia – Lochaber. Technical Report Online: http://www.mackillopgroup.com.au/

Contact details

Amanda Pearce
74 Struan House Road, Naracoorte SA 5271
PO Box 618, Naracoorte SA 5271
0407 400 939
Amanda.pearce@sa.gov.au

Return to contents

Notes

TOP 10 TIPS

FOR REDUCING SPRAY DRIFT

01 **Choose all products in the tank mix carefully**, which includes the choice of active ingredient, the formulation type and the adjuvant used.

02 **Understand** how product uptake and translocation may impact on coverage requirements for the target. Read the label and technical literature for guidance on spray quality, buffer (no-spray) zones and wind speed requirements.

03 **Select the coarsest** spray quality that will provide an acceptable level of control. Be prepared to increase application volumes when coarser spray qualities are used, or when the delta T value approaches 10 to 12. Use water-sensitive paper and the Snapcard app to assess the impact of coarser spray qualities on coverage at the target.

04 **Always expect** that surface temperature inversions will form later in the day, as sunset approaches, and that they are likely to persist overnight and beyond sunrise on many occasions. If the spray operator cannot determine that an inversion is not present, spraying should NOT occur.

05 **Use weather forecasting** information to plan the application. BoM meteograms and forecasting websites can provide information on likely wind speed and direction for 5 to 7 days in advance of the intended day of spraying. Indications of the likely presence of a hazardous surface inversion include: variation between maximum and minimum daily temperatures are greater than 5°C, delta T values are below 2 and low overnight wind speeds (less than 11km/h).

06 **Only start spraying** after the sun has risen more than 20 degrees above the horizon and the wind speed has been above 4 to 5km/h for more than 20 to 30 minutes, with a clear direction that is away from adjacent sensitive areas.

07 **Higher booms increase drift**. Set the boom height to achieve double overlap of the spray pattern, with a 110-degree nozzle using a 50cm nozzle spacing (this is 50cm above the top of the stubble or crop canopy). Boom height and stability are critical. Use height control systems for wider booms or reduce the spraying speed to maintain boom height. An increase in boom height from 50 to 70cm above the target can increase drift fourfold.

08 **Avoid high spraying speeds**, particularly when ground cover is minimal. Spraying speeds more than 16 to 18km/h with trailing rigs and more than 20 to 22km/h with self-propelled sprayers greatly increase losses due to effects at the nozzle and the aerodynamics of the machine.

09 **Be prepared** to leave unsprayed buffers when the label requires, or when the wind direction is towards sensitive areas. Always refer to the spray drift restraints on the product label.

10 **Continually monitor** the conditions at the site of application. Where wind direction is a concern move operations to another paddock. Always stop spraying if the weather conditions become unfavourable.
Always record the date, start and finish times, wind direction and speed, temperature and relative humidity, product(s) and rate(s), nozzle details and spray system pressure for every tank load. Plus any additional record keeping requirements according to the label.

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

THE 2017-2020 GRDC SOUTHERN REGIONAL PANEL

JANUARY 2020

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

CHAIR - JOHN BENNETT

Based at Lawloit, between Nhill and Kaniva in Victoria's West Wimmera, John, his wife Allison and family run a mixed farming operation across diverse soil types. The farming system is 70 to 80 percent cropping, with cereals, oilseeds, legumes and hay grown. John believes in the science-based research, new technologies and opportunities that the GRDC delivers to graingrowers. He wants to see RD&E investments promote resilient and sustainable farming systems that deliver more profit to growers and ultimately make agriculture an exciting career path for young people.

M 0429 919 223 **E** john.bennett5@bigpond.com

DEPUTY CHAIR - MIKE MCLAUGHLIN

Mike is a researcher with the University of Adelaide, based at the Waite campus in South Australia. He specialises in soil fertility and crop nutrition, contaminants in fertilisers, wastes, soils and crops. Mike manages the Fertiliser Technology Research Centre at the University of Adelaide and has a wide network of contacts and collaborators nationally and internationally in the fertiliser industry and in soil fertility research.

M 0434 765 574
E michael.mclaughlin@adelaide.edu.au

PETER KUHLMANN

Peter is a farmer at Mudamuckla near Ceduna on South Australia's Western Eyre Peninsula. He uses liquid fertiliser, no-till and variable rate technology to assist in the challenge of dealing with low rainfall and subsoil constraints. Peter has been a board member of and chaired the Eyre Peninsula Agricultural Research Foundation and the South Australian Grain Industry Trust.

M 0428 258 032 **E** mudabie@bigpond.com

JON MIDWOOD

Jon has worked in agriculture for the past three decades, both in the UK and in Australia. In 2004 he moved to Geelong, Victoria, and managed Grainsearch, a grower-funded company evaluating European wheat and barley varieties for the high rainfall zone.
In 2007, his consultancy managed the commercial contract trials for Southern Farming Systems (SFS). In 2010 he became Chief Executive of SFS, which has five branches covering southern Victoria and Tasmania. In 2012, Jon became a member of the GRDC's HRZ Regional Cropping Solutions Network.

M 0400 666 434 **E** jmidwood@sfs.org.au

FIONA MARSHALL

Fiona has been farming with her husband Craig for 21 years at Mulwala in the Southern Riverina. They are broadacre, dryland grain producers and also operate a sheep enterprise. Fiona has a background in applied science and education and is currently serving as a committee member of Riverine Plains Inc, an independent farming systems group. She is passionate about improving the profile and profitability of Australian grain growers.

M 0427 324 123 **E** redbank615@bigpond.com

LOUISE FLOHR

Lou is a farmer based at Lameroo in the Southern Mallee of South Australia. Along with her parents and partner, she runs a mixed farming enterprise including export oaten hay, wheat, barley a variety of legumes and a self-replacing Merino flock. After graduating Lou spent 3 years as a sales agronomist where she gained valuable on-farm experience about the retail industry and then returned to her home town of Lameroo. She started her own consultancy business three years ago and is passionate about upskilling women working on farms.

M 0429 083 927 **E** flohrlouise@gmail.com

RICHARD MURDOCH

Richard along with wife Lee-Anne, son Will and staff, grow wheat, canola, lentils and faba beans on some challenging soil types at Warooka on South Australia's Yorke Peninsula. They also operate a self-replacing Murray Grey cattle herd and Merino sheep flock. Sharing knowledge and strategies with the next generation is important to Richard whose passion for agriculture has extended beyond the farm to include involvement in the Agricultural Bureau of SA, Advisory Board of Agriculture SA, Agribusiness Council of Australia SA, the YP Alkaline Soils Group and grain marketing groups.

M 0419 842 419 **E** tuckokcowie@internode.on.net

MICHAEL CHILVERS

Michael runs a collaborative family farming enterprise at Nile in the Northern Midlands of Tasmania (with property also in northern NSW) having transitioned the business from a dryland grazing enterprise to an intensive mixed farming enterprise. He has a broad range of experience from resource management, strategic planning and risk profiling to human resource management and operational logistics, and has served as a member of the the High Rainfall Zone Regional Cropping Solutions Network for the past seven years.

M 0409 974 556 **E** fchilvers@bigpond.com

KATE WILSON

Kate is a partner in a large grain producing operation in Victoria's Southern Mallee region. Kate and husband Grant are fourth generation farmers producing wheat, canola, lentils, lupins and field peas. Kate has been an agronomic consultant for more than 20 years, servicing clients throughout the Mallee and northern Wimmera. Having witnessed and implemented much change in farming practices over the past two decades, Kate is passionate about RD&E to bring about positive practice change to growers.

M 0427 571 360 **E** kate.wilson@agrivision.net.au

ANDREW RUSSELL

Andrew is a forth generation grain grower and is currently the Managing Director and Shareholder of Lilliput AG and a Director and Shareholder of the affiliated Baker Seed Co - a family owned farming and seed cleaning business. He manages the family farm in the Rutherglen area, a 2,500 ha mixed cropping enterprise and also runs 2000 cross bred ewes. Lilliput AG consists of wheat, canola, lupin, faba bean, triticale and oats and clover for seed, along with hay cropping operations. Andrew has been a member of GRDC's Medium Rainfall Zone Regional Cropping Solutions Network and has a passion for rural communities, sustainable and profitable agriculture and small business resilience.

M 0417 401 004 **E** arussell@lilliput-ag.com.au

DR NICOLE JENSEN

Nicole Jensen is GRDC General Manager for the newly created Genetics and Enabling Technologies business group. Nicole brings a wealth of experience in plant breeding and related activities arising from several roles she has held in Australia and internationally in the seed industry including positions as Supply Innovation Lead with the Climate Corporation - Monsanto's digital agricultural flagship, Global Trait Integration Breeding Lead for Monsanto.

T 02 6166 4500 **E** Nicole.Jensen@grdc.com.au

T +61 8 8198 8407
P Grains Research and Development Corporation (GRDC) | Level 1 | 187 Fullarton Road, Dulwich 5065, South Australia

KEY CONTACTS

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

SOUTHERN REGION

ADELAIDE
Level 1
187 Fullarton Road
DULWICH SA 5065

P: +61 8 8198 8400
southern@grdc.com.au

OPERATIONS GROUP

SENIOR REGIONAL MANAGER
Craig Ruchs
Craig.Ruchs@grdc.com.au
M: +61 4 7771 0813

BUSINESS SUPPORT TEAM LEADER
Amanda Kendall
Amanda.Kendall@grdc.com.au
P: +61 8 8198 8402

CONTRACT AND TEAM ADMINISTRATOR
Claire West
Claire.West@grdc.com.au
P: +61 8 8198 8401

CONTRACT ADMINISTRATOR
Mark Waterhouse
Mark.Waterhouse@grdc.com.au
P: +61 8 8198 8406

APPLIED RESEARCH AND DEVELOPMENT GROUP

MANAGER AGRONOMY, SOILS, NUTRITION AND FARMING SYSTEMS
Stephen Loss
Stephen.Loss@grdc.com.au
M: +61 4 0841 2453

MANAGER AGRONOMY, SOILS, NUTRITION AND FARMING SYSTEMS
Allison Pearson
Allison.Pearson@grdc.com.au
M: +61 4 1887 4748

MANAGER WEEDS (NATIONAL)
Jason Emms
Jason.Emms@grdc.com.au
M: +61 4 3954 9950

CROP PROTECTION MANAGER SOUTH
Ruth Peek
Ruth.Peek@grdc.com.au
M: +61 4 5553 4040

GENETICS AND ENABLING TECHNOLOGIES GROUP

SENIOR MANAGER ENABLING TECHNOLOGIES
Tom Giles
Tom.Giles@grdc.com.au
M: +61 4 1788 9860

SENIOR MANAGER NATIONAL VARIETY TRIALS
Sean Coffey
Sean.Coffey@grdc.com.au
M: +61 4 2865 2226

MANAGER NATIONAL VARIETY TRIALS SOUTH
Rob Wheeler
Rob.Wheeler@grdc.com.au
M: +61 4 0114 8935

MANAGER NATIONAL VARIETY TRIALS SYSTEMS
Neale Sutton
Neale.Sutton@grdc.com.au
M: +61 4 3857 9992

MANAGER RESEARCH PLATFORMS
Trevor Garnett
Trevor.Garnett@grdc.com.au
M: +61 4 5790 6770

NATIONAL VARIETY TRIALS OFFICER
Ben O'Connor
Ben.O'Connor@grdc.com.au
M: +61 4 9988 7749

CONTRACT ADMINISTRATOR
Cindy Hall
Cindy.Hall@grdc.com.au
P: +61 8 8198 8407

GROWER EXTENSION AND COMMUNICATIONS GROUP

GROWER RELATIONS MANAGER
Courtney Ramsey
Courtney.Ramsey@grdc.com.au
M: +61 4 2827 4018

GROWER RELATIONS MANAGER
Randall Wilksch
Randall.Wilksch@grdc.com.au
M: +61 4 3776 9098

GROWER RELATIONS MANAGER
Tom Blake
Tom.Blake@grdc.com.au
M: +61 4 1889 3186

COMMUNICATIONS MANAGER
Sharon Watt
Sharon.Watt@grdc.com.au
M: +61 4 0967 5100

BUSINESS AND COMMERCIAL GROUP

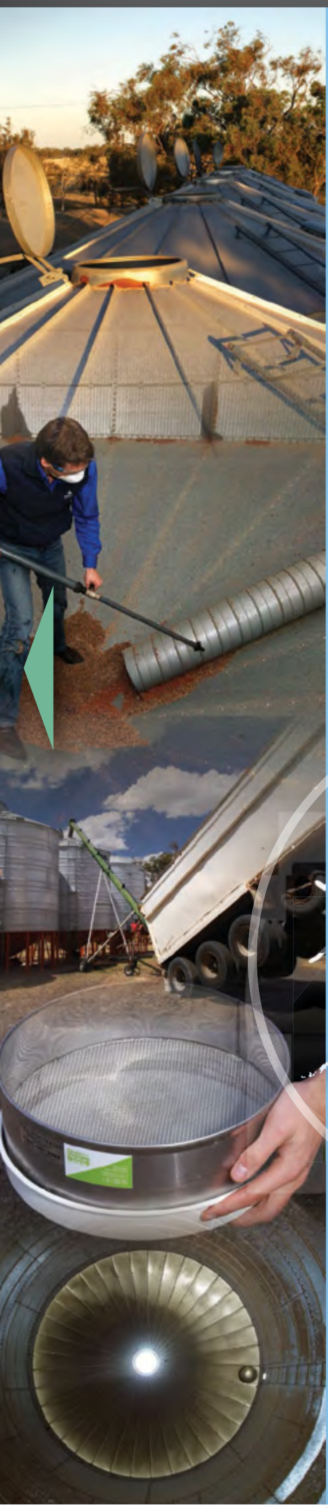
ACTING GM – BUSINESS DEVELOPMENT AND ECONOMICS GROUP
Ron Osmond
Ron.Osmond@grdc.com.au
M: +61 4 000 2640

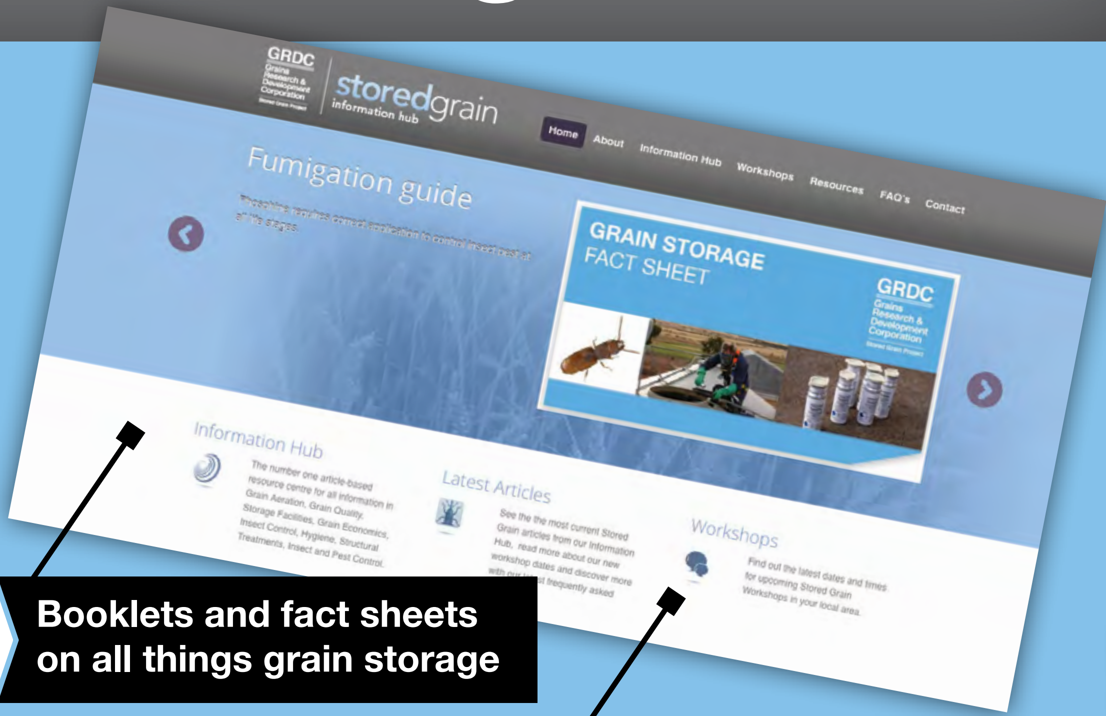
MANAGER COMMERCIALISATION
Fernando Felquer
Fernando.Felquer@grdc.com.au
M: +61 4 1351 1412

GET THE LATEST STORED GRAIN INFORMATION ONLINE

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION
STORED GRAIN PROJECT

storedgrain.com.au





Booklets and fact sheets on all things grain storage

Workshops in all regions covering topics such as:

- Economics of on-farm storage
- Grain storage hygiene
- Aeration cooling or drying
- Managing high moisture
- Fumigation
- Insect pest management
- Managing different storages
- Storage facility design
- Storing pulses and oilseeds

Call the National Grain Storage Information Hotline **1800 WEEVIL** (1800 933 845) to speak to your local grain storage specialist for advice or to arrange a workshop

Download the new storedgrain app to get the latest information and storage recording tool on your iPhone or iPad

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION
STORED GRAIN PROJECT

www.grdc.com.au | www.storedgrain.com.au | 02 6166 4500