# GRAINS RESEARCH UPDATE

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# Corowa

Thursday 20 February

9.00am to 2.00pm

Corowa RSL Club

30 Betterment Parade

**#GRDCUpdates**

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**Corowa GRDC Grains Research Update**
**convened by ORM Pty Ltd.**

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GRDC Grains Research Update
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# Contents

# Dealing with the Dry

**As grain growers across Queensland and New South Wales and parts of Victoria and South Australia continue to be challenged by drought conditions, the GRDC is committed to providing access to practical agronomic advice and support to assist with on-farm decision making during tough times.**

Visit our ‘Dealing with the Dry’ resource page for useful information on agronomy in dry times and tips for planning and being prepared when it does rain.

**www.grdc.com.au/dealingwiththedry**

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# Program

| | | |
|---|---|---|
| 9.00 am | **Announcements** | ***Matt McCarthy,*** *ORM* |
| 9.05 am | **GRDC welcome and update** | ***GRDC representative*** |
| 9:15 am | **Latest strategies in canola disease control** | ***Steve Marcroft,*** *Marcroft Grains Pathology* |
| 9:55 am | **Legacy effects of N nutrition and hay versus grain crop choice** | ***Graeme Sandral,*** *NSW DPI* |
| 10:45 am | ***Morning tea*** | |
| 11.15 am | **Riverine Plains research in progress** | ***Cassandra Schefe,*** *Riverine Plains Inc.* |
| 11:35 am | **Cover crops and their impacts on the farming system – what does the local data suggest** | ***Col McMaster,*** *NSW DPI* |
| 12.15 pm | **Drivers of yield stability in wheat and barley – picking a winner in variable seasons** | ***Felicity Harris,*** *NSW DPI* |
| 12.55 pm | **Hitting production targets in the UK amidst a highly regulated environment** | ***Keith Norman,*** *Keith Norman Consultancy Ltd* |
| 1.35 pm | ***Close and evaluation*** | ***Matt McCarthy,*** *ORM* |
| 1.40 pm | ***Lunch*** | |

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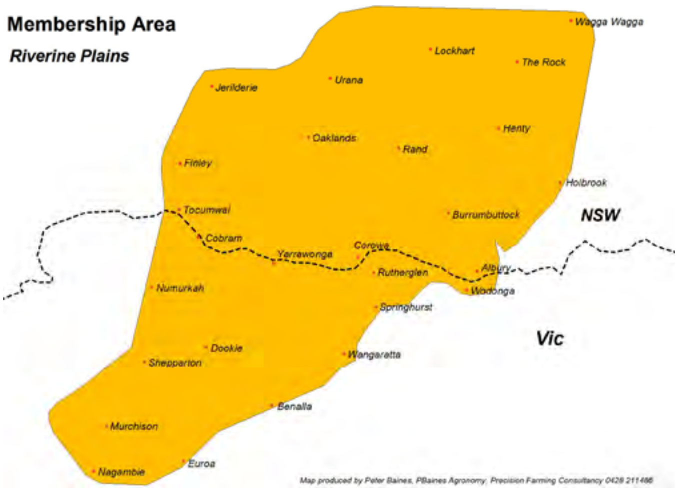
# Riverine Plains Inc

**Riverine Plains Inc is an independent farming systems group dedicated to improving the productivity of broadacre farming systems in northeast Victoria and southern NSW.**

Our membership, and our name, is drawn from the agro-ecological zone known as the Riverine Plain.

Riverine Plains Inc specialises in farmer driven research and extension that delivers on-the-ground benefits to the region's growers. Our focus is on providing independent, timely and relevant information through a rigorous research program and our annual schedule of events and publications.

As an independent organisation operating across state boundaries, Riverine Plains Inc works to enhance the extension of state and regionally based research results to the region's growers. Our ties to industry, research and funding organisations means that we can also design and develop new projects to address regionally specific or cross-border issues.




## Providing quality information

Riverine Plains Inc delivers information and research results across a range of formats to meet the needs of members. We publish a bi-monthly hardcopy newsletter and send out regular email communications, including our grower updates, event invitations and the Grower Bulletin.

Our flagship annual publication "*Research for the Riverine Plains*" delivers the results of research carried out by the group, as well as other research relevant to the Riverine Plains region.

## Sharing ideas

Central to our philosophy of *Farmers inspiring Farmers* is our annual events program, which includes field and machinery days, paddock walks, seminars, discussion groups and study tours. Our events bring together farmers, researchers and industry experts to share ideas, seasonal information, research results, technical experience and business expertise.

## Leading research

The research capacity of Riverine Plains Inc is widely recognised across the Australian grains industry and we partner with a range of leading research and extension organisations to carry out locally-relevant, farming systems projects. This delivers meaningful, local results that address the challenges faced by our members and the wider grains community.

## The John Hanrahan Scholarship

Riverine Plains Inc has established the John Hanrahan Scholarship to recognise and encourage agricultural excellence. The scholarship, awarded annually, aims to support a local second year student through their agriculture or agribusiness bachelor or diploma degree studies, with applications opening mid-year.

## Membership

We have 3 different membership options available; $80/year Farming Membership ($220 for 3 years), $350/year Corporate Membership, or a free Student Membership for tertiary students.

For further information, or to download a membership application form please visit our website [riverineplains.org.au](riverineplains.org.au) or contact the office on 03 5744 1713.

*Farmers inspiring farmers*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Farmers 2Founders

# Supporting producers to commercialise ideas, new products and tech inventions

## Ideas Program 2020

**Key Dates:**

**Applications now open!**

**Closing date extended to 28 February**

**Program kick-off mid-March**

**Apply at:**

https://www.farmers2founders.com/ideas-program

**For more information register to join one of our webinars or virtual 'office hours' at:**

https://www.farmers2founders.com/events

**Contact:** Alexander Leat
admin@farmers2founders.com

The Farmers2Founders Ideas Program is designed for primary producers in the agri-food and fibre industry with an idea for a new business, an agtech or foodtech invention, or who are working on a value-added product.

We have already graduated our first group of 12 producer-led teams from the Ideas Program in 2019 and we are now looking to help the next batch of 12 get started! Over 12 weeks, F2F provides the producer-led teams with funding, coaching, tools and networking. We help them work out if their tech or value-added product idea is worth pursuing to the next stage of commercialisation. To fit in with core farming business commitments, the program is largely delivered remotely, with in person workshops at the kick-off in March and then at the 8-week point.

This program is a great fit for primary producers who:

- Have a business, tech or product idea they want to explore
- Have a team of 1-4 people
- Can commit ~ 5 hours per week over the 12-week period
- Are available to attend the workshops in March and at the 8-week point (travel funding provided)
- Are willing and enthusiastic to embark on a new venture journey

Whether you are a primary producer, a supplier or service provider to producers, or you think you know someone who would be interested in participating in the Ideas Program – we look forward to hearing from you and sharing our passion for supporting Australia's agrifood and fibre industry.

***Farmers2Founders (F2F) is a world-first innovation program tailored to producers that equips them to act as frontline innovators and supports them to develop entrepreneurship & technology capabilities, so they can solve critical industry challenges.***

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# Blackleg – new seed treatment, stubble management and fungicide resistance

***Steve Marcroft[1], Angela van de Wouw[2] and Susie Sprague[3].***

*[1]Marcroft Grains Pathology, Horsham, Vic; [2]School of BioSciences, University of Melbourne, Vic; [3] CSIRO Agriculture & Food, Canberra, ACT.*

**GRDC project codes:** UOM1904-004RTX, UM00051, CSP00187, MGP1905-001SAX

## Keywords

- canola, blackleg, stubble management, fungicide resistance, seed treatment

## Take home messages

- Blackleg crown canker results from infection during early seedling growth. Prior to sowing, use the BlacklegCM decision support tool to identify high risk paddocks and explore management strategies to reduce yield loss.
- New succinate dehydrogenase inhibitor (SDHI) seed treatment fungicides have higher efficacy, increased longevity and improved seed safety.
- The improved efficacy of SDHI fungicide may result in a reduced need for early foliar application of fungicide (4-10 leaf applications).
- Modern farming systems that enable earlier sowing/germination may result in reduced damage from blackleg crown cankers.
- Blackleg pathogen populations with resistance to the triazole fungicides fluquinconazole, flutriafol and a tebuconazole + prothioconazole mixture have been detected. No resistance has been detected for new SDHI and quinine-outside inhibitor (QoI) chemistries.
- Blackleg upper canopy infection (UCI) is the collective term for flower, peduncle, pod, main stem and branch infection, but does not include crown canker.
- UCI can cause yield losses of up to 30%. Yield loss is reduced by selecting cultivars with effective major gene resistance and using crop management strategies to delay the commencement of flowering to later in the growing season, especially in high disease risk areas.
- Fungicide applications at 30% bloom often controls UCI but does not always result in yield gains. Thirty per cent bloom fungicide application is unlikely to control pod infection.

## Blackleg crown canker - seed treatment

### *Do you need a seed treatment?*

Severe crown canker is most likely to develop when plants are infected during the early seedling stage (cotyledon to 4th leaf). The fungus grows from the cotyledons and leaves asymptomatically through the vascular tissues to the crown, where it causes necrosis resulting in a crown canker at the base of the plant. Cankers at harvest are due to infection at the seedling stage. Yield loss results from restricted water and nutrient uptake by the plant.

The driving factor for seedling infection is the length of time that the plant is exposed to blackleg infection while in the seedling stage. Therefore, the risk of seedling infection, which leads to crown cankers, is very variable from season to season. For infection to occur blackleg fruiting bodies on the canola stubble must be ripe and ready to release spores. Fruiting bodies typically become ripe approximately three weeks after the break of the season when the stubble has stayed consistently moist. Spore are then released with each rainfall event. Temperature also has a large influence as it will determine the length of time that the plant remains in the vulnerable seedling stage. Once plants progress to the 4th leaf stage they are significantly less vulnerable. That is, older plants will still get leaf lesions, but the pathogen is less likely to cause damaging crown cankers as the fungus cannot grow fast enough to get into the crown. Typically, plants sown early in the growing season (April) will develop quickly under warmer conditions and progress rapidly past the vulnerable seedling stage whereas, plants sown later (mid-May) will progress slowly and remain in the vulnerable seedling stage for an extended period.

Plants sown early often have reduced crown canker severity due to rapid growth through the vulnerable seedling stage and the seedlings are likely to avoid blackleg spores as fruiting bodies are less likely to be mature and able to release spores early in the growing season. Consequently, modern farming systems that enable early sowing will reduce crown canker susceptibility. However, early sowing will likely result in earlier flowering times, which increases the risk of UCI (see following sections within this paper).

*Seed treatments*

Fungicide seed treatments are extremely effective control against blackleg for crown cankers. As previously mentioned, plants are susceptible at the early seedling stage and this is when seed treatments are most effective. However, seed treatments will not provide complete control so they should be used in conjunction with genetic resistance, for instance moderately susceptible (MS) to moderately resistant (MR) cultivars protected with Jockey® (fluquinconazole) when gown under high blackleg severity conditions are likely to get a yield response from a seed treatment. Cultivars with inadequate resistance, for example; MS-S will get a response but may still have significant damage while cultivars rated very highly for resistance such as MR-R to R will generally not respond to a seed treatment. The BlacklegCM app will predict responses from seed treatments based on the crop parameters that you enter.

*New SDHI seed treatments*

In 2020 new seed treatments from the SDHI fungicide class will be commercially available to growers. These new fungicides will be adopted very quickly and extensively for two reasons; firstly, they do not have the seed safety issues that may be associated with some other seed treatments. Secondly, the SDHI fungicides have a higher efficacy and provide a longer period of protection compared to the demethylation inhibitors (DMI) fungicide. Further research is required, but it is likely that in some situations an early foliar fungicide may no longer be required if cultivars are protected with a SDHI fungicide rather than the current DMI fungicide seed treatment.

A decision support tool, BlacklegCM, is available and should be used to assess the risk for blackleg crown canker prior to cultivar selection and sowing. BlacklegCM is available for iPad or android tablets. BlacklegCM does not work on iPhones. The tool is interactive, allowing growers and advisers to determine the blackleg risk for each paddock and consider the possible economic return of different management strategies. The tool also provides in-season support for the application of foliar fungicides.

*Fungicide resistance*

With the high use of fungicides comes the risk of fungicide resistance developing. In 2018 and 2019, 300+ *Leptosphaeria maculans* populations have been screened for resistance to all commercially available and soon to be released fungicides (Table 1). The 2019 screens showed similar results to 2018 whereby 25% and 20% of populations have a high frequency of isolates resistant to the DMI fungicides, flutriafol and fluquinconazole, while only 7% of populations have a high frequency of resistance to the tebuconazole + prothioconazole mixture. No resistance was detected to any of the SDHI or QoI fungicides. Screening of populations in 2020 will continue, to monitor changes in the frequency of resistance to both the old DMI chemistries and the new SDHI and QoI chemistries.

Although these screens have detected fungicide resistance within Australian populations, it is currently unknown what proportion of the isolates within a population have resistance. Therefore, it remains unclear whether these resistance isolates are impacting on the efficacy of fungicide use or not. Further work is underway to try and determine the impact of these fungicide resistant isolates to on-farm practices.

The development of fungicide resistance in blackleg pathogen populations in Australia highlights the importance of fungicide-use stewardship. Oversees experience informs us that the new SDHI fungicides are more likely than the current DMI fungicides to develop resistance. To reduce the potential risk of fungicide resistance evolving, it is recommended that a maximum of two chemical applications from a single fungicide class be used within a growing season.

## Fungicide resistance screening sample submission

If you would like to screen your blackleg populations for fungicide resistance in 2020, 30 pieces of canola stubble from your 2019 paddock are required. Please email Angela Van de Wouw at angela@grainspathology.com.au for stubbles collection protocol. The fungicide resistance results for the current DMI blackleg fungicides and the new SDHIs will be provided to you. The cost is free to growers/advisers. Costs are covered by an Australian Research Council (ARC)/private industry investment.

## Blackleg spore release has changed with modern farming systems

Prior to inter-row sowing, canola stubble was knocked down each year via various tillage practices. The stubble lying in contact with the soil stayed moist during the growing season and released blackleg spores with each rainfall event. Stubble which was two or three years old produced very few spores that were highly unlikely to add to annual disease severity. Research work undertaken in the mid-1990s led to the recommendations to maintain a 500m buffer between your current canola crop and the previous year's stubble and to not be so concerned with rotation length as was the prior recommendation. However, recent work has shown that stubble that remains standing in modern farming practices stays dry, is not developing sexual fruiting bodies at the same rate as the lying down stubble, and therefore, releases fewer spores and the release is later in the growing season (Figure 1). It is hypothesised that delayed spore release in the growing season may result in increased UCI as the reproductive parts of the plant are directly infected rather than seedlings and leaves.

However, what happened to the standing stubble when it is eventually knocked down in the second year? This is particularly pertinent as it is the second year that is often sown back to a canola crop.

Experiments undertaken in Horsham in 2019 (Table 2) found that stubble which is standing in year 1 and lying in year 2 released fewer spores in the first half of the growing season but increased in proportion of released spores in the second half of the growing season. The data missing from this experiment is the tonnes/ha of stubble that is available to produce blackleg spores. In the 1990s experiments found that few canola stalks survive lying/lying for two years (stalks are either buried or decompose). Therefore, it is now known that standing stubble in year 1 releases few spores but it will release spores in the second year if it is knocked down and becomes lying stubble in year 2. The key driver in this situation is that the stubble has been preserved in the inter-row sowing system and has therefore not been buried or decomposed. The other very intriguing part of this story is that if stubble is maintained standing in the second year it will produce very few spores (Table 2).

**Table 1.** The percentage of populations with high, moderate and low levels of resistance to all currently used and upcoming fungicides.

| Fungicide | Fungicide class | Percentage of populations with high, moderate and low levels of resistance | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2019 results | | | 2018 results | | |
| | | High | Moderate | Low | High | Moderate | Low |
| Flutriafol® | DMI | **25.1** | 22.0 | 52.9 | **28.6** | 31.6 | 39.8 |
| Jockey® | DMI | **20.4** | 24.6 | 55.0 | **22.4** | 22.4 | 45.9 |
| Prosaro® | DMI | **7.3** | 13.1 | 79.6 | **7.1** | 7.1 | 75.5 |
| Saltro® | SDHI | **0** | 0 | 100.0 | **0** | 0 | 100.0 |
| Veritas® | QoI + DMI | **0** | 3.1 | 96.9 | **0** | 1.0 | 99.0 |
| Aviator® | SDHI + DMI | **0** | 0 | 100.0 | **0** | 0 | 100.0 |
| ILeVo® | SDHI | **0** | 0 | 100.0 | **0** | 0 | 100.0 |
| Miravis® | SDHI | **0** | 0 | 100.0 | **0** | 0 | 100.0 |

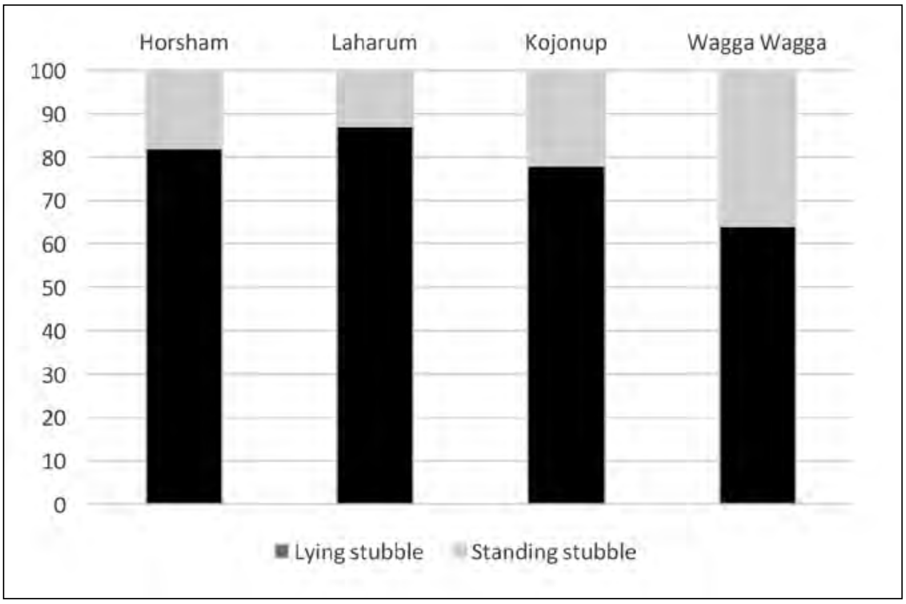


**Figure 1.** Proportion of total spores from specific stubble types and sections produced over a growing season for four sites in 2018.

Further investigation is required to determine what impact standing stubble has on disease pressure, and therefore, yield losses associated with blackleg.

## Blackleg upper canopy infection (UCI)

Blackleg can infect all parts of the canola plant. UCI is a collective term that describes infection of flowers, peduncles, pods, upper main stem and branches (Figure 2). UCI has become increasingly prevalent over recent years and may be associated with earlier flowering crops because of the earlier sowing of cultivars and more rapid phenological development during warmer autumns and winters. There is also evidence of delayed and prolonged release of blackleg spore release in stubble-retained systems and increased intensity of canola production. While crown canker blackleg is well understood, the factors contributing to UCI and possible control strategies are currently under investigation. An outline of findings to date are presented.

**Figure 2.** Upper canopy infection includes blackleg infection of flowers, peduncles, pods, main stems and branches

**Table 2.** Percentage of total blackleg spore released from two year old canola stubble that is either lying or standing.

| Stubble standing or lying | Month | | | | | | | Season spore release |
|---|---|---|---|---|---|---|---|---|
| | May | June | July | August | Sept | Oct | Nov | |
| Lying yr 1 / lying yr 2 | 64 | 70 | 69 | 44 | 40 | 69 | 4 | 58 |
| Standing yr 1 / lying yr 2 | 31 | 29 | 29 | 55 | 42 | 18 | 38 | 36 |
| Standing yr 1 / standing yr 2 | 6 | 2 | 2 | 1 | 17 | 12 | 58 | 6 |

*Blackleg upper canopy infection research results*

In field experiments, UCI has caused up to 30% yield loss. The impact on yield varies depending on the timing of infection and the plant part infected. Flower loss from infection of flowers or peduncles is unlikely to directly reduce yield as the plant can compensate by producing more flowers. However, the fungus can grow into the associated branch which can then affect seed set and grain filling in surrounding pods. Infection of pods or peduncles after pod formation can result in significant yield loss. Infected branches and upper main stems can affect all developing flowers and pods above the point of infection causing a reduction in pod and seed set as well as smaller seed. Severe infection can cause stems and branches to break off, premature ripening leading to shattering or difficulty in ascertaining correct windrow timing due to maturity differences between seed affected or unaffected by blackleg.

*New knowledge from 2019*

Entry of UCI blackleg into the plant is via the stomatal openings and/or physical damage to the plant by insects, hail or frost. Up until 2018 it was thought that the damage UCI caused was the physical lesion or death of the flower. However, it is now evident that UCI infections are also systemic, causing damage to the plant's vascular tissue similar to traditional blackleg crown infections. The issue for growers is that the external symptoms may appear insignificant, but internal vascular damage may cause significant yield losses. Preliminary results indicate that this may be why fungicide applications on crops with few symptoms can still result in economic yield returns. Interestingly, researchers have noted that symptoms of internal vascular damage result in blackened stems post the windrowing growth stage; post 100% seed colour change (Figure 3).

**Figure 3.** Blackened branches caused by internal vascular damage; symptoms become visible post 100% seed colour change. These symptoms may not occur in crops that received the Sclerotinia 30% bloom fungicide application.

During 2019 two experiments were managed to develop new techniques for artificially inoculating plants to enable specific experiments to be undertaken. A laboratory/controlled environment glasshouse experiment (Table 3) showed that on average the external lesions from the artificial inoculation were 38mm long but when the plants were individually cut open the blackleg pith inside was 134mm. Polymerase chain reaction (PCR) and microscopy are currently being done to determine if symptomless infection has also occurred. This data shows clearly that blackleg is invading the vascular tissue of the plant, and therefore, a small external lesion may reduce moisture and nutrient supply to the entire branch because of vascular tissue damage.

The other meaningful finding from 2019 is that the plant development stage at infection must also be considered with the seasonal timing of infection. For instance, June inoculation at 30% bloom appears to cause more damage than identical inoculation in August or September. The data from 2019 suggests that the fungus requires sufficient time to colonise the vascular tissue and then cause yield reducing damage. Early sown/flowering plants mature slower under cooler conditions compared to later sown/flowering plants that mature quickly under warmer spring conditions. This is a major finding and is likely to provide knowledge on why yield responses to

**Table 3.** Artificial infection of canola plants for upper canopy blackleg, effect of internal infection and timing of infection.

| Experiment location | Time of sowing | Inoculated at 30% bloom | External lesion length (mm) Average | Internal pith colonisation (mm) Average |
|---|---|---|---|---|
| Glasshouse lab inoculation | 21-Mar | 10-Jun | 38 | 134 |
| Glasshouse lab inoculation | 3-Jun | 21-Aug | 12 | 5 |
| Spore shower from stubble | 21-Mar | 29-Jun | 183 | NA |
| Spore shower from stubble | 24-May | 6-Sep | 43 | NA |

**Table 4.** Regional effectiveness of major gene resistance across 34 monitoring sites across Australia. Cultivars representing each of the resistance groups were sown adjacent to 34 canola trials across Australia and monitored for levels of blackleg. These data indicate which resistance groups have high levels of disease compared to the other groups at a particular site.

**Key:**

| |
|---|
| Low (L) blackleg severity compared to other groups at that site suggesting major gene resistance still effective - Continue with current management strategy. |
| Moderate (M) blackleg severity compared to other groups at that site – monitor crops for disease, see the Blackleg Management Guide for management options. |
| High (H) blackleg severity compared to other groups at that site – suggests major gene is ineffective and therefore disease control relies on quantitative resistance. If growing cultivars from this resistance group, select cultivar with appropriate blackleg rating for your region and consider a fungicide control for upper canopy infection if seasonal conditions are conducive – see the Blackleg Management Guide for management options. |
| No data (blank) |

| Site | Resistance Group | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Victoria | A | B | C | ABD | ABDF | BF | BC | H |
| Charlton | H | M | H | L | L | H | M | |
| Diggora | H | M | H | L | L | M | M | L |
| Hamilton | H | H | H | M | L | H | H | L |
| Kaniva | H | H | M | L | L | H | M | L |
| Lake Bolac | H | H | H | M | M | H | H | L |
| Minyip | H | H | H | L | L | H | M | |
| Wunghnu | H | H | H | L | L | H | M | L |
| Yarrawonga | H | M | H | L | L | H | M | |
| Site | Resistance Group | | | | | | | |
| SA | A | B | C | ABD | ABDF | BF | BC | H |
| Arthurton | H | H | M | L | L | H | M | |
| Bordertown | H | H | H | L | L | H | M | L |
| Cummins | H | M | H | M | L | H | M | L |
| Riverton | M | M | H | L | L | H | M | |
| Roseworthy | H | M | H | L | L | M | M | |
| Spalding | H | M | H | L | L | M | M | |
| Wangary | H | H | H | H | M | H | H | |
| Yeelanna | H | H | H | M | M | H | M | M |
| Site | Resistance Group | | | | | | | |
| NSW | A | B | C | ABD | ABDF | BF | BC | H |
| Beckom | Insufficient data due to drought | | | | | | | |
| Condobolin | Insufficient data due to drought | | | | | | | |
| Cootamundra | H | H | H | L | L | M | M | L |
| Cudal | H | H | H | L | L | H | M | L |
| Gerogery | H | H | H | L | L | H | M | |
| Grenfell | Insufficient data due to drought | | | | | | | |
| Lockhart | Insufficient data due to drought | | | | | | | |
| Parkes | Insufficient data due to drought | | | | | | | |
| Wagga Wagga | H | H | H | L | L | H | M | L |
| Wellington | Insufficient data due to drought | | | | | | | |
| Site | Resistance Group | | | | | | | |
| WA | A | B | C | ABD | ABDF | BF | BC | H |
| Bolgart | H | H | H | L | L | H | M | |
| Gibson | H | H | H | L | L | L | M | L |
| Katanning | H | H | M | L | L | M | M | L |
| Kendenup | No data | | | | | | | |
| Kojonup | H | H | H | L | L | L | M | L |
| Stirlings South | H | H | H | L | L | M | M | L |
| Williams | H | H | H | L | L | H | H | L |
| Yealering | H | M | H | L | L | M | M | |

fungicides can vary so much across regions. If a plant is infected earlier in the growing season the vascular damage will be greater than an identical plant infected at the same growth stage but infected later in the season.

The above new knowledge appears to correlate with 2019 field results in Victoria; wet conditions in late August triggered severe leaf and flower infections. In some cases, these infections resulted in yield responses from fungicide applications whereas, in other situations the same blackleg severity in late August did not result in yield gains from fungicide. It may have been that the blackleg had not caused enough damage to the vascular tissue by windrowing.

*Blackleg upper canopy infection control strategies*

*Genetic resistance*

Effective major gene resistance prevents infection of all canola plant parts (cotyledons, leaves, stems, branches, flowers, pods). Effective major genes can thereby prevent both crown canker and blackleg UCIs. Unfortunately, most major genes present in current cultivars have been overcome by the blackleg pathogen across many canola producing regions. It is therefore crucial to know if major genes are effective or have been overcome in your growing region. A network of 34 blackleg monitoring sites are established across Australia each year, sown with cultivars representing each resistance group. These sites are used to provide regional information on the effectiveness of resistance genes (Table 4). The Blackleg Management Guide (www.grdc.com.au/resources-and-publications/all-publications/publications/2019/blackleg-management-guide) provides information that is relevant for control of blackleg crown canker.

*Commencement of flowering*

There is a strong relationship between the earlier onset of flowering and yield loss caused by UCI.

Plants commencing flowering early in the growing season are more likely to be infected as they will flower under cooler and wetter conditions which are conducive for lesion development. However, it is now also known that plants infected earlier in the growing season have more time for the fungus to damage the vascular tissue prior to plant maturity and harvest.

Canola plants are particularly susceptible to stress during the early stages of flowering (Kirkegaard et al. 2018). Evidence from controlled environment and field experiments indicates that plants infected by blackleg on the upper main stems and branches during the early flowering period results in the greatest reduction of grain yield compared to crops that flower later or are infected at later growth stages. Yield loss can be due to a reduction in seed size, seeds/pod and/or pods per m2. Oil content can also be reduced. By delaying the commencement of canola flowering, growers may be able to avoid severe UCI infections.

*Fungicides*

If UCI occurs, it has been shown that fungicides that are used to control Sclerotinia will also reduce UCI severity and yield losses. Application of Prosaro®/Aviator® Xpro for Sclerotinia control around 30% bloom can also provide protection from blackleg infection during early flowering. The 30% bloom spray may control flower, peduncle, stem and branch infections but is unlikely to provide pod protection. There are currently no control strategies for pod infection. High levels of pod infection tend to occur in seasons with frequent late rainfall events (such as 2016) or where there is physical damage to the pods from hail (such as 2018). In 2019, fungicide applications gave excellent control of UCI but did not control pod lesions. Although UCI was controlled it did not always result in yield returns from fungicides.

## Acknowledgements

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

## Useful resources and references

BlacklegCM App for iPad and android tablets

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www.nvt.com.au

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Notes

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# Variable legacy effects of crop sequences

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**GRDC project code:** CFF00011

## Keywords

- farming systems, grain, hay, soil water.

## Take home messages

- Crop legacy effects outlined in this paper relate to two consecutive dry seasons (2018 and 2019).
- Earnings before interest and tax (EBIT) in 2019 was highly correlated with the conversion efficiency of water to product (kg/ha/mm) and this was affected by crop species, sowing time and nitrogen management over both the 2018 and 2019 growing seasons.
- Barley (grain only) following canola (Greenethorpe) or wheat (Wagga Wagga) had an excellent water use conversion efficiency and was more profitable when harvested for grain compared with hay production.
- Higher EBITs were often achieved with wheaten hay compared with wheat grain, especially with early sown crops.
- Negative EBIT for wheat grain production could be avoided by opting for hay production, however this was not always true for canola.
- The 2019 EBIT for wheat or canola hay production was often lowest where early sown canola or wheat was grown in 2018 and low nitrogen management was applied.

## Background

Financial returns from a single crop ignore the potential impacts of longer-term financial performance of the crop sequence. Crop legacy effects include differences in nitrogen (N), water and disease carryover as well as weed management considerations. These effects are often impacted by crop choice, sowing time and in-season N management. Under drought conditions such as those in 2018 and 2019, most sequence effects will be driven by water availability. The profit of the current AND consecutive seasons can be influenced by crop choice, input costs, N management and management decisions to graze crops, cut hay or harvest grain.

In recent times optimising early sowing opportunities for establishing wheat and canola with potential increased rooting depths highlight how access to deep stored soil water can provide additional value that cannot be captured by other crop species or later sowing times. However, if previous crop history has dried the profile significantly then establishing early sown crops strategically after pulse crops may be one way to increase the probability of improved soil water status through the soil profile and facilitate deeper soil water replenishment.

In the 2018 and 2019 seasons, grain crop production was limited by drought conditions with many growers choosing to graze crops or cut crops for hay rather than harvesting for grain. The impact of hay cutting options on soil water are not always predictable. For example, early crop termination of canola will stop transpiration earlier in the growing season compared with canola left for grain production, provided complete and timely control of the canola regrowth is achieved. Conversely wheaten hay options often substantially decreased the residue cover to a greater extent than hay strategies applied to canola which may influence soil water storage. This may lead to different fallow efficiency and growing season transpiration efficiency, both of which have large impacts on subsequent crops. Based on this reasoning, one could speculate that there may be greater negative legacy effects on soil water from cutting wheaten hay (large residue loss) compared to canola hay (lower residue loss).

This paper considers the profitability of different options in the 2018 and 2019 seasons, and also the 2018 crop legacy effects that influenced the 2019 outcomes. The focus, in particular is on comparisons of crop choice and management impacts on grain or hay production as well as how these choices may impact on financial returns.

## Experiment outline

Four contrasting locations were selected in 2017 that represented a range of soil types, environmental factors and encompassed a diverse range of grower and consultant groups. The main core experiment site is located at the Wagga Wagga Agricultural Institute with three regional node sites located at Condobolin Research and Advisory Station, Greenethorpe and Urana. There are six treatment sequences that are common to all sites with the Wagga Wagga site encompassing all treatments. The crop sequence treatments applied are provided in Table 1. All sites were sown to wheat in 2017 with the treatment sequences starting in 2018. Data from the Wagga Wagga, Greenethorpe and Urana sites are presented in this paper.

### *Methods used for determining hay production*

Hay dry matter (t/ha) = total crop dry matter greater 15cm high x 0.7 (account for losses)

## Results and discussion

### *Wagga Wagga farming systems site in 2019*

The Wagga Wagga farming systems site received approximately 185mm of rainfall from April to October and an estimated summer fallow conservation of 20mm. Annual average rainfall from April to October at this site is 350mm and expected average summer fallow conservation is 42mm. Growing season soil evaporation is typically in the range of 70mm to 115mm. The crop sequence treatments applied are provided in Table 1.

**Table 1.** Farming system sites with sowing, nitrogen and winter grazing strategies applied to different crop sequences.

| Crop sequences | Urana | | Wagga Wagga | | Greenethorpe | |
|---|---|---|---|---|---|---|
| | Sowing | Nitrogen | Sowing + grazing | Nitrogen | Sowing + grazing | Nitrogen |
| Canola-Wheat | E, T | Low, High | E+G, T | Low, High | E+G, T | Low, High |
| Canola-Wheat-Barley | T | Low | T | Low, High | | |
| Canola-Wheat-Wheat | | | | | T, L | High |
| Lentil-Canola-Wheat | E | Low, High | E, T | Low, High | E | Low, High |
| Lupin-Canola-Wheat | | | T | Low | | |
| Faba bean-Canola-Wheat | T | Low | | | T | Low |
| Chickpea-Wheat | | | T | Low | T | Low |
| Biserrula-Wheat | | | T+G | High | | |
| *Legume-Canola-Wheat | T | Low | E+G, T | Low, High | E+G, T | Low |
| Faba bean/Canola-Wheat | | | T | Low | T | Low |
| Wheat-Wheat-Wheat | | | T | Low, High | T | Low |
| Fallow-Canola-Wheat | E | High | E, T | High | | |
| Canola-Wheat (12 t/ha) | | | T | Low | | |
| Canola-Wheat (6 t/ha) | | | T | Low | | |
| Flexible one | Flexible | Flexible | Flexible | Flexible | Flexible | Flexible |
| Flexible two | Flexible | Flexible | | | Flexible | Flexible |

*E = Sown early over late March to mid-April period, E+G = As above plus winter grazing, T = Sown timely over late April to mid-May period, Low = Low nitrogen budgeting based on decile 2 to 4 rainfall projections, High = High nitrogen budgeting based on decile 6 to 8 rainfall projections, *Legume = Vetch, balansa clover and arrowleaf clover, Flexibly = the local consultants' choice (James Madden and John Stephenson (Urana), Greg Condon (Wagga Wagga) and Tim Condon and Peter Watt (Greenthorpe), Chris Baker (Condobolin)).*

*Crop choice*

The 2019 EBIT performance for grain production tended to be highest for barley and lowest for canola with wheat intermediate. Similar comparison for hay production was obtained; barley equal to wheat and both of these crop choices often performed better than canola (Table 2).

*Sowing time*

Un-grazed early sown crops of wheat or canola in 2019 with the same 2018 sowing time and cropping history (for example; wheat/canola or canola/wheat) produced lower grain yields in 2019 than timely sowing of these species. Hay production for these treatments reduced differences between sowing times (early verses timely) as measured by financial outcomes (Table 2).

*Nitrogen*

Nitrogen added to timely sown wheat where the crop sequence was canola/wheat increased wheat **hay yield** and EBIT, while N added to this sequence decreased wheat **grain yield** and EBIT. Nitrogen added to 2019 timely sown canola in a wheat/canola rotation increased both hay and grain yields and EBIT (Table 2).

At the Wagga Wagga site, the 2018 crop choice and N management affected the hay production of the 2019 early sown canola (Hyola®970CL). Hay production was highest following lentils, and lowest following wheat (a difference of approximately 1.5t/ha) while the canola hay after the vetch-trifolium hay was intermediate. (Figure 1). The difference of approximately 1.5t/ha in hay production equated to a difference in EBIT of $169/ha. In this example the 2018 crop choice had a larger effect on hay production than N management. These results suggest multi-year returns need to be considered when making crop sequence decisions.

*2019 profits*

Earnings before interest and tax are provided for the Wagga Wagga farming systems site (Table 2 and Figure 2). The cluster (Figure 2) that provided the best positive earnings for grain and hay production included Planet(D) barley (closed circle), some treatments of timely (early May) sown Beckom(D) wheat with high N (open square) and all treatments of low N (open triangle) as well as some treatments of timely (late April) sown canola (var. Pioneer®43Y92 CL) with high (open diamond) and low N (open circle), (Figure 2).

The best financial results for 2019 timely canola occurred after the 2018 forage mix (vetch + Trifoliums) or lentil (var. Hallmark(D)) while best financial results for timely wheat where achieved after chickpea (var. Slasher(D)) or biserrula (var. Casbah). The poorest results for hay and grain production were obtained by early sown canola (var. Hyola®970, cross and dash symbols) which was grazed in winter. These treatments failed to respond to the rainfall and losses were greatest where the preceding crop (2018 crop) was early sown wheat (var. Kittyhawk(D)).

**Table 2.** A subset of the Wagga Wagga farming systems cropping only treatments for production (grain or hay, t/ha), income ($/ha), costs ($/ha) and earnings before interest and tax (EBIT, $/ha).

| Treatment | Sow | Nit | Crop 2018 | Crop 2019 | Hay cut (t/ha) | GROSS INCOME ($/ha) | TOTAL COSTS ($/ha) | Hay EBIT ($/ha) | Grain Yield (t/ha) | GROSS INCOME ($/ha) | TOTAL COSTS ($/ha) | Grain EBIT ($/ha) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wheat/vetch/canola | T | 2 | Beckom | Vetch | 2.9 | $920 | $445 | $475 | - | - | - | - |
| Wheat/barley/canola | T | 2 | Beckom | Planet | 4.6 | $1,072 | $613 | $459 | 3.2 | $1,150 | $540 | $610 |
| Biserrula/wheat | T | 7 | Cashbah | Beckom | 5.0 | $1,248 | $720 | $528 | 2.8 | $1,146 | $608 | $538 |
| Canola/wheat | T | 7 | 43Y92 CL | Beckom | 5.1 | $1,276 | $729 | $547 | 1.1 | $436 | $589 | -$153 |
| Canola/wheat | T | 2 | 43Y92 CL | Beckom | 4.2 | $1,059 | $625 | $434 | 1.8 | $747 | $522 | $225 |
| Chickpea/wheat | T | 2 | Slasher | Beckom | 5.2 | $1,302 | $692 | $610 | 2.7 | $1,096 | $563 | $533 |
| Canola/wheat | E | 7 | Hyola 070 | Kittyhawk | 4.7 | $1,168 | $692 | $476 | 0.1 | $45 | $576 | -$531 |
| Canola/wheat | E | 2 | Hyola 071 | Kittyhawk | 3.3 | $817 | $562 | $255 | 1.0 | $414 | $495 | -$81 |
| Canola/wheat | T | 7 | Beckom | 43Y92 CL | 4.2 | $1,048 | $723 | $325 | 1.4 | $848 | $613 | $235 |
| Canola/wheat | T | 2 | Beckom | 43Y92 CL | 3.2 | $791 | $609 | $182 | 1.1 | $682 | $540 | $142 |
| Canola/wheat | E | 7 | Kittyhawk | Hyola 970 | 2.0 | $656 | $598 | $58 | - | - | - | - |
| Canola/wheat | E | 2 | Kittyhawk | Hyola 970 | 1.7 | $494 | $550 | -$56 | - | - | - | - |
| Canola/wheat/lentil | T | 7 | Hallmark | 43Y92 CL | 4.7 | $1,175 | $757 | $418 | 1.5 | $887 | $625 | $262 |
| Canola/wheat/lentil | T | 2 | Hallmark | 43Y92 CL | 4.4 | $1,089 | $702 | $387 | 1.7 | $1,002 | $589 | $413 |
| Canola/wheat/lentil | E | 7 | Hallmark | Hyola 970 | 3.4 | $846 | $691 | $155 | - | - | - | - |
| Canola/wheat/lentil | E | 2 | Hallmark | Hyola 970 | 3.1 | $770 | $647 | $123 | - | - | - | - |

*E = Sown early over early April period, T = Sown timely over late April to mid-May period, Nit 2 = Low nitrogen budgeting based on decile 2 rainfall projections July to October, Nit 7 = High nitrogen budgeting based on decile 7 rainfall projections July to October.*

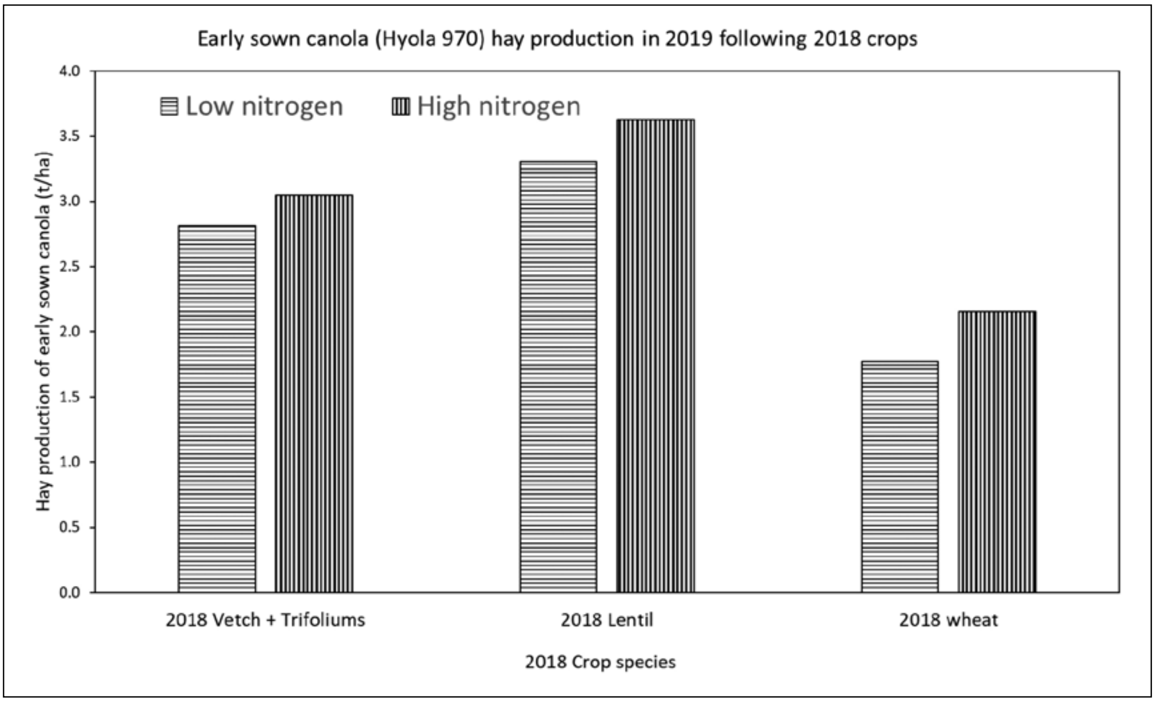


**Figure 1.** Early sown canola (var. Hyola®970) cut for hay in 2019 that was previously cropped in 2018 with either a vetch plus Trifolium mix cut for hay, lentils (var. Hallmark⁽ᵈ⁾) or wheat (var. Kittyhawk⁽ᵈ⁾) harvested for grain. Low nitrogen assumed July to October rainfall was decile 2 and high nitrogen management assumed July to October rainfall was decile 7.

Grain production for lentil (0.72t/ha), chickpea (0.54t/ha) and lupin (var. Batman (1.3t/ha)) in 2019 indicated that lupin was the most profitable under the conditions experienced (Figure 2). The same comparison for hay production indicates chickpea were the more profitable legume crop. In each case these grain legume crops were sown with Beckom⁽ᵈ⁾ wheat in 2018.

There was a tendency for high N fed crops of timely sown wheat (open square) and canola (open diamond) that had previously been cropped to canola and wheat to have better hay returns than

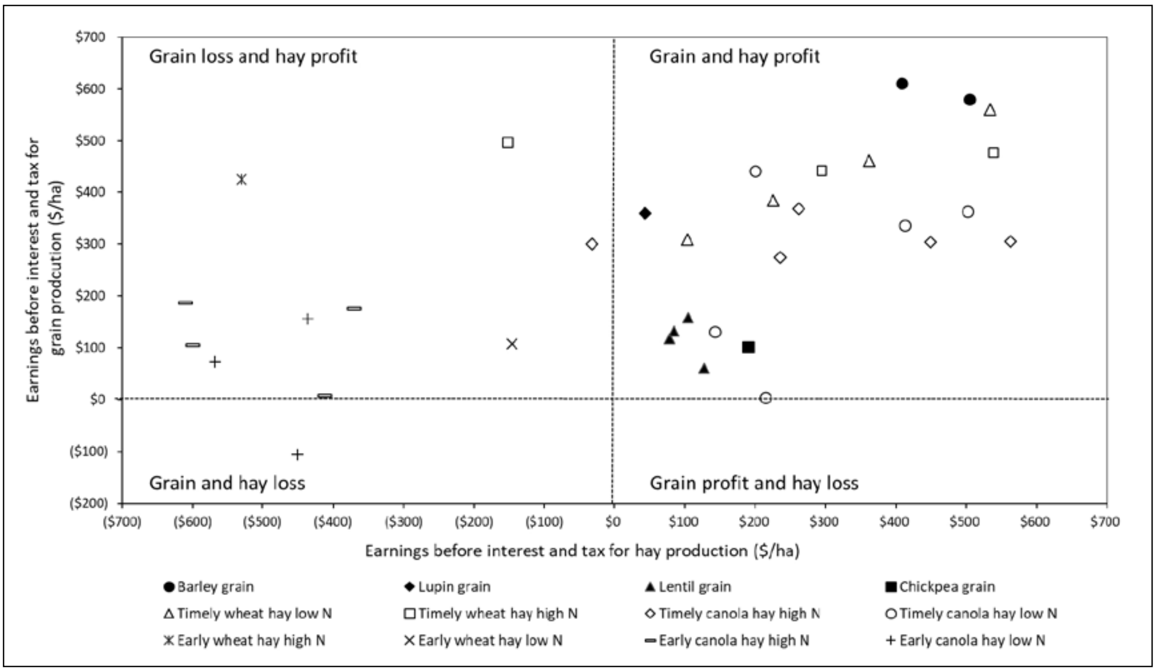


**Figure 2.** 2019 EBIT for grain or hay production for various crops and management practices at the Wagga Wagga farming systems site.

grain returns (Figure 2). However, the opposite was true if the timely sown wheat followed biserrula or the canola followed the forage legume mix (vetch + Trifoliums). This indicates the 2018 crop influenced the preferred financial choice for either grain or hay production in 2019 (2018 crop history not shown in Figure 2).

There was a strong positive correlation between EBIT and the amount of product produced per mm of water received. This emphasises the importance of crop legacy effects, summer fallow efficiency, and minimising in-crop evaporation. The best water use efficiency (WUE) of grain production in 2019 was achieved by barley (2019) following wheat (2018) while the best WUE for hay production was achieved by timely high N canola after vetch (open diamond) and timely wheat with high (open square) and low N (open triangle) after biserrula and chickpea, respectively (Figure 3).

*Greenethorpe farming systems site*

All treatments implemented at the Greenethorpe farming systems site are outlined in Table 1. In 2019, the Greenethorpe site received 98mm between the 23 and 31 March and 128mm of rainfall from April to October with the average estimated summer fallow water conservation of approximately 40mm (157mm December 2018 to February 2019). Early wheat and canola crops were sown between 23 and 27 March 2019, Planet(b) barley sown on the 24 April with all other timely crops sown between 1 and 14 May 2019. The production, income, costs and EBIT for a subset of the treatments that relate to a cropping only enterprise is provided in Table 3. In the cropping ONLY treatments, the top three most profitable sequences included barley harvested for grain following timely canola (4.7t/ha), legume hay following timely wheat (3.7t/ha hay dry matter (DM)) and timely wheat hay/low N following timely triazine tolerant canola (canolaTT) (5.1t/ha hay DM) (Table 3).

The highest hay yields and EBITs were produced from timely wheat following timely canola (average 5t/ha hay with $562/ha EBIT), compared to early wheat following early canola producing 3.5t/ha hay DM with $297/ha EBIT. The timely wheat grain yield ranged between 2.3t/ha and 2.8t/ha (EBITs $262/ha to $496/ha, respectively), with higher grain yields in any second year of timely wheat (2.8t/ha compared with less than 2.6t/ha) due to increased soil moisture concentration with higher surface stubble load.

The faba bean and chickpea pulse crops following timely wheat produced higher EBITs than timely canola ($406/ha and $277/ha compared with less than $34/ha). The timely canola averaged 3t/ha hay DM or 0.8t/ha to 1.1t/ha grain indicating in this dry season, canola hay was more profitable than canola grain. All early sown crops had insufficient moisture to produce a grain yield, so they were either cut for hay or grazed, with the early canola following lentils only producing approximately 2.4t/ha hay DM (and a negative EBIT) (Table 3). These results indicate that under two years of dry conditions early sown crops

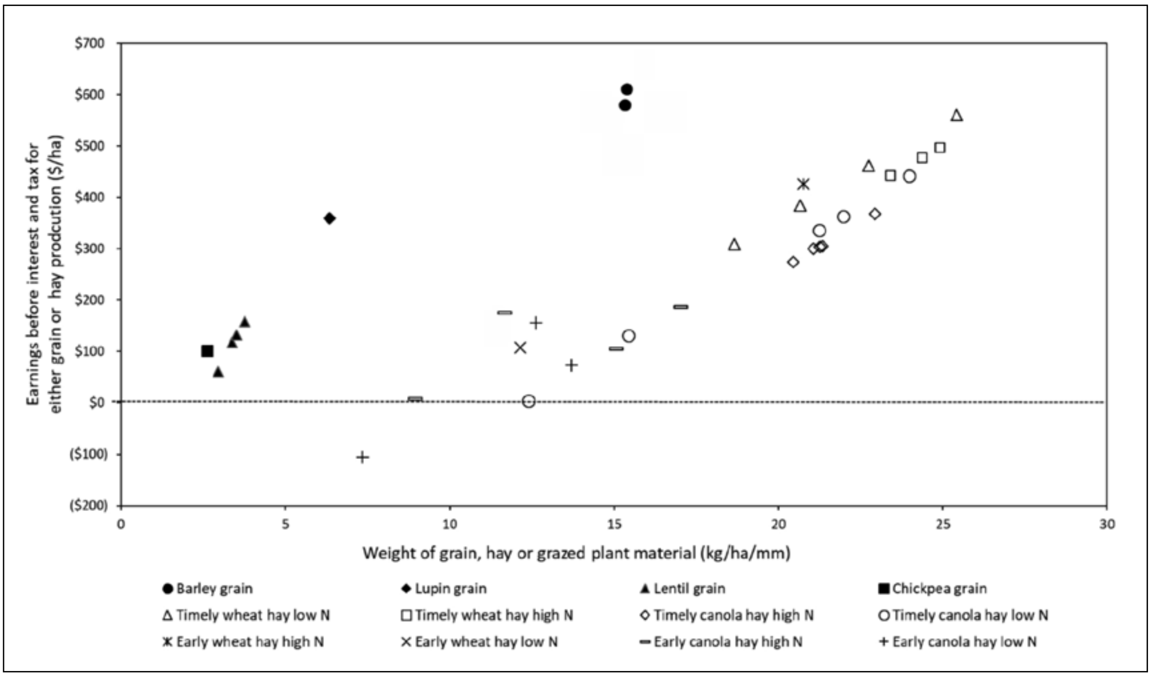


**Figure 3.** 2019 EBIT, for grain or hay production for various crops and management practises at the Wagga Wagga farming systems site.

**Table 3.** A subset of the Greenethorpe farming systems cropping only treatments for production (grain or hay, t/ha), income ($/ha), costs ($/ha) and earnings before interest and tax (EBIT, $/ha).

| Treatment 2019 | Crop 2018 | Crop 2019 | Sow | Nit | Var 2019 | Income Method | Hay DM (t/ha) | Grain Yield (t/ha) | GROSS INCOME ($/ha) | TOTAL COSTS ($/ha) | EBIT ($/ha) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Flexible 1 | Canola TT | Barley | F | F | Planet | Grain | | 4.7 | $1,398 | $470 | $928 |
| Legume (Hay)/Timely/NG | Wheat | Legume Hay | T | 2 | | Hay | 3.7 | | $1,280 | $527 | $754 |
| Wheat/Timely/N7 (C-W) HAY | Canola TT | Wheat | T | 7 | Coolah | Hay | 5.1 | | $1,270 | $683 | $587 |
| Wheat/Timely/N2 (C-W) HAY | Canola TT | Wheat | T | 2 | Coolah | Hay | 4.8 | | $1,212 | $674 | $538 |
| Wheatyr2/Timely/N2 (W-W-W) Grain | Wheat | Wheat | T | 2 | Coolah | Grain | | 2.8 | $1,031 | $535 | $496 |
| Wheatyr2/Timely/N2 (C-W-W) Grain | Wheat | Wheat yr 2 | T | 2 | Coolah | Grain | | 2.8 | $1,018 | $534 | $484 |
| Wheat/Timely/N2 (ChP-W) | Chickpea | Wheat | T | 2 | Coolah | Grain | | 2.6 | $939 | $527 | $411 |
| Fababean | Wheat | Fababean | T | 2 | Samira | Grain | | 2.3 | $1,404 | $999 | $406 |
| Wheat/Timely/N2 (C-W) Grain | Canola TT | Wheat | T | 2 | Coolah | Grain | | 2.4 | $860 | $523 | $337 |
| Wheat/Early/N7 (Len-C-W) HAY | Canola- Hyola 970 | Wheat | E | 7 | Bennett | Hay | 3.6 | | $889 | $571 | $318 |
| Chickpea | Wheat | Chickpeas | T | 2 | Slasher | Grain | | 1.2 | $996 | $719 | $278 |
| Wheat/Early/N2 (Len-C-W) HAY | Canola- Hyola 970 | Wheat | E | 2 | Bennett | Hay | 3.4 | | $840 | $563 | $277 |
| Wheat/Timely/N7 (C-W) Grain | Canola TT | Wheat | T | 7 | Coolah | Grain | | 2.1 | $781 | $519 | $262 |
| Canola/Timely/N2 (C-W) HAY | Wheat | Canola | T | 2 | HyTecTrophy | Hay | 3.1 | | $782 | $687 | $96 |
| Canola/Timely/N2 (C-W) Grain | Wheat | Canola | T | 2 | HyTecTrophy | Grain | | 1.2 | $682 | $648 | $34 |
| Canola/Timely/N7 (C-W) HAY | Wheat | Canola | T | 7 | HyTecTrophy | Hay | 2.9 | | $729 | $705 | $24 |
| Lentil/N7 | Wheat | Lentils | T | 7 | HallMarkXT | Grain | | 0.9 | $524 | $554 | -$30 |
| Canola/Early/N7 (Len-C-W) HAY | Lentil | Canola | E | 7 | Hyola 970 | Hay | 2.5 | | $614 | $657 | -$43 |
| Canola/Early/N2 (Len-C-W) HAY | Lentil | Canola | E | 2 | Hyola 970 | Hay | 2.3 | | $564 | $622 | -$58 |
| Canola/Timely/N7 (C-W) Grain | Wheat | Canola | T | 7 | HyTecTrophy | Grain | | 1.0 | $594 | $671 | -$77 |
| Canola/Timely/N2 (Leg-C-W) Grain | Legume Hay | Canola | T | 2 | HyTecTrophy | Grain | | 0.8 | $458 | $638 | -$180 |

*E = Sown early over late March to mid-April period, T = Sown timely over late April to mid-May period, Nit 2 = Low nitrogen budgeting based on decile 2 rainfall projections July to October, Nit 7 = High nitrogen budgeting based on decile 7 rainfall projections July to October, F = Flexibly = the local consultants' choice, Tim Condon and Peter Watt.*

are impacted the greatest, with timely canola being impacted more than timely wheat and timely wheat impacted more than timely barley.

At the Greenethorpe site the amount of product produced per mm of water was positively correlated with EBIT (Figure 4) and negatively correlated with cost of production (data not shown). High conversion efficiencies provided 20kg to 30kg of product per mm of water and low conversion efficiencies produced approximately 5kg of product per mm of water. Coolah⁽ᴰ wheat cut for hay and Planet⁽ᴰ barley harvested for grain produced the highest product weights per mm of water. HyTTec®Trophy canola and Hallmark⁽ᴰ lentils for grain production produced the

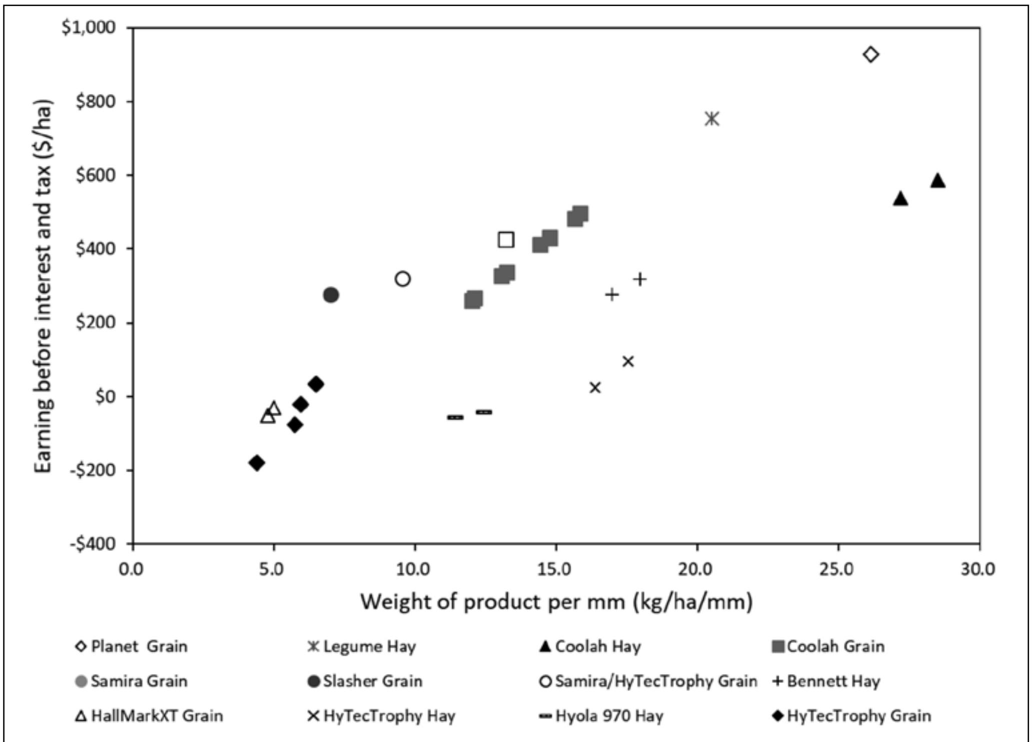


**Figure 4.** EBIT ($/ha) for grain, grazing and/or hay production of various crops and management practises and weight of product produced per mm of water (kg/ha/mm) for the Greenethorpe farming systems site.

**Table 4.** A subset of the Urana farming systems cropping only treatments for production (grain or hay, t/ha), income ($/ha), costs ($/ha) and earnings before interest and tax (EBIT, $/ha).

| Treatment | Sow | Nit | Crop 2018 | Crop 2019 | Hay cut (t/ha) | Grain Yield (t/ha) | GROSS INCOME ($/ha) | TOTAL COSTS ($/ha) | EBIT ($/ha) |
|---|---|---|---|---|---|---|---|---|---|
| Wheat/vetch/canola | T | 2 | Beckom | Vetch | 0.8 | - | $228 | $440 | -$212 |
| Wheat/barley/canola | T | 2 | Beckom | Planet | 1.1 | - | $259 | $480 | -$221 |
| Canola/wheat | T | 7 | 43Y92 CL | Beckom | - | 3.1 | $1,340 | $473 | $867 |
| Canola/wheat | T | 2 | 43Y92 CL | Beckom | - | 2.8 | $1,193 | $444 | $749 |
| Canola/wheat | E | 7 | Hyola 070 | Kittyhawk | - | 1.9 | $911 | $484 | $427 |
| Canola/wheat | E | 2 | Hyola 071 | Kittyhawk | - | 1.6 | $688 | $424 | $264 |
| Canola/wheat | T | 7 | Beckom | 43Y92 CL | - | 1.0 | $614 | $450 | $164 |
| Canola/wheat | T | 2 | Beckom | 43Y92 CL | - | 1.0 | $628 | $441 | $187 |
| Canola/wheat | E | 7 | Kittyhawk | Hyola 970 | 0.9 | - | $182 | $615 | -$434 |
| Canola/wheat | E | 2 | Kittyhawk | Hyola 970 | 0.6 | - | $157 | $542 | -$385 |
| Canola/wheat/lentil | T | 7 | Hallmark | 43Y92 CL | - | 1.0 | $626 | $488 | $137 |
| Canola/wheat/lentil | T | 2 | Hallmark | 43Y92 CL | - | 1.5 | $890 | $447 | $443 |
| Canola/wheat/Fababean | T | 2 | Samira | 43Y92 CL | - | 1.0 | $628 | $440 | $188 |

*E = Sown early over early April period, T = Sown timely over late April to mid-May period, Nit 2 = Low nitrogen budgeting based on decile 2 rainfall projections July to October, Nit 7 = High nitrogen budgeting based on decile 7 rainfall projections July to October, Note: Emu damage on Planet(b) barley reduced the amount that could be captured for hay production.*

lowest conversion efficiency of product per mm of water (Figure 4).

## Urana farming systems site

All hay production in 2019 at Urana produced negative EBIT while all grain production produced positive EBIT (Table 4). Wheat tended to produce higher returns than canola and higher N tended to produce high wheat returns but similar or lower canola returns. This N effect was in contrast to the Wagga Wagga site (Table 2 and 4). The highest 2019 canola EBIT was produced from timely sowing canola after lentils while the highest 2019 EBIT for wheat was produced from timely sown wheat grown after timely sown canola(Table 4).

## Conclusions

Crop choice, sowing time and N management in 2018 impacted on crop returns in 2019 and this challenges growers to think of the negative and positive effects of certain crops on the profitability of the crop sequence. While legume break crops provided consistent advantages for the subsequent crop this was not always the case with canola.

At the Greenethorpe and Wagga Wagga sites, hay options provided some advantages for specific 2018 and 2019 crop combinations. In some cases, this ensured losses from grain production were avoided but was not a guarantee for profitability. Grain production was still profitable at some sites (Urana) for certain crop combinations, particularly where timey sown cereal or canola followed legume forage or legume grain crops.

Crop species performance under drought conditions in southern NSW tended to be ranked as barley better than wheat, which is better than canola (barley > wheat > canola). Pulse crop performance under drought conditions in southern NSW tended to be ranked as faba bean which was equivalent to lupin which was better than chickpea which was equivalent to lentil (faba bean = lupin > chickpea = lentil).

The Vertisol soil at the Urana site provided better grain filling conditions and subsequently grain production was more profitable at this site than hay production.

## 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. This research was undertaken as part of GRDC project CFF00011 and with financial support from CSIRO and NSW Department of Primary Industry.

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# 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.

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# Nitrogen budgeting and carry-over

***Graeme Sandral.***

*New South Wales Department of Primary Industries, Wagga Wagga Agricultural Institute.*

This paper was under review at the time of publication of proceedings and can be found in full at https://grdc.com.au/resources-and-publications/grdc-update-papers

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# Riverine Plains Inc research update

***Cassandra Schefe.***

*Riverine Plains Inc.*

**GRDC project code:** DAN00206 – Innovative approaches to managing subsoil acidity in the southern grain region

## Keywords

- subsoil acidity, cropping diversity.

## Introduction

During 2019 Riverine Plains Inc contributed to a range of research projects. However, this research update will only summarise the key project information and results to date from two projects over the past year (2019), including subsoil acidity and plant-based amelioration of rhizosphere constraints.

## Project information

*Innovative approaches to managing subsoil acidity in the southern grain region – GRDC investment*-*

*Aim*

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

*Methods*

Riverine Plains Inc are managing two farm-scale trials in the region for this project, which is led by NSW DPI. A site at Rutherglen was established in February 2018, while a site near Bungeet was established in February 2019.

These trials are evaluating deep placement of lime, lucerne pellets and other products, compared to surface application of lime for the management of subsoil acidity. All deep ripping was done perpendicular to the seeding row, so that seeding tines did not run into the furrows. Plots were 100m long by 10m wide, with three replicates of each treatment.

<u>Rutherglen site</u>

The Rutherglen site compared the following treatments:

- Surface lime,
- deep lime,
- deep rip,
- deep lucerne pellets, and;
- deep reactive rock phosphate (RPR).

All lime applications were calculated based on the lime requirement to raise the pH to 5.9 in the 0-10cm depth and 5.4 down to 30cm.

In 2018 the triticale in the deep placed lucerne pellet treatment was visually greener than all other treatments through the season. However, there were no treatment differences in harvest biomass or yield.

In 2019 triticale was grown again on the established trial site. While there were no differences in anthesis biomass, there was a significant increase in harvest biomass with the deep lucerne pellet ($p<0.05$), compared to all other treatments (Figure 1). The yield data from the header yield monitor was not yet available at the time of reporting and will be presented at the 2020 Corowa GRDC Grains Research Update.

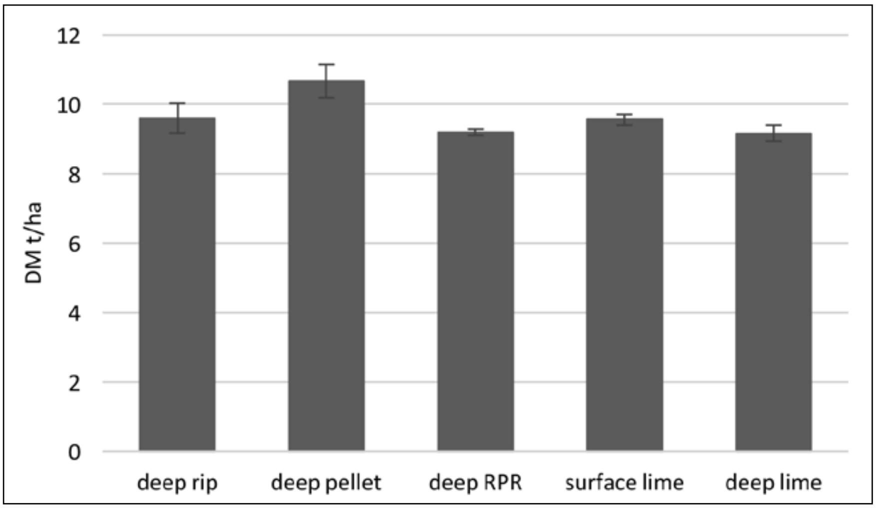


**Figure 1.** 2019 harvest triticale dry matter (DM) for subsoil acidity treatments at the Rutherglen site. Bars are measures of standard error.

Bungeet site

The Bungeet site was established in February 2019 and compared the following treatments:

- Surface lime,
- deep lime,
- deep rip, and;
- deep lucerne pellets.

Canola was grown on this site in 2019. The dry start to the season meant that there was no significant rain between the deep ripping operation in February and the seeding of the canola in late April 2019. Soon after the canola was sown, there was an intense rain event (3 May), which caused washing of canola seed into the fractured soil. This resulted in poor and variable germination of seed across the trial, with the most consistent emergence being in the surface lime treatment and in the buffer strips between the treatments.

The high variance within each plot contributed to no differences in anthesis biomass between treatments. While harvest biomass cuts were not taken due to the risk of pod shatter after desiccation, the yield from each plot was collected in large bulk bags and weighed, with no differences in canola yield measured between treatments (Figure 2).

Establishing the deep ripping treatment at Bungeet resulted in significant soil disturbance. The dry start to the 2019 season followed by intense rainfall after seeding meant that crop establishment was compromised.

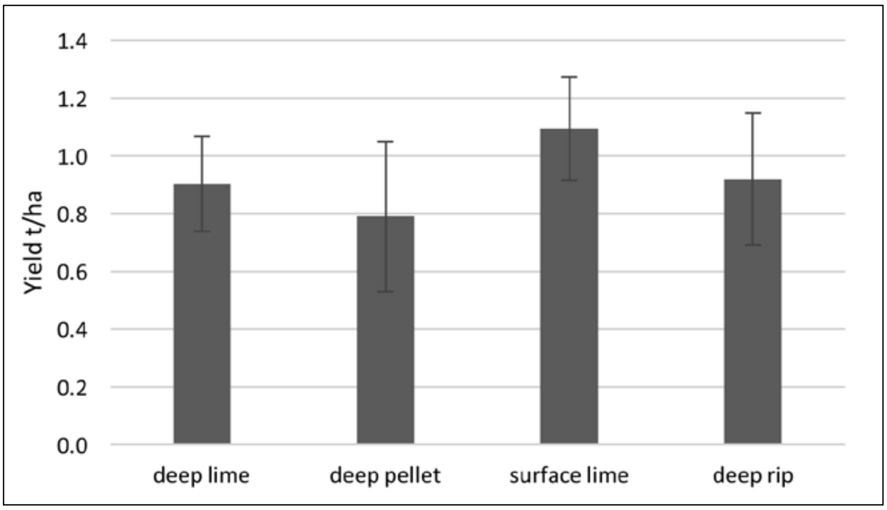


**Figure 2.** 2019 harvest canola yield for subsoil acidity treatments at the Bungeet site. Bars are measures of standard error.

The 2020 season is the last year of monitoring for both the Rutherglen and Bungeet sites, which should provide a clearer understanding of the long-term impacts of deep placement of ameliorants on subsoil acidity and plant growth.

*Plant-based amelioration of rhizosphere constraints – Soil CRC; GBCMA*

Riverine Plains Inc are a partner in the Soil Cooperative Research Centre (CRC), which is investing in a wide range of soil-based research, along with other industry partners. As such, Riverine Plains Inc are participating in a number of research projects, as are other farming groups, in order to provide clear linkages from research through to growers.

One such project (co-funded by the Goulburn Broken Catchment Management Authority (GBCMA)) aims to understand the impact of plants on amelioration of soil constraints in the rhizosphere, investigating the impact of certain crop plants on subsequent plants in the rotation. As part of this project, in 2019 Riverine Plains Inc established a long-term rotational cropping trial at Burramine, near Yarrawonga.

This trial is quantifying the impact of brown manures, pulses, intercropping/companion cropping and summer cover cropping methods on the soil biology, chemistry and water storage potential of subsequent crops.

The design of the trial will be presented at the 2020 Corowa GRDC Grains Research Update, highlighting the range of crop sequences and species mixes to be evaluated.

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GRDC GROWNOTES

# SPRAY APPLICATION GROWNOTES™ MANUAL



# SPRAY APPLICATION MANUAL FOR GRAIN GROWERS

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# Innovative approaches to subsoil liming and management

***Guangdi Li.***

*NSW Department of Primary Industries*

**GRDC project code:** DAN00206

## Keywords

- soil acidity, lime, organic amendments, deep ripping, pH, exchangeable aluminium.

## Take home messages

- Lime is the most effective ameliorant to increase soil pH
- Organic materials are not as effective as lime in changing pH, but reduced exchangeable Al% significantly
- Applying lime with organic materials could facilitate downward movement of alkalinity
- However, over a longer term applying large amounts of organic materials could acidify soil due to nitrification.

## Introduction

Subsoil acidity is a major constraint to ongoing productivity in the high rainfall zone (500–800 mm) of south-eastern Australia (Scott et al., 2000). Approximately 50% of Australia's agriculture zone (~50 M ha) has a surface soil pH < 5.5 in calcium chloride (pH, hereafter) and half of this area also has subsoil acidity (SoE, 2011). In southern NSW, there are 13.5 M ha of agricultural soils exhibiting a subsurface soil acidity problem (Dolling et al., 2001). The agricultural production loss from soil acidity is estimated as $387 million in NSW (SoE, 2011).

The surface application of lime is a widely accepted practice to combat soil acidification at the surface (Scott et al., 2000; Ryan, 2018). However, lime moves very slowly down the soil profile so subsoil acidity will only be ameliorated after decades of regular lime application at appropriate rates to the soil surface (Li et al., 2019). Research from a long-term field experiment, known as MASTER, showed that pH increased at 0.04 pH units per year at 10-20 cm by maintaining pH above 5.5 at 0-10 cm with adequate lime application (Li et al., 2019). However, the current commercial recommended rate of 2.5 t/ha every 6-10 years is not enough to stop further soil acidification, as most of the alkalinity added is consumed in the topsoil with very little remaining to counteract subsoil acidification. Results from two soil surveys conducted in 2006 and in 2015-2017 in southern NSW showed that soil acidity is continuing to move further down the soil profile even where lime application is applied regularly over the 10-year period (Burns and Norton, 2018). We are acidifying our soils under contemporary minimum tillage farming systems.

The challenge is how to stop further soil acidification and speed up amelioration of subsoil acidity. The research questions are:

- Does deep ripping speed up amelioration of subsoil acidity? What is the rate of amelioration under deep ripping? Farmers need this information to make decisions on their capital investment (e.g. lime) and to estimate the economic return from the further investment for the cost of the deep ripping

- What is the role of organic materials in the amelioration of soil acidity? What types of organic materials are effective and what rates are required to achieve fast movement of alkalinity down the soil profile? Farmers need to be informed to strategically implement soil organic amendments to maximise profits in a longer term.
- Is deep tillage a viable option to fix subsoil acidity? Farmers need to know the benefit of a "quick" fix of mixing soil with soil amendments by vigorous tillage compared with the perceived detrimental damage to soil structure and the environment in the short, medium and long term.

## Methodology

A national coordinated project "Innovative approaches to managing subsoil acidity in the southern grain region" funded by GRDC (DAN00206) is testing whether aggressive application methods such as deep placement of lime and/or organic materials will achieve rapid changes to pH at depth.

A series of lab incubation studies and soil column experiments have been conducted under controlled conditions to:

a) Compare the effectiveness of a range of inorganic and organic amendments, and their combinations, to ameliorate soil acidity; and

b) Optimise the application rates and application depth in soil profiles to identify the most effective soil amendments.

Four small plot field experiments and eight large-scale on-farm field experiments have been set up across southern NSW to north west Victoria to test optimum rates of the most effective soil amendments at various soil depths to validate their effectiveness under field conditions.

The inorganic amendments tested include lime, dolomite, magnesium silicate (MgSi), calcium nitrate, reactive phosphate rock (RPR), gypsum etc. The organic amendments tested include plant residues/materials (such as lucerne hay, pea hay, cereal crop straw, garden composts), animal wastes (such as poultry litters, dairy compost, sheep manure) as well as biochar, biosolids and k-humates.

## Key results

### *Magnesium silicate*

Magnesium silicate (MgSi) is a novel product that has potential as a soil ameliorant to elevate soil pH. The neutralizing value of pure MgSi is estimated as 1.4 times higher than that of limestone.

A blended product of MgSi (70% Doonba dunite and 30% F70 superfine lime) with neutralizing value about 100% was used at the Holbrook site from 2015-2017. Results showed that both deep liming and deep MgSi treatments increased soil

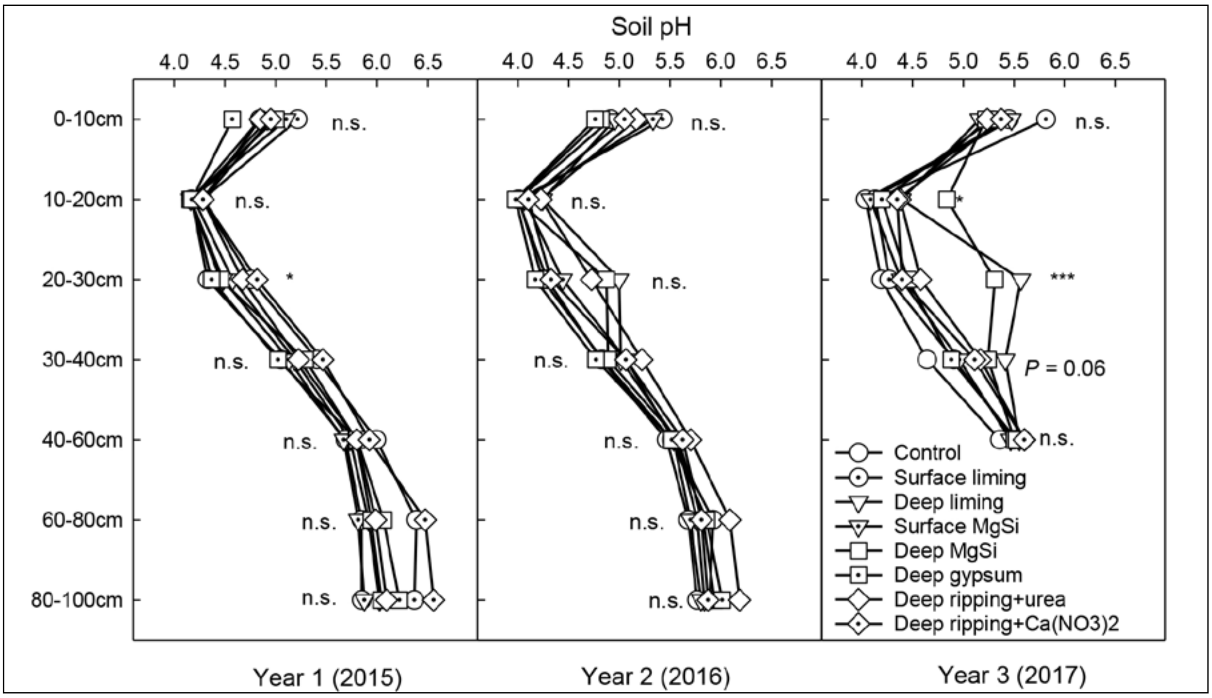


**Figure 1.** Soil pH in $CaCl_2$ under different soil amendment treatments in autumn in years 1-3 at the Holbrook site.

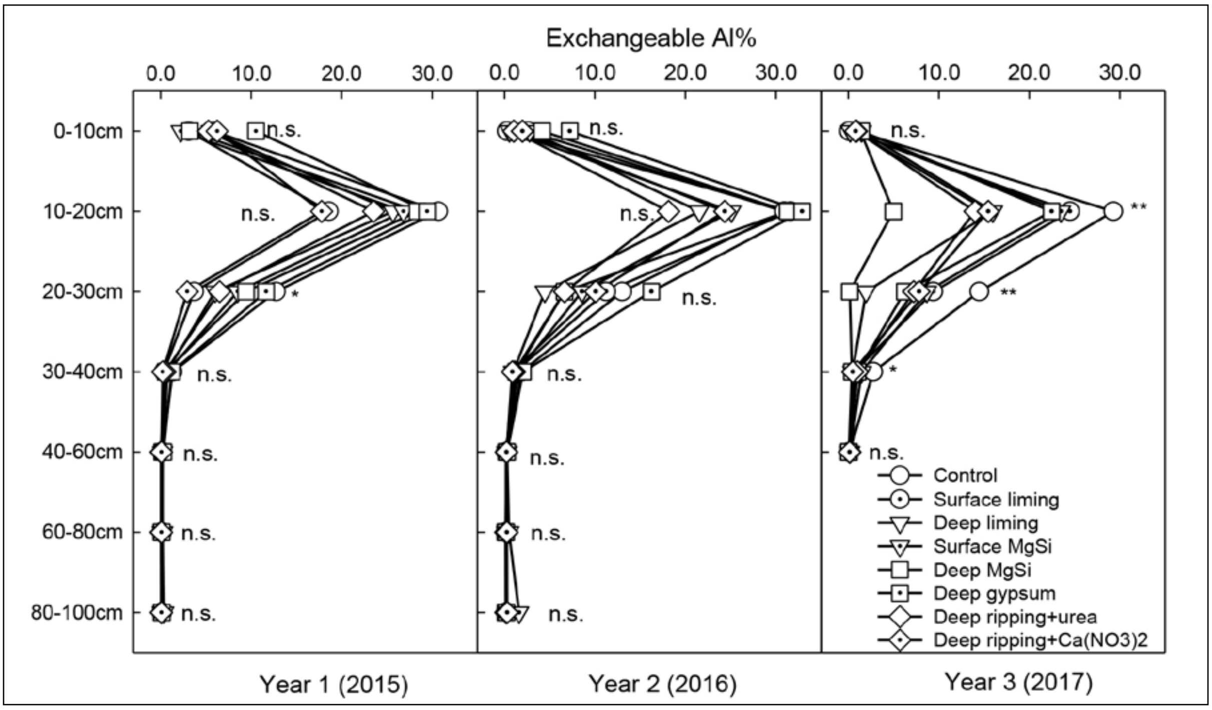


**Figure 2.** Soil exchangeable Al% under different soil amendment treatments in autumn in years 1-3 at the Holbrook site.

pH significantly at the 20–30 cm depth (*P*<0.001) where soil amendments were applied compared with the no amendment treatment, three years after treatments were implemented (Figure 1). However, there was no significant difference in soil pH between deep liming and deep MgSi treatments at either 10–20 cm or 20–30 cm.

MgSi reduced exchangeable Al% (Al as percentage of effective cation exchange capacity) significantly at 10–20 cm (*P*<0.01) and 20–30 cm (*P*<0.05, Figure 2). The exchangeable Al% tended to be lower in the deep MgSi treatment than that in the deep liming treatment, but no significant difference was detected. Further research is required to explore whether MgSi is more efficient in decreasing Al toxicity than lime as claimed by Castro and Crusciol (2013).

*Calcium nitrate*

Calcium nitrate supplies plants with nitrogen in the form of nitrate, which would promote great anion uptake, leading to the release of $OH^-$ ions into the rhizosphere and thus increase of rhizosphere pH. There is potential for effect of root-induced alkalization in the rhizosphere to expand to ameliorate acidity in the bulk soil beyond the rhizosphere (Conyers et al.,2011; Tang et al., 2013).

Results from a pot experiment conducted by the La Trobe University researchers involved in this project showed that calcium nitrate not only increased rhizosphere pH, but it also increased bulk soil pH by 0.25 units in the Rutherglen and Bethungra soils, compared with those treated with urea over a short period (28 days)(Figure 3). Calcium nitrate addition also increased shoot biomass by 20% compared with urea in Rutherglen and Bethungra soils, but there were no treatment differences in shoot biomass in Frankston, Holbrook and Welshpool soils (data not shown). Results from a field experiment conducted at Holbrook showed that there was no significant difference in either pH or exchangeable Al between sources of N (urea vs calcium nitrate) over 3 years (Figure 1 and Figure 2). Thus, there is limited benefit to change of soil pH in the bulk soil over a long-term.

*Reactive phosphate rock*

Reactive phosphate rock (RPR) contains slow release P with reasonable high alkalinity that could be used as a P source as well as a soil ameliorant for soil acidity. At the Rutherglen site, RPR at low (4t/ha) and high rates (8t/ha) increased canola grain yield by 0.5 t/ha compared with the limed control in year 1 (Figure 4), which was similar to the treatment with high rate of lucerne hay pellets (15t/ha). There were no yield responses with any other soil amendments (Figure 4).

Deep placement of organic materials may induce manganese toxicity due to enhanced oxygen consumption by microorganisms and poor aeration at depth. Positive results of RPR and lucerne hay

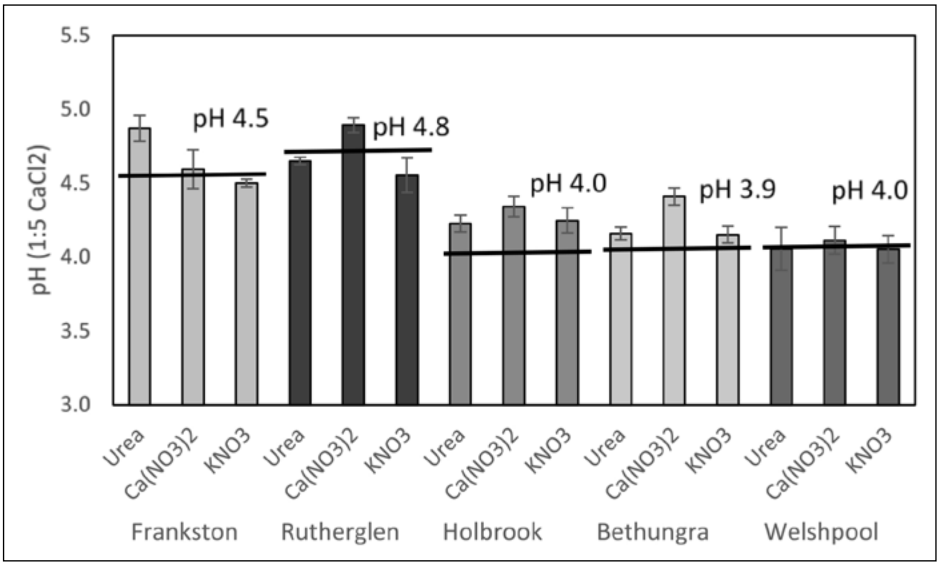


**Figure 3.** Bulk soil pH for soils treated with urea, calcium nitrate [$Ca(NO_3)_2$] and slow release KNO3. Bars indicate standard errors of the mean (n=3). Black solid lines indicate initial soil pH.

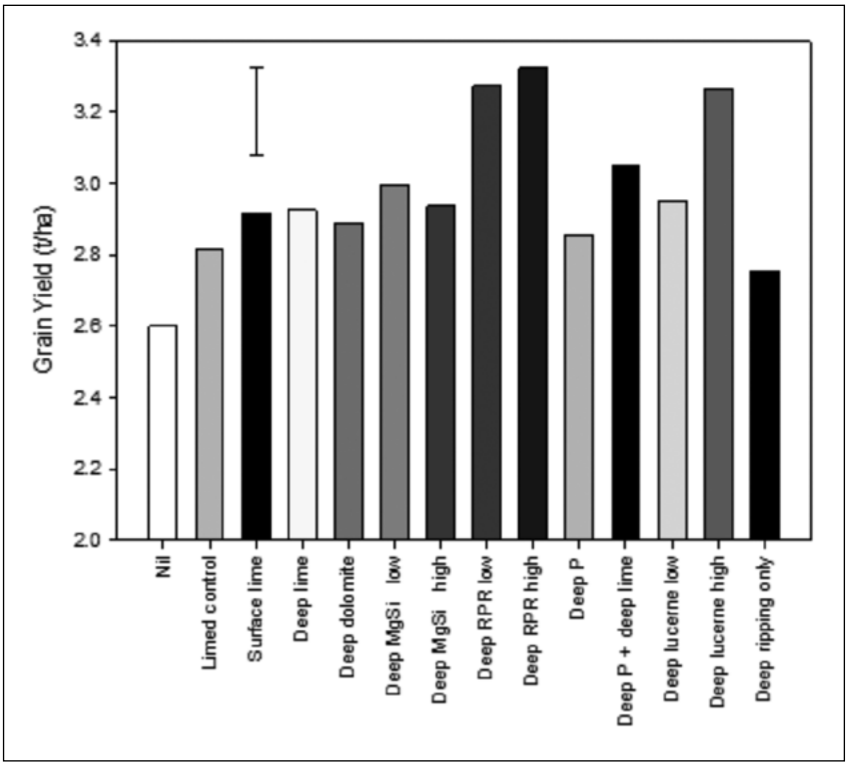


**Figure 4.** Harvest yield of canola (t/ha) for amendment treatments at Rutherglen site. Data are treatment means of 3 replicates. Bar indicates l.s.d. (P=0.05).

pellets on yield may be due to improved nutrition and pH increase, indicating that interactions of these factors need to be investigated for growers to realise efficiency gains of amendment additions at depth.

In the second growing season, treatment effects were observed visually in the first 4 weeks of growth. Plants in the untreated control and surface liming treatments were small and spindly, whilst plants in deep amended treatments appeared healthier. However, due to harsh conditions during the 2018 growing season, the early visual symptoms did not carry through, resulting in non-significant differences between treatments at harvest. Despite this poor agronomic result in 2018, the results from soil sampling indicated that, in general, liming agents applied at the start of the 2017 season were maintaining positive effects on soil pH and exchangeable aluminium concentrations, which should improve plant growth under better seasonal conditions in future years.

*Organic materials*

Organic materials can have a liming effect and thus may also be used as soil ameliorants to manage acid soils. However, the magnitude of any pH rise varies between amendments is dependent on their ash alkalinity and the concentration of excess base cations, which is reflective of the concentration of stored organic acid anions (Tang and Yu, 1999).

Lucerne hay pellets were used as a soil amendment at a rate of 15t/ha throughout all field experiments. At the Cootamundra site, there was no difference in soil pH between treatments at any depth in year 1 prior to treatments being imposed. In autumn 2017, one year after treatments were applied, surface liming increased pH to 5.9 at 0-10cm. The deep limed treatment with and without lucerne pellets significantly increased soil pH at 10-20cm and 20-30cm as expected. A similar trend was observed in 2018 (Figure 5).

The deep liming treatments, either with or without lucerne hay pellets, reduced exchangeable Al to less than 2% in 2017 and 3% in 2018 at 10-30cm (Figure 6). Although lucerne hay pellets did not increase soil pH as much as expected, it did reduce exchangeable Al% significantly at 10–20 cm and 20–30 cm (Figure 3) compared with the no amendment treatment. This is likely to be the result of the soluble organic molecules from lucerne hay pellets combining with active $Al^{3+}$ to form insoluble hydroxy-Al compounds (Haynes and Mokolobate, 2001), which would reduce Al toxicity to plant growth. The exchangeable Al remained high in the 10-30cm depths under ripping only and surface lime treatments. The nil amendment treatment had the highest exchangeable Al at all three depths at 0-30cm.

A range of organic materials with and without lime were tested in the field at the Holbrook site. At anthesis in year 1, the lucerne hay pellet treatment had the highest dry matter (DM) (9.6 t/ha), whereas the biochar with lime and wheat straw treatment had the lowest (5.2 t/ha) (Figure 7). Both poultry litter treatments had more than 8 t/ha of DM. At harvest, grain yield followed a similar trend to anthesis DM. The lucerne hay pellet treatment had the highest grain yield, close to 2 t/ha, followed by the poultry litter with lime treatment, whereas the lime treatment had similar grain yield to the control treatment (Figure 7). At seedling stage through to anthesis, the nitrogen content in plant tissues were higher under lucerne pellets and poultry litter treatments due to their high nitrogen content in the products. It is concluded that in the first year after treatments were implemented, crops responded to increased nutrient levels, particularly nitrogen, rather than to the amelioration of soil acidity.

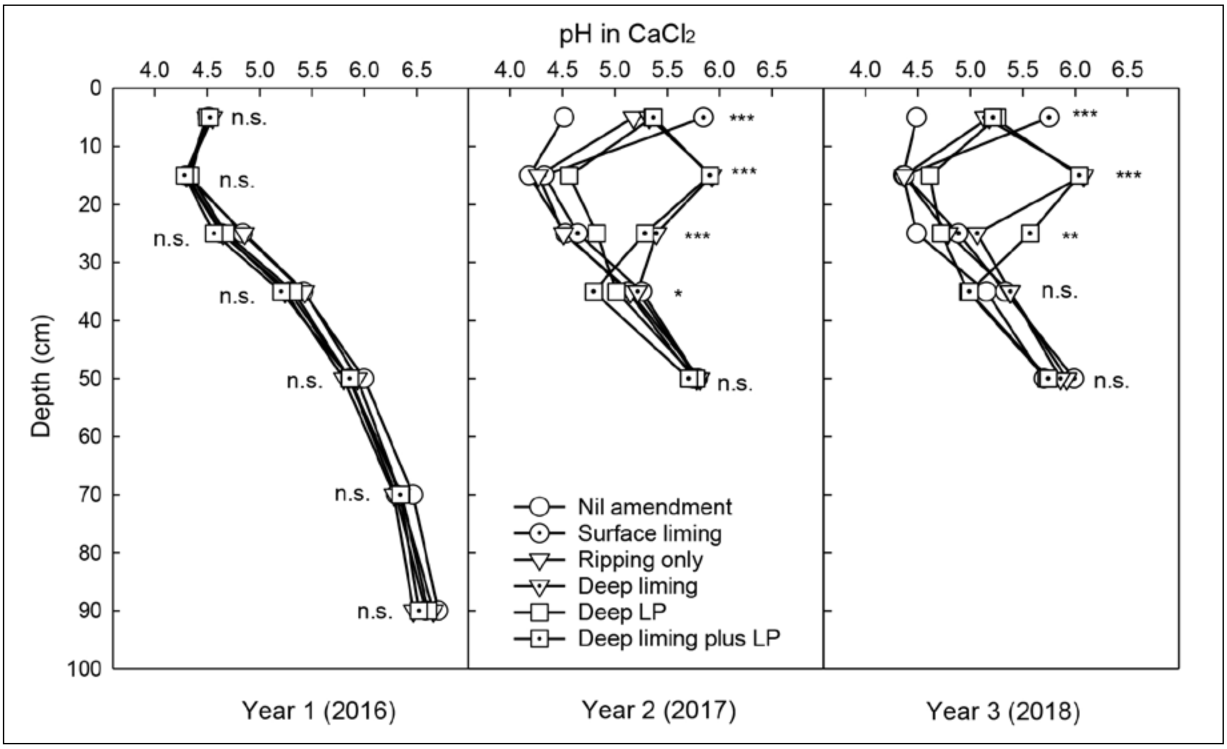


**Figure 5.** Soil pH in $CaCl_2$ under different soil amendment treatments in autumn in years 1–3 at the Cootamundra site. n.s., not significant.

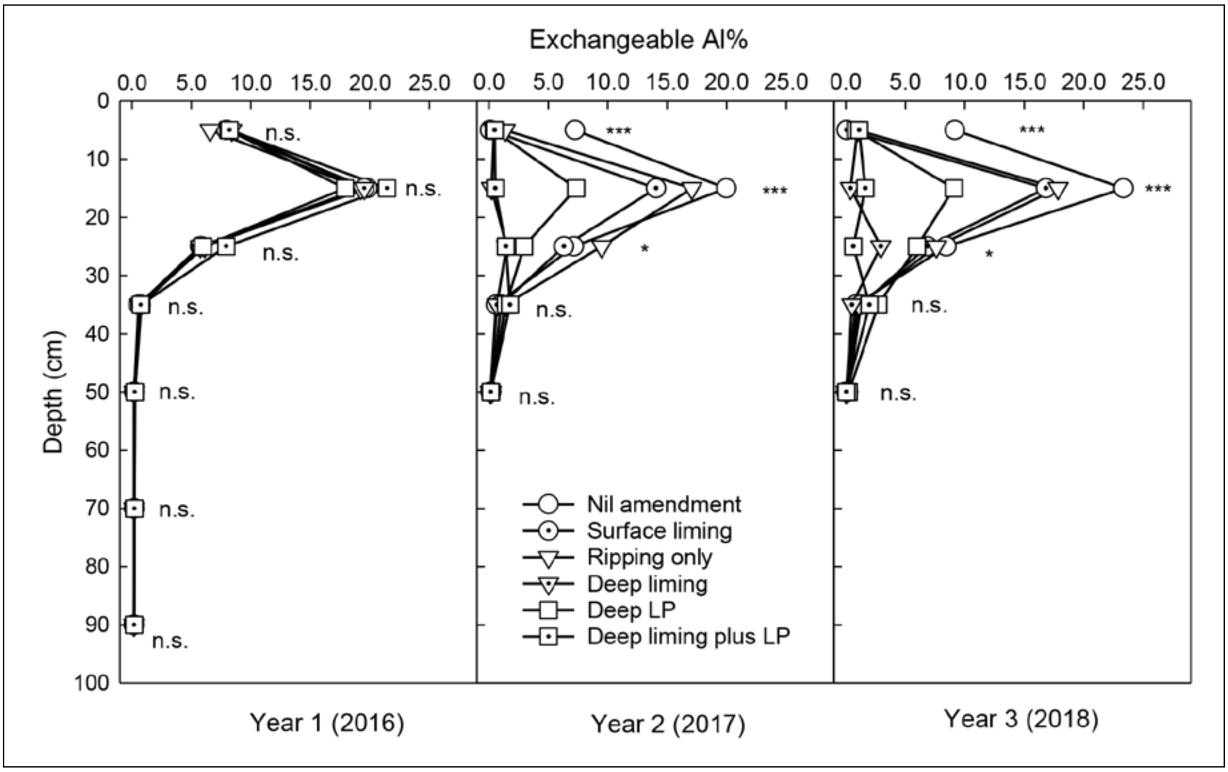


**Figure 6.** Soil exchangeable Al% under different soil amendment treatments in autumn in years 1–3 at the Cootamundra site. n.s., not significant.

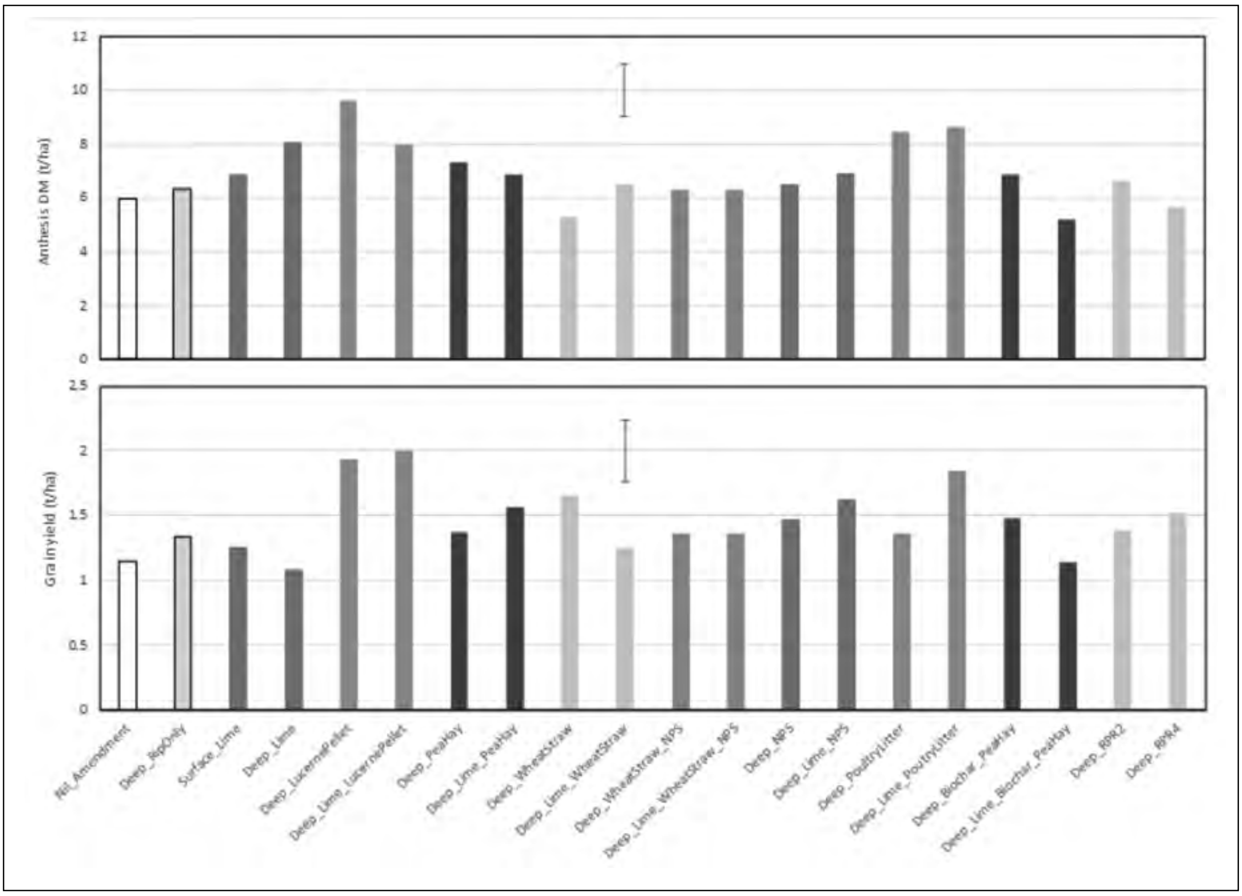


**Figure 7.** Crop dry matter (DM) at anthesis and grain yield at harvest under different treatments at the Holbrook site. The paired treatments with same colour are with and without deep liming except for the first 4 treatments on the left.

*Lime + organic materials*

The mineralization of organic materials is an alkaline process that increases soil pH, but the nitrification is an acid process that decreases soil pH (Helyar, 1976). Butterly et al. (2013) showed that plant residues can produce alkalinity below the layer applied. This is due to the leaching of organic compounds and organic acids, with any subsequent effect on pH being a function of ammonification, nitrification, and release of alkalinity by decarboxylation further down the profile.

The addition of lime with plant residues can generate alkalinity below the amended layer, create favourable pH gradients and may facilitate the downward movement of alkalinity from lime as demonstrated in a leaching experiment (Figure 8). Lucerne residues showed the greatest short-term increase in pH one month after incubation, but re-acidified soil after three months of incubation (Figure 8).

In field conditions, however, the addition of large amount of organic materials could acidify soil further over the longer term. Results from an intensive soil grid sampling at the long-term site at Cootamundra showed that soil pH beyond the ripping depth was lower under lucerne hay pellet treatments, with and without lime, compared with that under surface liming and deep liming treatments, four years after treatments were implemented (Figure 9).

## Conclusion

Subsoil acidity is difficult to manage. It will take decades for the current lime programs that apply lime the surface 0-10 cm layer regularly with appropriate rates aiming to ameliorate subsoil acidity. Deep placement of lime could speed up the amelioration process compared with surface liming. Given the nature of the ripping operation (Poile et al., 2012), the soil disturbance (and so the volume of soil treated) is restricted into a narrow slot.

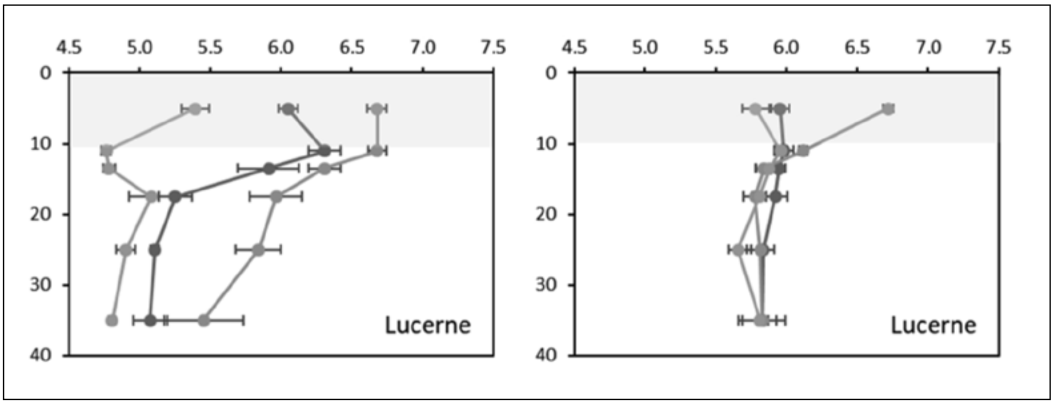


**Figure 8.** Soil pH profile in soil columns 1 month (left) and 3 months (right) after amendment (0-10 cm, shaded grey) with lucerne residues (blue line), lucerne + lime (orange line) and control (grey lines) (Clayton Butterly, La Trobe University, unpublished data).

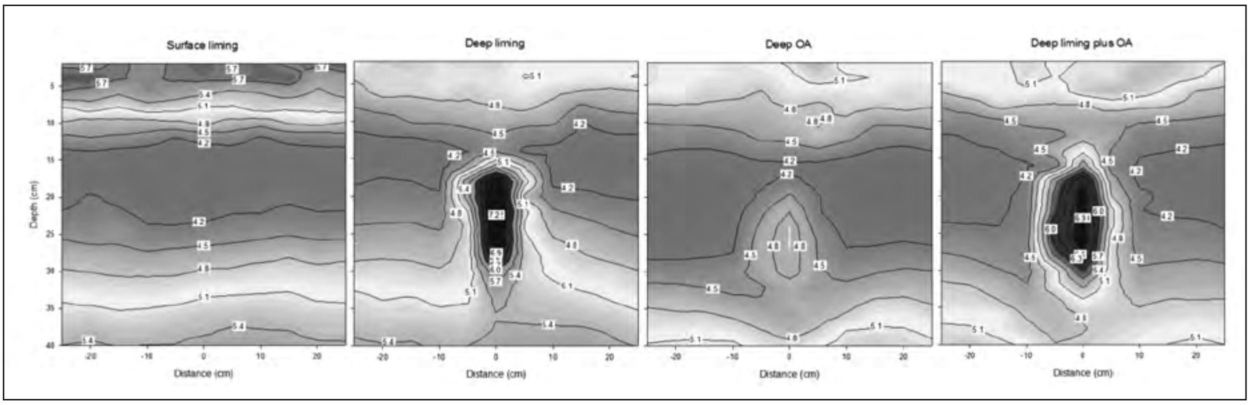


**Figure 9.** The spatial distribution of soil pH in $CaCl_2$ in soil profile with (a) surface liming, (b) deep liming, (c) deep organic amendment, and (d) deep liming plus organic amendment Four years after treatments were implemented at the Cootamundra site in 2019.

This is usually just 5-8 cm wide depending on the shape of the tyne used. This leaves large volumes of untreated soil. In addition, the vertical movement of lime is very slow and the lateral movement of lime is minimal (almost negligible). Therefore, it is unlikely that the constraint of subsoil acidity could be overcome in a short time frame. Further work is warranted to study whether a full tillage at depth is a viable option to amend the subsoil acidity problem. Growers want to know the economic benefit of the "quick" fix of mixing soil and soil amendment by vigorous tillage. They also want clarification on the perceived detrimental effects on soil structure and on the environment in the short, medium and long term.

A range of inorganic and organic soil amendments have been tested in a number of lab incubation studies and soil column experiments in glasshouse. Promising novel materials have been implemented in a number of field experiments and monitored over 2-3 growing seasons. The key findings are summarised below:

- Lime is the most effective ameliorant to increase soil pH
    - MgSi is potentially more efficient than lime in decreasing Al toxicity
    - Calcium nitrate can increase pH of the rhizosphere, but the effect on bulk soil pH is limited
    - Reactive phosphate rock has a positive effect on crop yield, probably due to improved nutrition. Its role in increasing pH needs further investigation.
- Organic materials are not as effective as lime in increasing pH, but reduce exchangeable Al% significantly
    - The mineralisation of organic matter increases soil pH in a short time frame
    - However, the nitrification would re-acidify soil and decrease soil pH in the medium to long term.
- The combination of lime with organic materials could facilitate downward movement of alkalinity from the lime in the short term.
    - However, applying large amounts of organic materials could acidify soil due to nitrification over a longer term.

## Acknowledgements

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Notes

# Summer cover crops in short fallow - do they have a place in central NSW?

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**GRDC project code:** DAQ00211

## Keywords

- cover crop, stubble cover, ground cover, short fallow.

## Take home messages

- Summer cover crops reduced the winter cash crop (wheat) grain yield by up to 1.5t/ha at Canowindra and 0.6t/ha at Parkes
- Grain yield losses were minimised by spraying out the cover crop early
- The grazing value ($/ha) generated from the cover crop more than compensated for the grain yield reduction based on current commodity prices
- Pros of summer cover crops include increased ground cover, reduced soil erosion from wind and water, cooler and more consistent soil temperatures, improved autumn sowing conditions, valuable summer forage for mixed farming operations, quicker soil water recharge compared with bare ground, reduced herbicide applications over the summer fallow, and improved total soil carbon % and assumed microbial activity
- Cons of summer cover crops include reduced mineral nitrogen (N) and reduced grain yield for the following winter cash crop, increased risk of soil water deficit in low rainfall years (or greater reliance on in-crop rainfall), additional seed costs, patchy establishment of summer cover crop due to rapidly drying soils, high herbicide rate required to terminate cover crop, and increased disease risk (stubble and soil) due to green bridge for the following winter cash crop
- Risks associated with cover crops are reduced by longer fallow period post cover crop for soil moisture recharge and mineralisation of cover residue; incorporating livestock within the system to convert surplus biomass to $/ha; seasons with high rainfall; additional N fertiliser application for winter cash crop
- The optimum 'crop type selection' and 'spray out timing' will vary depending on individual paddock and enterprise goals.

## Background

Dust storms have been a common sight in central NSW in the summer of 2019/2020 due to the combination of drought and low ground cover. Ground cover levels have been on a decline since 2017 with residual stubble decomposing over this time, and limited opportunity to grow fresh biomass over the past 2-3 years. Factors further reducing ground cover levels include growing low biomass pulse crops (e.g. chickpeas), incorporation of lime, grazing stubbles and baling of failed winter crops. Both the magnitude and duration of the current dry period has been unparalleled and is highlighting the value of ground cover.

The benefits of cover crops to protect the soil from wind or water erosion in low stubble scenarios is well understood, however the use of cover crops as a technique to improve water infiltration and storage to improve grain yield for the following winter cash crop is less clear. Recent GRDC funded research (McMaster 2015) has demonstrated that 50% of yield potential can be attributed to summer rainfall and summer fallow management as a result of increased stored water and N. Water and N increase grain yield through grain number (more tillers and more grains per head) and grain size, with a return on investment of controlling summer weeds between $2.20 and $7.20 ha for every dollar invested.

The primary purpose of these experiments was to evaluate if there is a net water gain to the subsequent winter cash crop (wheat) following a summer cover crop, and the associated result on grain yield. The secondary purpose of this project was to evaluate the impact of various spray-out timings (early, mid and late) and crop-types (including single species, mixed species and summer weeds) on the farming system, including grazing value of cover ($), crop nutrition (mineral N and total carbon %), disease pressure (stubble and soil), and soil temperature.

## Method

Two sites with zero ground cover were selected in central NSW at Canowindra (high rainfall zone – central east (CE) slopes) and Parkes (medium rainfall zone – central west (CW) plains). Each site consisted of a short and long fallow treatment and the experiment design was a randomised block with 4 replications. Individual plot size was 10m X 10m across all experiments. The following report provides results from the short fallow experiments only, and includes treatment combinations of four cover crops, three spray-out timings and one control (bare ground, weed-free). The summer cover crops were sown using a knife point press wheel plot seeder at 30cm row spacing and the subsequent winter cash crop was sown with a single disc plot seeder (30cm row spacing) due to trash flow requirements. Fertiliser was applied with the seed, at a rate of 50 kg/ha of mono ammonium phosphate (MAP) with the cover crop and 50 kg/ha MAP with the winter crop. The summer cover crops were sown on 26 November (2018) at Canowindra, and 9 December (2018) at Parkes. The subsequent winter crop (Wheat – cv Mustang⁽ᶦᵇ⁾) was sown on 18 May at Canowindra, and 25 May at Parkes.

*Short fallow trial (6-month fallow – November 2018 to April 2019)*

Treatment details:

- Treatment 1: Cover crop types = cow peas, forage sorghum, mixed species and summer weeds
- Treatment 2: Spray out timings = 50, 80 and 110 days after sowing the cover crop (DAS)
- Treatment 3: Control = bare ground kept weed-free.

The mixed species included cow peas, lab/lab, forage sorghum, millet, tillage radish and sunflower.

*Cover crop biomass*

*Canowindra site*

Biomass production ranged from 0.07 to 10.8 t/ha (Table 3) and was influenced by crop type ($P$<0.001), spray-out timing ($P$<0.001) and the interaction between both ($P$<0.001). Highest biomass produced across the site was 10.8t/ha of forage sorghum (sprayed out late), compared with the lowest biomass produced by summer weeds (sprayed out early) with 0.07t/ha.

On average across crop-types, forage sorghum (6.5t/ha) and mixed species (3.4t/ha) produced much higher biomass than the cow pea (1.3t/ha) and summer weed (1t/ha) treatments. Average biomass production further increased as spray-out timing was delayed from early, mid to late with a respective increase of 1.33t/ha, 2.99t/ha and 4.85t/ha. Nitrogen fertility at this site was high (refer to crop nutrients

**Table 1.** Monthly rainfall and long-term average (LTA) rainfall for Canowindra and Parkes, 2019.

| Month | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Canowindra | | | | | | | | | | | | | |
| Rainfall (mm) | 39 | 34 | 45 | 53 | 1 | 33 | 34 | 13 | 24 | 21 | 20 | 17 | 7 |
| LTA (mm) | 53 | 57 | 50 | 49 | 40 | 44 | 48 | 50 | 48 | 42 | 51 | 49 | 53 |
| Parkes | | | | | | | | | | | | | |
| Rainfall (mm) | 21 | 28 | 23 | 32 | 0 | 29 | 25 | 13 | 10 | 18 | 27 | 11 | 7 |
| LTA (mm) | 54 | 58 | 50 | 46 | 43 | 44 | 50 | 51 | 50 | 46 | 56 | 51 | 54 |

**Table 2.** Seed rate, seed cost and field establishment of summer cover crops at Canowindra and Parkes, 2019.

| Treatment | | Seed rate | Seed size | Seed cost | Seed cost | Canowindra | | Parkes | |
|---|---|---|---|---|---|---|---|---|---|
| | | (kg/ha) | Seeds/kg | (per kg) | (per ha) | (Plants $m^2$)[b] | Est (%) | (Plants $m^2$)[b] | Est (%) |
| Forage sorghum | | 9 | 32100 | $5.20 | $46.80 | 26.8 | 93% | 22.8 | 79% |
| Cow pea | | 16 | 9500 | $3.90 | $62.40 | 12.5 | 82% | 12.6 | 83% |
| Mixed species[a] | forage sorghum | 2 | 32100 | $5.20 | $10.40 | 4.9 | 76% | 5.2 | 81% |
| | millet | 5 | 124000 | $2.50 | $12.50 | 19.5 | 31% | 11.3 | 18% |
| | cow pea | 4 | 9500 | $3.90 | $15.60 | 2.6 | 68% | 3.5 | 92% |
| | lab lab | 4 | 4300 | $4.00 | $16.00 | 1.5 | 87% | 1.5 | 87% |
| | sunflower | 1 | 21052 | $20.00 | $20.00 | 1.3 | 62% | 0.6 | 29% |
| | tillage radish | 1 | 44642 | $9.50 | $9.50 | 5 | 112% | 3.7 | 83% |

*[a] = Total seed cost for the mixed species treatment was $84/ha*

*[b] = Actual plants established per $m^2$*

section) and might explain why biomass production was relatively high at this site. Refer to Table 3 for individual biomass treatment results and Table 5 for feed test results.

*Parkes site*

Biomass production varied from 0.10 to 2.09 t/ha (Table 4) and was influenced by crop type ($P$<0.001), spray out timing ($P$=0.005) and the interaction between both ($P$=0.05). Biomass results were much less than Canowindra, yet the treatments still ranked similarly with forage sorghum (sprayed out late) producing the highest biomass of 2.09t/ha, and summer weeds (sprayed out early) the lowest at 0.10t/ha.

On average, forage sorghum (1.48t/ha) produced more biomass than mixed species (0.94t/ha), cow pea (0.36t/ha) and summer weed (0.09t/ha) treatments. Biomass increased as spray-out timing was delayed from early (0.33t/ha) to mid (0.95t/ha), but there was no further increase from mid to late (0.87t/ha) spray-out timing. Refer to Table 4 for individual biomass treatment results and Table 6 for feed test results.

Interestingly, the millet seed was much less robust than forage sorghum due to lower plant establishment (Table 2) and crop growth appeared to be visually more affected by the higher temperatures than the forage sorghum. For example, the millet foliage turned limp and floppy whilst the forage sorghum foliage became spikier and more erect (similar to a drought stressed wheat crop). Consequently, millet contributed very little biomass in the mixed species treatment.

*Soil temperature at 10cm depth*

*Canowindra site (11 April at 3pm)*

The average soil temperature was 22.2°C and ranged from 18.9°C to 24.3°C. Soil temperature reduced as cover crop biomass increased and was affected by crop type ($P$<0.001), spray-out timing ($P$<0.001) and their interaction ($P$<0.015).

On average, the higher biomass crop types had cooler soil temperatures, with forage sorghum and mixed species being a respective 4.4°C and 3.8°C cooler than the bare ground, cow pea and summer weed treatments. There was no significant difference between the lower biomass crop types of cow peas, summer weeds and bare ground treatments. As spray out timing was delayed, the early and mid-timings were 1.3°C and 2.9°C cooler than the bare ground, respectively. Interestingly, there was no additional cooling effect from the mid and late spray-out timing. Refer to Table 3 for individual treatment results.

Additionally, higher biomass plots were cooler and provided a more consistent soil temperature around the mean when compared to bare ground (data not shown). During the period of 8 March to 20 May, when the bare ground treatment had a range (difference between the daily minimum and maximum temperature) of 10°C or 5°C, the forage sorghum (late spray-out) had a respective range of 6.4°C or 2.5°C.

Cooler soil temperatures would be an indication that evaporation rates were initially reduced under the higher biomass plots. Aside from soil water, higher biomass residues could enable earlier sowing opportunities for winter cereal grazing crops as cooler soil temperatures improve coleoptile length and establishment. Soil temperatures greater than 25°C can reduce crop establishment in winter cereals (Edwards 2006). Conversely, the more consistent soil temperatures of the higher biomass plots could potentially enable summer grain crops such as sorghum to be sown into cooler temperatures than previously practised (Serafin *pers. comm*).

*Parkes site (measured 12 April at 3pm)*

Parkes was 4.7°C hotter than Canowindra, with an average soil temperature of 26.9°C, ranging from 25.8°C to 27.6°C. Soil temperature was significantly affected by crop type ($P$=0.013), and the interaction between crop type and spray-out timing ($P$=0.052). Spray out timing was not significant ($P$=0.697). Parkes is a hotter region which explains the higher soil temperatures; however, the smaller range of soil temperatures is more of an indication of less biomass produced at this site.

Forage sorghum was 0.8°C cooler than the bare ground treatment. There were no significant differences between the lower biomass plots of bare ground, mixed species, cow peas or summer weed treatments. Refer to Table 4 for individual effects.

*Crop nutrients (mineral nitrogen and total carbon %)*

*Canowindra site*

Average mineral N was measured before sowing the winter crop on 1 April. Sampling depth was 1.2 metres and the site average was 272 kg N/ha and ranged from 195 kg N/ha to 343 kg N/ha. Mineral N was influenced by crop type ($P$=0.018) and spray out timing ($P$=0.053), but the interaction between both was not significant ($P$=0.676). Site mineral N was highly variable within treatments, and possibly a legacy effect from the previous canola crop (2018) that was grazed out due to drought.

Highest mineral N was achieved in the bare ground treatment (320.6 kg N/ha), and on average reduced by 79 kg N/ha for the higher biomass crop-types such as forage sorghum and mixed species, and by 46 kg N/ha and 10kgN/ha for the lower biomass crop-types such as cow peas and summer weeds, respectively. Cow peas had little positive effect on soil N levels and this may be due to poor nodulation caused from the high temperatures; lazy nodulation due to high N levels.

Average total carbon percentage was 2% in the 0-10cm soil depth and ranged from 1.75% to 2.25%. Compared with the bare ground treatment (1.76%), total carbon increased by 0.36%, 0.33%, 0.22% and 0.11% in the forage sorghum, mixed species, summer weed and cow pea treatment, respectively. The average total carbon percentage in the 10–30cm was 0.64%, and there were no treatment effects.

*Parkes site*

Average mineral N was 103.2 kg N/ha and ranged from 61.3 kg N/ha to 152.8 kg N/ha. Mineral N was reduced as the cover crop biomass increased and was affected by crop type ($P$=0.019), but not by spray-out timing ($P$=0.093) or interaction of both ($P$=0.414).

The bare fallow treatment had the highest mineral N with 152.8 kg N/ha, and then reduced on average by 69.5 kg N/ha, 61.1 kg N/ha, 50 kg N/ha and 34.6 kg N/ha for forage sorghum, mixed species, cow pea and summer weed treatments respectively. Refer to Table 4 for individual effects.

The average total carbon percentage was 1.01% in the 0–10cm depth, and 0.48% in the 10–30cm depth. There was not enough biomass produced to alter total carbon at either depth.

*Soil water accumulation*

*Canowindra site*

As expected, over the summer period the various cover crops extracted moisture from the soil profile to grow biomass. After cover crop termination there was approximately a 50mm water deficit between the driest and wettest plot (Figure 1). Soil water levels were affected by crop-type (Figure 2a) and spray-out timing (Figure 2b), but no interaction between the two.

The higher biomass crop-types such as forage sorghum and mixed species extracted more moisture than lower biomass crops such as cow pea and summer weeds (Figure 2a). Additionally, spray-out timing also impacted soil water with the mid and late spray-out timing being approximately 30mm dryer than the early spray-out (Figure 2b). Despite the soil water deficit at cover crop termination, the higher biomass plots recharged quicker than the bare ground treatment resulting in no statistical difference in soil moisture from the 16 April to 12 November. The rate of recharge was a surprising result and warrants further investigation to determine if the higher biomass treatment would overtake the bare fallow moisture levels in a normal year.

The legacy effect of the various forms of ground cover will be monitored throughout the 2020 season.

Summer weed results (soil water) are not included due to the uneven nature of summer weed establishment that was not picked up by the soil neutron probe.

*Predicta® B results – (stubble and soil pathogens)*

*Canowindra site*

Diseases that were significantly affected by the various cover crops and spray out timings included: Take all; *Pythium clade* F; *Pyrenophora tritici*

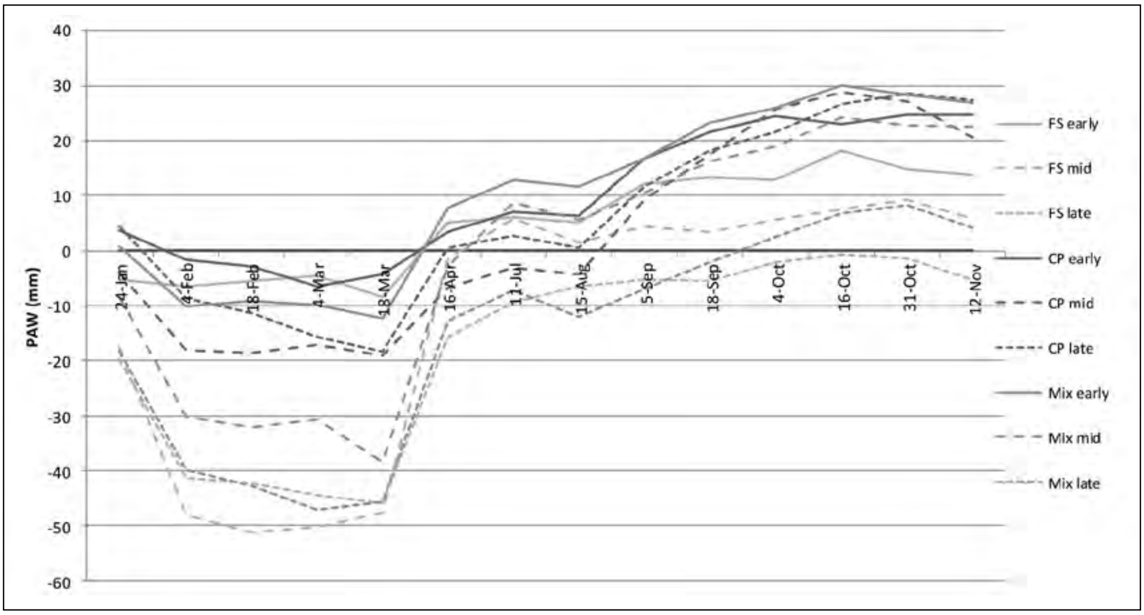


**Figure 1.** Individual treatment effects on soil water accumulation (+/- mm PAW) compared with the bare ground control at Canowindra NSW.

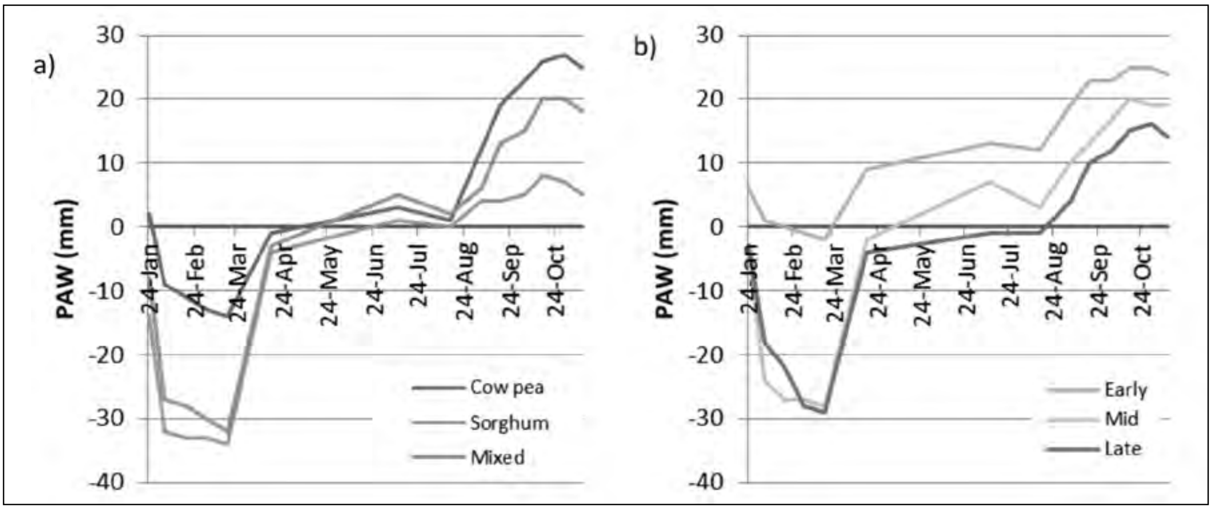


**Figure 2.** Main effects of cover crop-type (a) and spray-out timing (b) on soil water accumulation compared with the bare ground control at Canowindra NSW.

*repentis; Pratylenchus neglectus; Macrophomina phaseolina* and *Fusarium* spp. Results will be included in a separate report.

*Parkes site*

Diseases that were significantly affected by the various cover crops and spray out timings included: Take all; *Pythium clade* F; *Pratylenchus thornei; Macrophomina phaseolina; Didymella pinodes* and *Fusarium* spp.

*Grain yield results*

*Canowindra site*

The average grain yield was 1.91t/ha and ranged from 1.13 to 2.93 t/ha. Grain yield was affected by crop-type ($P$<0.001), spray-out timing ($P$<0.001) but not the interaction between both ($P$=0.459).

The highest grain yield (2.93t/ha) was from the bare ground treatment, and on average reduced by 1.4t/ha, 1.2t/ha, 1.2t/ha and 0.6t/ha from the cow pea, forage sorghum, mixed species and summer weed treatments, respectively. Grain yield reduced as spray out timing was delayed with early, mid and late yielding 2.43t/ha, 1.72t/ha and 1.33t/ha, respectively. Interestingly, the cow peas provided little benefit for the following winter cash crop.

*Parkes site*

The Parkes site was low yielding with an average grain yield of 0.35t/ha, ranging from 0.07 to 0.71 t/ha. Grain yield was affected by crop type (*P*<0.001), spray out timing ( *P* =0.003) and the interaction between crop type and spray out timing (*P*=0.032).

The highest grain yield (0.71t/ha) was in the control which was weed-free, bare ground, and on average, grain yield reduced by 0.56t/ha, 0.51t/ha, 0.33t/ha and 0.04t/ha following forage sorghum, mixed species, cow pea and summer weeds, respectively. Compared with the bare ground treatment, grain yield reduced by 0.27t/ha and 0.39t/ha following the early and mid-spray out timing, respectively. There was no further grain yield loss between mid and late spray-out timing. Refer to Table 4 for individual effects.

**Table 3.** Individual treatment results from short fallow cover crop experiment – Canowindra NSW.

| Crop type | Spray-out timing | Ground cover biomass (t/ha) | Soil temperature (°C) | Mineral N (kgN/ha) | Total carbon 0–10cm (%) | Total carbon 10–30cm (%) | Wheat grain yield (t/ha) |
|---|---|---|---|---|---|---|---|
| Bare | Weed- free | 0 | 24.3 | 321 | 1.76 | 0.637 | 2.93 |
| Cowpea | Early | 0.71 | 24.2 | 286 | 1.75 | 0.608 | 2.26 |
| | Mid | 1.5 | 23.6 | 275 | 1.87 | 0.623 | 1.23 |
| | Late | 1.73 | 23.5 | 266 | 2 | 0.675 | 1.23 |
| Forage sorghum | Early | 2.8 | 21.7 | 288 | 1.93 | 0.683 | 2.45 |
| | Mid | 5.9 | 18.9 | 195 | 2.17 | 0.595 | 1.56 |
| | Late | 10.8 | 19.3 | 245 | 2.26 | 0.738 | 1.13 |
| Mixed species | Early | 1.71 | 22.2 | 274 | 2.01 | 0.615 | 2.15 |
| | Mid | 4.03 | 19.4 | 241 | 2.14 | 0.55 | 1.76 |
| | Late | 4.51 | 20 | 212 | 2.12 | 0.72 | 1.19 |
| Summer weeds | Early | 0.1 | 24.1 | 343 | 2.07 | 0.608 | 2.84 |
| | Mid | 0.51 | 23.6 | 316 | 1.92 | 0.69 | 2.33 |
| | Late | 2.32 | 23.8 | 276 | 1.95 | 0.605 | 1.75 |
| *P value* | | *<0.001* | *<0.001* | *0.03* | *0.15* | *0.907* | *<0.001* |
| *5% Lsd* | | *1.1* | *1.1* | *80* | *0.36* | *0.236* | *0.5* |

**Table 4.** Individual treatment results from short fallow cover crop experiment – Parkes NSW.

| Crop type | Spray-out timing | Cover Biomass (t/ha) | Soil temperature (°C) | Mineral N (kgN/ha) | Total carbon 0–10cm (%) | Total carbon 10–30cm (%) | Grain yield (t/ha) |
|---|---|---|---|---|---|---|---|
| Bare | Weed free | 0 | 27.1 | 153 | 1.01 | 0.49 | 0.71 |
| Cowpea | Early | 0.27 | 27.1 | 126 | 1 | 0.51 | 0.48 |
| | Mid | 0.4 | 27.3 | 82 | 0.99 | 0.49 | 0.33 |
| | Late | 0.42 | 27 | 100 | 0.95 | 0.54 | 0.34 |
| Forage sorghum | Early | 0.47 | 26.5 | 104 | 1.02 | 0.43 | 0.28 |
| | Mid | 1.86 | 25.8 | 86 | 1.12 | 0.51 | 0.1 |
| | Late | 2.09 | 26.8 | 61 | 1.07 | 0.57 | 0.07 |
| Mixed species | Early | 0.47 | 27.2 | 96 | 1.01 | 0.45 | 0.37 |
| | Mid | 1.42 | 27 | 84 | 0.97 | 0.45 | 0.15 |
| | Late | 0.94 | 26.1 | 95 | 1.08 | 0.46 | 0.09 |
| Summer weeds | Early | 0.1 | 27 | 119 | 0.97 | 0.5 | 0.63 |
| | Mid | 0.12 | 26.9 | 116 | 0.1 | 0.43 | 0.62 |
| | Late | 0.04 | 27.6 | 120 | 1.02 | 0.46 | 0.77 |
| *P value* | | *<0.001* | *0.019* | *0.015* | *0.655* | *0.851* | *<0.001* |
| *5% Lsd* | | *0.754* | *0.9* | *42* | *0.153* | *0.159* | *0.159* |

**Table 5.** Cover crop feed quality results and potential lamb production results – Canowindra.

| Crop type | Spray out time | Yield (t DM/ha) | Metabolisable energy (MJ/kg DM) | Crude protein (%) | Liveweight gain (kg/ha) [1] | Value of gain ($/ha)[2] |
|---|---|---|---|---|---|---|
| Cowpea | Early | 0.7 | 10.7 | 23.3 | 85 | 297 |
| | Mid | 1.5 | 10.2 | 17.6 | 161 | 563 |
| | Late | 1.7 | 10.1 | 17.6 | 176 | 617 |
| Forage sorghum | Early | 2.8 | 10.2 | 14.5 | 300 | 1051 |
| | Mid | 5.9 | 10.3 | 10.2 | 522 | 1827 |
| | Late | 10.8 | 11.1 | 7.9 | 1062 | 3716 |
| Mixed species | Early | 1.7 | 11.0 | 19.9 | 228 | 799 |
| | Mid | 4.0 | 10.1 | 12.7 | 400 | 1399 |
| | Late | 4.5 | 10.4 | 11.3 | 469 | 1643 |

*1. Crossbred wether lambs (Border Leicester x Merino or Dorset x Merino), 6 months old, 30 kg live weight utilising 80% of the crop grown.*

*2. Lamb value of $3.50 per kg.*

*3. These results are based on feed test results conducted from dry matter samples; sheep were not actually grazed.*

**Table 6.** Cover crop feed quality results and potential lamb production results – Parkes.

| Crop type | Spray out time | Yield (t DM/ha) | Metabolisable energy (MJ/kg DM) | Crude protein (%) | Liveweight gain (kg/ha) [1] | Value of gain ($/ha)[2] |
|---|---|---|---|---|---|---|
| Cowpea | Early | 0.3 | 11.1 | 24.7 | 37 | 130 |
| | Mid | 0.4 | 10.0 | 23.0 | 40 | 138 |
| | Late | 0.4 | 10.9 | 20.3 | 53 | 185 |
| Forage sorghum | Early | 0.5 | 10.5 | 12.6 | 50 | 176 |
| | Mid | 1.9 | 11.0 | 12.8 | 234 | 818 |
| | Late | 2.1 | 10.5 | 9.7 | 218 | 761 |
| Mixed species | Early | 0.5 | 10.7 | 16.2 | 56 | 196 |
| | Mid | 1.4 | 10.9 | 13.9 | 177 | 619 |
| | Late | 0.9 | 10.6 | 11.3 | 100 | 352 |

*1. Crossbred wether lambs (Border Leicester x Merino or Dorset x Merino), 6 months old, 30 kg live weight utilising 80% of the crop grown.*

*2. Lamb value of $3.50 per kg.*

*3. These results are based on feed test results conducted from dry matter samples; sheep were not actually grazed.*

## Conclusion

Summer cover crops provide a series of pros and cons for the following winter cash crop. Individual paddock goals, enterprise mix, rainfall and commodity prices will ultimately determine if the pros outweigh the cons. There needs to be a clear understanding of how the cover crop will integrate and benefit the broader farming system.

Soil water recharge following a cover crop is much quicker than bare ground, yet a soil water deficit will occur if no rain falls after cover crop termination. Even in a wet year, there is likely to be a N deficit for the following winter cash crop that would require correcting with additional N fertiliser. Presumably, as total carbon % increases, the reliance on supplementary N could reduce over time with an understanding this will take several years.

Grain only cropping operations with short fallows (6 month) are likely to increase the financial risk profile when growing summer cover crops, as yield was reduced at both experiment sites following a cover crop compared with bare ground. Management techniques that retain stubbles and control summer weeds are still considered best practise, as no additional water is used to grow the biomass. However, the use of cover crops as a 'one off' technique to protect the soil from wind or water erosion in low ground cover scenario's may be warranted but considered a 'one off' rather than regular annual management operation.

Conversely, mixed farming enterprises have good reason to capitalise on the increased biomass of a summer cover crop given the current prices for red meat (Tables 5 and 6). According to these results, the grazing value would more than compensate for the winter crop grain yield penalty. Nutrients such as N would need to be adequate to support such a high output system, however the additional income from the livestock enterprise would compensate for the additional nutritional expenses.

Whilst not absolute, disc seeders are an integral part of the cover cropping system as they improve crop establishment in rapidly drying soils (associated with summer plantings) and provide for the high trash flow requirements of the cover crop system. A patchy cover crop will be no better than a weedy fallow, so crop establishment is an important factor. Consideration needs to be given to seeding depth, particularly for multi-species mixes as the seed size range within the mix will determine the potential seeding depth. For example, millet needs to be sown shallow, but forage sorghum and cow peas can be sown much deeper.

The improved rate of soil water recharge was interesting, and the legacy effects will be monitored throughout the 2020 season to evaluate if the higher biomass treatments overtake the bare fallow.

A separate report will detail results from summer cover crops in LONG fallow paddock scenarios.

## Useful resources

http://grdc.com.au/Resources/Factsheets/2015/09/Blackleg-Management-Guide-Fact-Sheet

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## 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. Sincere thankyou to John Piltz (NSW DPI) for feed test analysis, Peter Roberts and Jess Perry for field work assistance and the local grower and advisor committee that helped direct this research. Special thankyou to our trial hosts Stuart and Ellen McDonald of Canowindra, and Matt Burkitt of North Parkes Mines.

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Notes

# Yield stability across sowing dates: how to pick a winner in variable seasons?

***Felicity Harris*[1], *Hongtao Xing*[1], *David Burch*[2], *Greg Brooke*[3], *Darren Aisthorpe*[4], *Peter Matthews*[5] and *Rick Graham*[6].**

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## Keywords

- flowering time, adaptation, sowing opportunity

## Take home messages

- Match optimal flowering period to growing environment to maximise grain yield potential.
- One variety doesn't fit all; there are no commercially available varieties that are broadly adapted across a wide range of sowing times or growing environments.
- Optimising variety phenology and sowing time combinations achieves grain yield stability across a wide sowing window.
- Probability of sowing opportunities will influence variety choice and sowing time decisions.

## Background

Across the Northern grains region (NGR), wheat is sown across a window from early to late autumn (April–May). There are a range of commercial cultivars which vary in their phenology from slow developing winter types to fast developing spring types, providing growers with flexibility in their sowing window. Field experiments were sown at ten locations in the NGR to determine phenology and yield responses across different environments. The experiments were conducted from 2017 to 2019, and annual rainfall at the ten locations ranged from 184mm to 620mm. The aim of these experiments is to provide growers with regional information about variety adaptation and recommended sowing times.

## Aim to target optimal flowering period (OFP) for your growing environment

Across the environments of the NGR, one of the primary drivers of yield and grain quality is flowering time. When considering variety options at sowing, growers should aim to synchronise crop development with seasonal patterns so that flowering occurs at an optimal time. This period is a trade-off between increasing drought and heat threat, and declining frost risk. Across the NGR, the optimal flowering period (OFP) varies from late July in central Queensland to mid-late October in southern NSW. There is no 'perfect' time to flower when there is no risk, rather there is an optimal period based on minimising risks, and maximising grain yield based on probabilities from previous seasons.

Previously, we proposed OFPs from simulations using the APSIM cropping systems for locations across the NGR, based on historical climatic records (1961–2018) according to the parameters outlined by Flohr et al. (2017) for a fast spring genotype (Harris et al. 2019). These OFPs have now been validated using recorded flowering dates and grain yield from field experiments conducted across the NGR from

2017 to 2019. It was determined that the OFP varies significantly in timing and duration, as well as for different yield levels across environments (Figure 1). As flowering time is a function of the interaction between variety, management and environment; the variety x sowing time combinations capable of achieving OFP and maximum grain yield also varied across environments of the NGR (Figure 1).

In very dry seasons, such as 2019, yields are often higher when the crops flower earlier than the OFP; while in wetter seasons, such as 2016, flowering later does not induce the same yield penalties. Despite this, our field data supports the idea that growers should target the OFP for their growing environment to achieve maximum grain yield potential.

## One cultivar doesn't fit all - need to match variety and sowing time

Timing of flowering is influenced by phenology (genotype (G)), location and season (environment (E)) and sowing time (management (M)). Significant G × E × M interactions influencing grain yield responses across environments have been identified. The implication of these findings is that there are no commercially available varieties that are broadly adapted across a wide range of sowing times or growing environments. Differences in seasonal rainfall and temperature extremes imposed during the critical flowering period, which could have been influenced by sowing time, indicated that variety performance is also highly dependent on season. Despite this, there is evidence to suggest that variety choice can be exploited by growers to achieve OFPs and relatively stable yields across a wide sowing window. For example, in Wagga Wagga, southern NSW, winter wheat (for example; LongReach⁽ᴰ, Kittyhawk⁽ᴰ and Longsword⁽ᴰ) require earlier sowing to flower within the optimal period, due to their extended phase duration and slower development pattern. Slower developing spring types (for example; Lancer⁽ᴰ) are suited to late-April, early-May sowing dates, while mid to fast spring types (for example; Beckom⁽ᴰ, Condo⁽ᴰ) are sown mid-late May to synchronise development and target the OFP (Figure 2).

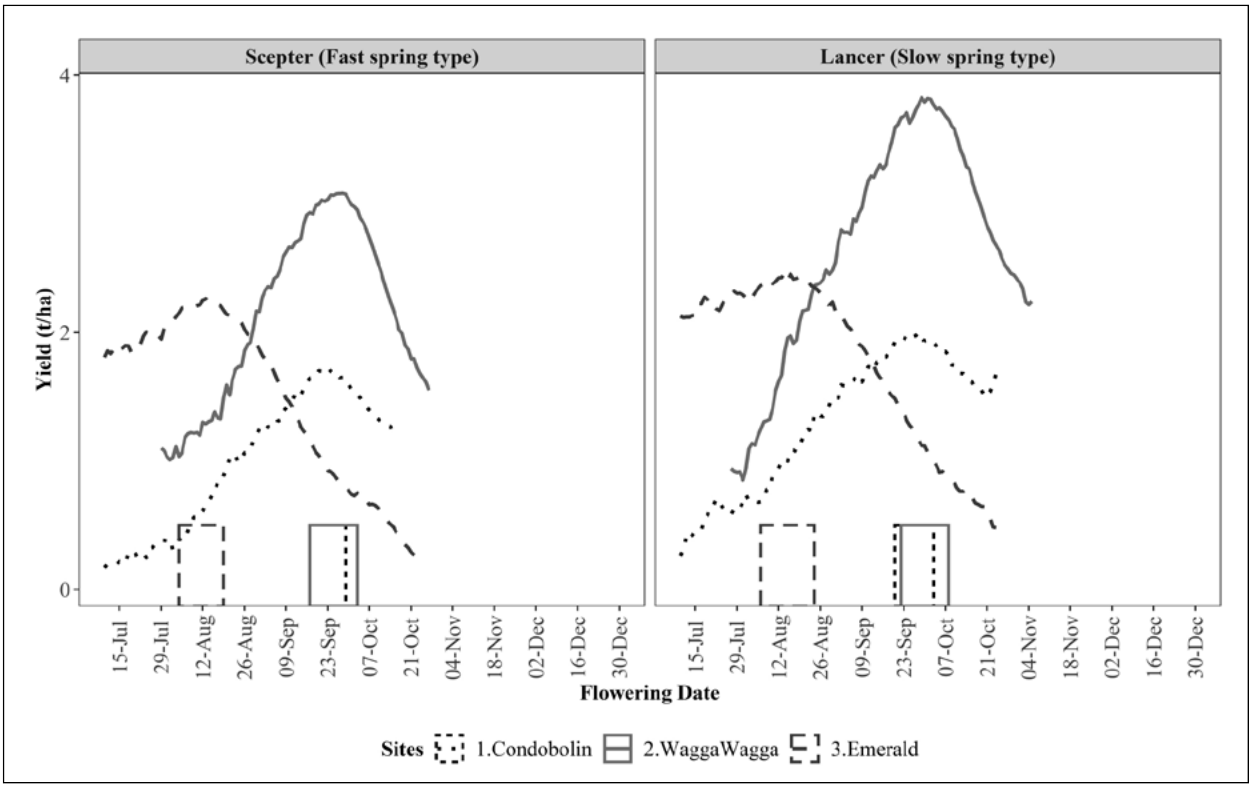


**Figure 1.** The optimal flowering period (OFP) for a fast spring variety (Scepter⁽ᴰ) and a slow spring variety (Lancer⁽ᴰ) determined by combining field data from experiments (2017-2019) and APSIM simulation using methods of Flohr et al. (2017) for Condobolin, Wagga Wagga and Emerald. The lines represent frost and heat limited yield (kg/ha), while the boxes on the x-axis represent the predicted OFP defined as ≥ 95% of the maximum mean yield.

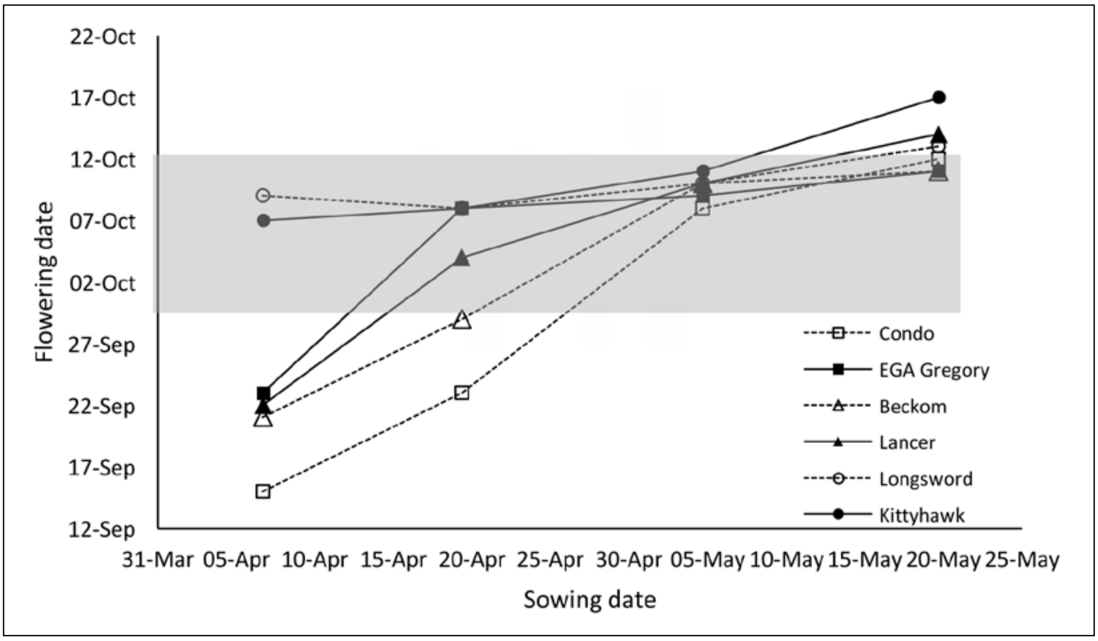


**Figure 2.** Mean heading date responses from selected winter and spring cultivars at Wagga Wagga (2017-18) and Marrar (2019) across all sowing times. Shaded area represents the optimal flowering period.

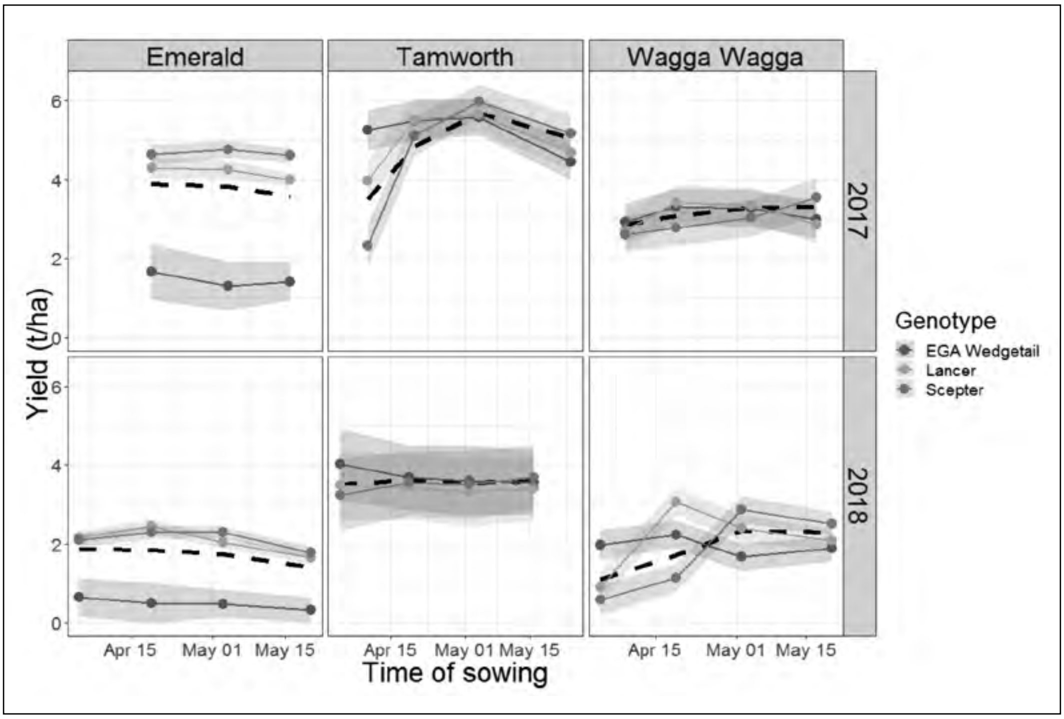


**Figure 3.** Predicted grain yield responses across sowing dates from early-April to late-May at Emerald, Tamworth and Wagga Wagga sites in 2017 and 2018 for selected genotypes; EGA Wedgetail⊕ (winter type), Lancer⊕ (mid spring type), Scepter⊕ (fast spring type).

In southern NSW, when slower developing varieties (for example; winter type EGA Wedgetail⊕) are sown early and achieve OFP, they are capable of higher water-limited yields compared with faster developing spring varieties sown later. However, faster developing varieties (for example; Scepter⊕) are better adapted to regions with shorter growing seasons, and in environments or later sowing scenarios where frost and heat stresses occur in close proximity to each other (Figure 3). **Relevant sowing date and variety recommendations will be presented regionally at GRDC Grains Research Updates in February and March.**

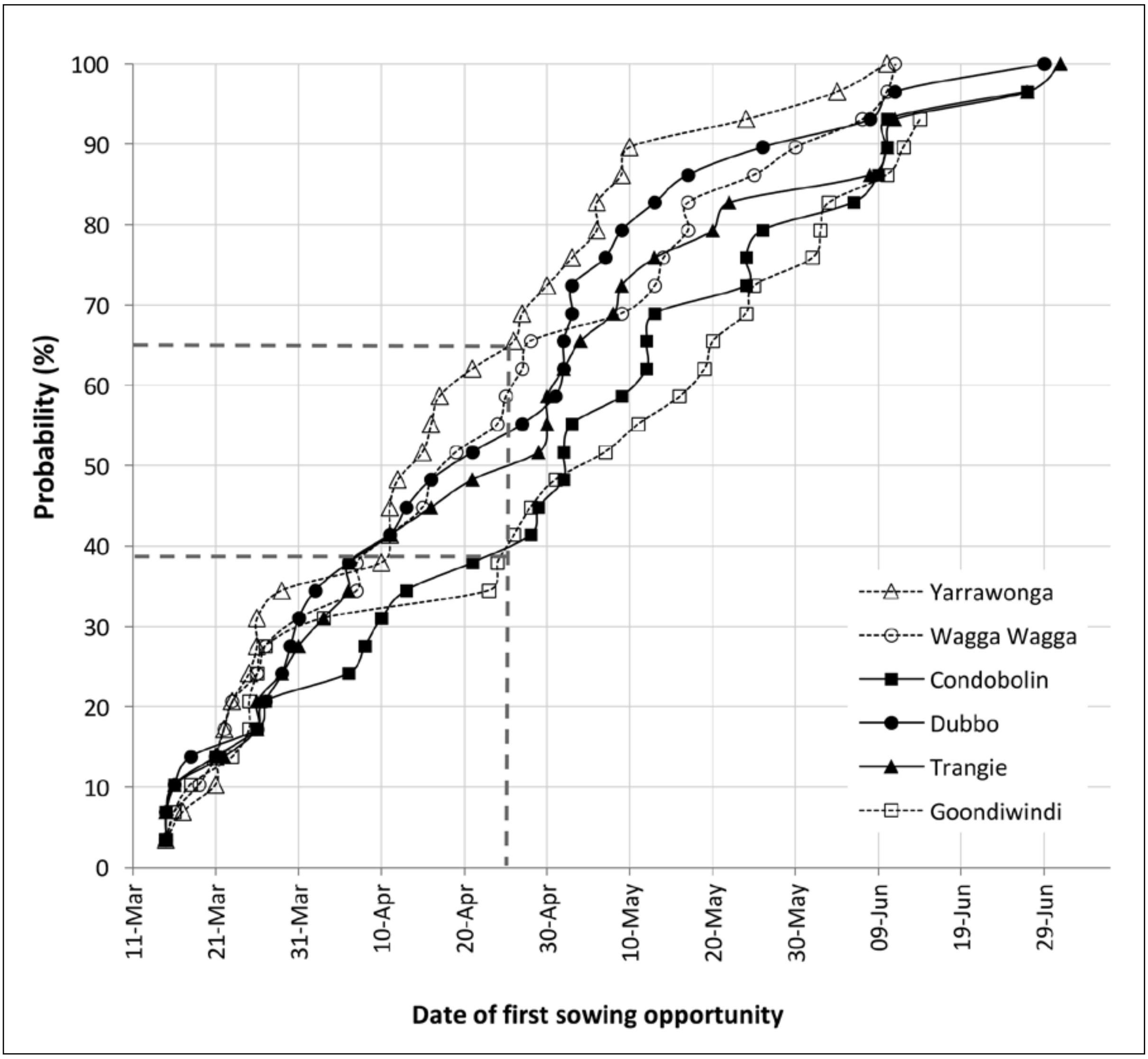


**Figure 4.** Probability distribution of first sowing opportunity for sites across the Northern grains region from 2000-2018 using the methods of Unkovich (2010). The dashed grey line pinpoints the probability of the sowing opportunity prior to 25 April for Condobolin and Yarrawonga.

## Likelihood and timing of sowing opportunities varies across growing environments

Matching flowering date to a growing environment can be a challenge, as the timing of the seasonal break is highly variable. A simulation was conducted to determine the probability of a sowing opportunity occurring across locations of the NGR using methods described in Unkovich (2010). According to this sowing rule, the timing of a sowing opportunity whereby there is sufficient seedbed moisture to establish a wheat crop, differs across environments. Therefore, sowing opportunities will influence variety choice and sowing time decisions also. For example, the probability of a sowing opportunity prior to 25 April was 38% at Condobolin, compared to 65% of years at Yarrawonga (Figure 4). As such, there are limited opportunities to sow a winter wheat at Condobolin, however probability increases to approximately 70% by early-May and the opportunities increase for mid-fast developing varieties. In contrast, growers in Yarrawonga have more flexibility in their sowing window and could consider incorporating slower developing or winter types for earlier sowing in their program.

## Conclusion

There were significant interactions between G × E × M, whereby genotypic responses to sowing date varied across sites in the NGR, and within seasons for varieties with varied phenology patterns. These findings indicate that the varieties tested are not broadly adapted to environment or management, and as such there is scope for growers to optimise grain yield through variety selection and management of sowing date by considering phenology responses and target OFPs.

## Acknowledgements

This research was a co-investment by GRDC and NSW DPI under the Grains Agronomy and Pathology Partnership (GAPP) project in collaboration with Department of Agriculture and Fisheries, Queensland. The research presented in this paper was 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.

Sincere thank you for the technical assistance of Hugh Kanaley, Cameron Copeland, Dean Maccallum, Mary Matthews, Jessica Simpson, Ian Menz, Bren Wilson and Javier Atayde at the Wagga Wagga, Marrar and Wallendbeen sites; Nick Moody, Braden Donnelly and Daryl Reardon at the Condobolin site; Peter Roberts and Jess Perry at the Cargo site; Jayne Jenkins and Paddy Steele at the Trangie and Wongarbon sites; Stephen Morphett, Michael Dal Santo, Jim Perfrement, Jan Hosking and Bruce Haig at the Tamworth, Breeza and Narrabri sites; John Lehane at the Wellcamp and Pampas sites; Ellie McCoske and Jane Auer at the Emerald site.

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Notes

# How does phenology influence yield responses in barley?

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## Keywords

- optimal flowering period, frost, sowing date, adaptation.

## Take home messages

- The optimal flowering period (OFP) to maximise grain yield potential and minimise effects of abiotic stresses in barley is earlier than for wheat and varies across growing environments
- Flowering time and grain yield is optimised with different variety x sowing date combinations, and varietal suitability varies across growing environments
- Relative frost risk of barley is lower than for wheat, and commercial barley varieties differ in frost tolerance

## Background

Maximum grain yield potential is achieved when crop development is synchronised with growing environment. Typically, barley is sown in a window from early–late autumn (April–May), to ensure flowering occurs at an optimal time in spring. This optimal flowering period (OFP) is defined early, by the risk of reproductive frost damage, and later, by high temperatures and terminal water stress during grain filling. Barley is considered to be more widely adapted, have superior frost tolerance, and has a yield advantage compared to wheat across environments of southern Australia (Harris et al., 2019), despite this, OFPs for barley have not been adequately defined which has implications for variety choice and sowing dates for growers.

## Field experiments – Condobolin and Marrar, 2019

In 2019, field experiments were conducted at Condobolin and Marrar to investigate interactions between phenology, sowing date and growing environment. Cultivar responses were significantly influenced by seasonal conditions, with both sites recording below average growing season rainfall (April to October) and severe heat stress events which coincided with the late flowering to early grain filling period (Table 1).

### *Phenology and yield responses to sowing date, 2019*

Variety and sowing date combinations which flowered in early-mid September at Condobolin, and in mid-late September at Marrar achieved the highest yields in 2019. This indicates that OFPs vary in timing and duration across different yield environments, as described for wheat (Flohr et al., 2017). As flowering time is a function of the interaction between variety, management and environment, the variety x sowing time combinations capable of achieving OFP and maximum grain yield also vary across environments (Figure 1). At both sites, optimal flowering time were achieved by fast winter type Urambie$^{\phi}$ sown mid-late April, spring cultivars sown mid-May, and some faster finishing spring types (e.g. La Trobe$^{\phi}$ and Fathom$^{\phi}$ ) capable of flowering within the optimal window when sown late-May. However in 2019, which was characterised by minimal frost risk, significant heat stress and terminal drought (Table 1), earlier flowering resulted in higher grain yields at both sites (Table 2).

**Table 1.** Growing season rainfall (GSR) April to October, frost and heat events at Condobolin and Marrar, 2019.

| Site | GSR (mm)^ | Frost events (days <0°C) | Heat events (days >30°C) | Comments |
|---|---|---|---|---|
| Condobolin | 144 (246) | 5 | 9 | • Minimal frost, no days <-2°C |
| | | | | • Heat events coincided with late grain-filling phases: 1 day >30°C early October, 4 days >30°C late October-early November |
| | | | | • 60 mm supplementary irrigation prior to sowing, additional 110 mm irrigation in-crop (May-September) to target Decile 5-6 yield potential. |
| Marrar | 194 (272) | 3 | 8 | • Minimal frost, no days <-2°C |
| | | | | • Heat events coincided with early grain-filling phases: 2 days >30°C early October, including 31.1°C (3 Oct) and 34.1°C (6 Oct); 7 days >30°C (23 Oct-2 Nov) |
| | | | | • SD1 (18 April) established with 10 mm supplementary irrigation via drippers; site rain fed thereafter. |

*^Long term average (LTA) in parentheses*

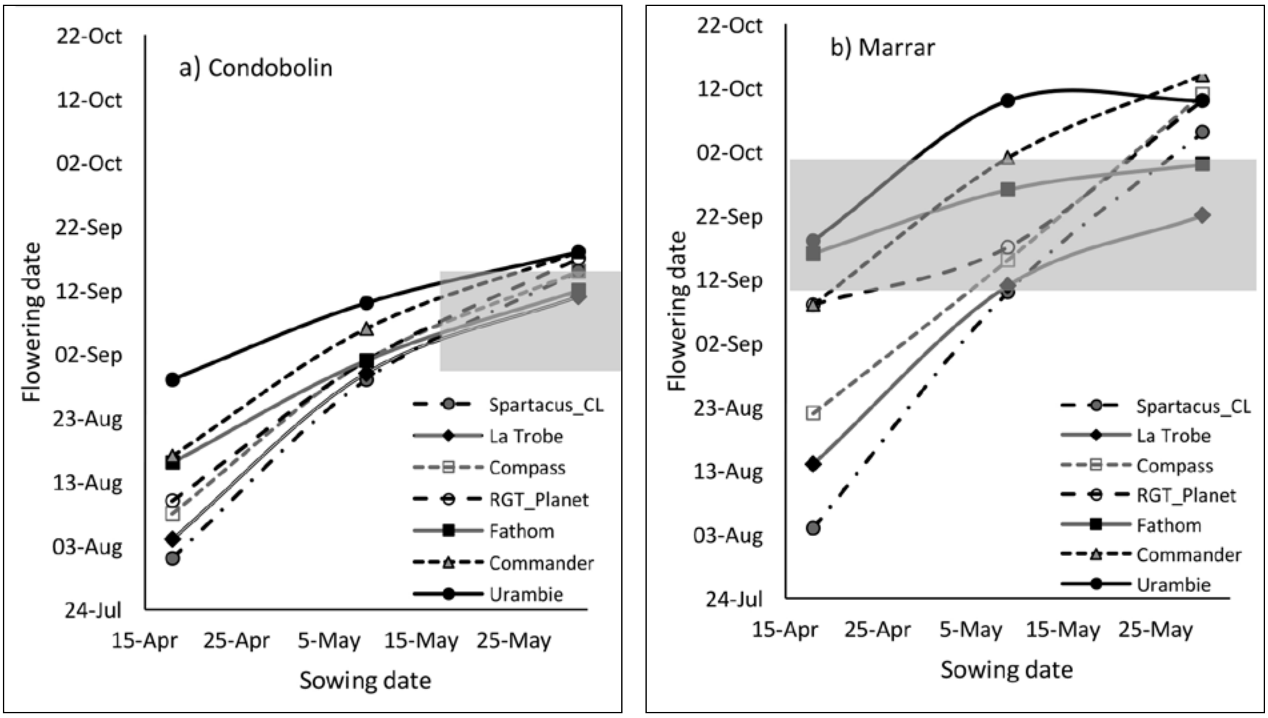


**Figure 1.** Flowering date responses to sowing date for selected varieties at a) Condobolin and b) Marrar field experiments in 2019. Shaded area indicates proposed optimal flowering period (OFP) at each location.

*How does barley optimal flowering period (OFP) compare to wheat?*

A preliminary comparison of co-located wheat and barley field experiments conducted in two contrasting seasons (Wagga Wagga, 2018 and Marrar, 2019) suggests that the OFP, whereby grain yield was maximised, for barley is significantly earlier, and relative frost risk lower than wheat, which has implications for variety choice in relation to sowing time for growers (Figure 2).

*Cultivar adaptation to growing environment*

A comparative analysis between yields of RGT Planet⦶ and La Trobe⦶ from field experiments conducted at Condobolin (2017-19), Matong (2017), Wagga Wagga (2016-18), Marrar (2019) and Wallendbeen (2018-19) showed that these cultivars often achieved similar grain yields (Figure 3).

Generally, in environments where grain yields were less than 2.5-3 t/ha, or in seasons such as 2019, with severe heat and terminal drought stress,

**Table 2.** Grain yield responses to sowing date for barley varieties at Condobolin and Marrar, 2019.

| Variety | Condobolin | | | Marrar | | |
|---|---|---|---|---|---|---|
| | 18 April | 9 May | 1 June | 18 April | 9 May | 30 May |
| Banks⟨PBR⟩ *(Mid spring)* | 3.54 | 3.13 | 2.14 | 3.53 | 3.35 | 2.80 |
| Biere⟨PBR⟩ *(Fast spring)* | 2.64 | 2.65 | 2.00 | 3.67 | 2.66 | 2.59 |
| Cassiopée *(French winter)* | 1.59 | 1.17 | 0.79 | 1.80 | 1.64 | 1.17 |
| Commander⟨PBR⟩ *(Mid spring)* | 3.73 | 2.35 | 1.86 | 3.62 | 3.00 | 2.43 |
| Compass⟨PBR⟩ *(Fast spring)* | 4.00 | 2.99 | 2.56 | 3.96 | 3.09 | 3.03 |
| Fathom⟨PBR⟩ *(Mid-fast spring)* | 3.80 | 3.07 | 2.54 | 4.57 | 3.58 | 3.00 |
| La Trobe⟨PBR⟩ *(Fast spring)* | 4.05 | 2.90 | 2.54 | 4.28 | 3.42 | 2.69 |
| RGT Planet⟨PBR⟩ *(Mid-fast spring)* | 4.02 | 2.38 | 1.90 | 3.07 | 2.87 | 2.60 |
| Rosalind⟨PBR⟩ *(Fast spring)* | 3.54 | 2.71 | 2.93 | 4.06 | 3.76 | 3.07 |
| Spartacus CL⟨PBR⟩ *(Fast spring)* | 3.64 | 3.44 | 2.42 | 4.06 | 3.95 | 2.97 |
| Traveler⟨PBR⟩ *(Slow spring)* | 3.41 | 2.69 | 1.83 | 3.21 | 3.39 | 2.52 |
| Urambie⟨PBR⟩ *(Fast winter)* | 3.49 | 2.41 | 1.96 | 3.54 | 2.74 | 2.51 |
| **Mean** | **3.45** | **2.66** | **2.12** | **3.61** | **3.12** | **2.62** |
| **LSD (Variety)** | **0.54** | | | **0.31** | | |
| **LSD (SD)** | **0.27** | | | **0.15** | | |
| **LSD (Variety x SD)** | **0.93** | | | **0.53** | | |

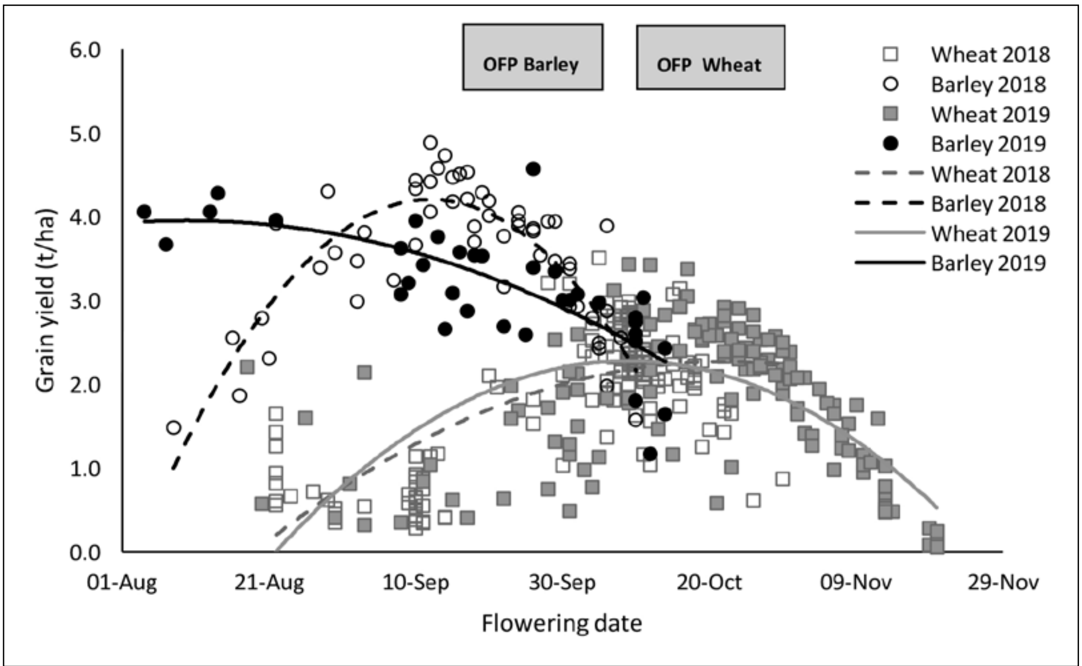


**Figure 2.** Grain yield responses to flowering date for a range of wheat and barley varieties sown from early April-late May in co-located experiments conducted at Wagga Wagga (2018) and Marrar (2019).

La Trobe⟨PBR⟩ or faster finishing types were favoured; whilst when grain yields were greater than 2.5-3 t/ha, RGT Planet⟨PBR⟩ was capable of a yield advantage. Differences in comparable yields were also apparent in relation to management, whereby RGT Planet⟨PBR⟩ offers an opportunity for slightly earlier sowing (early May) compared to benchmark fast spring type La Trobe⟨PBR⟩ which is better suited to traditional mid-late May sowing dates.

Varietal differences have been observed under high frost risk seasons, such as those experienced at Wagga Wagga in 2018, whereby RGT Planet⟨PBR⟩ was better able to maintain yield under frost conditions (SD1) compared to La Trobe⟨PBR⟩ (Figure 4). This aligns with the National Frost Initiative (NFI) barley variety rankings (Figure 5) which is a useful resource for both barley and wheat.

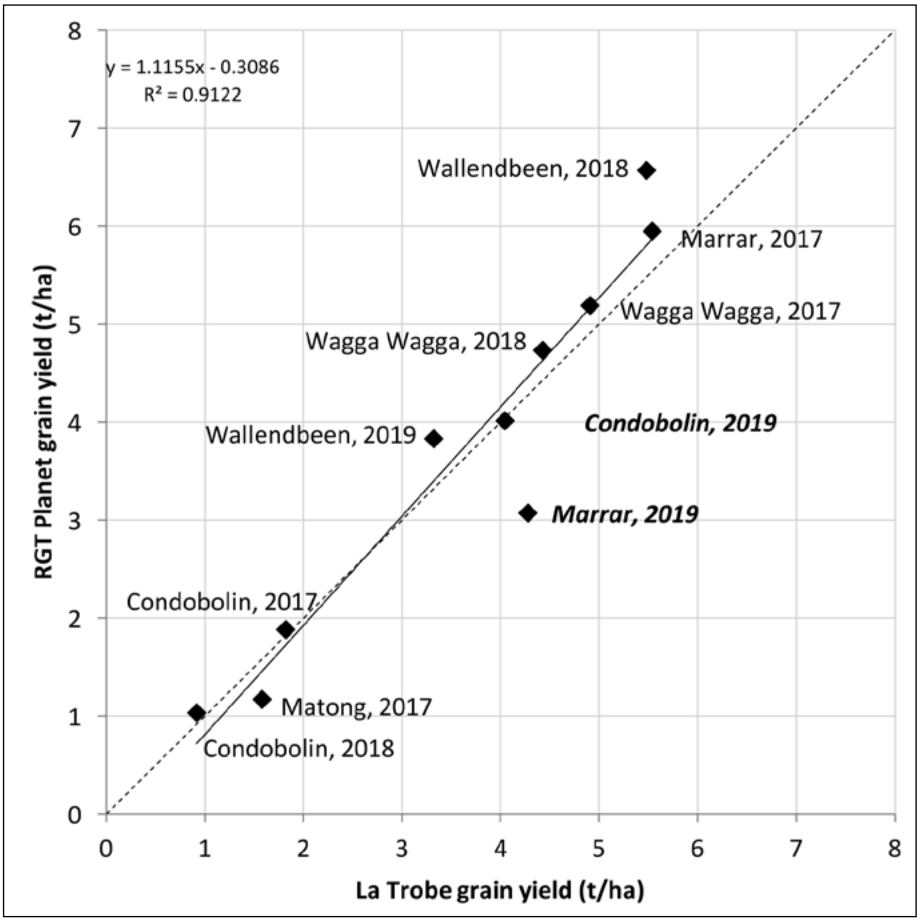


**Figure 3.** The relationship between highest yields of RGT Planet^(h) and La Trobe^(h) from field experiments at Condobolin (2017-19), Matong (2017), Wagga Wagga (2016-18), Marrar (2019) and Wallendbeen (2018-19). Dotted line indicates 1:1 relationship.

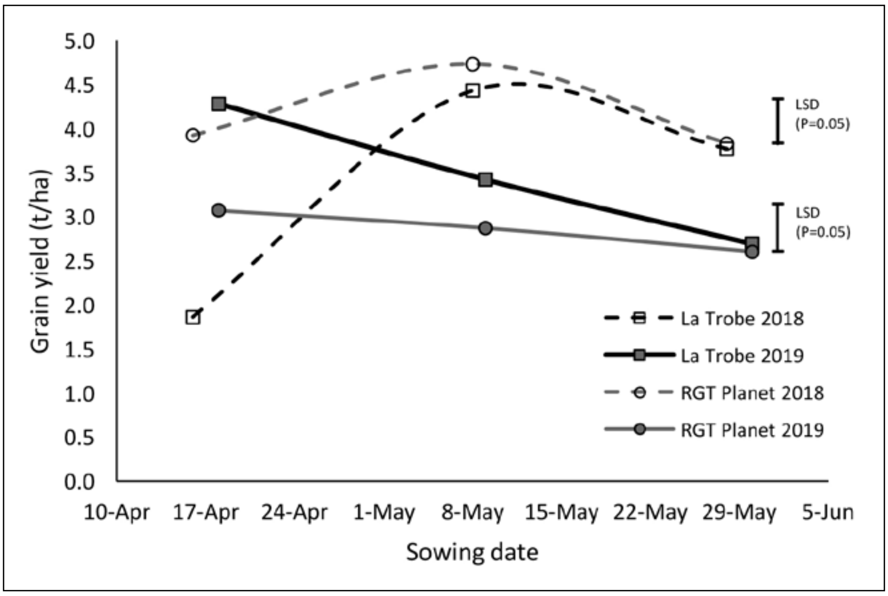


**Figure 4.** Grain yield responses to sowing date for RGT Planet^(h) and La Trobe^(h) at Wagga Wagga (2018) and Marrar (2019).

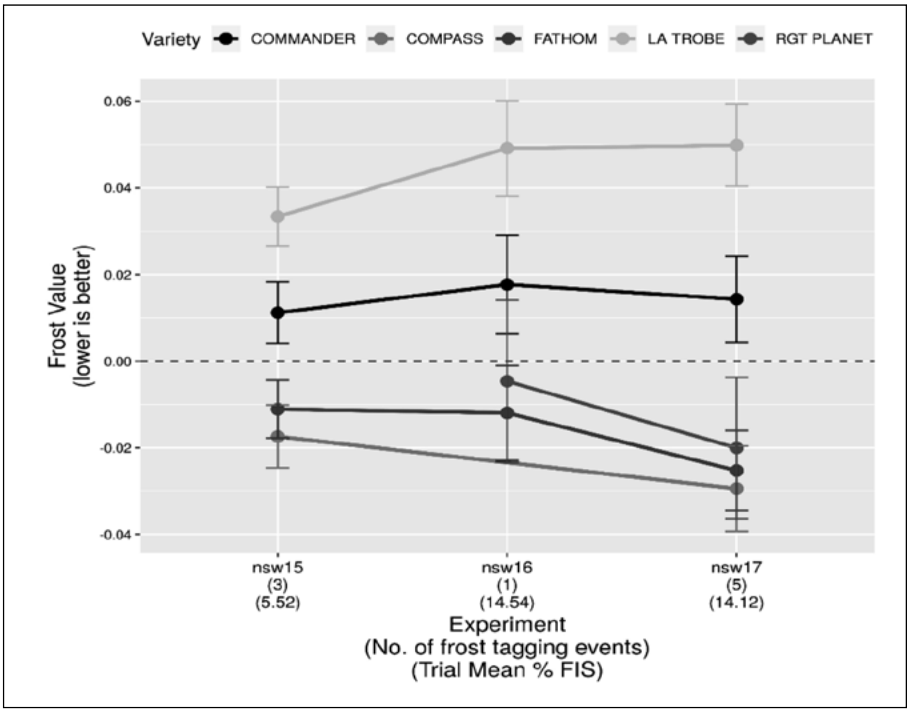


**Figure 5.** National Frost Initiative (NFI) variety rankings for selected barley varieties in northern region, based on experiments conducted in NSW (2015-2017). (Source: https://www.nvtonline.com.au/frost/)

## Conclusion

Initial comparisons indicate that the optimal flowering time (OFP) for barley is earlier than for wheat, and timing and duration of barley OFPs varies with environment. Timing of flowering and grain yield is optimised with different variety x sowing date combinations, and variety responses and suitability differ across growing environments. Most spring barley varieties are still suited to traditional May sowing dates, however some longer season spring types such as RGT Planet⁽ᵖ⁾ offer opportunities for slightly earlier sowing (early May) compared with benchmark fast spring types such as La Trobe⁽ᵖ⁾.

Whilst early sowing options in frost prone environments of southern NSW are currently limited by suitable winter varieties, there are differences in relative frost susceptibility within current commercially available varieties in NSW.

## Useful resources

https://www.nvtonline.com.au/frost/

## References

Flohr, BM, Hunt, JR, Kirkegaard, JA, Evans, JR (2017) Water and temperature stress define the optimal flowering period for wheat in south-eastern Australia. Field Crops Research 209, 108-119.

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## Acknowledgements

Sincere thank you for the technical assistance of Cameron Copeland, Dean Maccallum, Mary Matthews, Jessica Simpson, Ian Menz, Bren Wilson and Javier Atayde at the Marrar site and Braden Donnelly and Daryl Reardon at the Condobolin site.

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Notes

# Cereal production in the United Kingdom (UK) with regulation, resistance and a changing climate

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## Keywords

- regulation, resistance, yield plateau, yield gap, remote sensing, soil health, soil nutrition, fungicides, immune enhancers, semiochemicals, robotics, big data.

## Take home messages

- Reliance on conventional pesticides will diminish from the effects of regulation and resistance.
- Plant breeding and genetics have a vital part to play in the sustainability of crop production.
- There are many emerging applied technologies that will underpin the sustainability of future crop production.

## Regulation

The European Union (EU) has one of the most heavily regulated agricultural industries globally. The United Kingdom (UK)'s agrochemical (Agchem) market is affected by all of the following regulations:

- Regulation 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH).
- Regulation 1107/2009 on the Placing on the Market of Plant Protection Products (PPPR). Aims to draft 'specific scientific criteria for the determination of endocrine disrupting properties'. Deadline was originally 2013, the criteria were adopted only in 2018.
- Regulation 528/2012 on Biocidal Products (BPR).
- Regulation 2018/605 Endocrine Disruption.
- Regulation 2000/60 Water Framework Directive.

In 1993, the EU launched a review of approximately all of the 1000 active substances in the EU.

Each substance had to be evaluated with respect to human health (consumers, farmers, local residents and passers-by) the environment, groundwater, and non-target organisms, such as birds, mammals, earthworms and bees. This review program was finalised in March 2009. Some manufacturers decided not to submit dossiers. Some products were no longer profitable, or the active substances would not pass the stricter safety testing requirements. Only 26% of the actives survived the review.

**Table 1.** Active ingredients that are no longer available.

| | | | | |
|---|---|---|---|---|
| Chlorothalonil | Carbendazim | Diquat | CIPC | Fenoxaprop |
| Neonicotinoids | Methiocarb | Flupyrsulfuron | Flurtamone | Flusilazole |
| Fenpropimorph | Fluazifop | Iprodione | Isoproturon | Linuron |
| Glufosinate | Ioxynil | Paraquat | Permethrin | Picoxystrobin |
| Mecoprop | Omethoate | Simazine | Tepraloxydim | Terbutryn |
| Quinoxyfen | Quizalofop | Tralkoxydim | Tridemorph | Vinclozolin |
| Thiamefoxam | Thiram | Desmedipham | Dimethanamid | Gamma HCH |

Active Ingredients that are considered high risk of being removed in the next two to three years:

| | |
|---|---|
| **Fungicides** | Epoxiconazole, Tebuconazole, Cyproconazole, Metconazole, Mancozeb. |
| **Herbicides** | 2,4-D, Bifenox, Carbetamide, Chlortoluron, Clopyralid, Fluroxypyr, Glyphosate (Austria, France and Germany have already announced a ban), Metazachlor, MCPA, Pendamethalin Propyzamide. |
| **Insecticides** | Cypermethrin, Deltamethrin, Esfenvalerate, Thiacloprid, Metaldehyde. |

## What have been the effects of this more stringent system?

Tougher regulation has led to manufacturers submitting less actives for approval.

During the 1990s over 120 new actives were submitted for approval, but this has reduced to less than 40 in the last decade.

Because of the more stringent criteria the costs of bringing a new active to market has increased from $184m in 2000 to $286m (current). Maximum Residue Levels, Ecotox, Environmental Chemistry and Toxicology are some of the significant costs of registering a new product.

There is a much greater threat of resistance development due to fewer modes of action being available for fungicide, herbicide and insecticide options, and therefore, increased selection pressure on what remains.

Active ingredients (AIs) with a single site of action are more favoured in the new system and are more vulnerable to forming resistance than the broad-spectrum multiple site of action AIs.

The manufacturer pipeline of new actives does not seem likely to deliver a wide range of replacement AIs.

Biological controls are in their infancy and are not ready for scale up. They are also very poorly understood and early indications of their performance reliability is hugely variable and weather dependent.

## What are UK growers doing to mitigate the dwindling stock of effective plant protection products?

Strategies used by UK growers to mitigate dwindling stock of effective plant protection products:

- Choosing varieties with greater disease resistance.
- Seeding later which reduces disease potential.
- Being more selective of where they grow crops on the farm. They don't grow crops on areas with heavy weed burdens, or inherently less productive areas due to topography, soil type, drainage, etc. Environmental payments are going to take the place of subsidies, the details are yet to be announced.
- Growing more barley and less wheat. It's cheaper to grow and yields are sometimes as good as wheat.
- More spring cropping; which enables an increase in use of non-selective grass weed herbicides and spreads autumn workload.
- Spring beans, spring barley and maize for anaerobic digestors have had the most significant increases.
- The Environmental Land Management Scheme will replace subsidies and will generate income on less favoured areas for crop production.
- Reduce the area of combinable crops and rent land out for potato, sugar beet and vegetables on short-term agreements.
- Greater use of high-technology monitoring tools. For example, DNA fungal spore detectors, insect suction traps, remote sensing using unmanned aerial vehicles (UAVs), satellites, etc.
- Decision support modelling is being developed to use the information from the new Internet of Things together with location, weather, cultivars and the growth period.
- Investigations into the many biological products coming onto market is beginning to take place. In the last three years, registration applications for biologicals have been greater than conventional chemistry.

## Resistance in the UK

Resistance is becoming more widespread and at a faster rate of development than ever before. The following are examples of major resistances UK growers are having to manage.

| Fungicides | Herbicide | Insecticide |
|---|---|---|
| Septoria | Blackgrass | Grain aphid |
| Mildew | Ryegrass | Peach Potato Aphid |
| Light Leaf Spot | Poppy | Cabbage Stem Flea Beetle |
| Potato Blight | Chickweed | Pollen beetle |
| | Mayweed | Pea and Bean Weevil |

Repeated use of a smaller number of active ingredients adds more selection pressure to the remaining options.

Over the last 20 years, we have seen the efficacy of triazoles in a protectant and curative capacity drop significantly from > 90% from when they were first introduced to approximately 30% today.

In more detailed studies, the $EC_{50}$ (effective concentration) of the two key triazoles; epoxiconazole and prothioconazole have steadily increased from 0.01ppm to 5ppm for epoxiconazole, and from 0.001ppm to 1.5ppm for prothioconazole.

It is common to find the coexistence of between five to eight resistant populations in the one field. Not only are there mutations to the CYP51 protein that the triazoles bind to, but there are also two other types of resistance becoming commonplace; an over-expression gene whereby the mutated protein amplifies to greater levels than normal. There is also a mutation that affects the Efflux pump mechanism, whereby the Septoria cells actively pump out the fungicide from within to minimise the effect of the fungicide on them.

Likewise, we are seeing a marked reduction in the efficacy of succinate dehygrogenase inhibitors (SDHIs). From 2015 to 2019, their average performance had dropped from >90% to approximately 60%

The increase of resistance to pyrethroids is also concerning, especially now that neonicotinoid seed treatments are no longer permitted. It is estimated that between 30-50% of grain aphids (English Grain Aphid, *Sitobion avenae*) now carry the KdR gene. This is also reflected in the decrease of the area sown to oilseed rape due to the lack of control of the Cabbage Stem Flea beetle (*Psylliodes chrysocephalus*). Oilseed rape (OSR) grown in the UK has dropped from 758,000ha in 2012 to an estimated 483,00ha for harvest 2020.

Autumn 2019 saw the arrival of the first barley yellow dwarf virus (BYDV) resistant wheat from RAGT, a variety called Wolverine. Wolverine's resistance originates from a goat grass, *Thinopyrum intermedium*, a distant wheat relative. A genetic segment from Thinopyrum containing the resistance gene Bdv2 has been translocated onto a wheat chromosome via an Australian research line known as TC14.

*Myzus persicae* is totally resistant to pyrethroids causing problems for virus control in potatoes and sugar beet There are two BYDV resistant barley varieties and six TuMV resistant OSR varieties on the market presently.

Grass weed herbicide resistance, principally black grass and ryegrass, is a significant problem on approximately 1M hectares of wheat (50% of the UK hectarage) Both target site and enhanced metabolic resistance coexist within fields. We are beginning to see resistance building with some of the residual chemistry too; flufenacet and pendimethalin.

Of greatest concern is the observation of some blackgrass populations now becoming insensitive to doses of 540g/ha of glyphosate which would normally have been effective.

Finally, there are four broadleaved weed species that are now resistant to sulfonylurea herbicides, they are poppy (*Papaver somniferum*), chickweed (*Stellaria media*), mayweed (*Matricaria*) and sowthistle (*Sonchus asper*).

## The Yield Plateau

The phenomenon of the 'yield plateau' extends further than just the UK. A similar situation exists in other countries of Western Europe. From 1980 to 1996, UK wheat yields improved rapidly; by an average of 0.10t/ha per year. Since then, yields have stagnated, increasing by only 0.05t/ha per year.

No single agronomic factor has had a clear dominant influence on trends in UK wheat yields over the last 30 years. A proportion of the lost yield improvement remains unexplained, with aspects of climate change being amongst the likely causes. Plant breeding has continued to deliver genetic improvement.

Several theories have been put forward as to why yield has plateaued such as soil health, soil management and cultivations, compaction from heavier machinery, suboptimal nitrogen (N) and sulphur use, pesticide resistance, sowing dates and seed rates.

## The Yield Gap

There is a considerable 'yield gap' between average UK wheat yields, currently approximately 8.5t/ha and the top achieving growers. In 2019, the top Yield Enhancement Network (YEN) of growers reported an actual yield of between 14t/ha to 16t/ha, with the world record still set at 16.5t/ha.

According to YEN, 75% of yield variation is influenced by the farm's physical characteristics, crop husbandry, the agronomist and the farmer. High biomass and ear numbers are essential for high yields. The foundation period; seeding to GS31, is a very important period and crop development within this period is very heavily influenced by soil management, nutrition and good root development.

Moisture retentive soils are key to ensuring grain fill is optimum. There is a positive association with organic amendments, particularly slurry and digestate. Site, weather and husbandry factors have a bigger influence than variety choice, and therefore, varieties should be chosen for quality traits, end markets, disease resistance and standing ability rather than just yield.

There is a positive association with soil pH and with straw incorporation. The association with N fertiliser rate is very strong.

Early indication is that phosphate (P) grain content is also correlated to yield, the critical value for grain P = 3200mg/kg.

There is a negative association with liquid N probably due to the scorching of the crop if it is applied in the wrong conditions. Because high biomass and ear numbers are important, plant growth regulator (PGR)-use has a strong positive association with yield. High straw N% and soluble stem carbohydrate reserves were considered very important to maintain photosynthesis during grain filling.

*New technologies being introduced*

There are several new technologies being developed which will hopefully increase production potential.

## Plant breeding and genetics

The first BYDV resistant wheat and barley in the UK has previously been discussed within this paper. However, there are also exciting developments using a Synthetic Hexaploid breeding approach whereby one of the three wheat genomes, the D genome, is being replaced from other sources of material resulting in greater yields, and greater resistance to biotic and abiotic stress.

Work at the John Innes Centre is also looking at producing grains with increased length and width, thereby increasing the 'sink' for higher yields. Other attributes are also being researched, for example; longer spikelets that produce approximately 20% more grains, a branched ear producing 50% more grains, etc.

Advances in genetic marker-assisted speed breeding, whereby up to six generations can be achieved per year through controlled environment and Light Emitting Diode (LED) technology are enabling more rapid translation of genetic discovery into elite lines.

## Remote sensing

There are many new capabilities being developed to assist the farmer and agronomist to manage crops more effectively, many of which are satellite based.

Monitoring of crop health through normalised difference vegetation index (NDVI) measurements, biomass measurements, Green Area Index, crop growth rate, plant stress are all operational and enable farmers/agronomists to target their time more effectively by targeting the inspection of problem areas of paddocks rather than general field walking.

Hyperspectral, pre-symptomatic disease signatures are currently being developed in Controlled Environment conditions by Hummingbird Technologies.

Ground Penetration Radar is now available from satellites and has the capability of penetrating soils up to 1m. This technology has the capability of detecting compaction in subsoils, as well as soil moisture for irrigation scheduling purposes.

Another form of remote sensing; Synthetic Aperture Radar, is an active wavelength which has the potential to penetrate cloud and can also deliver information in the dark.

Field based spore sensors that can be primed to detect the DNA of multiple diseases from the surrounding air are also being developed and would be another key feature in the early detection and intervention of disease ingression. Portable LAMP assay kits are now becoming available whereby growers can take leaf samples and look for the presence of pathogen DNA on recently emerged leaves.

Another approach is a 3D printed spore trap being developed by the University of Manchester and Sony. A mimic leaf is embedded with sensors that look for the presence of disease enzymes that are used to penetrate the vascular system of the plant and wreak havoc, or pressure sensors to detect the appressorium (pegs) that some diseases; such as rust, use to enter the leaf surface.

## Soil health and nutrition

Volatile Organic Compounds (VOCs) are the basis of a new infield technology being developed by PES technologies. The small detector, about the size of a matchbox, is filled with soil and the VOCs that are detected give an indication of the key indicators of soil health.

Variable rate N capabilities are now commonplace with the more progressive farmers.

The age-old debate as to whether to put more or less N on the poorer parts of the crop rages on. A new product from Hummingbird technologies enables growers to test the option of inversing the approach to N at the click of a box. In practical terms, if extra N applied on the lower biomass areas of the crop hasn't produced a positive effect, then less will be applied on the second split, thereby optimising gross margins.

More knowledge is being developed regarding optimum nutritional thresholds during the key stages of crop development. Tissue and grain testing are becoming a more reliable method to test nutrient levels compared to soil testing.

Infield soil sensors are starting to make an appearance. The Terralytic soil probe has 26 sensors and measures soil moisture, salinity, and N, phosphorus (P) and potassium (K) at three different depths, as well as aeration, respiration, air temperature, light, and humidity

The Terramap, which is a small measuring device fitted to an all-terrain vehicle (ATV), measures four naturally emitted isotopes - Caesium-137 (Cs), Uranium-238 (U), Potassium-40 (K) and Thorium-232 (Th). There are approximately 800 reference points per hectare. In comparison, grid sampling map layers have only a single data point per hectare. Strategic soil samples are taken from each paddock and then the scan data and soil sample results are combined and processed to produce up to 21 high-definition soil property layers; P, K, magnesium (Mg), pH and % of clay, sand, silt, calcium, sodium, manganese, boron, copper, molybdenum, iron, zinc, sulphur, organic matter (OM), salinity (CEC) and plant available water are all delivered.

## Fungicides, immune enhancers and semiochemicals

After a long time, two new fungicides have arrived on the UK market this season. The first is Revysol® (mefentrifluconazole), a new type of triazole, an isopropanol-Azole, which has been a top performer in AFD trials this year. The second is awaiting imminent approval, InatreqTM from Corteva which is based on a fermentation product of a soil borne Streptomyces bacteria. This has a very similar mode of action as the strobilurins; it acts on complex 3 of the mitochondria.

Plant immune enhancers have been introduced into the market, but their use in terms of timing, dose and frequency is still to be determined. They are based on both systemic acquired resistance and induced systemic resistance. They work by stimulating the salicylic and jasmonic acid pathways. If successful in their development, they could be an important part of a resistance management program

Semiochemical technologies are also currently being developed. An example is; jasmonic acid which naturally repels insects and tricks insects into believing the host is decaying and under attack, and therefore, the plant would not make a viable host.

Others disrupt the mating cycle of insects by confusing the male insect so that it is unable to find a female to mate with. This reduces pest populations.

Attractants can also be used to lure insects into traps containing insecticides. These can be used in conjunction with evolving 'smart trap' technologies whereby insect species are identified and counted, enabling more effective insect control management strategies.

## Alternatives to herbicides

The future of glyphosate still hangs in the balance following the current approval period which ends in 2022. Various other techniques are being investigated, for example; the use of pelargonic acid, laser weeding and electronic weeding.

Hight voltage weeding, while very effective and quick in the resulting kill, still must overcome the practical difficulties of generating enough tractor mounted voltage to optimise width and speed of travel.

Laser weeding, whether by robots or boom mounted is more appropriate for wide-row horticulture crops rather than broadacre commodity crops.

Pelargonic acid as a standalone product is not as active on weeds as glyphosate but can considerably enhance the effect of low rates of glyphosate. It has a high application rate of 20-30L/ha which has implications for application and storage

## Robotics

There is a lot of activity in this area, but most of the technologies are going to be more suited to horticulture/top fruit crops rather than broadacre commodity crops. Fruit sizing, colour detection and picking are all being developed as well as laser weeding.

The Small Robot Company is developing a partnership of robots – one detects, the other implements. They have a philosophy of 'per plant' establishment and management which they believe will replace conventional methods.

## Big data

Finally, 'big data' is a direct consequence of the Internet of Things in agriculture. I don't think we have yet seen the full extent of the advantages of the use of 'big data'. A new UK government funded Agritech Centre, Agrimetrics is developing new services for farming that utilise 'big data'.

Data, at a global level, is on an exponential rate of use, and has increased from 30-40 zettabytes from 2019 to 2020 (1 Zb = 1 trillion gigabytes).

Omnia, a GIS service on offer from Hutchinsons can analyse multi- layers of crop information to give more insight into the output potential of a specific paddock. Yield data from combines, soil sampling, etc. can be compared across many seasons and variable rate applications adjusted accordingly.

## Useful references


Regulation (EC) 1107/2009 on the Placing of Plant Protection Products on the Market,

http://www.europarl.europa.eu/RegData/etudes/STUD/2018/615668/EPRS_STU(2018)615668_EN.pdf

European Commission, Communication from the Commission to the Council and the European Parliament - Community strategy for endocrine disrupters - A range of substances suspected of interfering with the hormone systems of humans and wildlife, COM (1999)706 final, 1999. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:51999DC0706

Registering a Pesticide: http://www.pesticides.gov.uk/guidance/industries/pesticides/topics/pesticide-approvals/pesticidesregistration/ ; registering-a-pesticide.htm

Pesticides Usage Survey: https://secure.fera.defra.gov.uk/pusstats/surveys/

Fungicide resistance action group https://ahdb.org.uk/frag

Insecticide resistance action group https://www.irac-online.org/

Weed resistance action group https://ahdb.org.uk/wrag

Yield Plateau – report commissioned by AHDB https://ahdb.org.uk/Tags/Yield%20Plateau

Yield enhancement network (YEN), connects agricultural organisations and farmers who are striving to improve crop yields: https://www.yen.adas.co.uk/

AHDB Fungicide Performance, independent information on the efficacy of fungicides against key diseases in wheat, barley and oilseed rape: https://ahdb.org.uk › fungicide-performance

Tissue derived optimum nutrient thresholds for wheat: https://www.lancrop.com/

Teralytic Wireless NPK soil probe and an analytics platform: https://teralytic.com/

Terramap – passive, gamma-ray detection technology providing high-definition mapping of all common nutrient properties: https://www.omniaprecision.co.uk/terramap/

Omnia Precision: https://www.omniaprecision.co.uk/

Small Robot Company: https://www.smallrobotcompany.com/meet-the-robots#weed-killing

Hummingbird Technologies, crop data analytics using satellites, fixed wing and drones: https://hummingbirdtech.com/

Electronic weeding: https://zasso.com/

Agrimetrics, provides data, tools and services to agrifood businesses: https://agrimetrics.co.uk/


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Notes

Notes

# THE 2017-2020 GRDC NORTHERN REGIONAL PANEL

JANUARY 2020

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

### CHAIR - JOHN MINOGUE

➡ John Minogue runs a mixed broadacre farming business and an agricultural consultancy, Agriculture and General Consulting, at Barmedman in south-west NSW. John is chair of the district council of the NSW Farmers' Association, sits on the grains committee of NSW Farmers' Assn and is a winner of the Central West Conservation Farmer of the Year award. His vast agricultural experience in central west NSW has given him a valuable insight into the long-term grains industry challenges.

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### DEPUTY CHAIR - ARTHUR GEARON

➡ Arthur is a grain, cotton and beef producer near Chinchilla, Queensland. He has a business degree from the Queensland University of Technology in international business and management and has completed the Australian Institute of Company Directors course. He is a previous vice-president of AgForce Grains and has an extensive industry network throughout Queensland. Arthur believes technology and the ability to apply it across industry will be the key driver for economic growth in the grains industry.

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### ROGER BOLTE

➡ Roger Bolte is a fourth-generation farmer from the West Wyalong area in NSW, operating a 6500 ha winter cropping program with his wife and family focusing on cereals, legumes and hay. During his 35-years in the industry, Roger has been involved in R&D in various capacities and has had the opportunity to travel abroad and observe a variety of farming systems. He believes that R&D and education are the cornerstones of the industry and feels privileged to be afforded the opportunity to share his experiences.

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### ROY HAMILTON

➡ Roy Hamilton operates Riverina with his wife Leanne, son Sandy and daughter-in-law Sara. He was an early adopter of minimum till practices and direct drill and press wheel technology and is currentlycurrently running CTF on 12m 3-1. The majority of the property (80%) is cropped with wheat, canola, barley, triticale, faba beans while the remainder under pasture runs 1,400 ewes and trade lambs. He has held roles on the south east NSW Regional Advisory Committee, the GRDC's southern region Regional Cropping Solutions Network and was a founding committee member of the Riverine Plains farming systems group.

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### DR TONY HAMILTON

➡ Tony is an agricultural consultant. He was a farmer in the Forbes region for 30 years. He is a director of the Rural Industries Research and Development Corporation. He has worked as an agricultural consultant in WA and southern NSW. With a Bachelor of Agricultural Science and a PhD in agronomy, Tony advocates agricultural RD&E and evidence based agriculture.

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### ANDREW MCFADYEN

➡ Andrew is a grower and private agricultural consultant near Lake Cargelligo NSW with more than 21 years agronomy and and practical farm management experience. He is an active member of the grains industry with former roles on the Central East Research Advisory Committee, NSW Farmers Coolah branch and has served on the GRDC northern panel since 2015. He is also a board member and the chair of Grain Orana Alliance.

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### PETER MCKENZIE

➡ Peter operates a private agronomy consulting business based in Quirindi NSW. Prior to this he was facilitator/agronomist for AgVance Farming group, a communications conduit between industry and growers. He is a passionate supporter of research and has been active in extending weed management research information to industry, particularly in central west NSW, is a former director of Conservation Farmers Inc., a former member of the North East Regional Advisory Committee and a participant in Northern Growers Alliance local research group on the Liverpool Plains.

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### GRAHAM SPACKMAN

➡ Graham has conducted a private agricultural consultancy at Emerald, Queensland, for the past 30 years which provides agronomy and farm business management advice in summer and winter, dryland and irrigated crops in grain and mixed grain/grazing farming systems in the region. He has participated in two decades of GRDC and Qld DPI funded farming systems research, development and extension projects, particularly in the areas of weed management, soil fertility and adaption of agronomy practices in CQ climate and farming systems.

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### BRUCE WATSON

➡ Bruce and his family operate a 3400 ha family grain growing business near Parkes NSW, which

produces a mixture of dryland winter cereals, pulses and oilseeds as well as summer dryland cereals, pulses and cotton grown on a 12m zero till CTF platform with full stubble retention. Bruce holds a Bachelor of Agricultural Economics from the University of Sydney and previously worked with PricewaterhouseCoopers in its Transfer Pricing practice. He is an active member of the grains industry and was awarded a Nuffield Scholarship in 2009. Bruce is interested in both transformational or blue sky research and continues to ensure that existing research delivers profitability to grower's businesses.

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### DR JO WHITE

➡ Dr Jo White is an experienced researcher with over 15 years' experience in agricultural research programs based at the Department of Agriculture and Fisheries in Queensland (DAFQ) and the University of Southern Queensland (USQ), including 10 years' experience in the field of plant pathology of broad acre summer crops. Jo has a keen interest in developing and delivering on-ground practical research solutions to growers which improve productivity and profitability of their farms and is now working as a private consultant based in Queensland.

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NORTHERN REGION*

# PREDICTA® B

# KNOW BEFORE YOU SOW

*NORTHERN NSW AND QUEENSLAND

**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
- Root lesion nematodes
- Yellow leaf spot
- Common root rot
- Pythium clade f
- Charcoal rot
- Ascochyta blight of chickpea
- Sclerotinia stem rot
- Long fallow disorder
- Phytophthora root rot
- Fusarium stalk rot
- 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

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We would like to thank those who have contributed to the successful staging of the Corowa GRDC Grains Research Update:

- The local GRDC Grains Research Update planning committee including both government and private consultants and GRDC representatives.

- Partnering organisation: Riverine Plains Inc.

- Industry supporters: Seed Force and Goanna Ag


Prefer to provide your feedback electronically or ‘as you go’? The electronic evaluation form can be accessed by typing the URL address below into your internet browsers:

www.surveymonkey.com/r/Corowa-GRU

To make the process as easy as possible, please follow these points:

- Complete the survey on one device
- One person per device
- You can start and stop the survey whenever you choose, **just click ‘Next’ to save responses before exiting the survey**. For example, after a session you can complete the relevant questions and then re-access the survey following other sessions.

# 2020 Corowa GRDC Grains Research Update Evaluation

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

*We are committed to providing the best possible Update & welcome your feedback.*

**Your name** (optional): ______________________

**Your role in the grains industry:**

- ❑ Gov adviser
- ❑ Retail adviser
- ❑ Agribusiness
- ❑ Private consultant
- ❑ Grower
- ❑ Researcher
- ❑ Other

**Years involved in the grains industry:**

0-3 4-6 7-9 9-11 11-15 16+

*For the next four statements, please **circle the number** that best represents how you feel about each statement* ***(1 = strongly disagree, 5 = strongly agree)***

**The Update was valuable.**

**1 2 3 4 5**

**Participation increased my knowledge or awareness of grains research.**

**1 2 3 4 5**

**Participation reinforced or enhanced my industry networks.**

**1 2 3 4 5**

**Participation reinforced or improved my awareness of where to find information or who to talk to.**

**1 2 3 4 5**

**Did the Update provide information that will assist adoption of new practices or improve decision making?**

❑ Yes ❑ No ❑ Maybe

**How was the balance between new and familiar topics?**

❑ Too much new ❑ Well balanced ❑ Too little new

**What % of topics had information that will assist adoption of new practices or improve on-farm decision making?**

0 1-20 21-40 41-60 61-80 81-99 100%

Which sessions in particular?

**What % of topics contained information that was new to you?**

0 1-20 21-40 41-60 61-80 81-99 100%

Which sessions in particular?

**How many hectares of arable land (cropping country) do you manage or advise?**

**How did you hear about the Update?**

- ❑ Radio
- ❑ Flier in letterbox
- ❑ Email
- ❑ Agronomist
- ❑ Neighbour
- ❑ Website
- ❑ SMS
- ❑ Other

**How could the Update be improved?** (e.g. different session timing, more relevant topics)

**Would you attend an Update again?**

❑ Yes ❑ No

**Why or why not?**

❑ I would like to be on a **planning committee** for a future Update in my area. (If yes, please ensure your name is recorded at the top of the page.)

*Please turn over*

## HOW DID YOU VALUE THE DIFFERENT SESSIONS?

**Please review the sessions for their value to you as a grain grower/ industry** adviser by providing a **rating** (1=low value, 5 = high value), and **comments** – why did you rate this session high or low?

**1. Latest strategies in canola disease control: *Steve Marcroft***

Value Comments – why did you rate this session high or low?

/5

**2. Legacy effects of N nutrition and hay versus grain crop choice: *Graeme Sandral***

Value Comments – why did you rate this session high or low?

/5

**3. Riverine Plains research in progress: *Cassandra Schefe***

Value Comments – why did you rate this session high or low?

/5

**4. Cover crops and their impacts on the farming system – what does the local data suggest: *Col McMaster***

Value Comments – why did you rate this session high or low?

/5

**5. Drivers of yield stability in wheat and barley - picking a winner in variable seasons: *Felicity Harris***

Value Comments – why did you rate this session high or low?

/5

**6. Hitting production targets in the UK amidst a highly regulated environment: *Keith Norman***

Value Comments – why did you rate this session high or low?

/5

**7. What issues or areas of research do you see as priorities for GRDC investment? *Please list at least three.***