GRAINS RESEARCH UPDATE

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Numurkah

Wednesday 31st July

9.00am to 1.00pm

Numurkah Town Hall,
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#GRDCUpdates

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GRDC Grains
Research Update
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Contents

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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Program

9:00 am	**Announcements and GRDC welcome**	***GRDC representative***
9:15 am	**Double and triple knock strategies for managing ryegrass**	***Chris Preston,*** *University of Adelaide*
9:55 am	**An integrated approach to slug management**	***Michael Nash,*** *What Bugs You*
10:35 am	**Morning tea**	
11.05 am	**Effective fertiliser planning and budgeting**	***Lee Menhenett,*** *Incitec Pivot*
11:45 am	**The looming threat of subsurface acidity**	***Jane McInnes,*** *Riverine Plains*
12.25 pm	**Strategies for managing Crown Rot**	***Grant Hollaway,*** *Astute Ag*
1.05 pm	**Close and evaluations**	***GRDC representative***
1.10 pm	**Lunch**	

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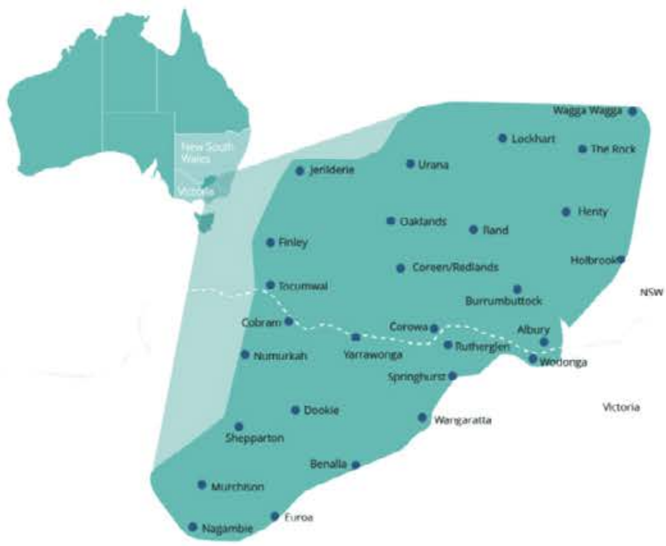
Agricultural commodities 2020-21 by local government area, Australian Bureau of Statistics



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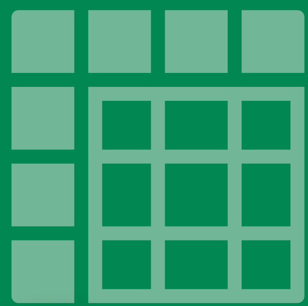

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Double and triple knock strategies for managing ryegrass

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School of Agriculture, Food and Wine, University of Adelaide.

GRDC project codes: UCS2008-001RTX, UOA2007-007RTX

Keywords

- dry sowing, glufosinate, glyphosate, paraquat, resistance.

Take home messages

- Glyphosate and paraquat resistance in annual ryegrass will make knockdown weed control prior to sowing more difficult.
- Be aware of plant backs when using Group 14 herbicides in knockdown applications or if using glufosinate as a knockdown herbicide.
- Glufosinate has potential as the first herbicide in a double knock approach.
- Dry sowing can offer a different alternative to manage glyphosate and paraquat resistant annual ryegrass, however, an effective pre-emergent strategy needs to be employed.

Resistance to glyphosate and paraquat in ryegrass

Recent weed resistance surveys are indicating an increase in glyphosate resistant annual ryegrass (Table 1). Only two samples with resistance to paraquat were identified in this survey, both from South Australia. However, resistance to paraquat has been detected in an increasing number of annual ryegrass populations sent for testing. Resistance to both paraquat and glyphosate makes control of annual ryegrass prior to sowing much more challenging.

Table 1: Extent of resistance to glyphosate in annual ryegrass collected in a random survey of cropping fields across Australia in 2020/2021. Samples were considered resistant if more than 20% of the individuals survived herbicide treatment.

State	Samples tested	Resistance to glyphosate	Resistance to paraquat
		(% of samples)	(% of samples)
New South Wales	317	23	0
Victoria	183	22	0
Tasmania	21	0	0
South Australia	279	14	0.7
Western Australia	554	12	0
Total	1354	16	0.1

Double knocks and more

The strategy for managing glyphosate resistance is to use a double knock approach. Typically, this is glyphosate followed by paraquat 1–5 days later. The timing of the paraquat application is very important as application at some times can lead to a reduction in efficacy of paraquat on glyphosate resistant annual ryegrass (Figure 1).

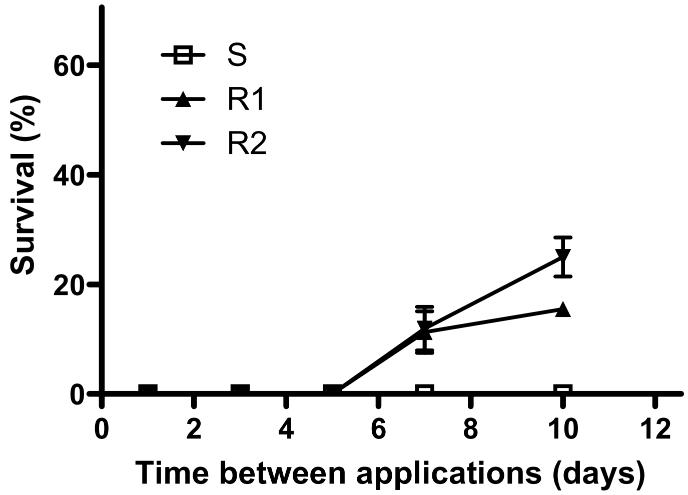

Figure 1. Effect of time between applications for glyphosate followed by paraquat double knock on glyphosate resistant annual ryegrass populations. S is a glyphosate susceptible population. R1 and R2 are two glyphosate resistant populations.

With both glyphosate and paraquat resistance, should we be thinking about a triple knock? It will be very challenging to find time to put three knockdown applications out prior to sowing. In any case, the choice of the third knockdown herbicide could delay sowing due to plant backs.

The newer Group 14 herbicides Terrad'or® and Voraxor® are now being frequently used with knockdown herbicides in an effort to get better weed control. Due to plant backs with the higher rates of Voraxor, it is better to use Voraxor with glyphosate in the first knock or to use Terrad'or with paraquat in the second knock.

Is there a role for glufosinate

A set of trials funded by the South Australian Drought Hub was conducted looking at the potential for glufosinate and mixtures of glufosinate with Group 14 herbicides as a potential alternative to glyphosate for pre-sowing weed control (Table 2). Glufosinate mixtures worked best at sites with smaller weeds. For glufosinate to provide effective control of annual ryegrass, the weeds should have no more than three leaves.

Table 2: Biomass present at 28 days after application of glufosinate and glufosinate mixtures at Wangary, Minnipa and Struan in 2022 and at Struan in 2023. Some use patterns are not registered and are included for experimental purposes. Always read and follow product labels.

Herbicide	Rate (g a.i. ha^{-1})	Wangary	Minnipa	Struan 2022	Struan 2023
		Biomass (g/m^2)			
Nil		163.2 a	106.9 a	62.1 a	107.0 a
Glufosinate	750	12.3 b	27.6 bc	40.4 a	36.5 bc
Glufosinate +	750	29.9 b	22.3 c	21.4 ab	39.6 bc
Tiafenacil	14				
Glufosinate +	750	5.1 b	27.0 bc	22.8 ab	32.6 bc
Saflufenacil +	25				
	12.5				
Trifludimoxazin					
Glyphosate	810 8	6.7 b	20.8 c	0.0 b	9.4 c
+					
Carfentrazone-ethyl					

Different letters within columns indicate treatment means that are significantly different.

There are many challenges to getting glufosinate to be effective as a pre-sowing knockdown herbicide. In addition to efficacy issues against large weeds, particularly annual ryegrass and wild radish, there is also the need to wait 14 days to sow. This means that glufosinate may prove better as the first application in a double knock use, with paraquat applied 14 days later.

Dry sowing

An alternative approach to manage glyphosate resistant annual ryegrass when the season conditions are appropriate is to dry sow and use pre-emergent herbicides and crop competition to manage the weeds. However, with dry sowing, it is important to choose the pre-emergent herbicides wisely. For dry sowing, more persistent herbicides are better than using less persistent herbicides, such as Boxer Gold® (Table 3). Including an early post-emergent application of Boxer Gold, Arcade® or Mateno® Complete can provide better control of annual ryegrass and provide insurance against poor control of weeds by pre-emergent herbicides due to seasonal conditions (Table 3).

Acknowledgements

Some of the information in this report was from a project Cropping Without Glyphosate funded by the SA Drought Resilience Adoption and Innovation Hub as an Innovation project funded by the Commonwealth Department of Agriculture, Fisheries and Forestry. The authors thank project partners Hart Fieldsite Group, Mackillop Farm Management Group, AIR EP and Elders for conducting the trials in that project.

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Table 3: Annual ryegrass control in a dry sown wheat trial at Concordia, SA in 2023. Weed counts were made 49 days after sowing. fb = followed by, early post-emergent herbicide products applied 21 days after sowing.

Herbicide product	Active ingredients	Rate used	Annual ryegrass (plants/m^2)
Nil			76.8 a
TriflurX	Trifluralin 480 g L^{-1}	2 L ha^{-1}	24.9 b
Sakura Flow	Pyroxasulfone 480 g L^{-1}	210 mL ha^{-1}	13.2 bc
Boxer Gold	Prosulfocarb 800 g L^{-1} + S-metolachlor 120 g L^{-1}	2.5 L ha^{-1}	37.6 ab
Luximax	Cinmethylin 750 g L^{-1}	0.5 L ha^{-1}	15.2 bc
Mateno Complete	Pyroxasulfone 100 g L^{-1} + diflufenican 66 g L^{-1} + aclonifen 400 g L^{-1}	0.75 L ha^{-1}	24.0 b
Mateno Complete	Pyroxasulfone 100 g L^{-1} + diflufenican 66 g L^{-1} + aclonifen 400 g L^{-1}	1.0 L ha^{-1}	15.2 bc
Overwatch	Bixlozone 400 g L^{-1}	1.25 L ha^{-1}	14.2 bc
TriflurX fb Mateno Complete	Trifluralin 480 g L^{-1} Pyroxasulfone 100 g L^{-1} + diflufenican 66 g L^{-1} + aclonifen 400 g L^{-1}	2 L ha^{-1} 0.75 L ha^{-1}	14.7 bc
TriflurX fb Mateno Complete	Trifluralin 480 g L^{-1} Pyroxasulfone 100 g L^{-1} + diflufenican 66 g L^{-1} + aclonifen 400 g L^{-1}	2 L ha^{-1} 1 L ha^{-1}	6.8 bc
Overwatch fb Mateno Complete	Bixlozone 400 g L^{-1} Pyroxasulfone 100 g L^{-1} + diflufenican 66 g L^{-1} + aclonifen 400 g L^{-1}	1.25 L ha^{-1} 1 L ha^{-1}	0.5 c
TriflurX fb Boxer Gold	Trifluralin 480 g L^{-1} Prosulfocarb 800 g L^{-1} + S-metolachlor 120 g L^{-1}	2 L ha^{-1} 3 L ha^{-1}	8.3 bc

Different letters indicate treatment means that are significantly different.

Notes

Notes

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Strategies to limit slug threats other than baits

Michael Nash[1] and Col McMaster[2].

[1]La Trobe University *and* The University of Adelaide*; [2]NSW DPI.*

GRDC project codes: GRS80, DAS00127, DAS00134, MAN2204_001SAX, UOA2308-004RTX

Keywords

- canola establishment, carabid beetles, integrated pest management (IPM), molluscs.

Take home messages

- Enhance ecosystem services by providing food for beneficial invertebrates and limiting disruption to their populations.
- Incorporate bottom-up approaches to Integrated Pest Management: for example, improve crop tolerance to herbivores by increasing seedling vigour.
- Integrate management practices to limit slug activity: that is, cultivation prior to and rolling after sowing before applying molluscicide baits.

Background

The adoption of conservation tillage systems to retain soil moisture in marginal Australian farming systems is associated with changing pest threats. Modern farming practices include the increased use of pesticides yet fail to reduce threats to production (Nash et al. 2023). Published research indicates an increased prevalence of slugs in broadacre cropping systems due to the application of insecticides, either as a foliar sprays and/or seed treatments, which affect carabid beetles, a natural predator of slugs (Hill et al. 2017, Douglas et al. 2014).

Slugs are particularly damaging to establishing canola, with yield losses in untreated areas of experiments at 60–80% (GRDC DAS00134 data). One way to estimate the cost of slugs is expenditure on molluscicide baits, which continues to increase in Australia, with over $49 million spent last season (2022–23 APVMA data). Locally costs are greater, for example growers in southwest Victoria spend $30–$120/ha on bait to protect canola from slugs. Additionally, 95% of canola is sown into burnt and/or cultivated ground in these areas. In areas where slugs are a high risk, some growers have shifted away from growing canola, especially where they cannot implement strategic burning and cultivation. That lost opportunity cost is estimated upwards of $270 million annually to the canola industry. A 5% production loss by slug and snail activity represents a loss of more than $130 million to the Australian canola industry.

Management changes that are improving canola establishment, hence tolerance to slugs, include:

- increased usage of baits applied as crop protectants
- earlier sowing
- increased seedling vigour
- improved plant nutrition; and
- integration of cultural practices that improve germination and growth.

To establish crops where slugs are a threat, molluscicides are used as a crop protectant, integrated with cultural controls to achieve successful establishment of canola. One key factor in successful establishment has been the shift to earlier sowing (Figure 1) when soil temperatures are still warm and the crop emerges and grows more quickly, if moisture is available. However, slugs have been, and continue to be, a major threat despite a dry autumn and late break in 2024.

This paper presents strategies adopted by Australian growers which complement molluscicides and improve canola establishment in areas threatened by slugs.

Discussion

Limiting disruption to natural enemies

Enhancing natural enemies is a cornerstone of IPM, including reducing slugs by maintaining predatory beetles (Hill et al. 2017). By limiting the use of disruptive pesticides, ecosystem services; such as pest control, pollination (for example, bees) and soil engineering (for example, ants); will be maintained. To help growers and advisers make informed choices around pesticide use in Australian grain crops, a rating score can be used to calculate cumulative disruption over two years, with values above this score expected to disrupt natural enemies (Nash et al. 2008). Impacts may vary in the field, especially if multiple applications of a chemical occur. Evidence of non-target impacts due to seed treatments is scant, but does exist for Carabidae (Douglas et al. 2014, Douglas and Tooker 2016), a ground beetle that feeds on slugs, earthworms and caterpillars. Some data are available for fungicide impacts from the International Organisation for Biological and Integrated Control (IOBC) database, however these do not account for additive impacts. For example, pyrethroid and triazole/imidazole fungicide combinations increase the toxicity to beneficial invertebrates, by reducing repellence of pyrethroids, hence increasing exposure. Table 1 provides information for growers about the pesticides they commonly use that are limiting slug control by predatory ground beetles, and potentially reducing some soil functions. Despite knowing the disruption pesticides can cause to ecosystem services provided by beneficial invertebrates, in particular insecticides (see https://cesaraustralia.com/resources/beneficials-toxicity-table/), the grains industry continues to use them prophylactically as a 'cheap' form of insurance against sporadic production threats. For a change to management to occur, perceptions need to shift.

Bottom-up IPM

A new approach is needed that is underpinned by host plant resistance, new cultural practices, ecological indicators, reliable predictors and infrequent emergency intervention strategies that move away from heavy reliance on monitoring and economic thresholds traditionally supported by rigid chemical-based management strategies (Nash and Hoffman 2012). This bottom-up approach to IPM (Han et al. 2022) needs to be based on developing stable crop environments that can limit fundamental niches available for exploitation by sporadic pest populations and increases crop resilience to resident herbivores.

Top-down forces have been conceptualised for practices in agriculture (for example, release of predatory wasps), yet bottom-up forces have received little attention in the framework of IPM. Bottom-up effects are major ecological forces in crop-invertebrate pest-natural enemy multitrophic interactions and need to be considered to optimise IPM. Irrigation, fertiliser use, crop resistance, habitat manipulation, organic management practices and landscape characteristics have all been shown to trigger marked bottom-up effects and thus impact pest management (Han et al. 2022). An experiment in the US (Le Gall et al. 2022) demonstrated a reduction in damage caused by slugs where maize was sown directly into cover crops after no-till soybeans, compared to no cover crop or terminated cover crop. This result points to other processes, rather than top-down control of slugs by predatory beetles, as natural enemy activity-density was greatest in bare plots. Green plots had the lowest activity-density. This leads to the hypothesis that the plants growing in the green plots were less favourable for slug populations to increase, and/or something had changed in the unterminated, green-on-green biome.

Australian research on cover crop interactions with pests leads to two questions:

Are the cash crop plants following cover crops 'healthier'?

Can Australian growers grow 'healthier crops' more tolerant to establishment pests?

Table 1: The impacts of pesticides commonly applied in Australian broadacre cropping on beneficials, based on IOBC ratings that relate to reduction in the tested species' ability to provide pest control (from Nash 2023). Ratings range from 1 to 4, where 1 = harmless <25% (green), 2 = 25%–50% (yellow), 3 = 50%–75% (orange), 4 = >75% (red). Some rates are based on specific references as listed in the following notes.

LD_{50} values <2µg/bee are considered toxic, 2–11µg/bee moderately toxic, 11–100µg/bee slightly toxic, and >100µg/bee not toxic. Only fungicides that are disruptive to predatory ground beetles are included. ND = No Data available; ST = applied as seed treatment; B = applied as bait.

Product example	Active compound (group)	Target	Ants	Ground Beetles	LC_{50} µg/bee	Overall Rating
Ironmax Pro®	iron	slugs	1	1		1
Vivus Max	NPV (31)	heliothis	ND	1		1
Dipel® SC	Bt (11)	caterpillars	ND	1		1
Vantacor®	chlorantraniliprole (28)	caterpillars	ND	1	>100	1
Metarex Inov®	metaldehyde	slugs	1	1		1
Apron® XL	metalaxyl-M (4)	damping off	ND	1	97.3	2
Spin Flo®[2]	carbendazim (1)	fungal diseases	ND	1	>100	2
Impact®	flutriafol (3)	black leg	ND	1	>100	2
Sumisclex®	procymidone (2)	fungal diseases	ND	2	>100	2
Steward®	indoxacarb (22A)	caterpillars	4	1	0.0266	2
Success® Neo	spinetoram (5)	caterpillars	ND	1	3.0	3
Methomyl 225	methomyl (1A)	broad	ND	4	9.5	4
Gaucho®	imidacloprid (4A)	aphids / mites	4	3	0.007	4
Cruiser®	thiamethoxam (4A)	aphids / mites	4	3	0.005	4
Talstar®	synthetic pyrethroids (3A)	broad	4	4	0.015	4
Lorsban®	organophosphates (1B)	broad	4	4	0.059	4
Cosmos®	fipronil (2B)	broad	4	4	0.0125	4
Poncho® Plus[1]	clothianidin (4A)	broad	4	4	0.004	4
MethioSHIELD™	methiocarb	slugs / broad	4	4		4
Veritas®[3]	tebuconazole (3) + azoxystrobin (11)	fungal diseases	ND	4	>200	4

Notes: [1]Poncho® Plus also contains imidacloprid so ratings are based on both; [2]carbendazim disrupts earthworms, hence the rating; [3]The individual actives of Veritas are not toxic to predatory beetles, yet in combination they are toxic.

Early sowing

One strategy to avoid establishment pests, such as slugs, is to create a mismatch in crop/pest phenology. By sowing susceptible crops before slugs emerge from the soil, the plants get a chance to establish before slugs become active on the soil surface associated with relative humidity above 96%. However, in irrigated situations and seasons where a full soil moisture profile exists, combined with full stubble retention, slugs are often active early: for example, southeastern Australia in 2023 when slugs were observed causing seedling losses to lentils, wheat and faba beans.

The main advantage of early sowing is quick establishment of susceptible crops. In effect, the management aim is to outgrow the herbivorous slugs. The thermal time for canola emergence is reported to be between 90°C.d and 115°C.d. In southern Australian environments, this typically translates to 4–5 days under average late March to early April soil temperatures of 25°C, 7–8 days at 15°C in late April to early May, and over 12 days in May when temperatures drop below 10°C (McDonald and Desbiolles 2023). With canola now generally being sown a month earlier, in April, across southern Australia (Figure 1), this has seen quicker establishment. However, a late break hinders this strategy. Current GRDC investments are researching ways to improve establishment, such as deeper sowing with improvements to seed quality, including novel traits as used in Europe, to overcome pest issues and seeding equipment requirements.

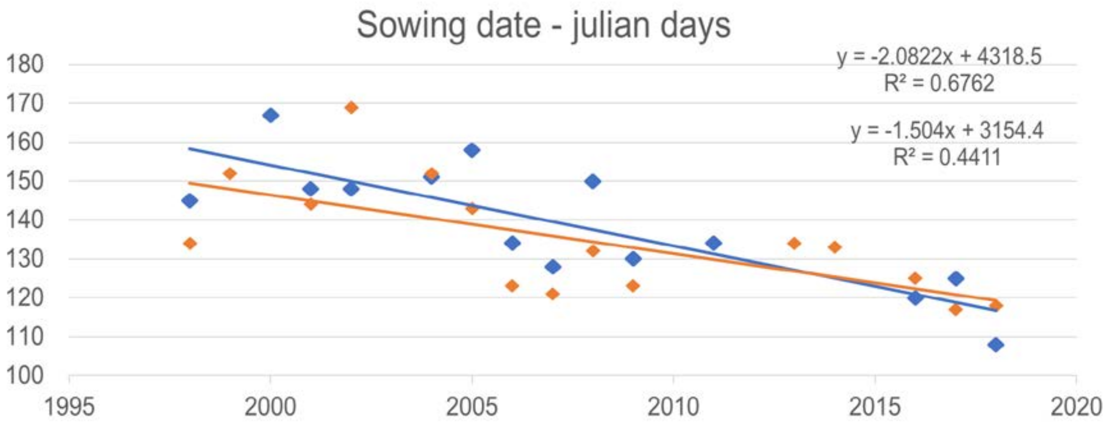

Figure 1. Sowing dates of canola extracted from two NVT sites in southwest Victoria. These indicate sowing of canola is now one month earlier than when canola was traditionally sown in May. The y-axis presents julian days as a count of days since Jan 01 being one (1).

Cultivation before and rolling after seeding before applying baits

Research (GRDC project SFS00023) demonstrated 'a positive result from rolling immediately after sowing compared to not rolling. This was especially noticeable at Inverleigh and at Hamilton where there were higher slug numbers and damage. This was nicely demonstrated at Hamilton where the control treatment was rolled and resulted in less crop damage compared to applying bait but not rolling. This is a cheap, non-chemical, cultural control technique which restricts slug movement in the seed bed and also helps to consolidate soil around the newly sown seed, and therefore, improve establishment.'

Research (GRDC project DAS00136) also demonstrated light cultivation with speed discs prior to sowing reduced slug activity, equivalent to a single application of a 50g/kg metaldehyde bait, but with some loss in canola plants (Figure 2). Cultivation as a single factor was not able to significantly reduce seedling loss to slugs (X^2 2.5, P = 0.113), however there was a significant interaction with baits (X^2 11.6, P = 0.021), indicating cultivation combined with slug baits improved canola seedling survival where slugs were active. This result was concordant with a second site tested in 2014 and previous results which demonstrated that speed tillers reduce slug activity (Nash et al. 2008). Unfortunately, cultivation has a deleterious impact on carabid beetles that feed on slugs (Nash et al. 2008).

Old data highlight the advantages of cultural practices to limit slug damage, especially when dry sowing. These advantages are:

- protecting the seed from slugs that are active
- reducing soil surface relative humidity below 96%, which is considered optimal for slug activity, and
- improving moisture conditions around the seed to aid germination.

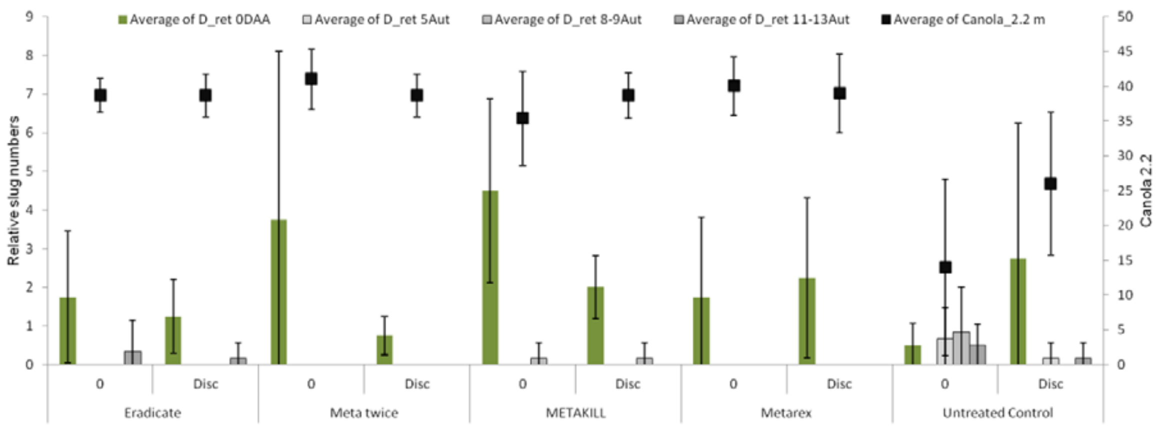

Figure 2. Grey field slug (*Deroceras reticulatum* [D_ret) relative surface abundance (columns with error bars being s.e. mean) prior to and after application of cultivation, sowing of ATR Wahoo canola and bait treatments May 2014. Squares with error bars (s.e. mean) indicate seedling numbers with two true leaves, June 2014.

The "one percenters" that make a difference in canola establishment

A few, but not all suggestions, are provided below:

- new cultivars
  - longer season allows for earlier sowing seedling vigour
  - herbicide tolerance that allows for knockdown in-crop
- grade for larger seed – that is, >1.8mm – increases biomass
- reduce stubble to increase light interception and reduce damping off
- time of sowing – mid April into warm soils, that is, >14°C
- improved seeding equipment, thus better seed placement – that is, do not sow >5cm
- seeding speed <8km/h
- nutrient placement – that is, higher rates of N and P (>25kg/ha MAP) placed below the seed especially with disc seeders, and
- avoid herbicides and seed treatments that reduce seedling vigour.

Burning

Removal of slug habitat by burning is used to improve crop establishment but does burning reduce slug populations? Overseas research indicates retention of straw does increase grey field slug numbers (Glen et al. 1984, Symondson et al. 1996). An Australian survey (in press 2024) of native roadside vegetation across southwest Victoria used generalised linear models to estimate 'slug' density. Black keeled slugs were positively associated with fire frequency (F_1= 9.34, P = 0.004): that is, the more often a roadside was burnt, the more slugs were found under tiles.

How does burning improve canola establishment? Limited data have been collected to answer this question, but the available evidence supports three hypotheses:

- Burning increases light interception. It has been recorded that 8% less light intercepts two leaf canola seedlings when comparing stubble retained (20cm) to burnt ground at Streatham VIC in May 2016.
- Burning decreases damping off. Where Apron XL was applied to canola seed, all seedling loss was accounted for in models testing significance of slugs causing seedling loss.
- Camera analysis of slug activity indicated slugs were less active on windy nights. Burning increases soil surface wind speed, hence reduces slug activity.

Burning may be thought of as a simple management option, however the underlying mechanisms reducing slug impacts on canola establishment in response to burning are complex. Further research is needed to fit the many pieces of the ecological puzzle together to improve canola establishment, hence reduce the cost of establishment pests, such as slugs, to industry.

Conclusion

Management of slugs under Australian conditions can be difficult due to seasonal climate differences. Invertebrate communities are changing in response to conservation agriculture (Nash et al. 2019) and intensification: that is, overuse of pesticides. Yet industry often fails to attribute the true cost of intensification to growers' bottom line (Hill et al. 2017). To manage crop threats like slugs in a cost-effective way, the biology of those pests and the context in which controls are applied must be understood. Ecological knowledge is necessary to improve canola establishment, empowering growers to shift to bottom-up IPM.

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 also thank the retail agronomists and commercial clients who supported the research presented in this paper.

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Notes

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

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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.

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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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Best practice liming demonstration to address subsoil acidity in northeast Victoria

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GRDC project code: RPI2104-001SAX

Keywords

- incorporation, lime, productivity, subsoil acidity.

Take home messages

- Growers in the Riverine Plains should assume that their farm has some degree of subsurface acidification, unless soil test results prove otherwise.
- Lime incorporation is essential in broadacre cropping soils to optimise benefits.
- Growers should only incorporate lime to the depth that is suitable for that soil, as cultivating soil with other soil constraints (for example, sodicity, slaking) may result in poor seedbed preparation, emergence and trafficability.

Background

This GRDC project investment is designed to demonstrate different lime incorporation methods, evaluate the impact of different lime types and sources, as well as extend findings including comparisons of the economic and agronomic returns using the Acid Soils SA calculator tools. As part of the project, a replicated field trial was established to demonstrate best practice liming strategies, with unreplicated demonstration strips to monitor the impact of lime quality, over three years. Trials were established in the Rutherglen district and monitored for three years from 2022–2024. Treatments were initially established in 2022, however, yield data was not captured in that year due to waterlogging and slug damage as confounding variables.

Extension efforts continue to focus on raising grower awareness on the rate of acidification and pH stratification of soils in this region, including providing resources and tools available to assist management decisions. Soil analysis over time has been used to illustrate the impact of lime incorporation methods and the impact of lime source and quality on addressing stratified subsoil acidity. This is in addition to assessing the economic benefits of each treatment, and potential losses of production and decline in pH. A nil control — with no lime applied — was used to highlight the cost of complacency when addressing pH issues in both the short and long term. The data generated through this project is supporting growers to evaluate the most practical and economical methods to manage soil pH and paddock variability.

The objective of the project is for growers and advisers in northeast Victoria to have improved understanding of the state of topsoil and subsoil acidity, the limitations to crop profitability it causes, and finally, an improved knowledge of the agronomic and economic benefits of different lime sources, lime quality and incorporation methods.

Method

Treatments for the project were developed after consultation with a steering committee, made up of growers and researchers. These treatments are shown in Table 1.

Table 1: Best practice liming trial treatments.	
Treatment #	**Details**
1	Control – nil lime: nil incorporation
2	Nil lime, with shallow incorporation
3	Lime to target pH 5.2, incorporated by sowing
4	High rate of lime (to pH 5.8 [0-10cm]), incorporated by sowing
5	High rate of lime (to pH 5.8 [0-10cm]), incorporation by shallow discs to 10 cm depth
6	High rate of lime (to pH 5.8 [0-10cm]), deep incorporation (HORSCHE TIGER) to 20 cm depth, follow up with speed-tiller
7	High rate of lime (to pH 5.8 [0-20cm]), deep incorporation (HORSCHE TIGER) to 20 cm depth, follow up with speed-tiller DELUXE option

An intense soil sampling regime was completed in February 2022 across each replicate. This provided baseline information to characterise the whole site (Table 2), as well as an understanding of current pH levels to ensure that the proposed incorporation methods were appropriate. Using this information, it was calculated that the rates of lime used in that year would be:

- lime required to achieve a target pH of 5.2: 1.2t/ha
- lime required to achieve a target pH of 5.8 (high rate): 5.0t/ha
- lime required to achieve a target pH of 5.8 to depth (high rate to depth): 8.5t/ha.

Table 2: Starting pH, Al and CEC values as measured from a transect sampling plan across the site.				
Sample depth from (cm)	**Sample depth to (cm)**	**pH (1:5 $CaCl_2$)**	**CEC (cmol(+)/kg)**	**Aluminium saturation (%)**
0	5	5.0	6.0	<1.0
5	10	4.5	4.4	8.7
10	15	4.3	3.6	28.0
15	20	4.2	3.1	35.0

The application of lime to these levels was done using a range of surface and incorporation techniques, including a shallow incorporation by sowing, incorporation by discs to a depth of 10cm, and a deeper incorporation by a Horsch Tiger to 20cm depth. Fine lime was sourced from a manufacturer in Galong and coarser lime was sourced from a manufacturer in Mt Gambier.

Figure 1 shows the layout of the field-scale replicated trial, which includes a buffer sown to wheat, in 2023. The plots are 40m x 13m, with a 20m buffer in between. At one end of the replicated trial, strip trials were established to assess the impacts of two types of lime quality, granular (Mt Gambier lime) and fine (Galong lime), applied at 3t/ha and incorporated with sowing. The lime from Galong was very fine (neutralising value [NV] 97.6), with bulk density of 1.4, while the Mt Gambier lime (NV 99.6) was much coarser with a bulk density of 1.1.

<table>
<tr><td colspan="3">Demonstration 1: Mount Gambier lime 3t/ha, incorporate by sowing</td></tr>
<tr><td colspan="3">Demonstration 2: Nil lime, incorporate by sowing</td></tr>
<tr><td colspan="3">Demonstration 3: Galong lime 3t/ha, incorporate by sowing</td></tr>
<tr><td>1 Lime 5 t/ha, incorporate deep (TIGER)</td><td rowspan="14">Buffer</td><td>28 Lime 5t/ha, incorporate by sowing</td></tr>
<tr><td>2 Lime 5 t/ha, incorporate shallow (discs)</td><td>27 Nil Lime, incorporate shallow (discs)</td></tr>
<tr><td>3 Control, nil lime, nil incorporation</td><td>26 Lime 1.2 t/ha, incorporate by sowing</td></tr>
<tr><td>4 Lime 1.2 t/ha, incorporate by sowing</td><td>25 Lime 5 t/ha, incorporate shallow (discs)</td></tr>
<tr><td>5 Nil Lime, incorporate shallow (discs)</td><td>24 Lime 8.5 t/ha, incorporate deep (TIGER)</td></tr>
<tr><td>6 Lime 8.5 t/ha, incorporate deep (TIGER)</td><td>23 Lime 5 t/ha, incorporate deep (TIGER)</td></tr>
<tr><td>7 Lime 5t/ha, incorporate by sowing</td><td>22 Control, nil lime, nil incorporation</td></tr>
<tr><td>8 Control, nil lime, nil incorporation</td><td>21 Lime 8.5 t/ha, incorporate deep (TIGER)</td></tr>
<tr><td>9 Lime 5t/ha, incorporate by sowing</td><td>20 Lime 5 t/ha, incorporate shallow (discs)</td></tr>
<tr><td>10 Lime 5 t/ha, incorporate shallow (discs)</td><td>19 Lime 5t/ha, incorporate by sowing</td></tr>
<tr><td>11 Nil Lime, incorporate shallow (discs)</td><td>18 Lime 1.2 t/ha, incorporate by sowing</td></tr>
<tr><td>12 Lime 5 t/ha, incorporate deep (TIGER)</td><td>17 Nil Lime, incorporate shallow (discs)</td></tr>
<tr><td>13 Lime 8.5 t/ha, incorporate deep (TIGER)</td><td>16 Control, nil lime, nil incorporation</td></tr>
<tr><td>14 Lime 1.2 t/ha, incorporate by sowing</td><td>15 Lime 5 t/ha, incorporate deep (TIGER)</td></tr>
</table>

Figure 1. Liming incorporation trial layout.

Lime was applied on 16 February 2022, with the incorporation completed on 17 February 2022. A Horsch Tiger was used for the deep incorporation, with calibration to ensure that the depth of the lime incorporation was kept above 20cm. The speed tiller was run over both incorporated treatments to ensure a smooth surface for ease of sowing. Once the treatments were completed, the host grower sowed and managed the trial site in line with the management practices used for the remainder of the paddock.

Soil sampling was conducted in January 2022, before the treatments were established, and resampled in January 2023 and 2024 to enable a direct comparison of liming treatments and their effect on soil properties over time. Soil samples were collected in increments of 0–5cm, 5–10cm, 10–15cm and 15–20cm, from 20 sampling locations across each plot using a hand corer, while the 20–30cm, 30–40cm and 40–50cm depth increments were collected from four GPS-located sampling locations in each plot using a hydraulic trailer-mounted corer.

Results and discussion

Soil pH

Results from the trial to date show that, when lime is applied without incorporation, it impacts pH levels at the surface and does not change the pH down through the soil profile due to its poor soil mobility. Figure 2a highlights that if no lime is applied further acidification through crop production will occur. Figure 3a indicates that if no lime is applied, there could be mixing of the current soil through the shallow incorporation to give an initial benefit but the acidification continues in year 2. Figures 4a and 5a show that incorporating lime by sowing can result in lime influencing pH in the top 5cm, with the rate of change depending on the quantity of lime applied. Incorporation of lime using shallow discs (Figure 6a), or deeper incorporation with the Horsch Tiger (Figures 7a and 8a) enables the lime to move further down the profile, to the depth of incorporation. By enabling the lime to move down the profile it is able to increase the soil pH. Shallow discs resulted in lime movement to 10cm, while the Horsch Tiger moved lime to 20cm.

Per cent aluminium

Aluminium is present in all soils as a key component of clay minerals. While aluminium is generally present in solid or complexed forms that do not influence plant growth, aluminium solubility increases as soil pH values decrease, resulting in higher concentrations of phytotoxic species of aluminium in the soil solution, which can impede root growth.

Figures 7b and 8b show that the deep incorporation of both rates of lime results in significant reductions in exchangeable aluminium down to 30cm.

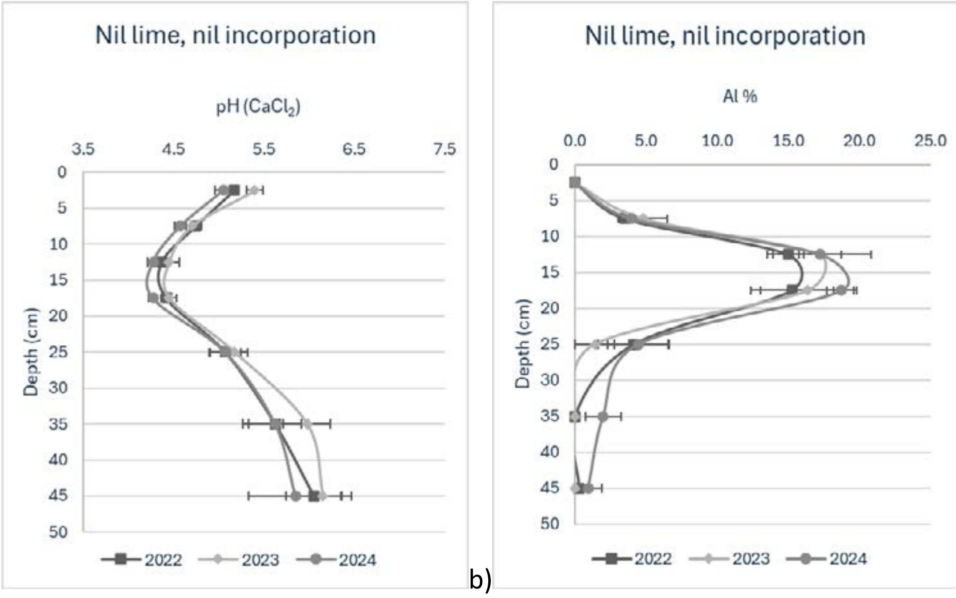


Figure 2. Treatment 1 – nil lime, nil incorporation (a) pH, (b) per cent aluminium.

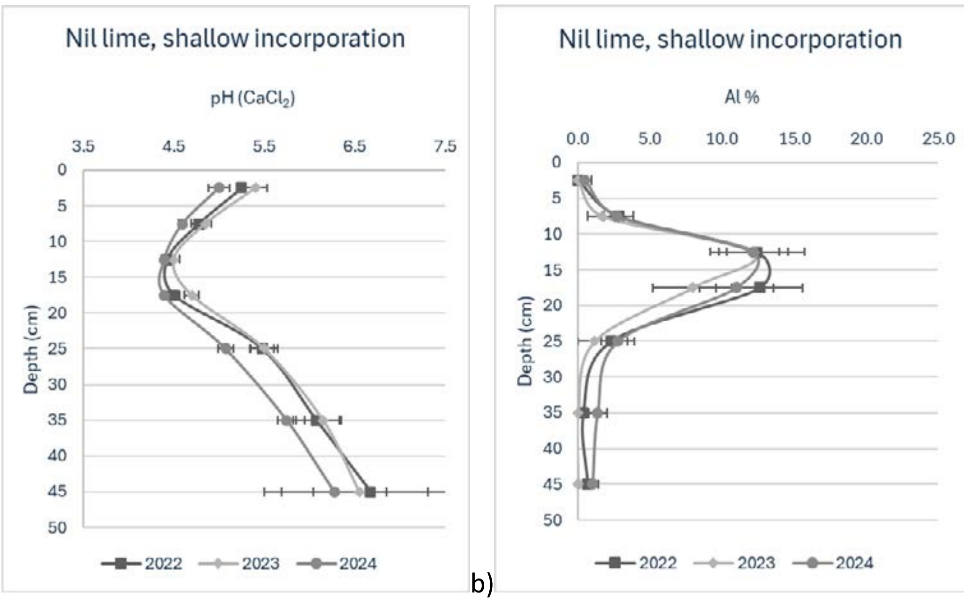


Figure 3. Treatment 2 – nil lime, shallow incorporation (a) pH, (b) per cent aluminium.

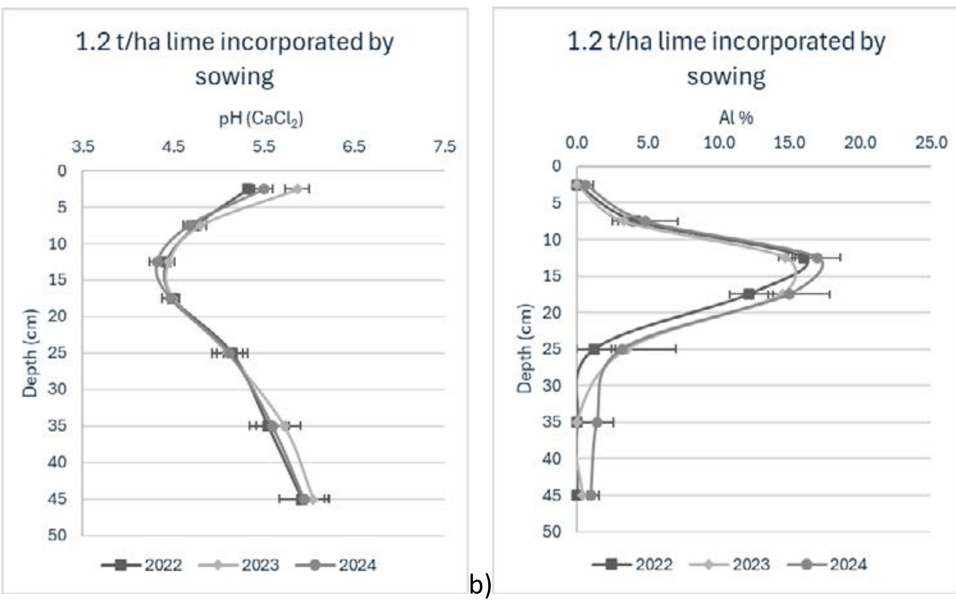


Figure 4. Treatment 3 – lime to target pH 5.2 (1.2t/ha), incorporated by sowing (a) pH, (b) per cent aluminium.

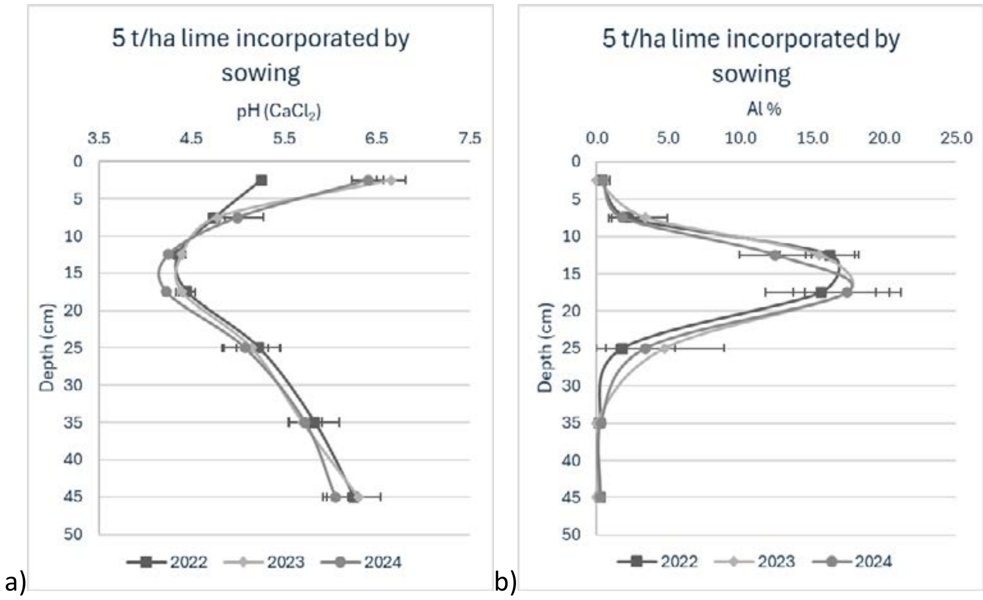


Figure 5. Treatment 4 – high rate of lime to pH 5.8 (5t/ha), incorporated by sowing (a) pH, (b) per cent aluminium.

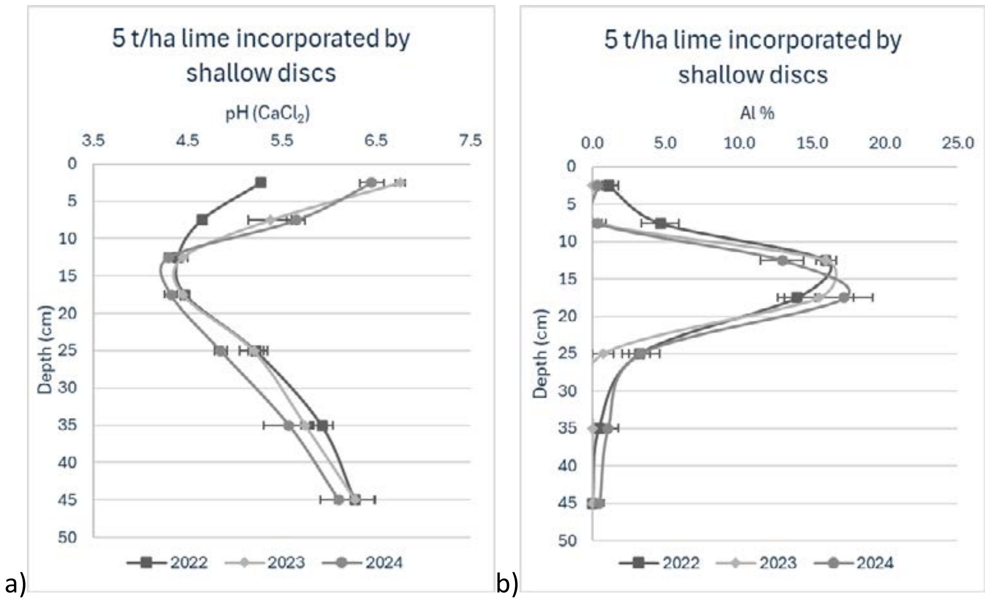
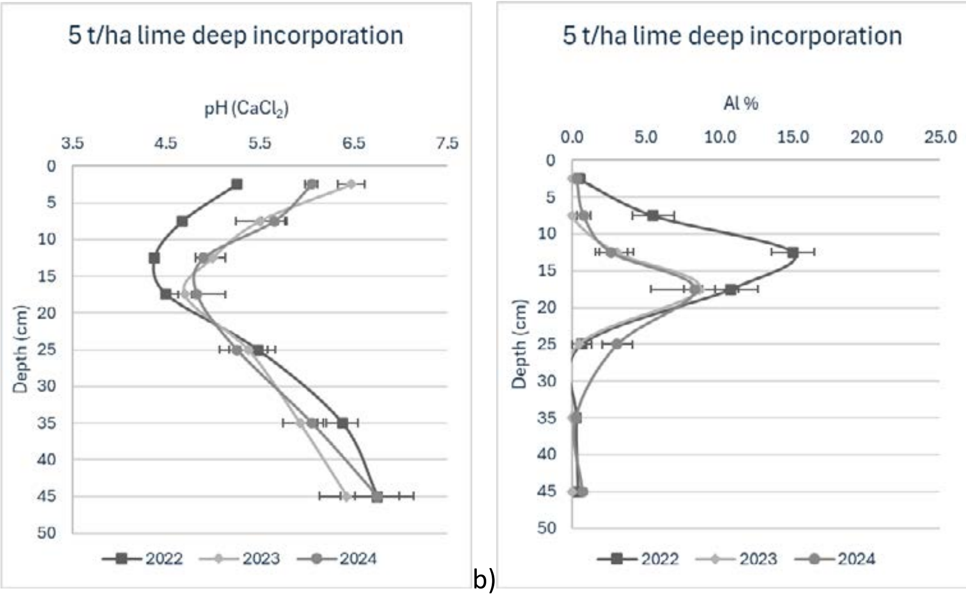
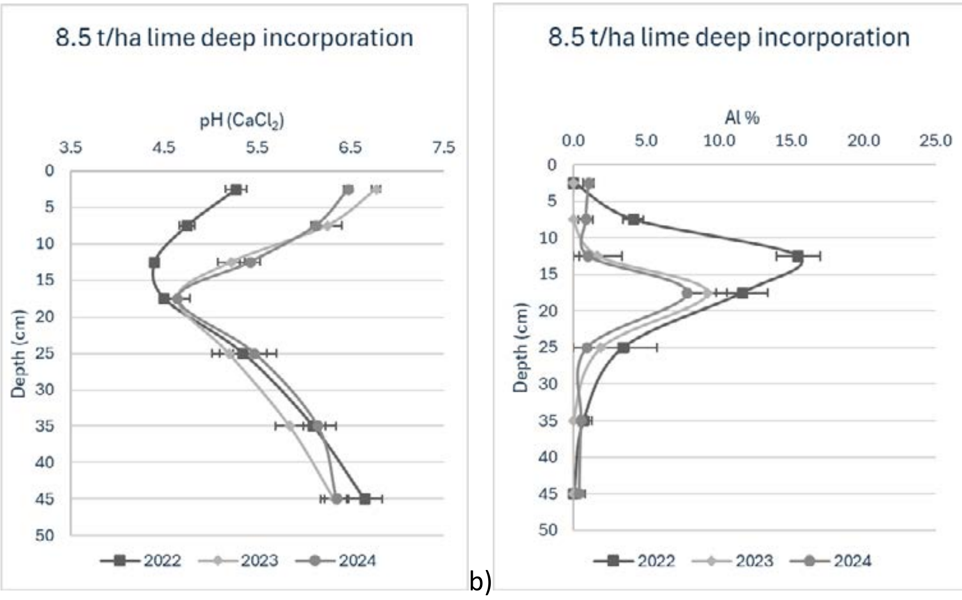


Figure 6. Treatment 5 – high rate of lime to pH 5.8 (5t/ha), incorporated by shallow discs sowing (a) pH, (b) per cent aluminium.



a) b)

Figure 7. Treatment 6 – high rate of lime to pH 5.8 (5 t/ha), deep incorporation sowing (a) pH, (b) per cent aluminium.



a) b)

Figure 8. Treatment 7 – Deluxe option: high rate of lime to pH 5.8 at depth (8.5 t/ha), deep incorporation sowing (a) pH, (b) per cent aluminium.

While deep incorporation has shown positive results, it is important that growers only incorporate lime to the depth that is suitable for that soil, as cultivating soil with other soil constraints (for example, sodicity, slaking) may result in poor seedbed preparation, emergence and trafficability.

For example, if you can only cultivate to a depth of 10cm, load up that zone with adequate lime for full amelioration of the target depth, so that there is sufficient lime to continue moving to depth over time.

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, and the authors would like to thank them for their continued support. The authors would like to thank the Spence family for hosting the site and AgriSci for their continued support, data collection and maintenance of the site.

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Notes

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.

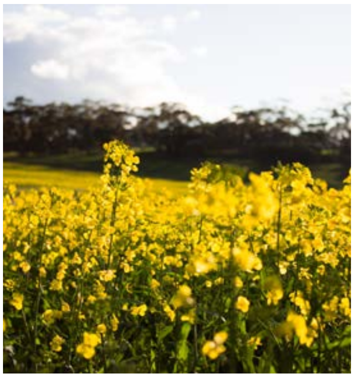
How many of the Big 6 are you doing on your farm?

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

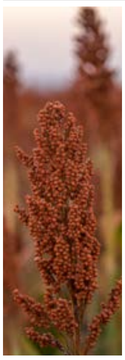
Preserve glyphosate and paraquat

- 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.

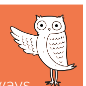


Implement Harvest Weed Seed Control

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.

Fusarium crown rot in central and southern cropping systems: it's all a numbers game

Steven Simpfendorfer[1]

[1] *NSW DPI Tamworth*

GRDC CODES DPI2207-004RTX: Integrated management of Fusarium crown rot in Northern and Southern Regions

DPI2207-002RTX: Disease surveillance and related diagnostics for the Australian grains industry

Keywords

- yield loss, crop rotation, canola, pulse, summer crop, double-break

Take home message

- Yield loss from Fusarium crown rot (FCR) is a function of the percentage of plants which get infected within a paddock
- The increased frequency of winter cereal crops within a rotation sequence elevated the probability of having much higher levels of FCR infection
- Rotation to non-host break crops such as canola and pulses does not fully eliminate FCR in all paddocks but considerably reduces the probability of having high levels of infection
- A two-year break may be required in paddocks with high FCR inoculum levels
- Rotation history remains a good indicator of likely FCR risk within individual paddocks but there is still some variability in actual levels of infection
- PreDicta®B or cereal stubble testing are useful tools to further refine crop rotation and other integrated disease management decisions to limit losses from FCR
- An integrated approach is required to reduced losses from FCR. There is no 'magic bullet'.

Background

Fusarium crown rot (FCR), caused predominantly by the fungus *Fusarium pseudograminearum* (*Fp*), remains a major constraint to winter cereal production across the central and northern NSW grain production region. FCR is also present in southern NSW but often goes unrecognised or can be misdiagnosed. The causal fungus is stubble-borne with inoculum surviving between seasons as mycelium (cottony-growth) inside retained winter cereal stubble and/or grass weed residues. Crop rotation to non-host break crops such as canola and pulses (e.g. chickpea, lupin or faba bean) remains a key management strategy for FCR. However, the process revolves around decomposition of *Fp* infected cereal stubble during these break crop and fallow phases which is in turn dependent on moisture availability and time. Consequently, the season in which a break crop is grown influences its effectiveness at facilitating decomposition of cereal stubble and reducing FCR inoculum levels. Conversely, recent research has highlighted when relative humidity is >92.5% that *Fp* can colonise vertically up retained standing cereal stubble in a process termed 'saprotrophic growth'. At 100% relative humidity this saprotrophic growth can occur at a maximum rate of 1 cm per day (Petronaitis *et al.,* 2020). The FCR fungus can therefore saprotrophically grow to the cut height of the cereal stubble under prolonged or accumulated periods of rainfall, effectively increasing inoculum loads. This can then result in FCR infected cereal stubble being spread out the back of the header during the harvest of lower stature break crops such as chickpeas, increasing FCR risk for the next cereal crop (Petronaitis *et al.,* 2022).

This dynamic between cereal stubble decomposition and saprotrophic growth appears to complicate the management of FCR within farming systems but what are paddocks across the region telling us?

What did we do?

Under a co-investment with GRDC, NSWDPI has been providing a free cereal stubble testing service to growers and advisors over the past two seasons. These samples were collected either during late grain filling or post-harvest from individual paddocks across central NSW, northern NSW and southern Qld, along with background information including the previous two crops within the rotation. Winter cereal stubble samples (bread wheat, durum, barley or oats) were trimmed and plated on laboratory media to determine the incidence of FCR based on distinctive growth of *Fp* in culture. Infection levels were then categorised as being either low (≤10% FCR), medium (11–25% FCR), high (26–50% FCR) or very high (≥51% FCR). This data provides an unbiased snapshot of FCR infection levels in winter cereal crops across the region under varying crop rotations over the last two seasons. But why is the level of FCR infection so important? It is simple, yield loss only occurs in cereal plants infected with FCR, with the actual extent of yield loss strongly dependent on the extent of moisture and temperature stress during grain filling. Growers may not have much influence over seasonal conditions and stress during this critical period, but they can influence the percentage of plants infected with FCR. Reduce FCR infection levels and you reduce the risk of yield loss by that same level. As a rough rule of thumb, 100% FCR infection can result in 80% yield loss in durum wheat, 60% in bread wheat and 40% in barley, if prolonged hot and dry conditions occur during grain filling. Granted that these are worst case scenario values from replicated and inoculated field trials across seasons, but even halving FCR infection levels to 50% reduces potential yield loss to 40% in durum, 30% in bread wheat and 20% in barley, if the spring conditions turn hot and dry.

What did we find?

Seasonal effects

In total, 718 winter cereal stubble samples were processed from the 2022 and 2023 harvest which consisted of 598 bread wheat, 62 barley and 58 durum wheat crops (data not shown). There were 249 cereal crops sampled in 2022 and 469 in 2023 (Figure 1). The levels of FCR infection have risen from 2022 to 2023, with the proportion of paddocks with very high levels (≥51% FCR) rising from 18% to 30%. Over the same period the proportion of paddocks with high levels of infection (26–50% FCR) have also risen from 20% in 2022 up to 30% in 2023 (Figure 1).

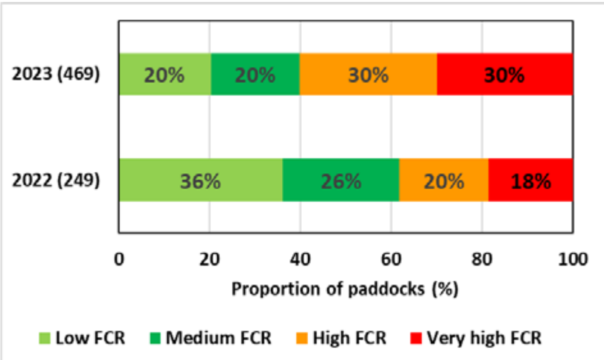


Figure 1. Proportion of winter cereal paddocks with varying levels of Fusarium crown rot (FCR) infection in 2022 and 2023.
Number in brackets (Y-axis) is the number of paddocks sampled in each year.
Low FCR = ≤10%, Medium FCR = 11–25%, High FCR = 26–50%, Very high FCR = ≥51%

FCR inoculum levels are a function of the percentage of plants infected and the quantity of stubble produced within a season. FCR infection is favoured by wet conditions which also generally increase biomass (i.e. stubble) production and yield of cereal crops. Consequently, larger inputs of FCR inoculum occur in wetter seasons such as 2021 and 2022 even though these conditions may not favour expression of FCR as whiteheads and yield loss from this disease. This data supports random crop disease surveys, conducted by NSWDPI with co-investment from GRDC, which have been showing a progressive build-up of FCR inoculum levels in this region from 2020 onwards. Milder temperatures and frequent rainfall during grain filling in 2021 and 2022 reduced FCR expression in these seasons. This was not the situation in 2023, with a return to warmer and drier conditions during spring which unfortunately also coincided with elevated FCR infection levels within central and northern cropping systems (Figure 1).

Sub-region levels of FCR

In total, 14 samples were from South Australia (SA), 14 from Victoria (Vic), 30 from south-west NSW (SWNSW), 43 from south-east NSW (SENSW), 131 from centra-west NSW (CWNSW), 57 from central-east NSW (CENSW), 163 from north-west NSW (NWNSW), 173 from north-east NSW (NENSW) and 93 from southern Qld (SQld). FCR infection levels in the last two cereal crops have been highest in SQld, NWNSW and NENSW with the proportion of paddocks with very high levels (≥51% FCR) at 38%, 33% and 32%, respectively (Figure 2). The proportion of paddocks in this highest category of FCR infection level was lower at 23% in SWNSW, 18% in CWNSW and 14% in CENSW. A lower proportion of paddocks with FCR in this highest category were measured at 7% in SA, 5% in SENSW and 0% in Vic. However, all regions had relatively high FCR levels (≥26% FCR in high or very high categories) ranging from 14% of paddocks in SA up to 62% in NENSW (Figure 2).

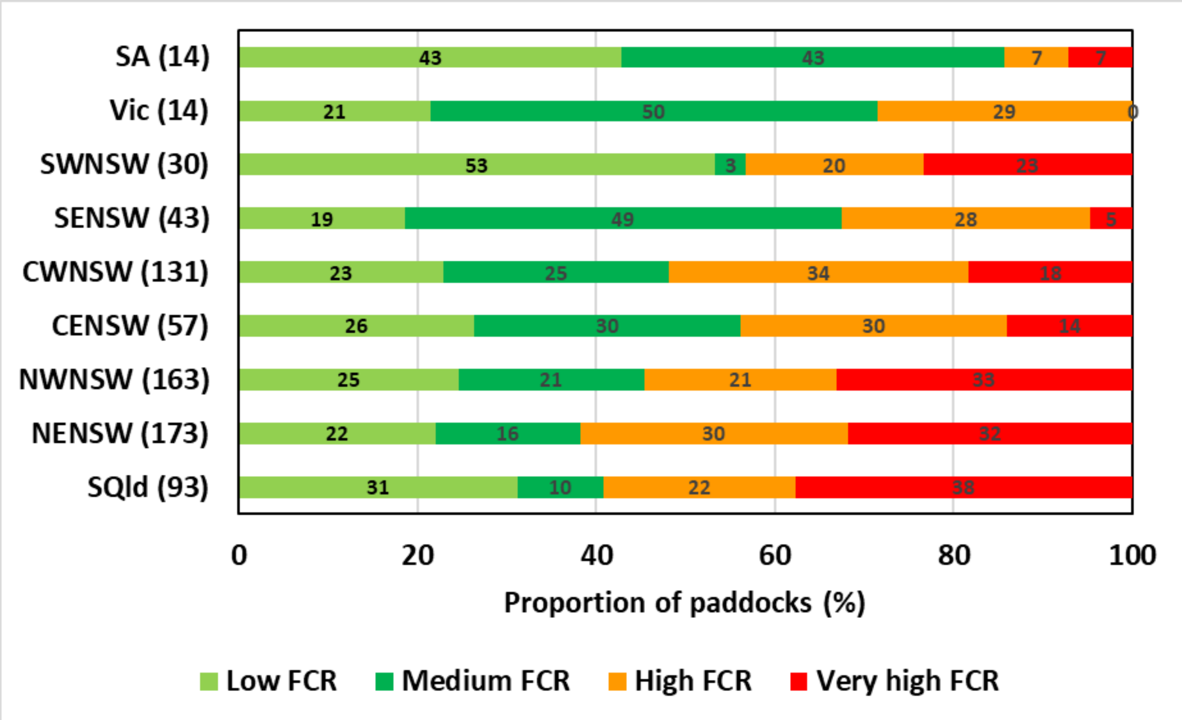


Figure 2. Proportion of winter cereal paddocks in 2022 and 2023 with varying levels of Fusarium crown rot (FCR) infection across sub-regions.
Number in brackets (Y-axis) is the number of paddocks sampled from each sub-region.
Low FCR = ≤10%, Medium FCR = 11–25%, High FCR = 26–50%, Very high FCR = ≥51%

Influence of a single break – what do the numbers say?

Adopt a cereal-cereal-cereal 'rotation' and there is a 27% chance of having high (26 to 50%) and 50% chance of having very high (≥51%) FCR infection (Figure 3). If the preceding crop was a summer break crop, then cotton (22% high FCR and 39% very high FCR in 18 paddocks) was potentially slightly better than sorghum (40% high FCR and 34% very high FCR in 35 paddocks. Fallowing the paddock rather than growing a crop did not reduce FCR levels in the subsequent 32 winter cereal crops tested with 35% having high and 41% very high FCR infection. If the preceding crop was a winter pulse or canola break crop then this risk of very high FCR in the 2022 or 2023 cereal crop was reduced further to 14% (average of pulse species) and 12%, respectively (Figure 3). In terms of pulse break crops, faba bean (14% high FCR and 7% very high FCR in 29 paddocks) was more effective than chickpea (22% high FCR and 20% very high FCR in 51 paddocks) and lupin (50% high FCR and 0% very high FCR in 17 paddocks; Figure 3).

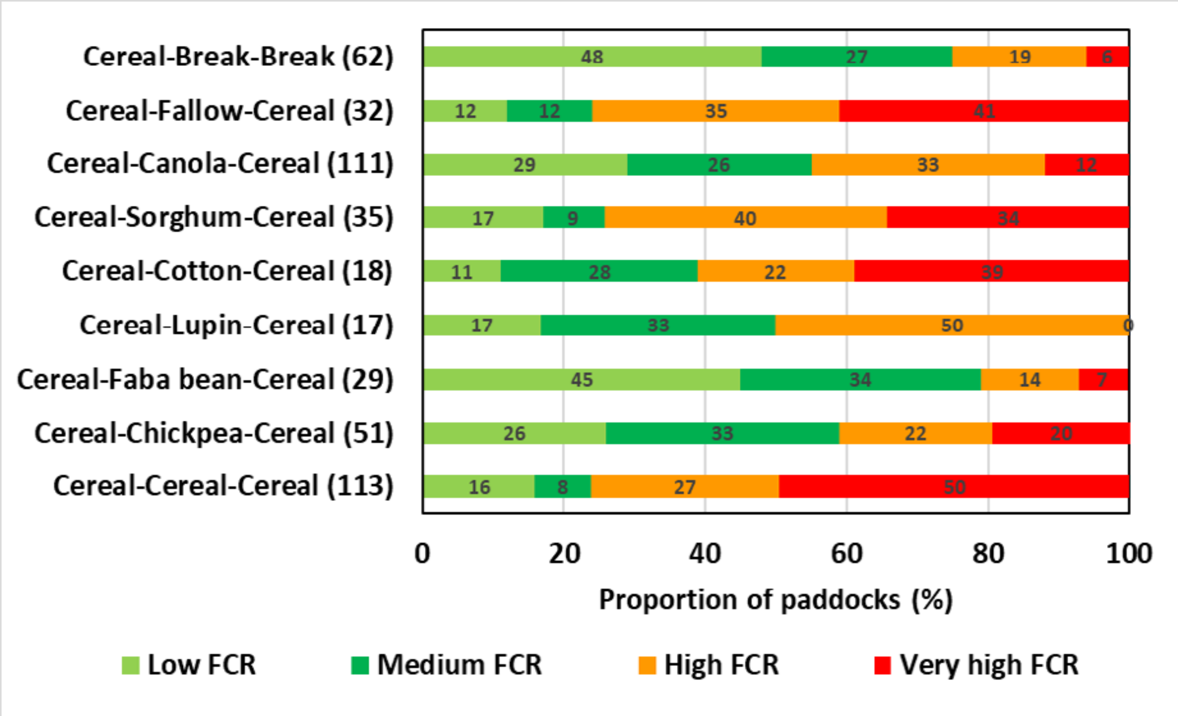


Figure 3. Proportion of winter cereal paddocks in 2022 and 2023 with varying levels of Fusarium crown rot (FCR) infection under different crop rotations.
Number in brackets (Y-axis) is the number of paddocks sampled from each rotation sequence.
Low FCR = ≤10%, Medium FCR = 11–25%, High FCR = 26–50%, Very high FCR = ≥51%

There are a number of potential variables such as FCR infection levels in cereal crops two years ago, stubble management (e.g. burning or cultivation), seed source (e.g. Fusarium grain infection from 2022 FHB epidemic), grass weed management, inter-row sowing, and harvest height which could also underly this data and introduce variability. Clearly non-host crop or fallow periods reduce the probability of higher FCR infection levels and consequently yield loss from this disease so playing the rotation numbers works. However, a one-year break may not be sufficient under higher FCR infection levels. A two-year break further reduced the probability of high and very high FCR infection levels in 2022 or 2023 cereal crops which dropped to 19% and 6%, respectively (Figure 3).

What is the effect of one break crop in three years?

Alright, let's try presenting differently and having a 'glass half full' approach. Assume low and medium FCR infection levels result in <25% whiteheads in a season conducive to disease expression, so does not trigger the 'I told you not to sow another cereal crop in that paddock' argument with your agronomist. In a three-year consecutive cereal situation (cereal-cereal-cereal), there is a 24% probability of this happening. This increased to 33% if the paddock was in fallow two years ago and 28% if it was a pulse crop two years ago. However, the likelihood of this outcome reduced to 23% if it was canola and 20% if it was a summer crop two years ago (Figure 4). Some may like these probabilities and continue to roll the dice whilst others may be swayed more by the probabilities around the second wheat crop having high or very high FCR infection levels (Figure 4).

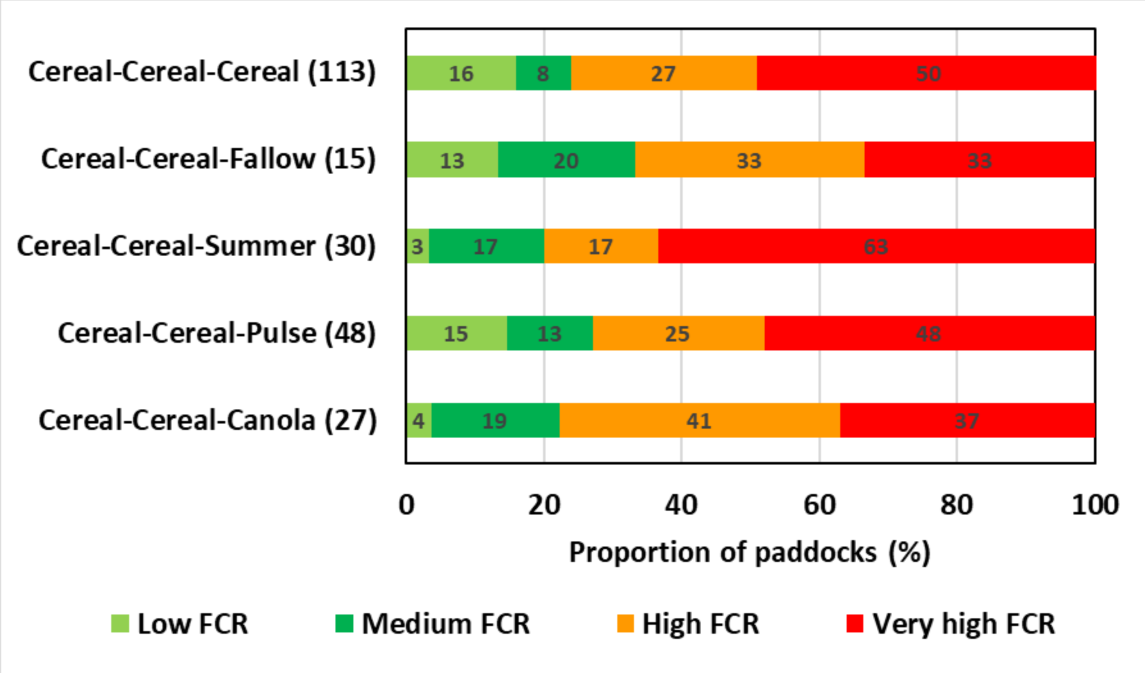


Figure 4. Proportion of winter cereal paddocks in 2022/23 with varying levels of Fusarium crown rot (FCR) infection under different crop rotations.
Number in brackets (Y-axis) is the number of paddocks sampled from each rotation sequence.
Low FCR = ≤10%, Medium FCR = 11–25%, High FCR = 26–50%, Very high FCR = ≥51%

Conclusions

Recent crop history within individual paddocks is a useful guide to the likely risk of FCR infection. However, not all paddocks and underlying crop management are the same so there is variability in the actual numbers, but the rotation sequence clearly drives the probability of having higher or lower levels of FCR infection. This further highlights the value of testing to establish actual FCR infection levels within a paddock using PreDicta®B or cereal stubble plating to further guide crop rotation and other integrated disease management decisions within individual paddocks.

Integrated management of FCR

To manage the risk of yield losses in cereals, firstly identify the risk of Fusarium crown rot in each paddock. High-risk paddocks generally include durum, bread wheat or barley crops being sown into a paddock with a history of stubble retention and tight cereal rotations (including oats). Other considerations include:

- Use effective weed management to reduce grass weed hosts in crop and fallow situations which serve as alternate hosts for the FCR fungus.
- Remember the larger the grass weed when controlled the longer that residue serves as a potential inoculum source
- Given the recent Fusarium head blight epidemic in 2022, ensure that you are sowing seed free of Fusarium infection as infected seed introduces FCR infection into paddocks.

All other management options are implemented prior to sowing so knowing the risk level within paddocks is important. This can be quantified through PreDicta® B testing (SARDI) or stubble testing (NSW DPI).

If medium to high FCR risk, then:

- Sow a non-host break crop (e.g., lentil, field pea, faba bean, chickpea, canola). A two-year break may be required if FCR inoculum levels are very high.

If still considering sowing a winter cereal:

- Consider stubble management options in terms of both impacts on FCR inoculum but also fallow soil moisture storage.

a. ***Cultivation*** accelerates stubble decomposition which can decrease FCR risk (as the causal pathogen is stubble-borne) BUT it takes moisture and time. Cultivation also increases the spread of Fusarium crown rot inoculum across a paddock in the short term and increases exposure of below ground infection points (coleoptile, crown and sub-crown internode) in cereal plants to contact stubble fragments infected with the FCR fungus. Cultivation close to sowing therefore increases the incidence of plants which get infected with FCR. Cultivation can also significantly reduce soil moisture storage during fallow periods.

b. ***Stubble baling*** removes a proportion of the above ground inoculum from a paddock potentially reducing FCR risk. The pathogen will then be concentrated in the shorter stubble butts and below ground in the previous rows. Hence, baling in combination with inter-row sowing is more likely to reduce FCR risk. Reduced ground cover after baling and removal of cereal straw can reduce fallow efficiency.

c. ***Stubble burning*** destroys above ground inoculum but depends on the completeness of the burn. Burning has no effect on the survival of the FCR fungus below ground in crown tissue even with a hotter summer burn. Hence the pathogen will be concentrated below ground in the previous rows with survival between seasons dependent on the extent of summer rainfall. Burning of cereal stubble can considerably reduce fallow soil moisture storage so a 'late Autumn' burn is preferable to an 'early Summer' burn. Stubble burning in combination with inter-row sowing is more likely to reduce FCR risk.

d. ***Reducing cereal stubble height*** limits the length of stubble which the FCR fungus can vertically grow up during wet fallow periods restricting the overall inoculum load within a paddock. Consequently, harvesting and leaving retained cereal stubble longer (e.g. stripper fronts) leaves a greater length of stubble for subsequent potential saprotrophic growth of the FCR fungus. This is not a major issue in terms of FCR risk if the retained infected cereal stubble is left standing and kept intact. However, if the infected stubble is disturbed and redistributed across a paddock through grazing, mulching, cultivation or the subsequent sowing process then this can increase the incidence of FCR infection. Recent research in NSW has also demonstrated that increased cereal harvest height allowed saprotrophic growth of the FCR fungus above the harvest height of a following chickpea crop. This resulted in FCR infected cereal stubble being spread out the back of the header during the chickpea harvest process increasing FCR risk for the next cereal crop (Petronaitis *et al.* 2022). Consider matching cereal stubble height at or after harvest in paddocks planned for a following shorter status break crop such as chickpea or lentils to prevent redistribution of retained FCR infected cereal stubble during the break crop harvest process.

- Select a cereal type and variety that has more tolerance to FCR and that is best suited to your region (see above results). Yield loss from FCR is generally durum>bread wheat>barley>oats. Recent research has shown that cereal type and varietal resistance has no impact on saprotrophic growth of the FCR fungus after harvest. Hence, cereal crop and variety choice does not have subsequent benefits for FCR risk with a paddock.
- Consider sowing a variety earlier within its recommended sowing window for your area. This will bring the grain filling period forward slightly and can reduce water and heat stress which exacerbates FCR expression and yield loss. However, this needs to be weighed against the risk of frost damage. Research across locations and seasons in NSW has shown that sowing at the start versus the end of a three-week recommended planting window can roughly halve the yield loss from FCR.
- If previous cereal rows are intact – consider inter-row sowing to increase the distance between the new and old plants, as most inoculum is in the stem bases of the previous cereal crop. Physical contact between an infected piece of stubble and the coleoptile, crown or sub-crown internode of the new cereal plants is required to initiate FCR infection. Research across locations and seasons in NSW (30–35 cm row spacings in stubble retained systems) has shown that inter-row sowing can roughly halve the number of wheat plants that become infected with FCR. Precision row placement can also provide greater benefits for FCR management when used in combination with rotation to non-host crops.
- Ensure nutrition is appropriate for the season. Excessive nitrogen will produce bulky crops that hastens moisture stress and makes the expression of FCR more severe. Whitehead expression can also be made more severe by zinc deficiency.
- Consider a seed fungicide treatment to suppress FCR. Fungicide seed treatmentsare not a stand-alone treatment and must be used as part of an integrated management approach.

References and further resources

PreDicta®B procedure - Sampling_protocol_PreDicta_B_Northern_regions.pdf (pir.sa.gov.au)

Petronaitis LT, Forknall C, Simpfendorfer S, Backhouse D (2020) Stubble Olympics: the cereal pathogen 10cm sprint - GRDC. GRDC Update paper

Petronaitis T, Forknall C, Simpfendorfer S, Flavel R, Backhouse D (2022) Harvest height implications for Fusarium crown rot management - GRDC. GRDC Update paper

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Notes

Notes

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Andrew is the managing director and a shareholder of Lilliput Ag, and a director and shareholder of the affiliated Baker Seed Co, a family owned farming and seed-cleaning business. He has served on GRDC's medium rainfall zone Regional Cropping Solutions Network and has held leadership roles with Riverine Plains Inc, Victorian Farmers Federation and the Rutherglen Group of fire brigades.

PRU COOK, DEPUTY CHAIR

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Ruth is an agroecologist who runs a consulting business. She has a Bachelor of Science in Ecology and Master of Applied Science in Wildlife Management from the University of Sydney, and has worked in sustainable agriculture research, development and extension and property management since 2002. Ruth has been the Upper North Farming Systems Group executive officer and project manager since 2013.

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Michael is a third-generation grain grower who produces wheat, barley, canola, beans, lupins and lentils on a range of soil types. He has been involved in a number of research organisations, including the South Australian Grain Industry Trust (of which he was chair for four years), the Lower Eyre Agricultural Development Association and the South Australian No-Till Farmers Association (both of which he has been a board member).

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Neil's family grain farming legacy dates back to 1889, giving him an extensive understanding of the challenges faced by grain growers in SA and Victoria across the Mallee, Wimmera and Riverina regions. With his wife Jenny, he retains a cropping/grazing property at Bordertown, producing wheat, canola, barley, beans and hay. He has held chief executive and board roles in organisations including Sugar Research Australia, Grains Council of Australia, Grape and Wine Research and Development Corporation and Plant Health Australia. Neil has previously worked for GRDC managing a large portfolio of research projects.

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Peter is a grower from north-western Tasmania with more than 10 years' experience growing and processing commercial grain crops. He holds a degree in agricultural science from the University of Tasmania. Peter has production, research and development experience in quinoa, oats, buckwheat, spelt, hemp, adzuki beans, wheat, barley, ryegrass and more. He is working at Tas Stockfeed, focusing on technical support, sales and grain procurement and processing. In 2017, he was recognised as the Young Farmer of the Year.

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Kathy is a strategic science leader with a strong track record in developing and leading national research programs with industry co-investment, including GRDC. Her own research background is in plant biosecurity and molecular detection of plant pathogens and she has a strong interest in capacity building and succession planning. Kathy is a former acting executive director of SARDI and a research director at Crop Sciences, covering applied research on plant biosecurity, crop improvement, climate risk management, water use efficiency and crop agronomy.

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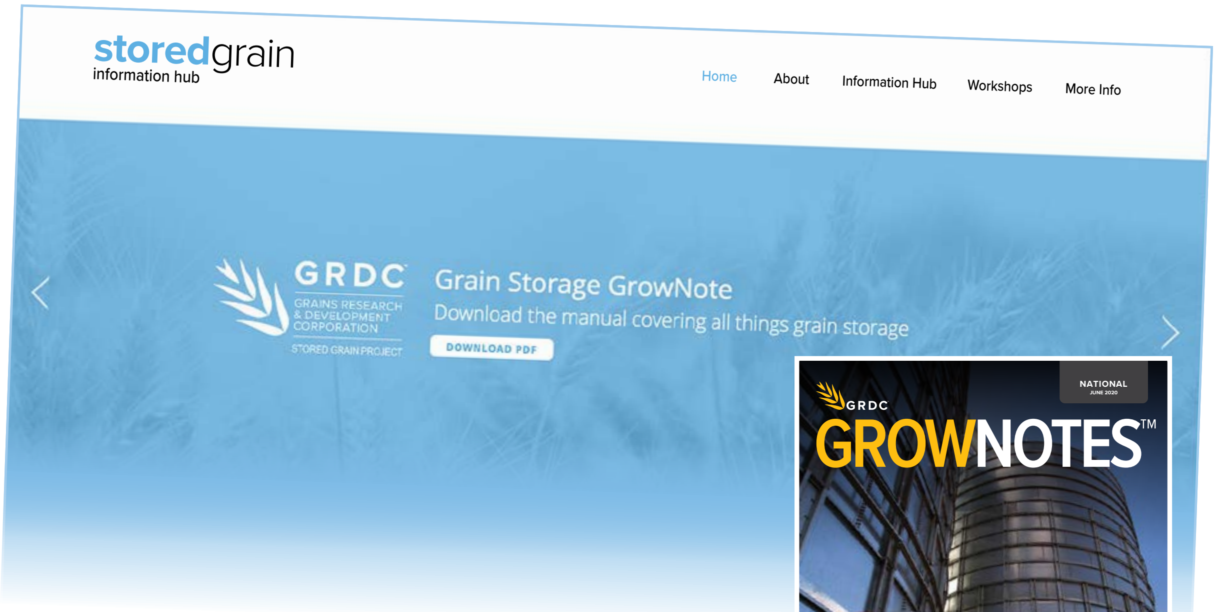

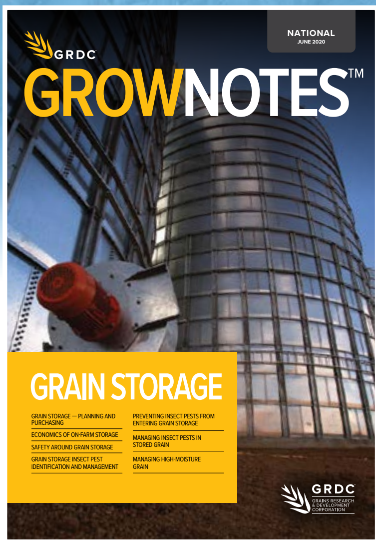

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- Partnering organisation: Riverine Plains

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Your feedback on the presentations

For each presentation you attended, please rate the content relevance and presentation quality on a scale of 0 to 10 by placing a number in the box (**10 = totally satisfactory, 0 = totally unsatisfactory**).

2. Double and triple knock strategies for managing ryegrass: *Chris Preston*

Content relevance ☐ /10 Presentation quality ☐ /10

Have you got any comments on the content or quality of the presentation?

3. An integrated approach to slug management: *Michael Nash*

Content relevance ☐ /10 Presentation quality ☐ /10

Have you got any comments on the content or quality of the presentation?

4. An integrated approach to slug management: *Lee Menhenett*

Content relevance ☐ /10 Presentation quality ☐ /10

Have you got any comments on the content or quality of the presentation?

5. The looming threat of subsurface acidity: *Jane McInnes*

Content relevance ☐ /10 Presentation quality ☐ /10

Have you got any comments on the content or quality of the presentation?

6. Strategies for managing Crown Rot: *Grant Hollaway*

Content relevance ☐ /10 Presentation quality ☐ /10

Have you got any comments on the content or quality of the presentation?

Your next steps

7. Please describe at least one new strategy you will undertake as a result of attending this Update event

8. What are the first steps you will take?
e.g. seek further information from a presenter, consider a new resource, talk to my network, start a trial in my business

Your feedback on the Update

9. This Update has increased my awareness and knowledge of the latest in grains research

Strongly agree	Agree	Neither agree nor Disagree	Disagree	Strongly disagree
❏	❏	❏	❏	❏

10. Do you have any comments or suggestions to improve the GRDC Update events?

Thank you for your feedback.