GRAINS RESEARCH UPDATE

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

GRDC South West Victoria

Thursday 12 August

9.00am to 11.30am AEST

#GRDCUpdates

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GRDC South West Victoria Grains Research Livestream convened by ORM Pty Ltd.

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GRDC Grains Research Update
SOUTH WEST VICTORIA
GRDC
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Contents

The WeedSmart
Big 6

Weeding out herbicide resistance in winter & summer cropping systems.

The WeedSmart Big 6 provides practical ways for farmers to fight herbicide resistance.

How many of the Big 6 are you doing on your farm?

We've weeded out the science into 6 simple messages which will help arm you in the war against weeds. By farming with diverse tactics, you can keep your herbicides working.

Rotate Crops & Pastures

Crop and pasture rotation is the recipe for diversity

- Use break crops and double break crops, fallow & pasture phases to drive the weed seed bank down,
- In summer cropping systems use diverse rotations of crops including cereals, pulses, cotton, oilseed crops, millets & fallows.

Mix & Rotate Herbicides

Rotating buys you time, mixing buys you shots.

- Rotate between herbicide groups,
- Mix different modes of action within the same herbicide mix or in consecutive applications,
- Always use full rates,
- In cotton systems, aim to target both grasses & broadleaf weeds using 2 non-glyphosate tactics in crop & 2 non-glyphosate tactics during the summer fallow & always remove any survivors (2 + 2 & 0).

Increase Crop Competition

Stay ahead of the pack

Adopt at least one competitive strategy (but two is better), including reduced row spacing, higher seeding rates, east-west sowing, early sowing, improving soil fertility & structure, precision seed placement, and competitive varieties.

Double Knock

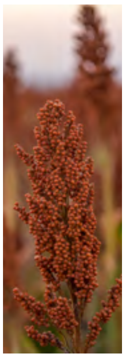
Preserve glyphosate and paraquat

- Incorporate multiple modes of action in the double knock, e.g. paraquat or glyphosate followed by paraquat + Group 14 (G) + pre-emergent herbicide
- Use two different weed control tactics (herbicide or non-herbicide) to control survivors.

Stop Weed Seed Set

Take no prisoners

- Aim for 100% control of weeds and diligently monitor for survivors in all post weed control inspections,
- Crop top or pre-harvest spray in crops to manage weedy paddocks,
- Consider hay or silage production, brown manure or long fallow in high-pressure situations,
- Spray top/spray fallow pasture prior to cropping phases to ensure a clean start to any seeding operation,
- Consider shielded spraying, optical spot spraying technology (OSST), targeted tillage, inter-row cultivation, chipping or spot spraying,
- Windrow (swath) to collect early shedding weed seed.



Implement Harvest Weed Seed Control

Capture weed seed survivors

Capture weed seed survivors at harvest using chaff lining, chaff tramlining/decking, chaff carts, narrow windrow burning, bale direct or weed seed impact mills.

WeedSmart Wisdom

Never cut the herbicide rate – always follow label directions

Spray well – choose correct nozzles, adjuvants, water rates and use reputable products,

Clean seed – don't seed resistant weeds,

Clean borders – avoid evolving resistance on fence lines,

Test – know your resistance levels,

'Come clean. Go clean' – don't let weeds hitch a ride with visitors & ensure good biosecurity.

SOUTHERN FARMING SYSTEMS

SUSTAINABLE FARMING SYSTEMS FOR THE HIGH RAINFALL ZONE

Innovative and independent; delivering relevant information.

THE BEGINNINGS

Southern Farming Systems (SFS) was founded in 1995 by a group of farmers who came together to find ways to diversify their income by making cropping in the high rainfall zone (HRZ) of Victoria more profitable through the introduction of raised bedding to minimise waterlogging.

NOW

SFS conducts practical research, development and extension in cropping, soils, pasture & livestock with 20 staff and 600 members.

WHO WE ARE

SFS is a farmer driven, non-profit organisation helping farmers with practical research and information in addressing productivity and sustainability issues in cropping, soils, pasture & livestock farming systems.

The largest farming systems group in the high rainfall zone, around six hundred members and partners in five branches across Victoria and Tasmania provide a network to share ideas, experiences and innovations.

SFS hold strong partnerships with industry, government, education and agribusiness developing information that is highly valued by its members for quality and independence.

WHAT WE DO

Our extensive research program in soils, cropping, pasture & livestock across the HRZ is accompanied by paddock walks, technical workshops, print/online resources & tools and field days throughout the season. SFS collaborates and manages major investment projects around best practice farming systems with GRDC, MLA and the Australian Government Programs.

SFS holds major events including an annual trial results meeting in March and AgriFocus on the third Wednesday of October, showcasing a range of research trials, technical tours and demonstrations. The much acclaimed SFS annual trial results eBook available to SFS members and Agronomists/advisors have access to a technical workshop annually. SFS work's collaboratively with other organisations to bring an array of workshops throughout the year, all relevant to Southern High Rainfall Zone farming enterprises.

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SFS Membership packages are flexible and offer great value; including biannual newsletters, fortnightly e-updates, Annual Trial Results ebook, free entry to all SFS field days, local crop walks and workshops, and access to our Members Only area of SFS website, previous trial report data, SFS weather station data and much more.

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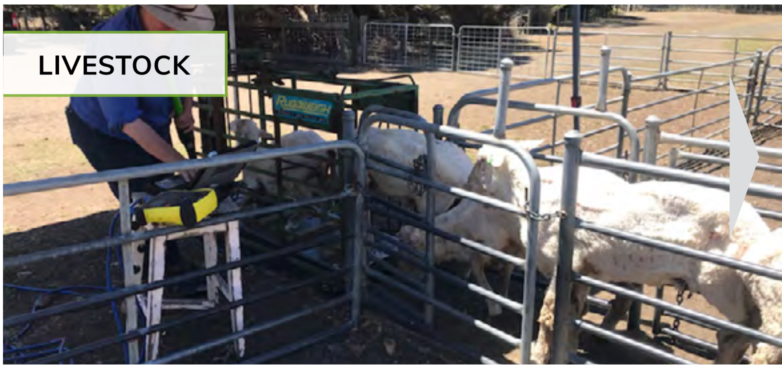
LIVESTOCK



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Yielding Crops – scaling up research results to the paddock

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GRDC project codes: FAR2004-002SAX, FAR00003

Keywords

- photo thermal quotient (PTQ), farming system fertility, nitrogen (N) fertiliser, plant growth regulators (PGRs), head wash fungicides.

The Hyper Yielding Crops (HYC) project is a GRDC national investment which aims to push the economically attainable yield boundaries of wheat, barley, and canola across five states.

Take home messages

1. Key development and environmental periods for establishing higher yield potential
   - To manage and monitor your wheat crops potential use two key development periods: 1. Start of stem elongation – flag leaf emergence (GS30 – 37) and 2. Start of flag leaf emergence to the start of flowering (GS37-61).
   - For a specific sowing date, the yield potential of wheat is set in the critical period approximately 3 weeks prior to flowering. Maximising growth and protecting the canopy in this period is critical for grain number which relates strongly to higher yields.
   - Maximising growth in this period requires the cultivar to flower in the correct window so that environmental conditions for GS37 – 61 provide optimal conditions for growth.
   - Brighter cooler days in this period ensure maximum growth of the canopy and set up the crop up for higher yields.
2. Nitrogen fertiliser input
   - Hyper yielding cereal crops cannot be produced with artificial fertiliser alone; rotations which lead to high levels of inherent fertility are essential to underpin high yields and the large N offtakes associated with bigger crop canopies.
   - It's been unusual for 10t/ha crops of wheat to generate yield responses to more than 200 - 225kg N/ha in the season that the fertiliser N is applied.
3. Plant growth regulation and its interaction with nutrition
   - To capture yields of 8 -10t/ha germplasm and or effective canopy management and PGR application is the key to keeping crops standing and harvestability.
4. Protecting the canopy from disease
   - **Disease management is one of the most important management components of growing high yielding cereal crops** in seasons that favour higher yield potential.
   - Where genetic resistance is insufficient to delay fungicide decisions until flag leaf emergence (GS37-39), look to target the following three key timings for fungicide intervention: **first node GS31, flag leaf emergence GS39 with an optional third application at head emergence GS59.**
   - Head emergence fungicides in HRZ wheat crops are effective **if the season is conducive to disease in the period from flag leaf to head emergence** or where cultivars are very susceptible to stripe rust.
   - Head emergence sprays have two primary roles; further protection to the top three leaves and to protect the head from disease.

Hyper Yielding Crops research and scaling up adoption in the field – "Seeing is believing".

Led by Field Applied Research (FAR) Australia, the Hyper Yielding Crops (HYC) project is a GRDC national investment which aims to push the economically attainable yield boundaries of wheat, barley, and canola in those regions with higher yield potential. In addition to five HYC research sites across the higher yielding regions of New South Wales (NSW), Western Australia (WA), South Australia (SA), Victoria (Vic) and Tasmania (Tas), the project engages with growers and advisers to scale up the results on farm and create a community of interest in lifting productivity. HYC grower/adviser innovation groups in each region (co-ordinated by the regional farming group and TechCrop Services) work on five Focus Farm paddocks and encourage participation in the Hyper Yielding Crops awards (10 wheat entries per state). The project has the central motto that the key to adoption of research is that "seeing is believing".

How do I monitor and manage my crops yield potential?

Assuming that drought stress is not the dominate feature of the environment, the yield potential of wheat crops is strongly influenced by canopy growth in the critical period approximately 3 weeks prior to flowering. Maximising growth and protecting the canopy in this period is imperative for higher grain number which typically relates to higher yields. Optimizing the flowering in the key period of October 20-30th for wheat helps to ensure that growth in the critical period of GS37 – 61 is aligned with the best growing conditions. The prospects for optimal growth in this period (assuming water stress is not limiting growth) are determined by what is referred to as the Photo Thermal Quotient (PTQ) which is a measure of both light intensity and temperature (basically the sum of solar radiation divided by temperature). Higher PTQ relates to generally brighter and cooler conditions during the critical period and increases growth in the three weeks before flowering GS37-61. Therefore, building and protecting the crop canopy for maximum interception of the solar radiation during this period gives rise to higher yield potential.

Importance of germplasm

The HYC project has given the ability to screen for germplasm (both Australian and overseas material) that is more suited to the longer season HRZ regions, since most breeding selections are made for the main grain belt. This screening process at FAR Australia's South Australia Crop Technology Centre (SA CTC) at Millicent has already established regional standouts such as the winter wheats newcomer RGT Cesario⟮D⟯, Anapurna and RGT Accroc. Frequently it has been found that overseas material such as RGT Planet⟮D⟯ (barley) has been well adapted to southern longer season environments in Southeast SA, southern Victoria, and Tasmania and in 2020 higher altitude sites in southern NSW. Hyper yielding crops for these mainland HRZ regions of SA and Victoria need wheat germplasm that flowers in the period from October 20th – 30th, has good resistance to Septoria tritici blotch (STB) and rust, stiff straw, and of course higher yield potential.

Nutrition and rotation for hyper yielding wheat

One of the learnings from 2020 and the Tasmania hyper yielding cereals project has been that simply applying more and more fertiliser is not the route to achieving big yields. Attempts to apply over 200kg N/ha as urea fertiliser have generally been unsuccessful in generating the highest yields, despite yields of 10-15t/ha. In fact, since 2016 in the Tasmanian research work optimum applied fertiliser N levels have rarely exceeded 200kg N/ha for the highest yielding crops, even though the crop canopies that these yields were dependent upon were observed to remove far more N (250 – 370kg N in the crop at harvest). The role of N was also highlighted by entries for the HYC Awards in SA and Victoria where the top 20-25% of yields were generated with no more than 200 kg N/ha of applied N fertiliser (Table 1). In Victoria 80% of the HYC wheat award entries were grown after break crops (22.7% Faba beans, 45.5% Canola, 4.5% Safflower, 4.5% Lupins, 4.5% Lucerne) with 18.2% following wheat. Where wheat was grown following wheat it typically followed a double break of faba beans followed by canola.

In 2020 both at the HYC research sites and in the focus farms paddock strip trials with wheat there was some evidence that wheat could be responsive to increases of applied nitrogen when increases were made in the range of 125 – 200kg N/ha total N applied. A good example of this was observed on farm at Bool Lagoon in the lower SE region of SA where identical treatments were applied in irrigated (Table 2) and dryland (Table 3) scenarios (RGT Accroc), with the irrigated crop giving a yield response of 15.6 and dryland 12.3% when the N application rate was increased from 158kg N/ha to 204kg N/ha.

Table 1. Mean yields (t/ha), total Nitrogen rates applied (Kg N/ha) for top 20-25% yields and 75-80% remaining wheat crops entered for the 2020 Victorian and SA =HYC Awards.				
Yield categories for wheat crop	SA (11 crops)		Victoria (22 crops)	
	Yield t/ha	Kg N/ha	Yield t/ha	Kg N/ha
Top 20% Vic, Top 25% SA	9.70	140.3	9.62	191.8
Remaining 75% Vic, 80% SA	8.00	138.6	7.26	155.2

Table 2. Teates Centre Pivot EAST (irrigated) wheat following chickpeas in 2019 cv RGT Accroc (courtesy Bruce McLean).				
	Standard N fertiliser		Additional N fertiliser	
MAP (10% N) prior and at sowing	200kg/ha	20kg/ha of N	200kg/ha	20kg/ha of N
Urea (46% N) @ late tillering	200kg/ha	92kg/ha of N	200kg/ha	92kg/ha of N
Urea (46% N) @ GS37	100kg/ha	46kg/ha of N	200kg/ha	92kg/ha of N
TOTAL N (kg/ha)		158		204
Yield achieved t/ha		8.9		9.99

Soil N (0-20cm) prior to urea applied 10 August, Nitrate N = 13 mg/kg, Ammonium N = 3.7mg/kg

Table 3. Teates Centre Pivot WEST (dryland) wheat following clover in 2019 cv RGT Accroc.				
TOTAL N (kg/ha)		158		204
Yield achieved t/ha		9.57		11.06

Soil N (0-20cm) prior to urea applied 10 August, Nitrate N = 16 mg/kg, Ammonium N = 2.5mg/kg

In HYC nutrition trials harvested in southern Victoria and Southeast SA at the FAR Crop Technology Centres, attempts to push yields with N applications above 150-160kg N/ha have led to an increase in grain protein but not yield (Table 4). Again, N recovered in the grain would indicate that more N has been removed (grain and straw) than the crop can respond to in that season. Therefore, having a farming system that is in good health to provide nitrogen throughout the root zone is a key factor underpinning the large N offtakes in high yielding crops.

Nitrogen deficiency remains the single biggest factor contributing to the sizeable exploitable yield gap in Australian wheat production (Hochman and Horan 2018) yet applying more fertiliser N has not necessarily removed this constraint even with leading farmers and favourable seasons (van Rees et al. 2014). Clearly, the fertility of farming systems and soil organic matter contents are a key component in achieving high yields and that simply applying more N fertiliser in the season with favourable yield potential has a limit to its success. Whether additional N fertiliser has a legacy effect for the following season (N bank reserve) in the same way as legume crops or applications of organic manures is a topic of great debate currently.

Table 4. Detailed treatment list, grain yield (t/ha) and grain quality, protein (%), test weight (kg/hL) & screenings (%) cv RGT Accroc, Gnarwarre, Southern Victoria.					
Trt.	Nutrition (kg/ha)	Yield (t/ha)	Protein (%)	Test Weight (Kg/hL)	Screenings (%)
1	148 N kg/ha	10.14 ab	9.7 c	78.4 -	1.3 b
2	183 N kg/ha, 30 S kg/ha	10.29 a	10.2 b	78.4 -	1.4 b
3	183 N kg/ha	9.92 ab	10.4 b	78.0 -	1.4 b
4	217 N kg/ha, 45 S kg/ha	9.73 b	10.4 b	78.0 -	1.7 a
5	217 N kg/ha	9.91 ab	11.0 a	77.4 -	1.7 a
Mean		**9.99**	**10.3**	**78.0**	**1.5**
Lsd (p=0.05)		0.49	0.5	ns	0.2
P Val	0.179	<0.001	0.829	0.005	

Note: 22kg/ha of phosphorus applied to all treatments.
GSR (April-November) 479mm (29mm above the long-term average).
Organic carbon (0 -10cm) – 2.37%

Keeping Hyper Yielding crops standing

In some cases, it is not more N fertiliser that is required, but more efficient use of what has already been applied, this was seen with on farm strip trials looking at the interaction of nitrogen fertiliser and the use of plant growth regulation to improve standing power (Table 5). In this dryland on farm HYC trial whilst increasing N from 123 to 169kg N/ha increased yield the same increase in yield was achieved by keeping the crop standing, illustrating just how important it is to recognise that management how inputs interact and should not be seen in isolation.

Crop canopies that support 10t/ha grain yields are dependent on good straw strength and or growth regulation to for fill their potential. It is important to recognise that PGR support for weaker strawed crops capable of yielding 10t/ha is not just about yield, it is about the harvestability, particularly the speed of harvest (Table 6). Additionally, HYC research and field trials have clearly illustrated that in barley prevention of head loss and brackling whilst crops wait for harvest is as an important role for PGRs as prevention of lodging during grain fill.

Disease management to protect higher yield potential

Disease management is one of the most important components of growing high yielding cereal crops in seasons with high yield potential. This is primarily a result of the growing season being typically longer, wetter and more disease prone than normal. In HYC research in wheat it was found that three key timings for fungicide intervention were essential to protect the upper leaves of the canopy, capture the highest yields, and provide the highest economic returns; these were first node growth stage (GS31, flag leaf emergence GS39 and head emergence GS59). In barley two timings are essential: GS31 and awn tipping GS49. The introduction of new fungicides over the last five years has lifted our ability to secure a greater proportion of our yield potential in wet seasons conducive to foliar diseases. Use the weather patterns in the two monitor periods outlined to track both disease development and weather pattern between applications.

The head emergence fungicide application targeted at head emergence/start of flowering (GS59-61) is in most mainland Australian environments uneconomic, however there are two scenarios where this application is noted to be of particular benefit. The first is where cultivars are very susceptible to stripe rust and late head infection and flag infection can be protracted, for example LongReach

Trojan⁽ᶦ⁾ or DS Bennett⁽ᶦ⁾, the second is in the HRZ where good growing conditions following flag leaf emerging (GS37) favour high yield potential but encourage disease development. It is important to understand that this application timing has two important roles, it protects the head from infection but more importantly it increases the period of protection given to the flag leaf and flag-1, the two most important upper canopy leaves in wheat. On the focus farms the benefit of a head wash spray was observed where stripe rust was aggressive in susceptible cultivars in both the MRZ and HRZ. With crops in the MRZ regions further north monitor growing conditions, canopy growth and disease

Table 5. Influence of total N application rate and PGR application (GS31) on yield (t/ha), protein (%), test weight (kg/hL) and lodging (1-10, where 10 is totally lodged) cv RGT Accroc, Bool Lagoon, SA (courtesy of Dave Hage).

Trt.	N rate (kg N/ha) & PGR	Yield (t/ha)	Protein (%)	Test Weight (kg/hL)	Lodging (1-10)
1	123 N applied - No PGR	5.95	12.0	75.5	4
2	169 N applied - No PGR	7.16	12.9	74.4	6
3	123 N –Moddus Evo® 400ml/ha	7.08	12.0	76.8	0
4	169 N –Moddus Evo® 400ml/ha	7.52	12.9	75.7	6

Table 6. Influence of PGR application on yield (t/ha), protein (%), test weight (kg/hL) & screenings (%) cv RGT Accroc, Furner, SA (courtesy of Sam Ballantyne).

Trt.	N rate (kg N/ha) & PGR	Yield (t/ha)	Protein (%)	Test Weight (kg/hL)	Screenings (%)
1	No PGR applied (control)	9.05	10	75.1	3.3
2	Split application Moddus Evo® [1] 200ml/ha	9.47	9.7	73.8	3.7
3	Single application Moddus Evo® 400ml/ha	10.33	9.7	74.5	4.1

[1] *The label rate for Moddus Evo® is 300-400 ml/ha*

pressure in the second monitoring period GS37 – 61. If the period is wetter and cooler than the average and the disease susceptibility of your cultivar has led to active disease on flag-1 and flag-2 a third fungicide application being a head wash spray should be considered. For HRZ region with longer growing seasons and susceptible cultivars it is typically used as an insurance spray. One of the most important aspects of head wash sprays is to be aware of the label timing cut offs, since many fungicides must be applied before the crop starts the flowering phase (GS60-69), so please always consult the product label with regards to last opportunity to make a specific fungicide application and always observe the timing and harvest interval restrictions on the label.

In 2020 the role of the head wash fungicide was also highlighted by wheat entries for the HYC Awards where all the growers achieving the top 25% of yields in SA and 60% of the growers achieving the top 20% in Victoria used a head wash fungicide. This compared to 50% and 30% of growers respectively using a head wash fungicide in the remaining 75 – 80% of wheat crops.

Interested in hyper yielding crops?

Make a date in your diary for the main field days at the Hyper yielding research sites at the Victorian and SA Crop Technology Centre at Gnarwarre on **14th October 2021** and at Millicent on **28th October 2021** (please contact **Rachel Hamilton** for more details (Rachel.Hamilton@faraustralia.com.au).

If you are interested in getting involved in the project in southeast SA or in southern Victoria then please get in touch with Jen Lillecrapp from MFMG, your regional HYC Project Officer (**Jen Lillecrapp** jen@brackenlea.com) in SA and **Ashley Amourgis** SFS (aamourgis@sfs.org.au) in Victoria or the national extension co-ordinator for the Focus Farms and HYC awards **Jon Midwood** of TechCrop Services.

Acknowledgements

The research undertaken as part of these projects 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. FAR Australia gratefully acknowledges the support of all its research and extension partners in the Hyper Yielding Crops project. These are CSIRO, the Department of Primary Industries and Regional Development (DPIRD) in WA, SA Research and Development Institute (SARDI), Brill Ag, Southern Farming Systems (SFS), Techcrop Services, the Centre for eResearch and Digital Innovation (CeRDI) at Federation University Australia, MacKillop Farm Management Group (MFMG), Riverine Plains Inc and Stirling to Coast Farmers.

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Notes

TOP 10 TIPS

FOR REDUCING SPRAY DRIFT

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

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

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

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

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

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

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

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

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

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

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Will I get an economic response from applying fungicide to canola for the control of blackleg?

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

Keywords

- stubble management, fungicide resistance, seed treatment, upper canopy blackleg, crown canker.

Take home messages

- The canola industry has become more reliant on fungicides to control blackleg, in some regions there is reduced emphasis on cultural practices to reduce disease.
- The decision to use a fungicide is not clear cut and should be based on the disease risk profile of the crop.
- Severe blackleg crown canker occurs when plants are infected 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.
- Early vegetative (4-10 leaf) foliar fungicide application should be based on the risk profile of the crop, cultivar blackleg rating and estimation of the potential yield after scouting for leaf lesions.
- Fungicide application decision-making for upper canopy infection is separate to the decision process for crown canker. Fungicide applications to control upper canopy infection can result in variable yield responses. It is important to understand the disease risk before applying a fungicide.
- Knowledge on upper canopy infection is improving and it is likely that decision making will become more reliable. A decision support tool is expected to be released via GRDC investment when there is sufficient confidence on recommendations to aid decision making.

Will I get an economic return from applying a fungicide to my canola crop?

Recently, new fungicide actives and timing recommendations have produced large yield responses. However, these are variable ranging from nil to 20% yield increases in on-farm strip trials and nil to 40% yield increases in small-plot research trials. So how do you determine where your crop will sit in 2021 (i.e., within the nil to 40% response range)?

Predicting a yield response would be very accurate if you knew exactly how much disease will occur, but the level of crop damage caused by disease is determined by numerous interconnected factors. Additionally, other diseases such as Sclerotinia stem rot, white leaf spot, powdery mildew and alternaria can also influence economic returns.

The key is to identify the blackleg risk for each individual crop and then determine the cost of application compared to that of potential yield loss. In most years, this is relatively easy. For example, a low rainfall year is low risk and in a high rainfall year with high yield potential, it is very easy to gain an economic advantage from fungicide application. But in the decile 4 to 7 years there is lots to be gained or lost from fungicide decisions.

Blackleg crown canker

Do I need a seed treatment and/or fungicide amended fertiliser?

Risk factors:

1. **Canola growing region** – high canola intensity and high rainfall = high risk. One in four-year rotations and 500m isolation between this year's crop and last year's stubble reduces risk.
2. **Cultivar resistance** – cultivars rated resistant (R) to moderately resistant (MR) or above have very low risk of developing crown cankers. Moderately resistant will develop cankers but only if grown under high disease pressure for example, canola/wheat/canola in high rainfall.
3. **Blackleg population** – if you've grown the same cultivar for a number of years and crown canker severity is increasing, you will be at a higher risk of crown cankers if you then sow a cultivar from the same resistance group.
4. **Timing of crop emergence** – severe crown canker is most likely to develop when plants are infected during the early seedling stage (cotyledon to 4th leaf). The driving factors for seedling infection are the growth stage at which first infection occurs and the length of time that the plant is exposed to blackleg infection while in the vulnerable seedling stage. Therefore, the risk of seedling infection that leads to crown canker varies from season to season. For infection to occur, blackleg spores must be mature and ready to release from stubble, a process reliant on a combination of moisture and suitable temperatures. Fruiting bodies typically become ripe approximately three weeks after the break of the season when the stubble has stayed consistently moist. Once mature, spores are then released with each rainfall event. Temperature also determines the length of time that plants remain in the vulnerable seedling stage. Plants are significantly less vulnerable to crown canker after the 4th leaf stage. Older plants will still get leaf lesions, but the pathogen is less likely to cause damaging crown canker as it cannot grow fast enough to get into the crown. Typically, plants sown earlier in the growing season (April) will develop quickly under warmer conditions and progress rapidly past the vulnerable seedling stage compared to plants sown later (mid-May) which progress slowly and remain in the vulnerable seedling stage for an extended period.
5. **Farming system** – inter-row sowing with full stubble retention influences the timing and quantity of ascospores from stubble, which are a primary source of inoculum. Standing stubble stays drier between rainfall events compared to stubble that is lying down and in contact with the soil. Standing stubble delays spore maturation and reduces the release of spores early in the season at the time when fungicide applied to seed and fertiliser are most effective. Standing stubble produces more spores later in the season, however these spores are unlikely to produce severe crown canker but may increase severity of upper canopy blackleg. However, standing stubble that is knocked down 12 months later can then produce spores early the following growing season.

In summary

An economic return is unlikely if sowing an R rated cultivar in a one in four-year rotation in mid-April with >500m from the previous year's canola crop (and you don't retain stubble). If sowing a MS rated cultivar in a canola / wheat / canola rotation at the end of May, you will likely get a large return from your fungicide application. The challenge with seed treatments and fungicide-amended fertiliser is that the decision to use these products is made a long time before sowing (or you don't have any influence over it when you purchase commercial seed), and therefore, you will not know the emergence date, and therefore, the individual season risk. But you will know the risks associated with your canola region, cultivar blackleg rating and distance to last year's stubble.

Do I need a vegetative foliar fungicide application?

As with fungicides applied at sowing, vegetative foliar fungicides applied during 4-10 leaf growth stage are also designed to protect plants from crown cankers. The main advantage with this fungicide timing is that the level of disease risk can be assessed at the time of application, considering the blackleg rating of the cultivar, whether a seed treatment and/or fungicide amended fertiliser has been used and the prevalence and severity of leaf lesions observed in the crop.

1. Cultivars with effective major gene resistance will have none or very few leaf lesions even under high disease situations and will therefore be protected from crown canker. Cultivars are classified into Blackleg resistance groups (A, B, C, etc) according to their complement of major genes. An abundance of lesions in cultivars which are expected to have effective major gene resistance indicates that the resistance is being overcome and application of a foliar fungicide may be prudent as the underlying level of quantitative resistance is uncertain. In cultivars lacking effective major genes, the blackleg rating gives an indication of the level of quantitative resistance to crown canker, i.e., the level of resistance to crown canker in the plant following leaf infection. All cultivars that are reliant on quantitative resistance may get a similar level of leaf infection but a cultivar with an R blackleg rating will not develop crown cankers whereas an MR cultivar may develop some crown cankers and an MS-S cultivar may have severe cankering and lodged plants.
2. Fungicides applied at sowing will reduce crown canker even on crops with quite severe leaf lesions. In most cases, if a cultivar with adequate resistance is sown with a seed or fertiliser fungicide treatment then a vegetative foliar fungicide is unlikely to be necessary. Monitor your crop and make an in-season decision.
3. Leaf lesions are most damaging on the cotyledons and early leaves, and therefore, a foliar fungicide is most likely to give an economic benefit to protect this vulnerable stage.

Analysis of the fungicide trials clearly showed that fungicides only provided a yield benefit in high disease situations, such as:

1. You may have chosen to grow a cultivar with a lower blackleg rating because the cultivar is the highest yielding or you have chosen to retain seed, etc. For example, it is common practice to grow older cultivars with reduced blackleg resistance and then protect these cultivars with fungicide applications.
2. The pathogen population has changed to render major genes ineffective.
3. The season is very conducive for blackleg with spore maturity coinciding with emergence and the vulnerable stage of crop growth.

Use of the BlacklegCM App is recommended to help make blackleg management decisions. BlacklegCM is an interactive tool allowing users to compare scenarios and determine the likely yield response from altering various disease management strategies.

Upper canopy blackleg fungicide application

Blackleg Upper Canopy Infection (UCI) refers to blackleg infection of the upper stem, branches, flowers and pods. Although research is improving the understanding of these symptoms, there is still a lack of knowledge on how individual cultivars react to UCI in terms of yield loss. Furthermore, our research shows that similar symptoms of UCI can cause severe yield loss in one season and no yield loss in another. As such, our recommendations for managing blackleg UCI are constantly improving.

Should I apply a fungicide for UCI protection?

The question of whether to apply a fungicide for UCI protection is a real dilemma. Get it wrong and it will cost your crop a lot of money, but currently there is no way to accurately predict economic return from fungicide application. GRDC investment is working on improving knowledge, including determining the timing of infection leading to yield loss, weather parameters associated with yield loss and strategies for screening for genetic resistance.

Some factors however that are driving disease risk:

1. **Timing of flowering.**

   Earlier flowering crops are at a higher risk than later flowering crops as they flower in conditions more conducive for blackleg infection. Earlier flowering crops also have a longer period until harvest which allows the fungus to proliferate within the plant, thereby reducing yield potential.

2. **Spring rainfall and temperature.**

   Our preliminary data suggests that UCI, given enough time, will cause damage to the vascular tissue in the stems and branches, reducing yield potential by restricting water and nutrient flow to developing flowers, pods and seed. However, similar levels of disease can cause different amounts of yield loss depending on the weather during pod fill. Plants without moisture/heat stress can tolerate a higher disease load before it impacts on yield.

3. **Genetic resistance.**

   Genetic resistance is the missing piece of the puzzle. As with crown canker, effective major gene resistance protects against UCI. If it is ineffective or has been overcome, the crop may be completely susceptible to UCI, however, this should have become evident by the prevalence and severity of leaf lesions observed during the seedling stage. The effect of quantitative resistance for crown canker on UCI is currently under investigation. It is clear that cultivars with good quantitative resistance do get UCI symptoms, but we are unsure whether these cultivars have less damage to the vascular tissue than more susceptible cultivars. This could be similar to the way cultivars react at the seedling stage, whereby varieties with the same level of leaf infection develop different levels of crown canker.

4. **Fungicides.**

   Our work has shown a wide window of response times with good results (if you have a damaging level of disease) from fungicide application from first flower to 50% bloom. However, for several reasons, it is suggested that 30% bloom is aimed for. Firstly, the 30% bloom stage is as late as you can go and still get good penetration into the canopy; your main aim is to protect the main stem as this will have a greater impact on yield compared to individual branches. Secondly, this timing may provide some control of any initial infections that have already occurred. Thirdly, the 30% bloom timing will provide protection for a few weeks into the future by which stage any later infections are less likely to result in significant yield loss. Pod infection is unlikely to be controlled through fungicide application. However, there was some control of pod infection at some sites in 2020 by spraying at 30% bloom but this has not been observed in previous seasons. Pod infection occurs when there are rainfall events during podding and the fungal spores land directly on the pods to cause disease, this results in an additional yield loss of up to 20%. Unfortunately, there are no fungicides registered for application during podding due to maximum residue limit (MRL) regulations. Effective major gene resistance will control pod infection.

What are the steps to determining a UCI spray decision?

1. **Yield potential** – yield potential is an economic driver. A 1% return on a 3t/ha crop is worth more money than a 1% return on a 1t/ha crop.
2. **Leaf lesions** – presence of leaf lesions indicates that blackleg is present, and that the cultivar does not have effective major gene resistance. No leaf lesions = no reason to spray.
3. **New leaf lesions on upper leaves as the plants are elongating** – this observation is not critical, but it does give an indication that blackleg is active as the crop is coming into the susceptible window. However, numerous wet days at early flowering stage will still be high risk even if there were no lesions on new leaves up to that point. Remember it will take two to three weeks after rainfall to observe leaf lesions. More lesions = higher blackleg severity.
4. **Date of first flower** – the earlier in the season that flowering occurs = higher risk. This date will vary for different regions. Generally, shorter season regions can, more safely, commence flowering at an earlier date compared to longer season regions. Earlier harvest date results in less time for the fungus to invade the vascular tissue and cause yield loss. Consequently, if you're in a long growing season rainfall region and your crop flowers in early August and is harvested in December, you are in a very high-risk situation.

How can I determine if I should have sprayed for UCI?

1. UCI symptoms are most readily observed at windrowing or even later as the plants mature. They can progress very quickly during this time.
2. Check for external lesions and ensure correct identification.
3. Where lesions are present, slice open the branch/stem and check for blackened pith which is indicative of vascular damage and likely yield loss.
4. Observe darkened branches; these branches go dark after vascular damage and are indicative of yield loss.

5. Pod infection will cause yield loss, unfortunately there is nothing that can be done to prevent pod infection.
6. Leave unsprayed strips to check for yield returns.

Which fungicide active should I use?

There are two parts to the question of which fungicide active should I use? Firstly, in terms of which active will give better control, there are few side by side comparisons that have been undertaken for blackleg control. However, the GRDC blackleg rating project has undertaken comparisons for the seed treatment fungicides which indicate the succinate dehydrogenase inhibitors (SDHI) fungicides provide longer protection compared to the demethylation inhibitors (DMI) fungicides. Ultimately, crop development stage, determining your risk, and therefore, potential economic return are more important factors when choosing a fungicide.

The second aspect of choosing a fungicide active is in regards to managing the risk of fungicide resistance. Resistance towards the DMI fungicides has been detected in approximately 30% of Australian blackleg populations over the past three years whilst no resistance has been detected for the SDHI fungicides. However, excessive use of the SDHI fungicides has the potential to select for fungicide resistance more quickly than DMIs. Therefore, limitations on the number of applications for each fungicide active within a growing season have been developed and can be found at the CropLife website (https://www.croplife.org.au/resources/programs/resistance-management/canola-blackleg/).

If you use a SDHI seed treatment you cannot use a SDHI early foliar (4-8 leaf) application. At this point, SDHI seed treatment and SDHI 30% bloom spray is considered safe. Research will be testing these different scenarios to provide accurate data for modelling fungicide management.

Acknowledgements

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Useful resources and references

BlacklegCM App for iPad and android tablets (https://www.agric.wa.gov.au/apps/blacklegcm-blackleg-management-app)

GRDC Publication – Blackleg Management Guide (www.grdc.com.au/resources-and-publications/all-publications/publications/2020/blackleg-management-guide)

GRDC Groundcover - Canola: The Ute Guide (https://grdc.com.au/resources-and-publications/groundcover/ground-cover-issue-27/canola-the-ute-guide)

Marcroft Grains Pathology website: www.marcroftgrainspathology.com.au

GRDC National Variety Trials™ website (www.nvtonline.com.au)

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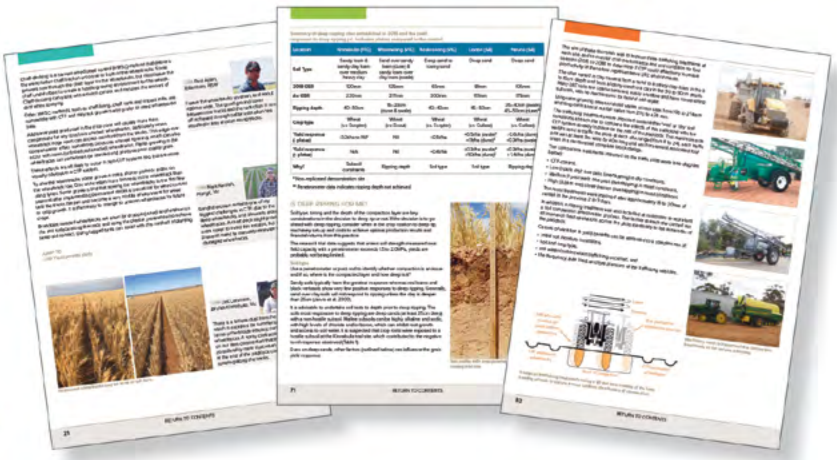

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www.blackdoginstitute.org.au The Black Dog Institute is a medical research institute that focuses on the identification, prevention and treatment of mental illness. Its website aims to lead you through the logical steps in seeking help for mood disorders,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

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

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

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

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

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

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

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Insecticide resistance in the green peach aphid *(Myzus persicae)* and redlegged earth mite *(Halotydeus destructor)* in Australia – current status and updated management strategies.

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Keywords

- green peach aphid, redlegged earth mites, insecticide resistance, parasitoid wasps, integrated pest management strategies.

Take home messages

- In the Australian grains industry, an over-reliance on broad-spectrum insecticides, combined with a limited number of registered chemicals, results in strong selection pressure favouring the evolution of resistance in multiple invertebrate pests.
- The green peach aphid (*Myzus persicae*; GPA) and the redlegged earth mite (*Halotydeus destructor*; RLEM) are two important grain pests that have evolved resistance to multiple insecticide groups in Australia. Surveillance demonstrates that resistance is expanding, emphasising the need for a re-evaluation of current management strategies.
- Taking an integrated approach to pest management limits the need for prophylactic insecticide applications by utilising biological and cultural control options, thereby reducing the likelihood of further insecticide resistance evolution.
- Biological management tools include ensuring correct pest identification and the promotion and use of naturally occurring and/or introduced beneficials.
- Cultural management options include creating refuge to reduce pyrethroid resistance in RLEM, sowing into stubble to reduce GPA landing rates, and reducing GPA weedy hosts such as capeweed, wild radish, and dock prior to sowing.

Background

Several important invertebrate pests of grain crops have evolved insecticide resistance in Australia, including in Victoria. These include the green peach aphid (*Myzus persicae*, GPA) and the redlegged earth mite (*Halotydeus destructor*, RLEM) (for overview including resistance in other invertebrate pests, see Umina et al. 2019), which have evolved resistance to multiple chemical classes in Australia.

This paper presents the current distribution status of insecticide resistance in the GPA and RLEM in Australia, with a focus on Victoria. Data on the current resistance status of these pests is presented. Current research into novel management strategies utilising modelling, refuge and natural enemies to manage insecticide resistant populations is described. Finally, the most recent guidelines on insecticide resistance management strategies (IRMS) are discussed.

Methods

Green peach aphid

Populations of GPA were collected throughout the grain growing regions during 2019 and 2020. Populations were screened for genetic mechanisms of insecticide resistance to four modes of action: dimethoate (organophosphates Insecticide Resistance Action Committee (IRAC) Group 1B) with esterase E4FE4 ratio, pirimicarb (carbamates IRAC Group 1A) with MACE mutation, alpha-cypermethrin (synthetic pyrethroids IRAC Group 3A) with kdr and super-kdr mutations, and imidacloprid (neonicotinoids IRAC Group 4A) with the gene copy number of the cytochrome P450 gene CYP6CY3. For neonicotinoid resistance testing, a subset of populations was also screened using phenotypic laboratory bioassays. Dose-response curves were generated by plotting percentage mortality against log concentration. Mortality data was analysed using a logistic regression model at each time point. Logistic regression is suited for the analysis of binary response data (i.e., dead/alive).

The occurrence, abundance and field distribution of known aphid parasitoid wasps, many of whom parasitise GPA, were investigated in canola crops (*Brassica napus* L.) in Victoria (further details in Ward et al. 2021). Briefly, a total of 10 canola fields were surveyed in 2017 and 2018. Monitoring was performed within the field, shelterbelts and refuge for each site. Monitoring was repeated three to six times per season for each field to provide temporal resolution. Four methods were used to detect parasitoid wasps; using yellow pan traps deployed for 24 hours, direct detection following two minutes surveying in the area, using a vacuum for one minute, and identification following the retrieval and rearing of aphid mummies in the laboratory. Aphids were also categorized by species and counted. Wasp identification was validated using molecular barcoding of the cytochrome c oxidase subunit 1 (CO1) gene.

Redlegged earth mite

RLEM populations were collected in grain and pasture growing regions across Australia, between 2011 to 2019 (further details in Arthur et al. 2021). Briefly, populations were collected from fields with reported spray failures and/or fields with a known history of high insecticide and intensive cropping usage. From 2017 to 2019, the majority of populations collected focussed on regions where the recently developed *H. destructor* models estimated resistance evolution would be greatest. Mite populations were screened against synthetic pyrethroids and organophosphates using phenotypic laboratory assays. Molecular screening was also undertaken to assess pyrethroid resistance by screening mites for the *kdr* genetic mutation known to confer pyrethroid resistance. The association between pyrethroid resistance and crop management factors was also evaluated using a regression model.

To assess the effect of unsprayed refuge strips on RLEM pyrethroid resistance, field trials and modelling approaches were tested (further details in Maino et al. 2021). The aim was to provide the optimal spatial configuration of susceptible refuges to reduce the likelihood of resistance evolution while minimising total yield impacts. Briefly, a lucerne (*Medicago sativa* L.) field, located in Tintinara SA, harbouring a low-level (15 % *kdr* allele) pyrethroid resistant RLEM population was selected. An area of 50 m^2 was sprayed with bifenthrin (Talstar®) in order to increase the proportion of resistant individuals in this given area. RLEM samples were collected at three time points (before initial spray, one month after spray, nine months after spray) along transects spanning the sprayed area and 15 m beyond into unsprayed paddocks. Mites were subsequently genotyped for pyrethroid resistance using the *kdr* allele. Changes in the estimated resistant allele frequency through time was estimated using a general linear model. Finally, a modelling framework for spatially fine-scaled resistance spread and evolution was utilized and updated with the quantified *kdr* recessiveness rates. Refuge size was then varied in across multiple simulations to observe the effect on canola yield and resistance so that an optimal refuge strategy could be recommended.

Results and discussion

Green peach aphid

Insecticide resistance status

Between 2015 and 2019, a total of 473 GPA populations were genetically screened against known pesticide resistance conferring alleles for carbamates, organophosphates, synthetic pyrethroids and neonicotinoids. This work identified target site resistance in almost all screened populations to carbamates and synthetic pyrethroids rendering these chemicals ineffective as a control option for GPA (Figure 1). Based on these findings, it is recommended growers to do not use either carbamates or synthetic pyrethroids to control GPA in grains crops.

This testing also detected resistance to organophosphates and neonicotinoids in a substantial number of GPA populations (Figure 1). Resistance to organophosphates was found to be moderate in many populations and a result of metabolic resistance. Therefore, organophosphates will provide control in some situations, but less or no control in others. Furthermore, continued use of organophosphates on such populations would likely increase their overall resistance to chemicals from this group. The neonicotinoid resistance inducing CYP6CY3 gene was only found at low copy numbers in the GPA populations screened, which indicates complete chemical field failures are unlikely to occur given the results presented here. Research is continuing to understand the impacts of this resistance on the effectiveness of neonicotinoid-based seed treatments.

Parasitoid wasps for control of GPA

GPA was the most abundant aphid species within canola crops at 61 % of total aphids surveyed across canola fields. Interestingly, GPA was not found in shelterbelts and was only found in low proportions (25 %) in refuges. Across all fields, aphid populations remained relatively low during the early stages of crop growth and increased as the season progressed. The most common parasitoid reared from GPA was *Diaeretiella rapae* (M'Intosh) at 96 % of total wasps reared (Table 1). More generally, *D. rapae* was the most common parasitoid for all aphid species with an average of 60 % reared from total wasps yet was present only in low abundance at field edges (data not shown). Mummification rate significantly increased from 3 to 4 % in September/October, increasing as crop growth stage progressed and peaking at 20 % by the end of November.

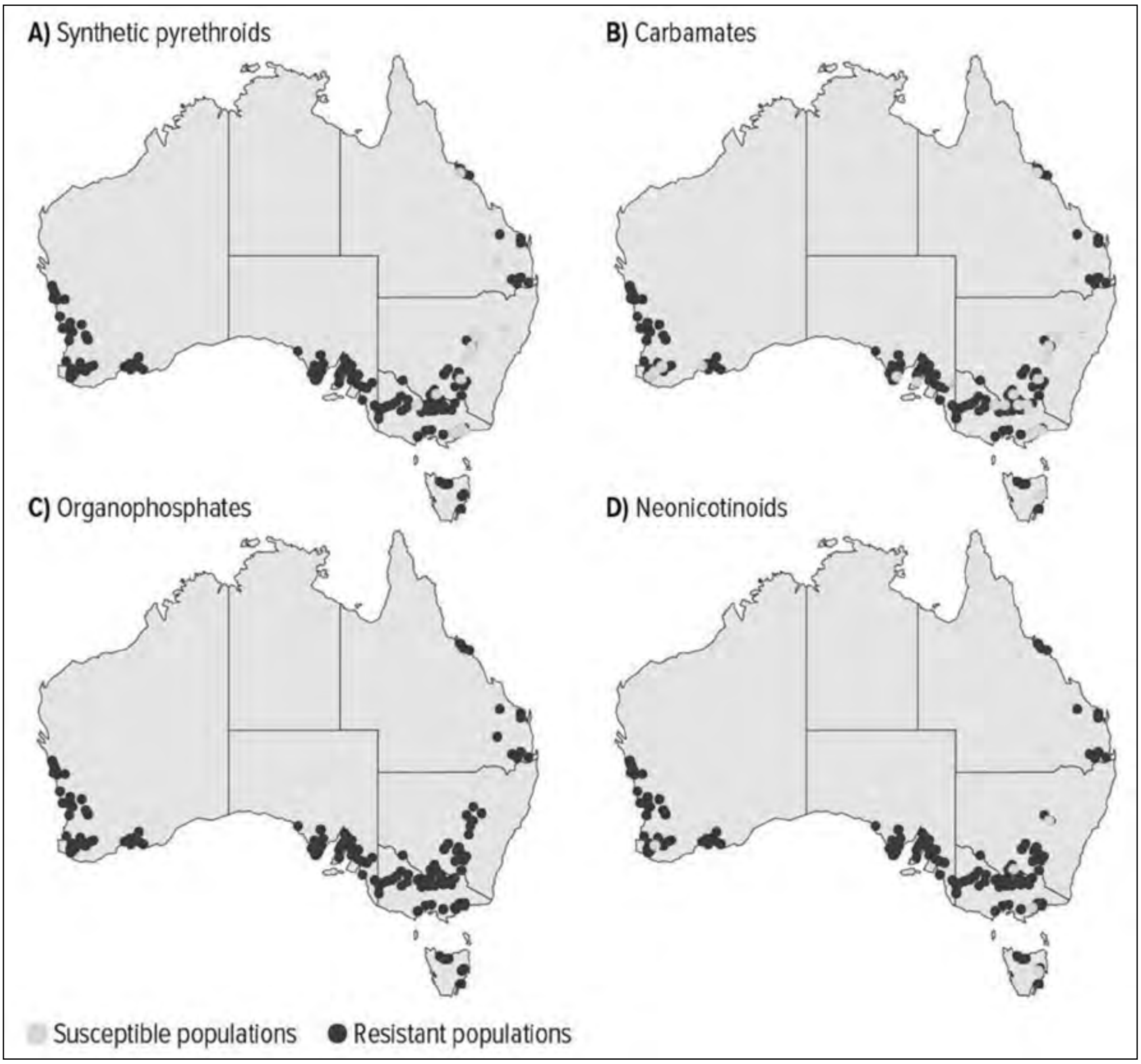

Figure 1. Resistance status of GPA populations tested for resistance to A) synthetic pyrethroids, B) carbamates, C) organophosphates and D) neonicotinoids. The darker coloured dots represent resistant populations while the lighter coloured represent susceptible populations. Source: McGrane et al. (2021).

Table 1. Percentage of primary parasitoid species composition of aphid species from fields and surrounding vegetation in 2017 and 2018. Modified from Ward et al. (2021) with permission.

Parasitoid wasp species	Aphid species				
	Green peach aphid *(Myzus persicae)*	Oat aphid *(Rhopalosiphum padi)*	Cabbage aphid *(Brevicoryne brassicae)*	Turnip aphid *(Lipaphis erysimi)*	Corn aphid *(Rhopalosiphum maidis)*
	n=379	n=1	n=62	n=81	n=50
Diaeretiella rapae	96 %	0 %	98 %	60 %	16 %
Lysiphlebus testaceipes	0.2 %	0 %	0 %	6 %	40 %
Aphidius matricariae	0.5 %	100%	2 %	29 %	24 %
Aphidius colemani	0.5 %	0 %	0 %	1 %	18 %
Aphidius absinthii	0 %	0 %	0 %	3 %	2 %
Aphidius ervi	3 %	0 %	0 %	0 %	0 %

Canola field edges did not appear to act as reservoirs for parasitoids, as there was little overlap in the community composition of either (data not shown). Location significantly affected the number of parasitoids collected within and surrounding canola fields, with higher numbers collected in the field compared with the grassy refuge (Mean square = 1.27, F = 49.42, $p < 0.001$).

Redlegged earth mite

Insecticide resistance status

Since the first detection of pyrethroid resistance in RLEM in 2006, resistance surveillance has been undertaken on a yearly basis. Throughout Australia, this has resulted in 1,029 populations being tested over the last 13 years. A total of 195 RLEM populations have now been detected with pyrethroid resistance, 59 populations with organophosphate resistance and 24 populations with resistance to both chemical groups. In Victoria, all populations tested were susceptible to synthetic pyrethroids, and only one population was resistant to organophosphates (Figure 2). Surveillance has covered a wide geographical range throughout eastern Australia, covering a large portion of the distribution of RLEM in this region (Figure 2). Resistance in RLEM is now present across three Australian states (WA, SA, and Vic) and covers more than 3,000 km.

Using field history information, we identified associations for the first time between crop management practices employed by farmers and

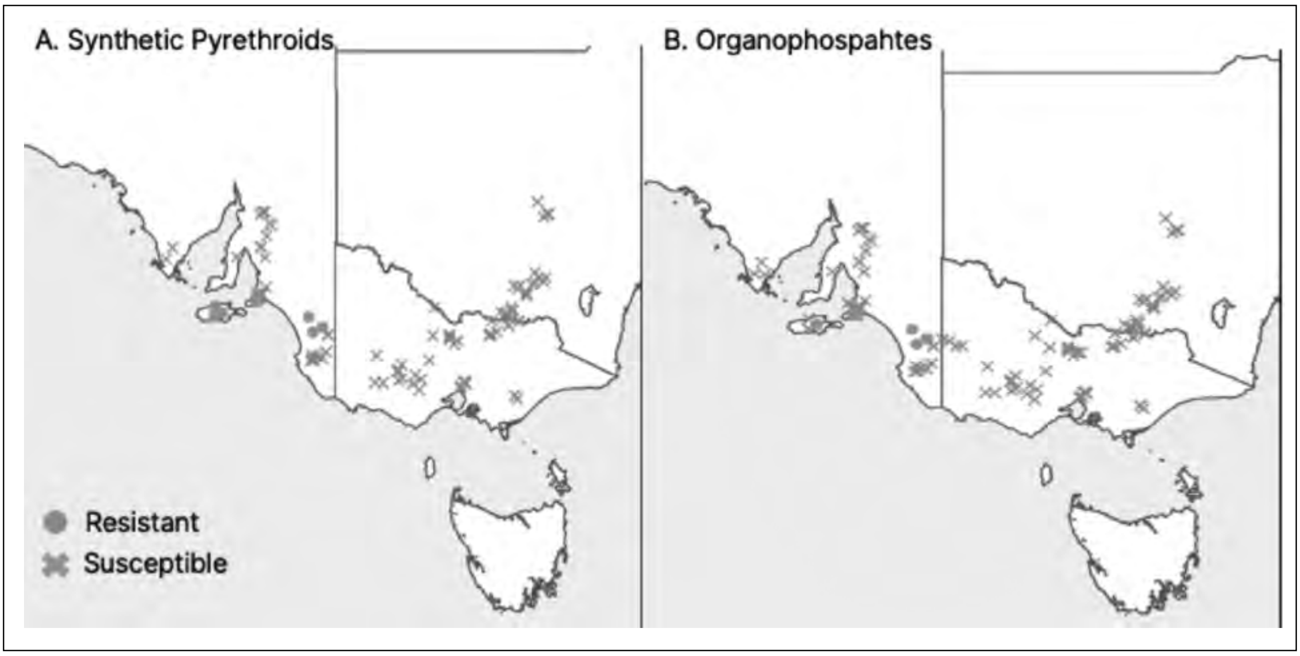

Figure 2. Resistance status of RLEM populations tested for resistance in eastern Australia to A) synthetic pyrethroids, B) organophosphates. Circles indicate resistant populations, while crosses indicate susceptible populations. Image modified from Arthur et al. (2021) with permission.

the presence of pyrethroid resistance. Management strategies that could minimise the risk of further resistance evolution include limiting local spread of resistance through farm hygiene practices, crop rotations and reducing pesticide usage.

Novel refuge strategy could delay pyrethroid resistance in RLEM

Experimental field studies demonstrated that a small, localised pyrethroid resistant mite population can revert to susceptibility at farm relevant scales and conditions. Computer simulation results found that certain field configurations (e.g., treatment strip width of 50 m and refuge spacing of 10 m) maintained very low levels of resistance across a 10-year time horizon (Figure 3). Mite population density was also estimated to be lower at this configuration compared with others. At the selected configuration (treatment strip width of 50 m and refuge spacing of 10 m), yield loss is also predicted to be minimal. Interestingly, a larger unsprayed refuge did not always delay resistance in these simulations due to the low migration ability of this pest – i.e., susceptible mites could not move back into the treated areas when both sprayed sections and untreated refuges were large.

Strip spraying to maintain refuges can be readily incorporated into RLEM management programs where sprayer widths in commercial cropping contexts are typically between 20 m to 40 m. A refuge approach to RLEM management that uses strip spraying may enhance long term control options in the absence of new chemical registrations.

This could be a successful strategy to manage RLEM as part of an IPM program. However, this novel approach will require further field validation in a variety of cropping contexts.

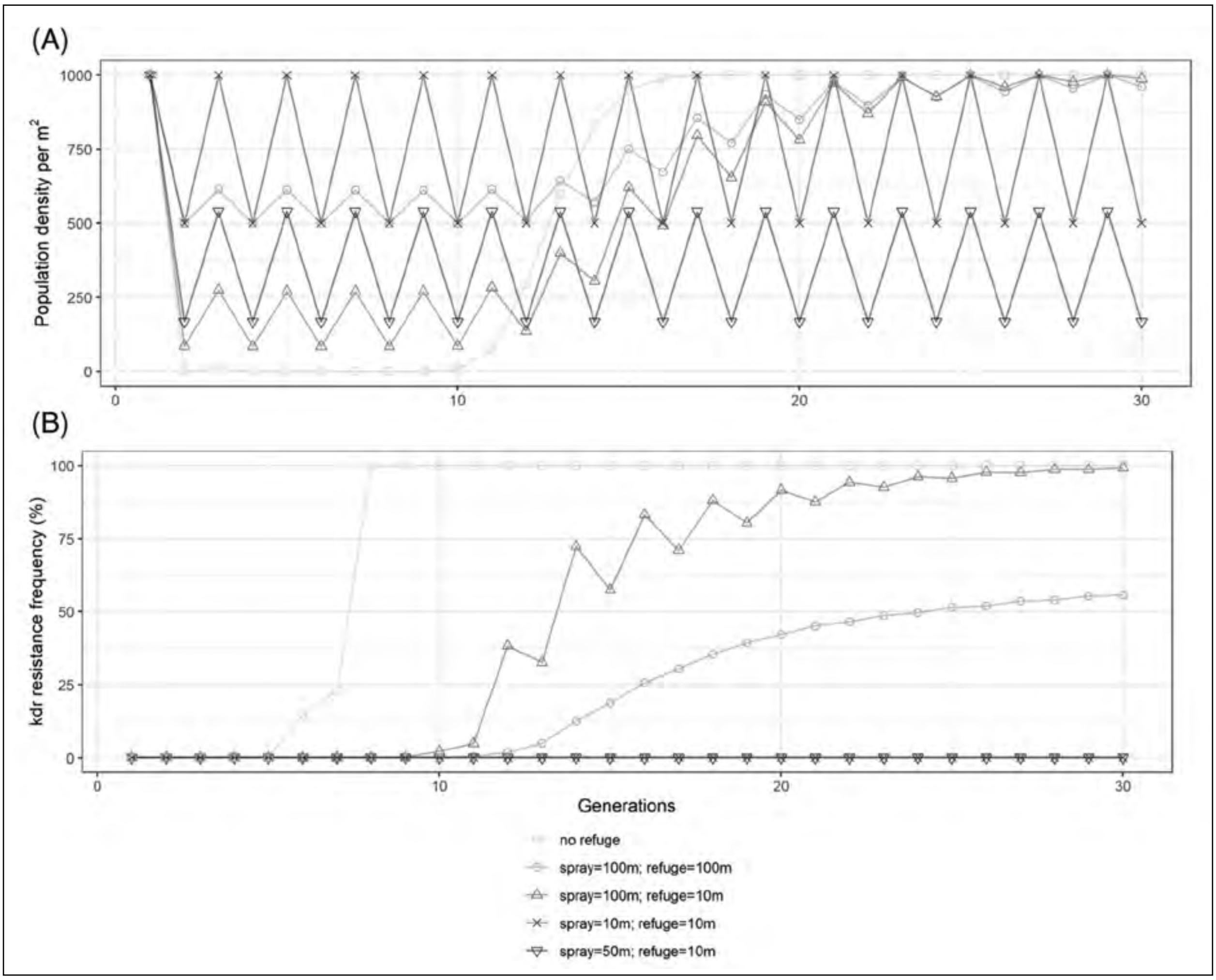

Figure 3. (A) Mean simulated abundance and **(B)** *kdr* resistant allele frequency through time under four strip spraying regimes. Source: Maino et al. (2021).

Conclusions

Growers are increasingly facing the challenges posed by insecticide resistance in GPA and RLEM in Victoria. Insecticides will continue to play an important role in GPA and RLEM control, however, the increasing spread and evolution of resistance raises concerns for the long-term viability of chemical control.

Future control of these pests should emphasise an IPM approach that aims to reduce chemical usage to limit selection pressures and decrease the risk of further resistance development. These new strategies should involve the use and conservation of parasitoid wasps against GPA, as well as the use of unsprayed refuges against pyrethroid resistant RLEM.

Resistant management strategies (RMSs) for RLEM and GPA are important resources that help maintain the effectiveness of existing chemistries. RMSs have been developed by the National Insecticide Resistance Management (NIRM) working group for major resistant invertebrate pests in grains. The RLEM and GPA RMSs provide recommendations regarding effective pest management practices. In addition, a recent GRDC investment (BWD1805-006SAX) has helped develop best management practice guides (BPMG) for RLEM and GPA, published in 2020 (see Useful Resources section below). Growers and advisers are encouraged to become familiar with these guides and the RMSs – all freely available to download from the GRDC website.

General resistance management strategies include the following key principles:

- Monitoring crops for pest and beneficial invertebrate presence.
- Accurate invertebrate pest identification to determine the appropriate control strategy.
- Utilising non-chemical control options that suppress invertebrate pest populations.
- Using economic spray thresholds to guide chemical applications.
- If applying multiple insecticides, rotating the chemical mode of action.
- Using selective chemicals, where possible, in place of broad-spectrum options.
- Considering the secondary impacts of chemicals to non-target invertebrate pests and beneficials.
- Complying with all directions for use on product labels including using full recommended rates and good coverage of the target area to ensure the best possible chance of contact and subsequent control of the invertebrate pest.

Acknowledgements

The research undertaken here is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC. We also thank Corteva Agriscience, BASF, ISK, CropLife Australia, and Bayer CropSciences for their support and acknowledge our project collaborators, CSIRO, SARDI, NSWDPI and WA DPIRD. In particular, we acknowledge Andrew Weeks, Xuan Chen, Matthew Binns, Moshe Jasper, Alan Lord, Svetlana Micic, Owain Edwards, Jenny Reidy-Crofts and Sarina Mcfayden. For the parasitoid wasp research, this work was further supported by the Michael Mavrogordato award from the Australian Native Animal Trust, the Albert Shimmins Fund, and the Australian Grains Pest Innovation Program.

Useful resources

https://grdc.com.au/green-peach-aphid-best-management-practice-guide-southern/

www.grdc.com.au/GPAResistanceStrategy

www.grdc.com.au/BPG-BeneficialInsects-SW

https://grdc.com.au/new-knowledge-on-pests-and-beneficials-in-grains

www.grdc.com.au/insecticide-resistance-in-the-southern-region

https://grdc.com.au/FS-RLEM-Resistance-strategy

https://grdc.com.au/redlegged-earth-mite-best-management-practice-guide-southern/

https://cesaraustralia.com/pestfacts/

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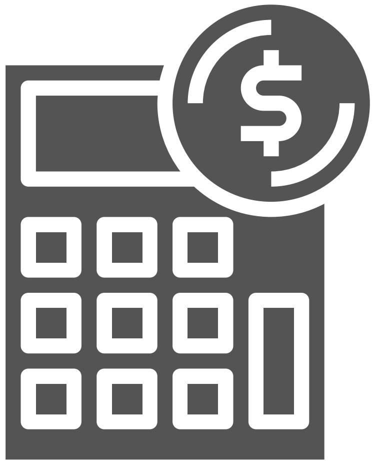
Notes

Download our latest Harvest Weed Seed Control Cost Calculator on the HWSC page of the Big 6!

weedsmart.org.au/big-6

WEED smart
every weed every seed
every farm every year



COST OF HARVEST WEED SEED CONTROL CALCULATOR

Herbicide MoA alignment: Stage 1

Herbicide Mode of Action (MoA) classifications have been updated internationally to capture new active constituents and ensure the MoA classification system is globally relevant.

The global MoA classification system is based on numerical codes which provides infinite capacity to accommodate new herbicide MoA coming to market, unlike the alphabetical codes currently used in Australia.

Farming is becoming increasingly global. Farmers, agronomists and academics around the world are now, more than ever, sharing and accessing information to assist them to grow crops, while managing sustainability issues such as herbicide resistant weeds.

It's important then that the herbicide MoA classification system utilised in Australia be aligned with the global classification system. This will ensure more efficient farming systems into the future and allow Australian farmers and advisors to access the most up-to-date information relating to managing herbicide resistance.

CropLife Australia is working with key herbicide resistance management experts, advisors and the APVMA to ensure farmers and agronomists are aware of the planned changes.

Growers can expect to start seeing herbicide labels with the new mode of action classification system from early 2022. There will be a transition period during which herbicide labels will exist in the supply chain, some bearing the legacy alphabetical MoA classifications, and others transitioned to the global numerical system.

The numerical classification system should be fully implemented by the end of 2024.

A mobile app compatible with Android and Apple systems is available via the **HRAC website** (hracglobal.com) at no cost to users. It will cross reference the herbicide active ingredient with its former MoA letter and new MoA number. Printed materials will also be made available to enable cross referencing of the changes.

Frequently asked questions

Q. Why change from letters to numbers?

A. A numerical code system is more globally relevant and sustainable, compared to the current alphabetic code used in Australia. Today there are 25 recognised MoAs. Over the next 10 years we anticipate up to four new modes of action to be commercialised, which will exceed the 26-letter maximum in the English alphabet.

Q. What is going to change?

A. The current alphabetical codes for herbicide active ingredients will change to numerical codes, in alignment with the global MoA classification system. For example, Group A herbicides will be labelled as Group 1 herbicides and Group M (glyphosate) will become Group 9.

Some new MoA will be introduced to accommodate some of the new chemistry being introduced world-wide. Some active ingredients will also be reclassified into different groups to better reflect their actual mode of action, not chemical structure.

A complete summary of the changes is available via the mobile app. More detailed information regarding the changes will be available in mid-2021.

Q. What are the main changes?

A. The main changes are outlined in the free mobile app, which you can download from the **HRAC website**. We are still working with industry experts to identify the consequences of these changes regarding how products fit into an integrated weed management program and will provide more specific guidance on the changes in mid-2021.

Q. How will the changes affect what we do?

A. The way growers use herbicides in the field will not change. The science hasn't changed and the mix and rotate messages remain correct. It is just the classification codes used on product labels and literature that will change from a letter to a number. Continue to follow your current IWM strategy and rotation plans.

Q. When will the changes take place?

A. There will be a transition period starting from July 2021, with growers likely to begin to see labels bearing the new MoA numbering system in the marketplace in early 2022.

Q. Does this mean the current MoA are wrong?

A. The science has not changed. Stick with your current IWM strategy and plans to rotate herbicides. In this era of multiple cross resistance, there is no magic bullet amongst the new modes of action.

Q. How will I know which products to rotate?

A. The science hasn't changed – stick with your current IWM strategy and plans to rotate herbicides. If in doubt, particularly with newer herbicides recently introduced, consult the manufacturer or your local agronomic advisor.

A summary of the changes is available via the mobile app. More detailed information regarding the changes will be available in mid-2021.

Q. Can I still use product on hand which has the old MoA printed on the label?

A. Yes. Legacy labels will be phased out over the next few years and will continue to be legally valid, although growers are encouraged to familiarise themselves with the new MoA classification system and corresponding resistance management strategies from 1 July 2021.

Q. Where can I find out more information?

A. You can find more information at the **CropLife website** and the free mobile app is available on the **HRAC website**.

Download the Global HRAC Herbicide MOA Classification app via Google Play or the App Store.

To find out more visit:

croplife.org.au/MoA

@CropLifeOz E info@croplife.org.au P 02 6273 2733

Faba bean agronomy and varieties

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GRDC project code: DAV00150

Keywords

- faba bean, canopy management, weed management, herbicide tolerance, disease resistance, soil constraints.

Take home messages

- Faba bean production has grown significantly in Victoria due to improved grower confidence with agronomy and varieties, which deliver profitable returns for the whole farming system.
- For commonly used varieties, sowing in April optimises grain yield in all rainfall zones across varying seasons, even in higher biomass production areas of the high rainfall zone (HRZ) (in the absence of lodging and when diseases are managed succesfully).
- In the HRZ of southwest Victoria, yield potential is likely to be limited at or above 25 plants/m^2 with any sowing date, suggesting that current practice is underutilising available light and moisture.
- To maintain a high yield potential across seasonal variability, growers should pursue growing manageably large canopies rather than trying to increase the pod-set of individual plants.
- In low rainfall areas, earlier flowering new varieties with higher yield potential and agronomic treatments that ameliorate soil constraints, like deep ripping on sands could give growers confidence to expand the area where faba bean is grown.
- Ongoing improvements in herbicide tolerance (PBA Bendoc⁽ᵇ⁾) and disease resistance (PBA Amberley⁽ᵇ⁾), combined with optimised agronomic management will improve economic yield and yield stability.

Background

Production of faba bean in Victoria has grown over the last 10 years from 35,000t produced from 22,000ha in 2009-10 season to 67,000t from 116,000ha in the 2018-19 season (Table 1). A peak in production was achieved in 2016-17 season with 220,000t and a peak in area sown was achieved at 147,000ha in 2017-18 season. These increases are due to improved grower confidence with agronomy and varieties which deliver profitable returns for the whole farming system. However, as illustrated by Table 1, the seasonal yield variability for faba bean is high due to a range of biotic and abiotic factors which when combined with price variability could constrain further growth and expansion.

Faba bean production across Victoria in 2020 was generally excellent with many crop yields of 4-5t/ha being reported within the medium and high rainfall zones. Unfortunately, prices have dropped dramatically from above $900/t in 2019, to less than $350/t in early 2021.

Most faba bean production occurs in the high and medium rainfall zones. However, there is increasing interest in the lower rainfall zones as new varieties with drought adaptation become available. Faba bean can be extremely profitable as a cash crop with long term average prices around $400/t, however prices can be volatile with peaks over $900/t in 2019 to a low of $220/t in 2018. An additional benefit reported by many growers is the higher growth rate of lambs grazed on bean stubbles, thereby providing additional profitability to the whole farm system. The 'break crop' benefits of faba bean also adds value to the following cereal crop and includes:

- Potentially, more than 100kg N/ha contributed to the following crop.
- Effective control of grass weeds.
- Effective break for many cereal foliar and root diseases.

When combined, these benefits are valued at improving yield of the following cereal crop by at least 0.5-1t/ha (Moodie et al. 2016).

To maintain a continued improvement in grower confidence to growing faba bean and support the growth in production and profitability several factors are being addressed through applied research and development activities to broaden the adaptability and improve the stability of faba bean yield. This paper presents some of the latest research findings that aim to overcome many of the key constraints across Victoria.

Table 1. Area sown and production of faba beans in Victoria from 2009-2010 to 2018-2019. (Source: ABARES, 2021).

Year	Area '000 ha	Production kt	Price at Harvest $[A]
2009–10	22	35	n/a
2010–11	63	104	n/a
2011–12	49	99	n/a
2012–13	67	126	440
2013–14	59	127	400
2014–15	62	112	400
2015–16	75	57	500
2016–17	120	220	240
2017–18	147	196	220
2018–19	116	67	900

[A]*Based on prices offered in Horsham in December of that season*

Results and discussion

Maximising yield potential through canopy management in southwest Victoria (HRZ)

Canopy size, plant size and yield potential

A substantial dataset has been generated over numerous years of trials in southwest Victoria where canopy size has been manipulated through time of sowing and sowing rate. The results from these trials suggest that growers should change their thinking on how canopy management affects faba bean yield potential.

For a canopy to maximise yield it must capture as many resources as possible and allocate them efficiently to grains. This can be increased by management options such as sowing earlier or increasing the plant density up to the point at which crop-to-crop competition becomes excessive.

At Inverleigh in 2020, results of trials showed that as plant density increased each individual plant was smaller and supported fewer pods/plant (Table 2). On balance however, having more small plants with fewer pods/plant increased overall pods/m^2 at the canopy level. This resulted in a correlation between increased yield and increased plant density. This shows that crop-to-crop competition was not limiting up to 34 plants/m^2 (Table 2). At Rokewood in 2016, yield also increased with plant density up to 26 plants/m^2 (Table 3).

Previous research on faba bean crops from a wide range of environments shows that good growing conditions favour low plant densities by enabling high biomass production (Lopez-Bellido et al. 2005). The current grower practice in southwest Victoria is to sow between 15 and 25 plants/m^2, so it might be expected that 15 plants/m2 would suit the high yielding years of 2016 and 2020. However, in the trials presented (Table 1 and Table 2), yield

Table 2. Grain yield, net return and pod-set of PBA Bendoc⦶ sown on 13 April, 2020 (199mm rainfall from 1 Aug to 31 Oct), at Inverleigh with four plant densities averaged across two row spacings (20cm and 40cm, n.s. *P*>0.05). Net return based on production costs of $340/ha, seed cost $0.59/kg, grain freight cost of $30/t and grain price of $300/t.

Plant density (pl/m^2)	Pods/plant	Pods/m^2	Grain yield (t/ha)	Net return ($/ha)
6	84 a	510 c	5.2 c	1026
16	38 b	615 bc	6.6 b	1361
26	31 b	786 ab	7.0 ab	1431
34	30 b	977 a	7.4 a	1501
Lsd (*P*<0.05)	14	227	0.8	-

Table 3. Grain yield and net return of Nura⁽ᴾ⁾ and PBA Zahra⁽ᴾ⁾ faba bean sown at Rokewood on 26 April 2016 (286mm rainfall from 1 Aug to 31 Oct), with five seeding rates. Net return based on production costs of $250/ha, $0.50/kg of seed sown and returns on grain of $240/t.

Plant density (pl/m²)	Grain Yield (t/ha)			Net Return ($/ha)		
	Nura⁽ᴾ⁾	PBA Zahra⁽ᴾ⁾	Ave	Nura⁽ᴾ⁾	PBA Zahra⁽ᴾ⁾	Ave
4	3.2	3.5	3.4	504	573	538
9	4.9	4.8	4.9	891	864	877
15	5.3	5.2	5.3	970	953	962
20	5.7	5.4	5.6	1052	985	1019
26	5.5	6.1	5.8	970	1118	1044
Ave	*4.9*	*5.0*	*5.0*	*877*	*899*	*899*
Lsd (P<0.05)$_{Var}$	ns			-		
Lsd (P<0.05)$_{SR}$	0.6			-		
Lsd (P<0.05)$_{VarxSR}$	ns			-		

increased with higher density plantings of 26 plants/m² (Table 3) and 34 plants/m² (Table 2). These crops were sown in April which also favours crop growth compared to a later sowing in May. These results suggest a density of at least 25 plants/m² could be required to maximise the yield potential of faba bean crops sown in favourable conditions.

Research has also shown that short or poor seasons favour high plant densities of faba bean because the high plant densities compensate for the loss in canopy growth (Lopez-Bellido et al. 2015). It does not appear to cause excessive growth when resources are limited. This has been observed in ‘dry’ seasons in the HRZ. For example, in a trial at Lake Bolac in 2018 where rainfall was below average (102mm during August 1 to October 31), yield increased with an increased plant density up to 45 plants/m² and was consistently greater following a 26 April sowing date compared to a 17 May sowing date (Table 4). A similar result was obtained in 2015, which was another season with a ‘dry’ spring (66mm during August 1 to October 31), and yield increased up to 35 plants/m² with no further increase in yield at 47 plants/m² (Table 5). These results suggest that sowing in late April, rather than mid-May, and increasing the plant density up to 35 plants/m² is likely to increase grain yield potential in unfavourable seasons.

These disease-free trials suggest that typical commercial sowing rates of 15 to 25 plants/m² are underutilising available moisture and light resources. Although southwest Victoria is a relatively favourable environment for crop growth, individual faba bean plants are not compensating enough through high growth or pod-set at these densities for crop-to-crop competition to become limiting and penalise yield potential. Soil constraints (e.g., soil acidity), cool temperatures and/or limits of genetic potential in current varieties could also be contributing to this observation.

Regardless of seasonal conditions, earlier sowing increased yield, and increasing the sowing rate further increased grain returns despite the cost of extra seed. Within the sowing rate range of current

Table 4. Grain yield and net return of PBA Samira⁽ᴾ⁾ sown on two sowing dates with three sowing rates at Lake Bolac in 2018 (102mm rainfall from Aug 1 to Oct 31). Net return based on production costs of $306/ha, seed cost $0.32/kg, grain freight cost $30/t, grain price of $330/t.

Plant density (pl/m²)	Grain Yield (t/ha)			Net Return ($/ha)		
	26 April	17 May	*Ave*	26 April	17 May	*Ave*
21	2.3	1.9	*2.1 c*	334	215	*275*
31	3.0	2.2	*2.6 b*	514	277	*395*
45	3.3	2.4	*2.8 a*	575	309	*442*
Ave	2.9 a	2.2 b		474	267	
Lsd (P<0.05)$_{TOS}$	0.2	-				
Lsd (P<0.05)$_{SR}$	0.2	-				
Lsd (P<0.05)$_{TOSxSR}$	ns	-				

Table 5. Grain yield and net return of PBA Zahra$^{\phi}$ and PBA Rana$^{\phi}$ sown at Westmere on 22 April, 2015 (66mm rainfall from Aug 1 to Oct 31). Net return based on production costs of $318/ha, seed cost $0.49/kg, grain freight cost $25/t, grain price of $400/t.		
Plant density (pl/m^2)	Grain Yield (t/ha)	Net Return ($/ha)
16	2.3 c	488
26	2.8 b	644
35	3.0 a	691
47	3.0 a	655
Lsd (P<0.05)$_{SR}$	0.2	-
Lsd (P<0.05)$_{v}$	0.2	-
Lsd (P<0.05)$_{SRxV}$	n.s.	-

industry practice, growers should focus on growing large canopies that fit their attitude to disease and lodging risk, while paying attention to extra seed costs and grain price variability. Trials have consistently demonstrated that late sowing or low plant densities will not compensate in yield potential through higher pod-set.

Higher sowing rates and/or earlier sowing could also add additional benefits to the farming system through greater competition with weeds, increased N fixation and increased feed availability for livestock post-harvest. These benefits should be weighed against the higher risk of lodging and disease.

Time of sowing and phenology

Early sowing generally increased crop biomass as well as enabling the key development phases of flowering and pod-set to occur earlier in the season. Compared to other pulses, faba bean are more tolerant to frost damage and cool temperatures, but more susceptible to heat damage and moisture stress. For instance, April sown trials out-yielded May sown trials in 2018, 2019 and 2020 which experienced high incidences of frost coinciding with flowering and pod-set, although the rainfall received during each spring differed.

At Lake Bolac in 2020, a time of sowing x variety trial found that across the seven cultivars tested an earlier time of sowing resulted in an increased grain yield (Table 6). AF12025 achieved the highest yield with the earliest flowering date of July 5 (compared to August 7 for PBA Samira$^{\phi}$) in the TOS1 treatment but had a lower yield than PBA Samira$^{\phi}$ with a 19 May sowing date.

Faba bean breeding trials are typically sown in a window between 27 April to 19 May and this is reflected in the high yield and yield stability of the popular variety PBA Samira$^{\phi}$, and the recently released PBA Amberley$^{\phi}$. The interactions between sowing date and cultivar type for yield indicate that more work can be done to match cultivars to a wider range of sowing dates for southwest Victoria. An exploration of phenological responses of current and upcoming breeding lines was undertaken in southwest Victoria and Tasmania in 2020 in collaboration with Pulse Breeding Australia to begin understanding optimum flowering windows for these regions.

Managing herbicide residues and weed management in Victoria

Weed management and herbicide residues are important constraints to maximising the productivity and profitability of faba bean across Victoria. Leading growers have always taken a long-term view to minimise potential weed burden in faba bean by effectively controlling broadleaf weeds in the cereal phase of the rotation and utilising herbicides that are unlikely to create significant residual issues in the faba bean phase.

The faba bean breeding program has developed cultivars with improved tolerance to Group B imidazolinone herbicides. The release of PBA Bendoc$^{\phi}$ in 2018, has increased options for the control of broadleaf weeds and enhanced tolerance to sulfonylurea residues. Several trials have been conducted over several years resulting

Table 6. . Grain yield of seven faba bean cultivars sown on three sowing dates at Lake Bolac in 2020.

TOS	PBA Samira$^{\phi}$	AF12025	PBA Amberley$^{\phi}$	PBA Nasma$^{\phi}$	PBA Zahra$^{\phi}$	Fiesta	PBA Bendoc$^{\phi}$	Mean (TOS)
9-Apr	5.8	6.5	5.5	4.7	4.9	5.6	4.8	5.4
27-Apr	4.7	4.5	4.7	4.6	4.5	3.8	3.7	4.4
19-May	3.6	3.1	3.6	3.9	2.7	2.6	3.1	3.2
Mean (Variety)	*4.7*	*4.7*	*4.6*	*4.4*	*4.0*	*4.0*	*3.8*	
Lsd$_{TOS}$ (P<0.05)	0.5							
Lsd$_{Variety}$ (P<0.05)	0.5							
Lsd$_{TOSxVAR}$ (P<0.05)	0.4							

Table 7. Visual herbicide damage score (0, No symptoms – 100, Crop death) and grain yield (t/ha) of the new imidazoline tolerant variety, PBA Bendoc$^{\phi}$, in comparison to the conventional variety, PBA Samira$^{\phi}$, in response to application of imidazolinone products post sowing pre-emergent (PSPE) at four node crop growth and a sulfonyl urea applied to simulate potential residuals at Horsham in 2019.

		Herbicide Damage (0-100)		Grain Yield (t/ha)	
Active ingredient (g/ha)	Application Timing	PBA Bendoc$^{\phi}$	PBA Samira$^{\phi}$	PBA Bendoc$^{\phi}$	PBA Samira$^{\phi}$
Nil (0)		0	0	4.49	4.50
Imazamox(25) & Imazapyr (11)	PSPE	0	3	4.38	3.74
	4 node	5	85	4.63	1.30
Imazethapyr (70)	PSPE	0	8	4.75	4.00
Metsulfuron-methyl (4)	Simulated Residue	18	72	3.91	0.49
Lsd $_{ChemTrt}$ (P<0.05)		*5*		*0.68*	
Lsd $_{Var}$ (P<0.05)		*2*		*0.09*	
Lsd $_{ChemTrt*Var}$ (P<0.05)		*8*		*0.73*	

in the registration of Intercept® for use in-crop. For example, in PBA Bendoc$^{\phi}$ no significant visual damage was observed from the application of imidazoline products and a very low level of damage occurred from simulated sulfonylurea residues in trials at Horsham 2019 (Table 7). Further, grain yield loss was not significant in PBA Bendoc$^{\phi}$ compared with the 'Nil' for any of the herbicide treatments, although the data indicates approximately 10% potential yield loss in the simulated residue treatment of metsulfuron-methyl compared to all other treatments. In comparison, severe crop damage and significant yield loss was observed for most herbicides applied to the conventional variety PBA Samira$^{\phi}$.

Breeding programs are continuing to develop improved tolerance to Group I (e.g., clopyralid) and Group C (e.g., metribuzin) herbicides, which will further enhance weed control and herbicide residue management options. There have also been several new herbicides (e.g. Group G) registered and recently released which will continue to improve the ability of growers to maximise weed control in faba bean and throughout the whole farming system.

Adaptability to the LRZ of Victoria – genetic and agronomic solutions

Faba bean can be extremely sensitive to hot, dry conditions, particularly during the reproductive phase. Faba bean is also poorly adapted to deep

Table 8. Grain yield (t/ha) and gross margin ($/ha) of selected faba bean varieties and breeding lines at Curyo (southern Mallee, Vic) from 2016 to 2020.

	2016		2017		2018		2019		2020		Average	
Variety	GY (t/ha)	GM[1] ($/ha)	GY (t/ha)	GM ($/ha)	GY (t/ha)	GM ($/ha)	GY (t/ha)	GM ($/ha)	GY (t/ha)	GM ($/ha)	GY (t/ha)	GM ($/ha)
AF12025	5.75	1079	3.12	386	0.43	87	5.22	3354	3.55	872	3.61	1156
Farah	4.54	790	2.73	301	0.43	87	4.06	2542	4.02	1027	3.16	949
PBA Bendoc$^{\phi}$			2.91	340	0.40	60	4.26	2682	4.37	1142	2.99	1056
PBA Marne$^{\phi}$	5.49	1019	2.59	270	0.40	60	4.18	2626	3.82	961	3.30	987
PBA Samira$^{\phi}$	4.12	688	3.13	389	0.47	123	3.42	2094	3.95	1004	3.02	859
PBA Zahra$^{\phi}$	4.42	762	2.99	358	0.28	-48	4.30	2710	4.50	1185	3.30	993
Lsd$_{GY}$ (P<0.05)	*0.97*		*0.48*		*0.08*		*0.43*		*0.61*			
Grain Price ($)		240		220		900		700		330		
Rainfall												
Annual	471		397		275		230		359			
GSR	356		243		131		180		238			

[1] Gross margins are based on estimated production costs of $300/ha.

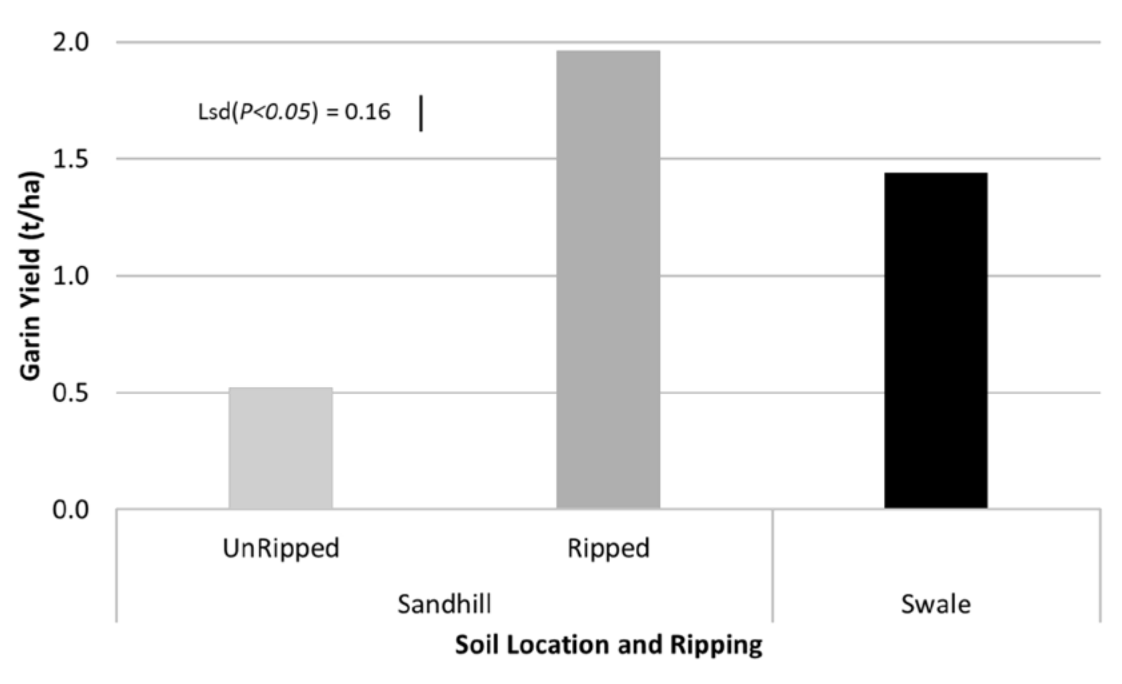

Figure 1. Effect of soil type and deep ripping sandy soils on the grain yield of faba bean at Kooloonong in 2020.

sandy soils which are found in 20-30% of the low rainfall Mallee. Several years ago, the breeding program focussed on improving adaptation through earlier flowering and maturity, which resulted in the release of PBA Marne⁽ᵇ⁾, which shows improved yield under drier conditions, particularly in SA. In Victoria, another breeding line, AF12025, which can flower two weeks earlier than PBA Samira⁽ᵇ⁾, has consistently shown high grain yields in the southern Mallee across a range of cropping seasons. (Table 8). Potential gross margins were above $3,000/t in 2019 when high yields and prices were achieved concurrently.

Recent agronomic research has highlighted that practices such as deep ripping, which reduce soil penetration resistance, can lead to substantial productivity gains of pulses on these deep sands. At Koolonong in 2020, ripping to 50cm prior to sowing improved faba bean grain yield by 300% in deep sand, increasing the yield from 0.5t/ha to 2t/ha (Figure 1). The yield on the ripped sand exceeded

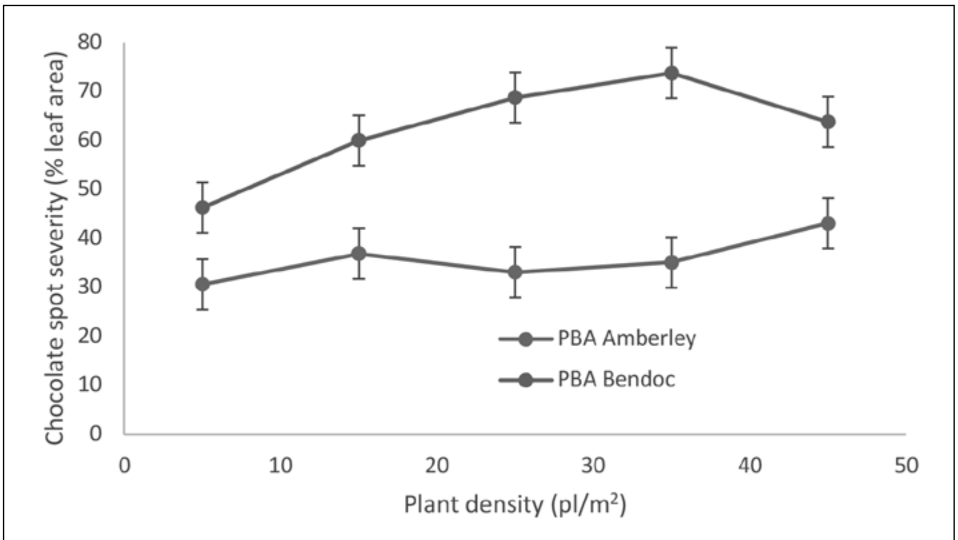

Figure 2. The effect of plant density on chocolate spot disease severity (% of canopy leaf area) evaluated on October 20, 2020 in PBA Amberly⁽ᵇ⁾ and PBA Bendoc⁽ᵇ⁾, which differ in their genetic resistance against diseases. Error bars are the l.s.d. for the Variety x Plant density interaction (P<0.05).

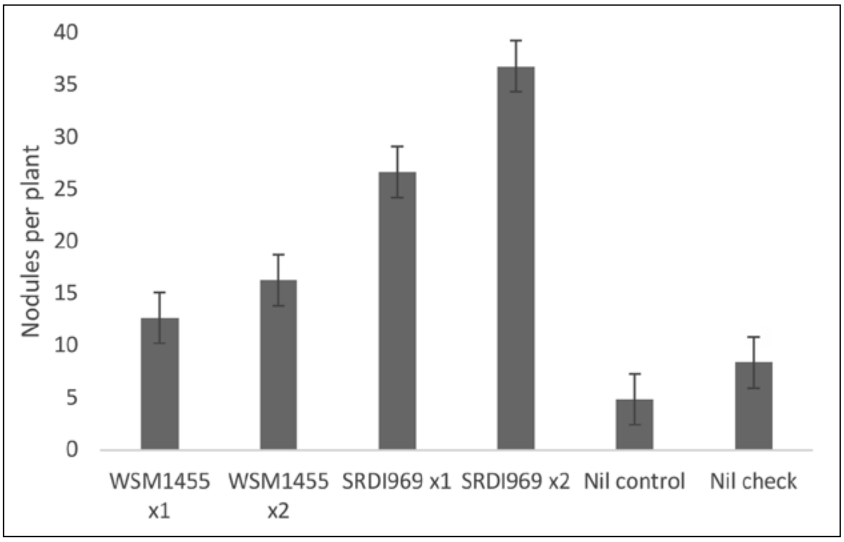

Figure 3. The effect of rhizobia strain and peat inoculation rate on faba bean nodulation at Winchelsea in 2020, compared to uninoculated and cross-contamination controls. Error bars are the Lsd of a one-way ANOVA ($P<0.05$).

yields on the heavier swale soil in the flat of the same paddock by approximately 0.5t/ha. These examples highlight that with ongoing agronomic and genetic improvement, further expansion of faba bean is feasible.

Genetic solutions to disease management

Diseases, notably chocolate spot, are a significant obstacle to closing the yield gap of faba bean, particularly in the HRZ. A significant step has been made with the recent release of varieties with enhanced chocolate spot resistance. For example, when plant density was increased, which increased biomass, disease increased in faba bean canopies (Figure 2). However, the rate of increase in PBA Amberley⁽ᵇ⁾ was smaller (2.3% more disease per 10 plants/m^2), than PBA Bendoc (4.9% more disease per 10 plants/m^2). Therefore, genetic resistance can change the relationship between canopy size and disease pressure revealing an opportunity to close the yield gap through growing profitably large canopies in the HRZ. Agronomy packages will need to be tailored appropriately to protect the higher yield potential of these large canopies, and further work is needed to clarify what that will entail. Further disease management results are discussed at this GRDC Update by Josh Fanning.

Agronomic solutions to acid soil constraints

Acid soils are a significant constraint for faba bean production in southwest Victoria. Low soil pH reduces crop productivity directly by reducing nodulation and nitrogen fixation. An acid-tolerant rhizobia strain developed at SARDI has been shown to increase nodulation in these conditions. For instance, at Winchelsea in 2020 this acid-tolerant strain (SRDI969) stimulated greater overall nodulation (Figure 3). In addition to this, when the rate of inoculant was doubled, nodules increased from 27 to 37 nodules/plant. In this trial, the current commercial strain (WSM1455) did not respond to a doubled rate of peat inoculant and averaged 14.5 nodules/plant.

These levels of nodulation are however lower than the suggested optimum of 50 nodules/plant. This is because the soil pH at this site was 4.4 $CaCl_2$ at 0 to 20cm depth. Liming is recommended to achieve a pH of 5.5 $CaCl_2$ in the top 10cm of soil which will maintain soil pH above 5.0 in the top 20cm of soil. This will enable greater nitrogen fixation in addition to the other system benefits improved pH brings.

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.

The authors are also grateful to all growers who have hosted trials on their farms and the input of industry representatives and colleagues to trial ideas and treatments.

Additionally, the authors are thankful to the technical teams of Agriculture Victoria and Southern Farming Systems, who have managed these trials.

Useful resources

Faba Bean Southern Region - GrowNotes™, 2017. Available on the GRDC website.

Online Farm Trials – All trial results from the Southern Pulse Agronomy Research program are published here.

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Subsoil amelioration - update on current research

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GRDC project code: DAV00149

Keywords

- soil constraints, clay soils, economic risk, subsoil water, sodicity, soil dispersion.

Take home messages

- Long-term trials throughout south eastern (SE) Australia indicate plant-based manures improved grain yields by an average of 19%. Animal manures improved yields by an average of 26% but can also produce negative effects with a trend for the residual benefits to be shorter-lasting than for plant-based amendments.
- Responses to amelioration are strongly influenced by water availability (subsoil reserves, seasonal rainfall patterns and potentially water logging).
- Responses to amelioration with organic materials appear soil type specific requiring an assessment of both subsoil and topsoil soil properties, including dispersion.

Background

Current grain yields in many sections of the high rainfall zone (HRZ) of SE Australia, as well as parts of the medium rainfall zone (MRZ) remain below water limited yield potential. This failure to achieve yield potentials have been attributed to a range of factors including nitrogen (N) deficiency, disease and seasonal conditions including frost (Armstrong et al. 2019; Hochman et al. 2019). Many soils in this region also contain a range of physicochemical constraints, especially in subsoils which limit root growth and efficient use of soil water and nutrients (Adcock et al. 2007).

Previous research including that by Peter Sale and his colleagues at La Trobe University, summarised in Sale et al. (2021), have recorded significant yield benefits from the application of animal-based manures to subsoils (referred to as 'subsoil manuring'), especially in HRZ systems. Despite the strong interest in this approach by some growers, overall rates of on-farm adoption currently remain very low. This lack of adoption has been attributed to several major logistical constraints including an inability to source sufficient quantities (at a low price) of ameliorant stock, particularly animal manures, and a lack of suitable commercial scale machinery for placing the ameliorants into the soil (Nicolson 2016). Most importantly the unpredictability of grain yield responses ('when, where, how much and how long') mean that most growers are not willing to undertake the significant financial risk resulting from the initial high upfront investment (approximately $1200-1400/ha (Sale and Malcom 2015)) needed.

In 2017, two major projects commenced with the support of GRDC investment, examining the use of soil amelioration to improve long-term crop productivity: one project focused on sandy soils in the low rainfall zone (LRZ) (CSP00203) and the other on clay soils in the HRZ and MRZ of SE Australia (DAV00149). This presentation provides an update on some of the latest research arising from DAV00149.

Method

Analysis of long-term trials

An analysis was undertaken of a large number of field-based trials (greater than 70) that have been undertaken over recent years by different groups under a variety of initiatives in SE-Australia comparing different combinations of plus/minus deep ripping, with and without the use of amendments including animal manures, plant biomass and gypsum and different placement (surface or subsoil). Several criteria were used to determine which trials should be included in the analysis, including presence of an unamended 'control', an ability to track the providence of the trial (including when the trial was commenced) and an ability to accurately locate plots. A response was only recorded if statistically different ($P = 0.05$) or if no replication was used the response had to be greater than 20%. There were 40 trial years of data for legume organic matter (comprising 14 sites but with only six of these trials with data older than five years) and 71 for animal manure (comprising 20 sites but with only five sites older than five years). The majority of trials (55%) were sown to cereals (wheat and barley). This analysis was then used to graph the relative grain yield response to either the application of animal manure or legume amendments to the subsoil compared to the non-amended control.

The effectiveness of different amendments and placement strategies

A network of 'new field experiments' were established (two in 2017 and another six in 2018) with four located in the HRZ (Rand, New South Wales (NSW); Nile, Tasmania; Tatyoon, Victoria and Marrabel, South Australia (SA)) and four in the MRZ (Grogan, NSW; Condowie in SA and Kiata and Plant Breeding Centre (PBC) (Horsham) in Victoria). The equivalent of 20t/ha of organic amendment was applied at HRZ sites (except for Marrabel where 15t/ha was applied) and 15t/ha at MRZ sites. All experiments had a common set of amelioration treatments (as well as additional ones of local interest) including a deep-ripping 'check', surface and subsoil application of animal manure, legume plant based amendment and gypsum. In addition, all experiments had a nutrient only treatment (phosphorus (P) plus N rates equivalent to 50% of that contained in organic material with supplementary N applied over the subsequent three crops. This strategy accounted for a predicted 50% mineralisation rate of N from the amendment each year so that the sum of N applied was equivalent to that in the organic material after three years) and a treatment comprising wheat straw plus nutrients. Amendments were applied once so that the residual value could be assessed in subsequent years.

Subsoil water and response to amendments

The effect of subsoil water on crop response to amelioration treatments was assessed by establishing irrigated subplots (1.6m wide x 2.7m long) in five treatments (control, deep nutrients, topsoil nutrient enriched organic matter (NEOM), subsoil NEOM, wheat plus nutrients) in the PBC DAV00149 experiment in March 2020 using gravity-fed drip irrigation. A total of four irrigation events were applied, each equivalent to 46mm. Changes in profile soil water balance (using neutron probes), dry matter and normalised difference vegetation index (NDVI) throughout the growing season and grain yield were monitored in the irrigated subplots and compared to adjacent dryland main plots.

Results and discussion

Analysis of long-term trials

Grain yields were improved by an average of 19% following application of plant based (legume) amendments into the subsoil across a range of soil type and environments compared to the control (no amendment) (Figure 1). In many cases the plant manure produced a marked improvement in dry matter production, but this did not translate to a response in grain yield. In contrast animal manures improved yields on average by a greater amount (26%) but produces strong negative effects on yield at several sites, whereas organic amendments produced a negative effect in one case only. Furthermore, although influenced by a small number of sites, there appeared to be a trend for the residual benefits of applying plant-based amendments into the subsoil to last longer whereas the residual benefits of the animal manures were somewhat shorter term. There were very few positive benefits (3 out of 18) in grain yield to deep ripping alone (data not presented). Four sites produced large negative responses to ripping. The overall net effect was that overall ripping alone did not change crop productivity.

Although these findings were based on both replicated and non-replicated trials, they indicate the same general trends observed to date in 'new field experiments' reported later. Two major barriers to the widespread commercial scale adoption of soil amelioration is the lack of sufficient quantities of animal manures. This analysis suggests that plant based (predominantly legume) manures are nearly as effective as the animal manures. As well as being more readily available, the use of plant manures potentially reduces the financial risk associated with subsoil manuring as there were no marked negative impacts that can occur with animal manures, especially in medium rainfall systems and there was a trend towards a much longer residual benefit which is critical to offsetting the initial high upfront costs of subsoil amelioration.

The effectiveness of different amendments and placement strategies

No positive yield responses to amendments were recorded in 2020 at either Condowie (SA) nor Kiata (Victoria), reflecting continued low growing season rainfall (GSR) experienced at these sites since 2017 and 2018, respectively (data not presented). There were significant (P<0.05) grain yield responses recorded at Grogan, NSW (GSR = 426mm) where wheat straw plus nutrients was 15% and deep gypsum was 11% greater than the control (7.2t/ha of wheat) respectively and at the PBC (Victoria) site (GSR = 287mm; Decile 7) where deep manure and deep wheat straw plus nutrient were 11% greater (P<0.05) than the control (barley = 5.1t/ha). This yield response at Grogan, which corresponded with high GSR, contrasts with previous seasons where crops have been cut for hay due to frost and dry seasonal conditions.

Prior to 2020 there have been large (20 to 65%) yield responses to soil amendment at all HRZ sites with the exception of Tatyoon (Victoria), where responses were small (15%) or less. In 2020 for the three sites harvested to date, treatment effects were much smaller with a small treatment effect (P=0.01) at Marrabel (barley yield of control was 6.22t/ha; GSR = 393mm) and no significant effect at Tatyoon (average faba bean yield of 4.75t/ha; GSR = 404mm). In contrast, at Rand (NSW), where GSR = 401mm, had significant grain yield (P<0.001) responses to deep gypsum (19%) and deep wheat straw plus nutrients (20%) compared to the control (wheat = 6.9t/ha). Although overall responses were smaller in 2020 than in the previous three seasons (highest yield treatment from deep gypsum was 20% greater than the control), the pattern of treatment differences remained, since the experiment commenced in 2017, with an average of greater than 23% for the most productive treatments compared to the control (Figure 3).

Subsoil water and response to amendments

Since project experimentation commenced in 2017, the largest (on both an absolute and relative scale) crop biomass and grain yield responses have been recorded in the HRZ rather than MRZ. Prior to 2020, of the nine MRZ site x year trials conducted to date, the highest annual and growing season rainfall had been decile 5 (at PBC in 2019) with most sites recording Decile 2 to 3. In this time, no MRZ site has recorded significant subsoil water reserves prior to sowing.

At sowing (in May 2020) at PBC, the irrigation produced significant increases in volumetric soil water content to depths greater than 80cm. Interestingly, there was a trend for this increased water to reach lower in the soil profile in amended

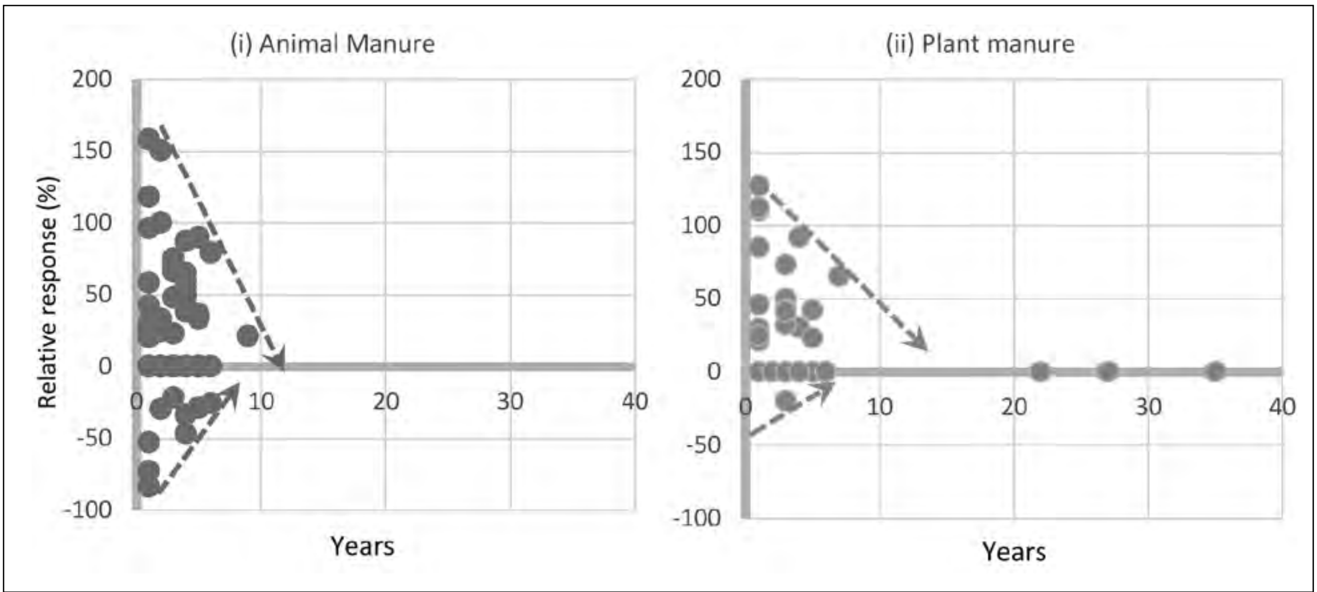

Figure 1. Relative grain yield response of crops to **(i)** application of animal manure and **(ii)** plant- based manures in a series of long-term fields in SE Australia.

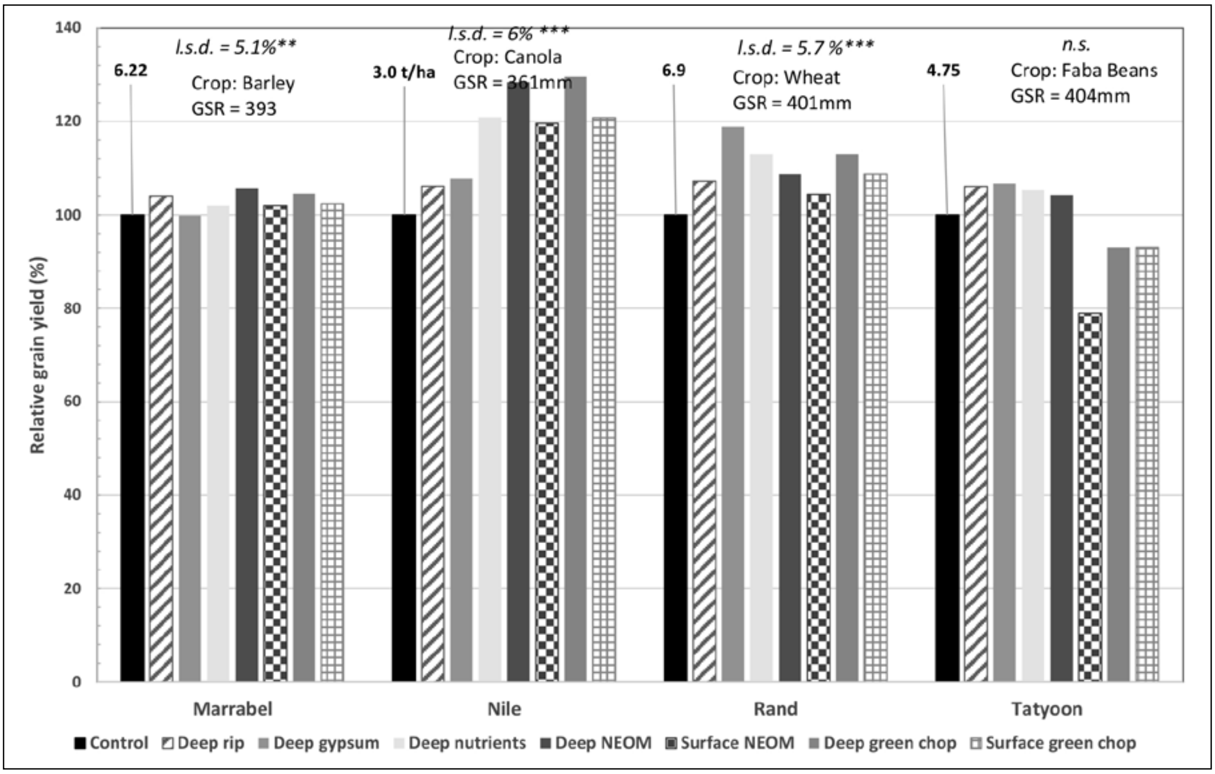

Figure 2. Relative grain yield response (%) to soil amendments (Control = 100%). Data is for the HRZ Tatyoon, Rand and Marrabel sites in 2020 and Nile in 2019 (2020 Nile trial had not been harvested at time of writing). Value above Control represents grain yield (t/ha). GSR = growing season rainfall.

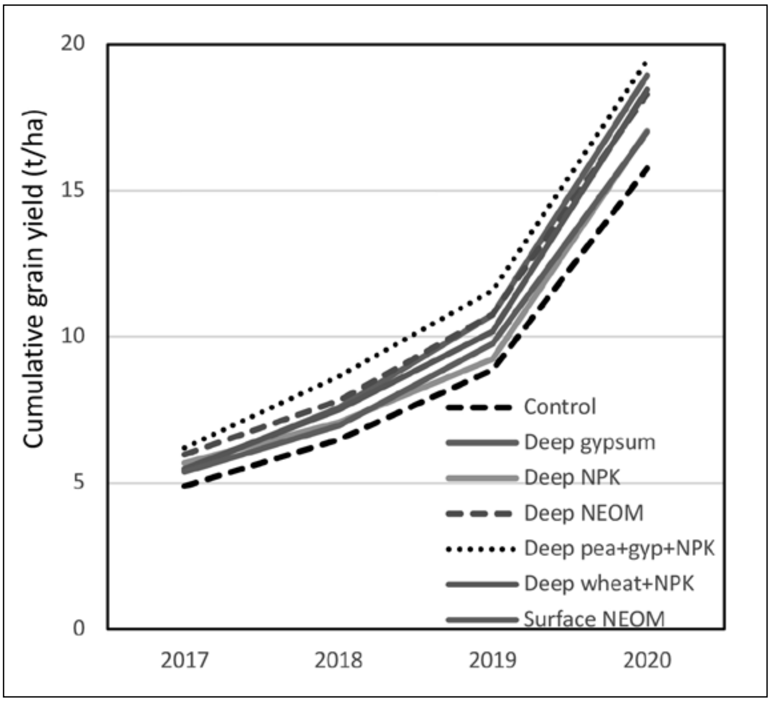

Figure 3. Cumulative grain yield responses to selected amendment treatments at Rand for 2017 (barley), 2018 (wheat), 2019 (canola) and 2020 (wheat).

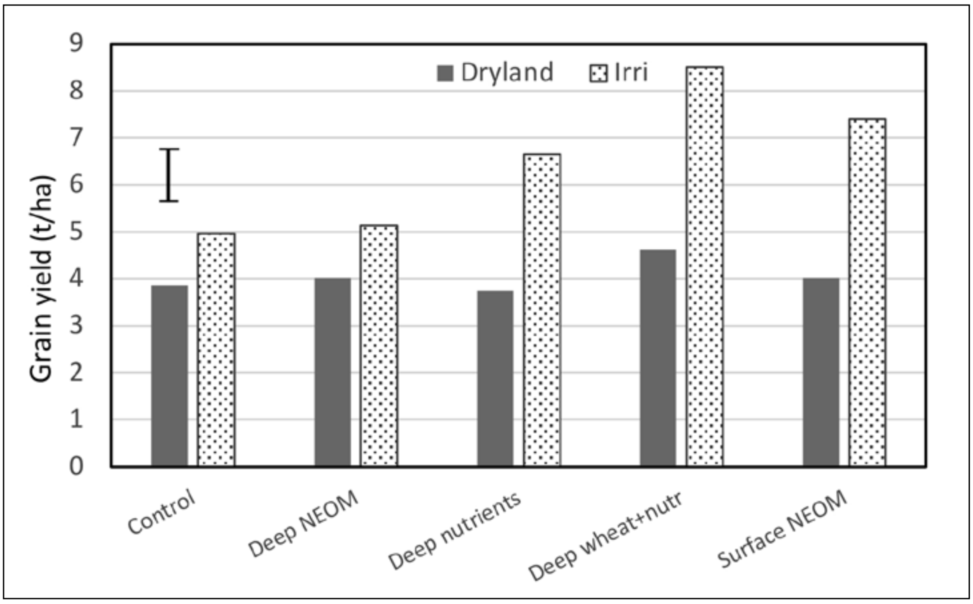

Figure 4. Effect of irrigation (prior to sowing) on grain yield responses of barley to soil amelioration (PBC, 2020). Vertical bar represents Lsd (P=0.05 = 1.01 t/ha) for interaction between amendment and irrigation.

treatments (applied to both topsoil and subsoil) compared with the irrigated control treatments (data not presented).

In the absence of subsoil water reserves, there was no significant difference (P<0.05) in wheat grain yield between soil treatments (mean = 4.05t/ha, dryland treatments) (Figure 4). In the irrigated microplots, grain yield increased on average by 2.48t/ha (61%). The impact of irrigating varied with the type of amelioration imposed, ranging from 28% in the control and Deep NEOM to 78% with Deep nutrients and 84% for both Deep wheat plus nutrient and Surface NEOM. The highest grain yields (8.51t/ha) were recorded for Deep wheat plus nutrient treatment. Differences in grain yield were reflected in total wheat biomass with a trend of lower harvest index in irrigated microplots (P=0.073).

Conclusion

The use of plant (legume) biomass appears to offer important advantages over animal manures when ameliorating clay subsoils in the MRZ and HRZ, because of the absence of potential negative impacts on grain yield and potentially longer residual value. Importantly, plant-based manures are generally easier to source than animal manures. Results over the past two years from several of the new field experiments in DAV00149 indicate that not only are legume residues effective but that applying wheat straw plus nutrients into subsoils can significantly improve grain yields.

Grain yield responses to soil amendment on these clay soils appear to be strongly influenced by soil water supply, with poor treatment responses in very dry seasons when there is very little subsoil moisture (as evidenced by the majority of MRZ experiments to date), or very wet seasons when crops can access sufficient moisture from the topsoil (as occurred at Tatyoon and Marrabel in 2020). Controlled environment experimentation has shown that the application of subsoil manures or nutrient rich plant-based materials can improve wheat growth in water-logged soils, possibly due to a reduction in soil redox potential. There was evidence that the presence of subsoil water appears to influence response to amendments. Soil amelioration can affect crop productivity by overcoming physicochemical constraints – nutritional, poor structure and potentially toxicities such as water logging, occurring in both the topsoil and subsoil. The effect of subsoil water on amendment response is not surprising given that subsoil water has the potential to produce twice the grain yield per mm of water used compared to surface soil water (Lilley and Kirkegaard 2007) and the finding that subsoil constraints can only limit grain yields when crops are reliant on subsoil water to realise yield potentials (Nuttall and Armstrong 2010).

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The research undertaken as part of the project, DAV00149 is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC. The author would like to thank them for their continued support. The authors would also like to thank Agriculture Victoria, NSW DPI, SARDI and TIAR for their ongoing support.

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GRDC GROWNOTES

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GRDC™ GRAINS RESEARCH & DEVELOPMENT CORPORATION

THE 2020-2022 GRDC SOUTHERN REGIONAL PANEL

May 2021

CHAIR - JOHN BENNETT

Lawloit, VIC

Based at Lawloit, between Nhill and Kaniva in Victoria's West Wimmera, John and his family run a mixed farming operation across diverse soil types. The farming system is 70 to 80 per cent cropping, with cereals, oilseeds, legumes and hay grown. He wants to see RD&E investments promote resilient and sustainable farming systems that deliver more profit to growers and ultimately make agriculture an exciting career path for young people.

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Kate is a partner in a large grain producing operation in Victoria's Southern Mallee region and produces wheat, canola, lentils, lupins and field peas. Kate has been an agronomic consultant for more than 20 years servicing the Mallee and northern Wimmera. Kate is passionate about producing high quality grain, whilst enhancing the natural ability of the soil. Kate is passionate about research and the extension of that research to bring about positive practice change to growers.

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Jon has worked in agriculture for the past three decades, both in the UK and in Australia. He has managed Grainsearch, a grower-funded company evaluating European wheat and barley varieties for the high rainfall zone, and his consultancy managed the commercial contract trials for Southern Farming Systems (SFS). Jon was a member of the GRDC's HRZ (RCSN (now National Grower Network) and became a GRDC Southern Panel member in 2015. In 2020 Jon set up an independent consultancy, TechnCrop Services.

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Lou is a farmer based at Lameroo in the Southern Mallee of South Australia. With her parents and partner, she runs a mixed farming enterprise which includes export oaten hay, wheat, barley, a variety of legumes and a self-replacing Merino flock. Prior to returning to the family farm, Lou had a 10-year agronomy career, servicing the Upper South East and Mallee. She is passionate about her industry, particularly in recognising the role that women play in the industry and on the land.

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Andrew is a research agronomist, based at Port Lincoln on SA's Eyre Peninsula. He started his career with the South Australian Research and Development Institute (SARDI) at the Minnipa Agriculture Centre, and then spent time at CSIRO in Adelaide. Andrew managed the family farm on Lower Eyre Peninsula for 10 years before returning to SARDI in late 2009. In 2019, Andrew started his own research company EPAG Research, delivering applied research across Eyre Peninsula. Andrew received the GRDC Southern Panel's Emerging Leader award in 2018, and prior to joining the Panel he served on the GRDC's low rainfall zone RCSN (now National Grower Network).

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Cummins, SA

Michael is a third-generation grain grower based at Cummins on South Australia's Eyre Peninsula, where he grows wheat, barley, canola, beans, lupins and lentils on a range of soil types. He has been involved in the South Australian Grains Industry Trust, the Lower Eyre Agricultural Development Association and the South Australian No Till Farmers Association. He believes research and development underpins profitability in Australian farming systems and the GRDC is pivotal in delivering research outcomes that support growers.

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In February 2020 Professor Michelle Watt was appointed the Adrienne Clarke Chair of Botany at the University of Melbourne. From 2015 to 2019, she was Director of the Plant Sciences Institute at the Helmholtz Centre and Professor of Crop Root Physiology at the University of Bonn in Germany. Prior to 2015 Michelle was at CSIRO. She has been in multi-partner projects with Australia, the USA, India, the Philippines, UK and Germany in the under-studied but critical area of plant roots. She is President of the International Society of Root Research and Co-Chair of the Root Phenotyping.

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SOUTHERN/WESTERN REGION*

PREDICTA® B
KNOW BEFORE YOU SOW

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

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

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

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

Potential high-risk paddocks:

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

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

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

Government of South Australia
Primary Industries and Regions SA

SARDI
South Australian Research and Development Institute

GRDC
Grains Research & Development Corporation

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- Partnering organisation: Southern Farming Systems

GRDC
GRAINS RESEARCH
& DEVELOPMENT
CORPORATION

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/StreathamGRU

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.