GRAINS RESEARCH UPDATE 2026

Quambatook

Wednesday 22 July

9.00am to 1.00pm

Quambatook Bowling Club,
29 River Street

#GRDCUpdates

QUAMBATOOK
GRDC Grains Research Update
convened by ORM Pty Ltd.

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GRDC Grains Research Update QUAMBATOOK

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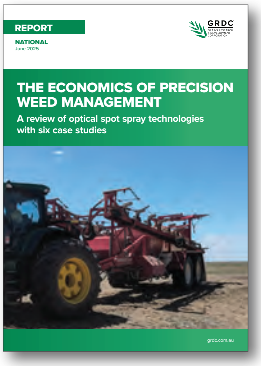

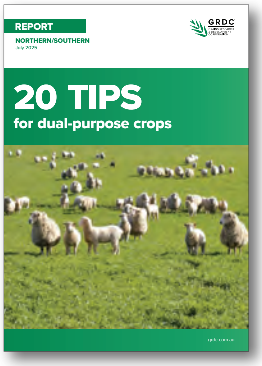

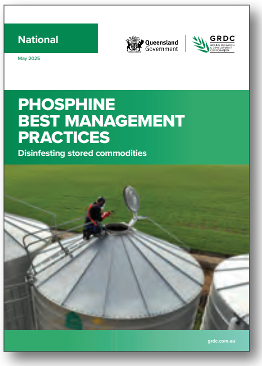

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GRAINS RESEARCH UPDATE 2026

GRDC

Quambatook Bowling Club, Wednesday 22 July

PROGRAM

9.00am	Announcements and GRDC welcome	*GRDC representative*
9.15am	Industry panel - pushing pulses for better crops in the southern Mallee	*Audrey Delahunty, Agriculture Victoria* *Claire Pickles, BCG* *Matt Bissett, ExceedAg* *Ash Wallace, Agriculture Victoria* *Josh Fanning, Agriculture Victoria*
9.55am	Evolution of clethodim resistance, what can we do?	*Peter Boutsalis, University of Adelaide and Plant Science Consulting*
10.35am	Morning Tea	
11.05am	Risk and reward of N fertiliser decision-making strategies - insights from a national network of RiskWi$e field experiments	*Yolanda Plowman, BCG*
11.45pm	Protecting your most perishable asset - latest tips on grain storage	*Chris Warrick, Primary Business*
12.25pm	Seasonal climate outlook: what is driving this season?	*Dale Grey, Agriculture Victoria*
1.10pm	Lunch	

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SOUTHERN PANEL

2025-27 GRDC SOUTHERN REGIONAL PANEL

ANDREW RUSSELL

PANEL CHAIR

Rutherglen, Victoria

Andrew is the director and a shareholder of Lilliput AG, and managing director of 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

Dimboola, Victoria

Raised on a mixed farm in Victoria's Wimmera region, Pru has spent her professional career working in extension for the grains industry. Starting her career at the DPI, she has worked at GRDC and the Birchip Cropping Group, managing a number of extension projects. In recent years she has managed her own business specialising in extension, project development and project management.

TIM MCCLELLAND

Birchip, Victoria

Tim farms with his wife, father and aunt on a 6500-hectare mixed property in the southern Mallee. After completing his Bachelor of Agriculture and Commerce at the University of Melbourne in 2006, he took on work at Advisor Edge, Birchip Cropping Group (BCG) and RMCG. In 2011, he moved back to Birchip to become formally involved in the family farm and continue his role with BCG.

RUTH SOMMERVILLE

Burra, South Australia

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 Operations Committee Member in recent years.

ANDREW WARE

Port Lincoln, South Australia

Andrew is a research agronomist who started his career with the South Australian Research and Development Institute (SARDI) and then spent time at CSIRO in Adelaide. This was followed by 10 years away from research, managing the family farm on the Lower Eyre Peninsula, before returning to SARDI. In 2019, he started his own research company, EPAG Research, delivering applied research across the Eyre Peninsula.

DR KATHY OPHEL-KELLER

Adelaide, South Australia

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.

WAYNE BURTON

Halls Gap, Victoria

Dr Wayne Burton has worked as an agricultural scientist and oilseeds breeder with over three decades of leadership across public and private sector research and development. Holding a PhD from the University of Melbourne and a Bachelor of Agricultural Sciences (Honours) from the University of Adelaide, he has played a pivotal role in the advancement of canola and mustard breeding and development in Australia.

MAX YOUNG

Ardrossan, South Australia

Max Young farms at Ardrossan on the Yorke Peninsula. He has more than 40 years' experience growing predominately wheat barley and lentils. Max holds a Roseworthy Diploma in Agriculture and is a graduate of the Australian Institute of Company Directors (GAICD). He has served in leadership roles in both the South Australian No Tillage Association SANTFA and South Australian Grains Industry Trust (SAGIT) and is keenly interested in improving sustainable production through research. Max understands the importance of local grower groups as a conduit between researchers and growers.

ADAM HANCOCK

Naracoorte, South Australia

Adam Hancock is a High Rainfall Zone agronomist with Elders, based in south-east South Australia. He has 15 years of experience advising grain growers to improve productivity and profitability through evidence-based agronomy and precision agriculture. He provides agronomic advice across a wide range of farming systems and environments, supporting clients with both in-season decision-making and long-term planning.

GRETA DUFF

Inverleigh, Victoria

Greta Duff graduated from the University of Melbourne with a Bachelor of Agriculture, spending part of her studies at Dookie College. She began her career in the dairy industry before joining Southern Farming Systems (SFS) in 2020. Since then, Greta has led and contributed to a wide range of projects, particularly with GRDC, and is passionate about supporting the next generation of growers. Through her involvement with the Young Agricultural Professionals Network, she actively works to promote and retain young people in the agricultural industry.

RON OSMOND

General Manager of Strategy & Business Development

Prior to joining GRDC in 2013, after completing a PhD in Agricultural Science, Ron worked in scientific and management roles in Intellectual Property Development and Commercialisation in the private sector. Ron's interest and expertise is in the translation of Research and Development into adoptable outcomes for Australian grain growers.

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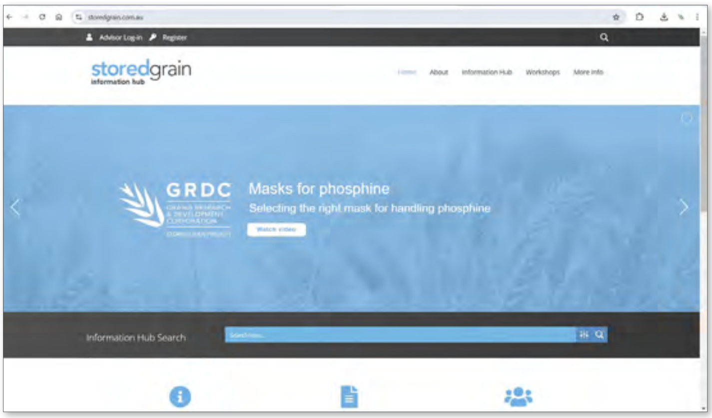

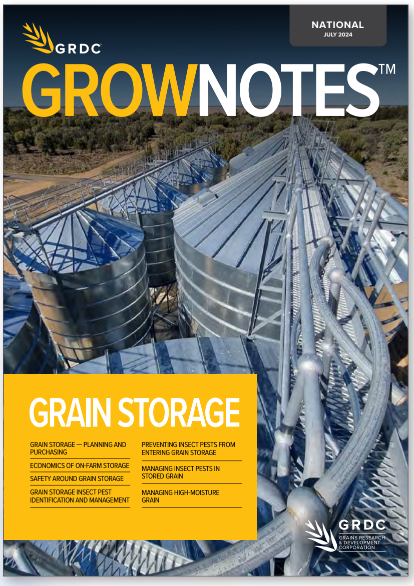

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Where to next for pulses in Victorian farming systems

Audrey Delahunty[1], Claire Pickles[2], Angus Butterfield[2], Jason Brand[3], Michael Moodie[4], Josh Fanning[1], Dale Grey[1] and Ash Wallace[1].

[1]Agriculture Victoria; [2]Birchip Cropping Group; [3]GEM Agronomy; [4]Frontier Farming Systems.

GRDC project code: DJP2105-006RTX

Keywords

- crop expansion, lentils, pulses, Victoria.

Take home messages

- Over the past 15 years, Victorian pulse production has grown substantially. The challenge is to identify the next steps to take this even further.
- Expansion of lentil area has been considerable in the Wimmera and Mallee. Expanding pulses in other regions requires careful consideration of soil type and species.
- Increasing intensity of pulse production has helped reduce certain weed and disease pressures while also introducing new challenges. Integrated combinations of control options continue to be the most robust approach to their management.

Background

Pulses are an integral part of Victorian farming systems, offering a profitable crop choice while delivering multiple system benefits. They contribute nitrogen, rotational diversity, provide disease and weed breaks, and open valuable market options. Since their widespread adoption in the 1990s, pulse yield potential has increased substantially. This shift has been supported by improved varietal adaptation, clearer agronomic guidelines, and practical extension programs, which have strengthened regional understanding of sowing windows and risk management for weeds and disease. Herbicide tolerant lentil varieties, such as PBA Hurricane XT and GIA Thunder[A], have further enabled expansion into new soils and regions, while high grower confidence and consistent profitability continue to drive adoption. These gains form a strong base for the next phase of RD&E across Victoria's diverse pulse-producing landscapes. As the 'pulse phase' becomes more embedded and matures within farming systems, the next challenge, and opportunity, is to expand production into new regions and position pulses for greater resilience, productivity, and profitability under challenging climatic and market conditions.

This panel draws on expertise from Matt Bissett (Exceed Ag), Michael Brougham (Brougham Ag Consulting) and Claire Pickles (BCG), and the session will explore the opportunities and challenges associated with pulse intensification, expansion into new production environments, and strategies to improve long-term profitability and system resilience.

The growing importance of pulses in Victorian cropping systems

Since 2010, the area sown to pulses in Victoria has increased from around 10% to 24% of the cropped area (Figure 1). This expansion has been driven largely by lentils, which increased from 8% to 23% of crop area in the Wimmera and from 1% to 23% in the Mallee. Vetch area in the Mallee also increased slightly (3.3%). In the Mallee, this expansion has occurred largely at the expense of wheat, with area declining from 67% in 2010 to 32% in 2025.

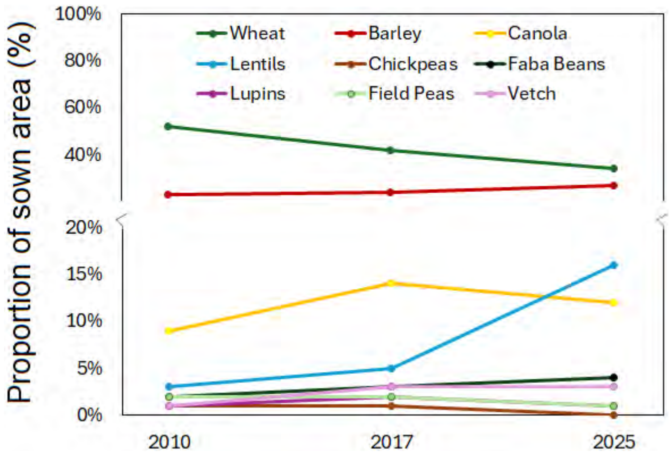

Figure 1. Proportion of area sown to various crop species across Victoria (Data courtesy of Dale Grey, Agriculture Victoria, 2025).

To better understand impediments to greater pulse uptake, evaluation surveys were conducted at pulse field days during 2025. A total of 108 respondents, comprising 64% growers and 23% agronomists, responded to questions on pulse use in local rotations, crop management and production constraints. In each region, responses were generally dominated by one or two key local issues, followed by a broader group of secondary constraints (Figure 2). Examples included problem weeds in the Wimmera and Mallee, and soil structure/other soil constraints (for example, localised acidity and compaction) as a key challenge in the Mallee.

Figure 2. Ranking of issues that challenge pulse production across Victorian grain growing regions. Data are based on evaluation surveys of growers and industry representatives attending pulse field days in 2025.

Opportunities to expand pulse production

Weed management and system integration

One of the key benefits traditionally attributed to pulses is their ability to improve whole-of-system weed control, particularly through the use of selective herbicides for grass weed management. However, as pulse intensity has increased across southern Australia, resistance in grass weeds to several selective herbicide groups has also increased. Broadleaf weed control has historically been more challenging due to limited herbicide options and the relatively poor competitive ability of many pulse crops. More recently, the release of pulse varieties with improved tolerance to imidazolinone (IMI, Group 2) herbicides, together with lentils tolerant to both IMI and in-crop metribuzin applications, and improved tolerance to residual clopyralid, has considerably expanded weed control options. Despite these advances, pre-emergent herbicides remain critical to successful weed management, and achieving consistent crop safety across different soils, environments and varieties continues to present a challenge.

Recent work through the Victorian Pulse Agronomy Project on lentil metribuzin tolerance demonstrates the value of targeted applied RD&E in expanding weed control options, defining safe use patterns across environments, and understanding interactions with other herbicides. For example, a trial conducted at Kulwin in 2024 evaluated the crop safety and weed control efficacy of metribuzin in GIA Metro⦽ lentils (Figure 3). Treatments applied at PSPE and the 4-node stage (the latter under APVMA permit PER92810), either alone or in combination with Intercept®, reduced populations of several key broadleaf weed species while maintaining acceptable crop safety. These results form a component of multi-environment datasets for defining safe use patterns, supporting regulatory approvals and building grower confidence in new management approaches. Note: some use patterns used are not registered and were included for experimental purposes. Always read and follow product labels.

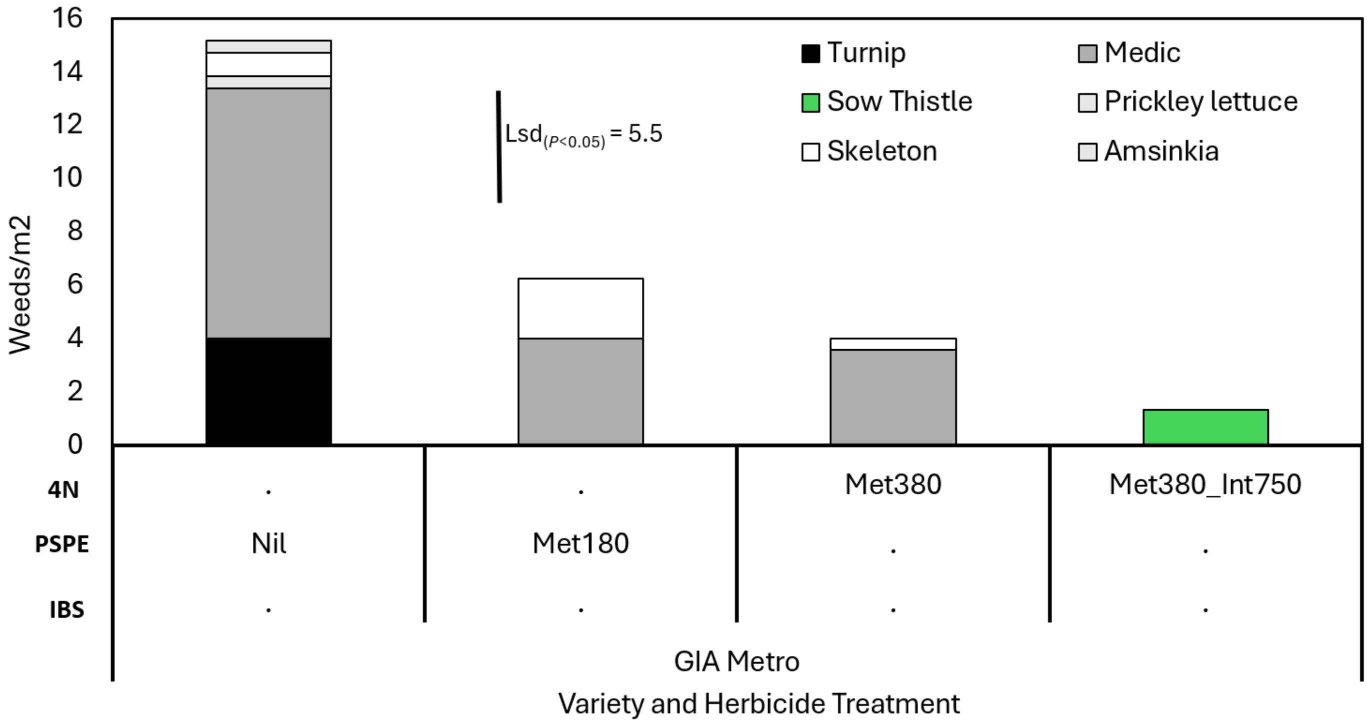

Figure 3. Use of metribuzin to control broadleaf weeds in GIA Metro⦽ at Kulwin in 2024. Weed populations are presented as weeds/m^2 for six weed species. Metribuzin (750 WG) was applied IBS, PSPE or at 4-node, with treatments including metribuzin alone or in combination with Intercept. Note: some use patterns tested are off label and were for experimental purposes only.

As the pulse industry has expanded, particularly lentils and faba beans, new weed management challenges have emerged. In lentils, the widespread use of IMI technology, combined with tighter rotations, has increased selection pressure for herbicide resistance in several broadleaf weeds, including milk thistle and wild radish. At the same time, weed species that are not adequately controlled by IMI herbicides, such as vetch and tares, have become increasingly problematic in major production zones. As lentils have expanded into more challenging soil types and former pasture-based systems in central and northern Victoria, weeds such as capeweed and medic, including Group 2-tolerant populations, have also become more difficult to manage.

Looking ahead, two challenges are likely to dominate weed management in pulse systems: increasing herbicide resistance and the emergence of weed species that were previously considered minor issues. However, there are also considerable opportunities. Continued breeding efforts are likely to deliver incremental improvements in herbicide tolerance, particularly to registered herbicides from Groups 5, 12 and 14, as well as novel tolerance traits. Advances in precision agriculture, including camera-based green-on-green weed detection systems, also have the potential to transform weed control, although these technologies will require new herbicide registrations, stewardship frameworks and management strategies. Future success will depend on integrating these new technologies with diverse crop rotations, effective herbicide use and regionally adapted agronomic practices. While no single solution is likely to address the evolving weed challenge, a combination of genetic, chemical and agronomic tools provides a pathway to maintain effective weed control and support the ongoing profitability of pulse-based farming systems.

Soil constraints and opportunities to expand into new ground

Soil type has traditionally had a large impact on the footprint of pulses across southern Australia and based on recent grower surveys, continues to influence their adoption in certain regions (Figure 2). Soil acidity, risk of waterlogging and poor soil structure have all impacted growers' willingness to expand pulses into new areas.

Recent pulse expansion has started to challenge some historical assumptions, exposing both new opportunities and production limits. Deep ripping of sands to address compacted layers, along with other amelioration techniques to improve topsoil water-holding capacity, has shown potential to increase system productivity, including pulses (Godwin 2023). While amelioration can be expensive, rising land values have changed the economics of investing in greater productivity on existing land. Importantly, amelioration must be targeted to the specific constraint. The aim may be to break compaction layers, incorporate organic matter, improve topsoil water-holding capacity or manage multiple constraints. Understanding the chemical characteristics of soil brought to the surface is also essential to avoid unintended consequences.

Soil acidity has historically been a key challenge for expansion of pulses. However, advances in acid tolerance of rhizobia and grower willingness to push boundaries has seen some expansion onto soils which were previously thought unsuitable. Additionally, ongoing improvements to farming system productivity, increased rates of N fertiliser inputs throughout the rotation and greater incorporation of pulses have, in some cases, contributed to acidification on certain soil types, such as sand-hills in the northern Mallee. Over time, these changes may require spatially targeted management or changes in rotation.

As soil constraints are addressed and production potential increases, nutrition becomes an increasingly important component of crop management. Improving nutrient supply can support early vigour, biomass accumulation and ultimately grain yield, allowing pulses to capitalise on the benefits of ameliorated soils. At Birchip in 2025, both lentil and chickpea responded to phosphorus despite reasonable Colwell P levels (Colwell P= 35mg/kg) and a moderate phosphorus buffering index (PBI) (Figure 4). These results highlight the importance of considering nutrition alongside physical soil constraints when seeking to maximise pulse productivity.

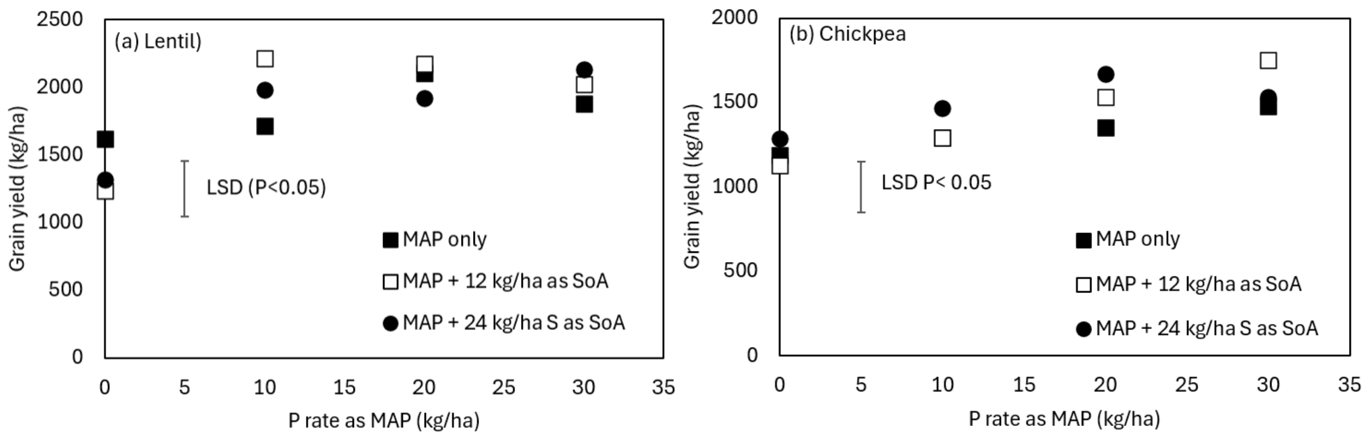

Figure 4. Grain yield responds to phosphorus (P) in lentil (a) and chickpea (b). Trial sown 12 June 2025 at Birchip. Fertiliser placed in-furrow with the seed. P rates applied as MAP. S rates applied as top-dressed SoA (24 July).

The rapid expansion of pulses over the past 15 years is unlikely to be repeated at the same scale, but careful soil selection, targeted amelioration and appropriate nutritional management may continue to open new opportunities for pulse production.

Disease management and pathology

Disease pressure in Victorian pulse systems continues to rise as pulses occupy a larger proportion of crop rotations. Key diseases include Ascochyta blight and Botrytis grey mould in lentil, chickpea and vetch; Ascochyta blight and powdery mildew in field pea; and chocolate spot in faba bean. Sclerotinia is also emerging as an important constraint across several pulse crops where management options remain limited. Disease incidence varies by season and region, with generally lower disease risk in the Mallee. This presents growers with a challenging decision-making environment when weighing up fungicide applications against disease risk and economic benefit.

Genetic resistance remains central to integrated disease management and varietal selection, but resistance durability is under increasing pressure. Continued expansion of lentil-dominant systems, often based on a narrow group of high-yielding varieties, has also increased selection pressure on pathogens. Combined with reduced use of complementary integrated disease management practices, this has contributed to resistance breakdowns, including the loss of Ascochyta blight resistance in PBA Hurricane XT⦸, and has increased fungicide resistance risk under tight host-crop sequencing.

Knowledge gaps remain around pathogen population dynamics, including shifts in virulence and fungicide sensitivity across environments and seasons. Pulse root rot pathogens, including ***Fusarium***, ***Aphanomyces***, ***Phoma*** and ***Rhizoctonia***, have now been confirmed as major yield-limiting constraints, with yield losses of up to 77% identified through the National Soilborne Disease Initiative (Gontar and Tonkin 2026). While rotations with non-host crops can reduce losses, these findings highlight the challenge for intensive pulse systems with limited rotational flexibility.

It is also important to note that resistance ratings alone do not always predict field performance, as sowing time, crop density, canopy structure and biomass can influence crop microclimate, disease development and the level of resistance expressed in the paddock. Resistance ratings need to be interpreted in the context of agronomy-adjusted disease risk and system-based management, while recognising that seasonal conditions remain a major driver of disease risk and are largely beyond grower control.

Better adaptation of pulses to Victorian environments

Grain yield and profitability remain the primary drivers of species and varietal choice and have underpinned recent pulse expansion in Victoria. Further growth will depend on breeding and management practices that sustain yield potential and profitability under increasing climatic variability, higher pulse intensity and expansion into new regions. In both established and emerging production areas, varietal performance also underpins broader farming system benefits through biologically fixed nitrogen.

The Quambatook region represents a district which covers well-established pulse production areas, where increasing pulse intensity is creating new weed, disease and herbicide-residue challenges, and newer production areas where growers are still determining which pulse species and management strategies provide the best fit. In these transitional regions, the focus is less on expanding pulse area and more on understanding how species choice, soil type, sowing time and management interact to influence profitability and risk. To support this, BCG has undertaken a series of trials across north-central Victoria investigating pulse fit within local farming systems, including species selection and management strategies to support expansion into more challenging soil types, such as acidic soils.

A key component of this work is understanding the profitability of different pulse options across environments and sowing windows. Gross margins from a trial conducted at Mitiamo in 2025 illustrate the importance of these decisions (Table 1), where vetch continues to provide a profitable hay option. Lentils were also highly competitive, particularly under stronger grain prices, but profitability declined with later sowing. These results reinforce the importance of time of sowing × species interactions in transitional pulse-growing regions.

Irrigation adds another layer of opportunity and complexity for northern Victorian pulse systems. Modernised irrigation infrastructure and more flexible water delivery have created opportunities to use irrigation strategically. At Boort in 2025, lentil yields exceeding 4t/ha were achieved using existing varieties, modest irrigation inputs and management similar to dryland production systems. This suggests there may be opportunities to use irrigation to reduce downside risk, support flowering and podding, or help finish crops in favourable seasons.

Table 1: Gross margin comparison between vetch hay and lentils for the 2025 season from Mitiamo. Gross margin was estimated using the 2025 Farm Gross Margin Guide.

Species	Variety	TOS	Yield (t/ha)	Income ($/ha)	Costs ($/ha)	Gross margin ($/ha)
Purple vetch ($350-375/t)*	Benetas	**TOS1**	7	2590	587	2003
		TOS2	4.8	1680	587	1093
Common vetch ($400/t)	Morava	**TOS1**	5.8	2320	587	1733
		TOS2	3.6	1440	587	853
Lentil ($640/t)	GIA Lightning⍉	**TOS1**	2.7	1728	462	1266
		TOS2	1.8	1152	462	690
Lentil ($900/t)	GIA Lightning⍉	**TOS1**	2.7	2430	462	1968
		TOS2	1.8	1620	462	1158

**Prices based of protein and quality % of DM for hay.*

However, results from other irrigated sites demonstrate that irrigation alone is not a guarantee of high yield or profitability. A similarly irrigated site further north yielded less than 2t/ha, highlighting the influence of soil type, sowing time, variety, disease pressure, canopy development and seasonal conditions. For regions such as Quambatook, the challenge is not simply determining whether pulses can be irrigated, but identifying when irrigation improves reliability and profitability, and how it can be integrated with species choice and agronomic management to maximise returns.

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.

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Evolution of clethodim resistance in annual ryegrass – what can we do

Peter Boutsalis*[1 2]*, Sam Kleemann*[2]*, Jenna Malone*[1] *and Christopher Preston*[1]*.

[1]School of Agriculture, Food and Wine, Adelaide University; [2]Plant Science Consulting P/L.

GRDC project code: UCS2407-001RTX

Keywords

- clethodim, group 1 resistance, ryegrass, target site resistance.

Take home messages

- Controlling ryegrass with DIM herbicides in canola and pulses is becoming more difficult.
- Ryegrass surviving DIM herbicides accumulates resistance, increasing levels further.
- Alternative mode-of-action herbicides control DIM herbicide resistance ryegrass.
- Surviving ryegrass is not always resistant; factors such as frost, tank mixes and application can often contribute to reduced efficacy.
- Testing for DIM resistance can optimise weed control strategies.

Background

Clethodim is the most important post-emergent herbicide used in broadleaf crops across southern Australia. It belongs to the Group 1 DIM (cyclohexanediones) subgroup along with butroxydim (e.g. Factor® 250 g ac/kg). Clethodim was first registered with the trade name Select® (240 g ac/L) in the early 1990s by Sumitomo Chemical Australia. The first label rates ranged from 150 mL/ha to 250 mL/ha. Prior to Select®, the only other DIM herbicide that was registered for control of ryegrass was Sertin® (186 g ac/L sethoxydim). Select® is however more active than Sertin® which had been used prior to the release of Select® to control Group 1 FOP (aryloxyphenoxypropionates)-resistant ryegrass. In 2007 the maximum registered rate of clethodim was increased to 500 mL/ha. The mechanism by which resistance to clethodim has increased will be discussed along with strategies to tackle clethodim resistance in ryegrass. The information in this paper represents a summary of decades of research, most funded by the GRDC.

Method

How much clethodim resistance is present in ryegrass? Clethodim resistance has been increasing, detected by GRDC funded random weed surveys across southern Australia (Table 1). Additionally, data from commercial testing institutions., highlights DIM resistance levels detected in ryegrass samples from the region surrounding Quambatook (Table 2), as well as from more than 1,000 ryegrass samples tested over the past 4 seasons from southern Australia (Table 3).

Results and discussion

DIM resistant levels in annual ryegrass

Herbicide resistance to clethodim in Victoria in 2020

Ryegrass is predominantly detected in greater densities in higher rainfall cropping regions. The probability of resistant individuals occurring within a population increases as population size increases, with a greater likelihood of resistance genes being present. A random weed survey was conducted in 2020 to detect the levels of herbicide resistance in cropping paddocks across southern Australia, including Victoria (Refer: UC2008-001RT 'Combatting ryegrass weed resistance - SA and Vic Mallee and Wimmera'). Ryegrass seeds were collected just prior to harvest. Resistance varied from 0% to 17% in southwest Victoria. Less clethodim resistance was detected in the Mallee, a traditionally less intensively cropped region with lower ryegrass populations, and in northeast Victoria, where there is a greater reliance on hay production that removes ryegrass from paddocks before seed production.

Table 1: The incidence of resistance detected in Victorian agricultural regions to clethodim 240EC applied at 500 mL/ha + 1% Hasten. Samples collected during the 2020 GRDC-funded random weed survey from continuously cropped paddocks. Ryegrass samples with 20% survival or greater in pot trials were scored as resistant.

Region	Mallee	Wimmera	North central	South west	North east
No. samples	32	39	13	60	43
% survival	0%	15%	15%	17%	2%

Table 2: DIM resistance in ryegrass originating in 10 central Victorian towns* nearby to Quambatook. Samples tested by Plant Science Consulting. Ryegrass samples with 20% survival or greater in pot trials were scored as resistant. Summarised data of per cent survival from 90 resistance tests over the last 20 years.

Rate (/ha)	Resistant	Susceptible
clethodim 240EC at 500 mL/ha	22%	78%
clethodim 240EC at 500 mL/ha + butroxydim 250WG at 180 g/ha	3%	97%

*Boort, Charlton, Culgoa, Kerang, Lalbert, Nullawil, Quambatook, Pyramid Hill, Wedderburn, Wycheproof

A common practice employed by growers is to tank mix 2 different DIM actives. Table 2 shows that in the Quambatook area, 22% of ryegrass tested was resistant to clethodim compared to 3% resistance to the combination of clethodim + butroxydim when applied at maximum label rates.

Table 3: DIM resistance in ryegrass originating from more than 1000 samples (origin: WA, SA, Vic and NSW) tested with clethodim and clethodim + butroxydim at maximum label rates. Samples tested by Plant Science Consulting. Ryegrass samples with 20% survival or greater in pot trials were scored as resistant.

Rate (/ha)	Resistant	Susceptible
clethodim 240EC at 500mL/ha	43%	57%
clethodim 240EC at 500mL/ha + butroxydim 250WG at 180g/ha	22%	78%

Of more than 1000 samples tested with clethodim and clethodim + butroxydim, approximately half of the ryegrass samples classified resistant to clethodim were not resistant when tested to clethodim + butroxydim.

Why is it becoming more difficult to control ryegrass with DIMs

Increasing FOP rates rarely improves control of FOP-resistant ryegrass. DIM herbicides can respond differently, with higher rates sometimes improving control. One practical approach is to apply clethodim and butroxydim together at label rates. Reduced control at standard DIM rates is often attributed to metabolic resistance, but Group 1 herbicide resistance in ryegrass is commonly driven by target-site resistance (TSR), making variation in DIM response more complex. FOPs, DENs and DIMs all bind to the same site on acetyl-CoA carboxylase, or ACCase. This binding reduces ACCase activity, disrupting the production of fatty acids, or lipids, which are essential for cell membranes and plant structure.

DIM resistance is summarised below across three layers.

Layer 1

The variation in DIM resistance is due to the presence of at least eight mutations at the binding site of ACC'ase, which cause differential binding (Yu et al. 2007). The mutations that confer FOP only resistance are more common than those conferring FOP and DIM resistance.

Layer 2

At each of the eight sites, different mutations can occur which can result in different Group 1 herbicide resistance profiles. All ACC'ase mutations result in FOP resistance, with fewer conferring resistance to DEN and fewer still to DIM. It also appears that the mutations conferring DIM resistance are less common, which is one reason ryegrass populations often develop resistance to FOPs more readily than to DIMs.

Layer 3

Ryegrass is an obligate outcrossing species; therefore it must cross-pollinate to produce viable seeds. Plants in close proximity surviving clethodim accumulate ACC'ase mutations via pollen transfer, thereby producing hybrids with multiple mutations. Multiple mutations cause large structural changes to the binding site of ACC'ase, reducing the ability of DIM herbicides to bind effectively at the target site. These changes can result in very high levels of DIM resistance.

Based on the three layers of DIM resistance, (1) the site, (2) the specific mutation at the site, and (3) the number of mutations in a single plant, many DIM resistance profiles can result (Malone et al. 2013).

Tackling DIM resistance in annual ryegrass

The first step in resistance management is to establish a baseline of the resistance status of the ryegrass population to DIM and other herbicide groups. The most practical and reliable method is to submit seeds or plants to a commercial testing service. There are several strategies to combat DIM resistance. When resistance testing detects little or no resistance, the appropriate response is to prevent resistance from developing further by implementing alternative management strategies. If testing identifies high levels of resistance, more drastic measures are required, as effective control with DIM herbicides may no longer be achievable.

Group 1 TSR only confers resistance to Group 1 herbicides. The use of alternative mode-of-action (MoA) herbicides is a common response to combat DIM-resistant ryegrass, assuming the ryegrass does not possess resistance mechanisms to other MoA herbicides. Below are some potential options.

Post-emergent

Glyphosate can be used in glyphosate-tolerant crops (i.e. Roundup Ready® or Truflex® canola) assuming glyphosate resistance is not present. The addition of glyphosate to clethodim in tank mixes can be effective, sometimes even on clethodim- and glyphosate-resistant ryegrass. Use of glufosinate (e.g. Liberty Ultra®) in glufosinate tolerant crops (i.e. LibertyLink canola) or atrazine in triazine tolerant crops are not affected by ACCase TSR.

Early post-emergent

Currently Mateno® Complete is registered in wheat and barley, and Tenet® and Edge Unify® for use in canola. These herbicides rarely control existing plants, particularly if tillering, but can prevent germination of subsequent cohorts. They can also severely stunt root growth in surviving plants, thereby reducing their ability to compete with the crop.

Post-sowing pre-emergent

These herbicides are applied soon after sowing and incorporated by rainfall, helping control ryegrass in both the crop furrow as well as the interrow. Ultro® herbicide is a recent example, with both pre-sowing and post-sowing pre-emergent registration.

Pre-emergent

There are many herbicides with diverse MoA in this group. Some of the above-mentioned herbicides are also registered for pre-emergence use. In addition, trifluralin, triallate, pyroxasulfone and prosulfocarb containing products, as well as Overwatch® and Luximax®, are registered.

Herbicide mixtures

Traditionally, single herbicides have been used to combat ryegrass. Research has shown that combining two or more different MoA herbicides at label rates can reduce herbicide resistance, example mixtures include trifluralin + triallate and Overwatch® + pyroxasulfone. As herbicides have different properties, such as binding to organic matter and solubility, using more than one pre-emergent herbicide serves to increase the chance of good efficacy under a range of soil conditions.

In addition to targeting ryegrass in the early stages of the crop, other tactics can aid in the control of DIM-resistant ryegrass. Crop-topping is a strategy by which herbicides such as glyphosate, paraquat and tiafenacil (Terrad'or® - Wheat ONLY) can be used late in the season to reduce seed production of surviving plants (Refer: 'Optimum crop-topping timing – getting better ryegrass control'). Killing weed seed during harvest is another strategy, with several companies' offering machinery that captures and destroys seed before it is returned to the paddock. Narrow windrow burning can also be effective, as can hay or silage production, which removes seed before it becomes viable.

Resistance is not always the reason why ryegrass has survived a DIM herbicide. This has been confirmed with commercial resistance testing. In some cases, other factors can result in reduced ryegrass efficacy. They include frost, growth stage, incorrect adjuvant choice, poor application, or a combination of these. Clethodim performance can be reduced by frost. It has been shown that during cold periods, greater efficacy can be expected if applications are made prior, rather than after, a frost (Saini et al. 2016) (Refer: 'Combatting herbicide resistance in ryegrass and sowthistle (milkthistle) in the Wimmera').

Certain products can also reduce the efficacy of clethodim when tank mixed. One such product is atrazine. The use of atrazine and clethodim in triazine-tolerant canola is common with both products often tank mixed, however applying together can be antagonistic resulting in reduced efficacy (Refer: 'Annual ryegrass weed management and paraquat resistance').

Conclusion

Ongoing support from the GRDC to monitor herbicide resistance, including resistance to DIM herbicides, has identified a recent increase in DIM resistance in ryegrass populations. This shift, in part, can be attributed to increased reliance on DIM herbicides in canola and pulse cropping systems, where fewer alternative options are available. The combination of selection of very rare ACC'ase mutations and their stacking in the same plants is responsible for higher levels of resistance. Using alternative MoA herbicides in addition to crop-topping and seed capture at harvest can serve to prevent or combat DIM resistance.

Acknowledgements

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Optimum crop-topping timing – getting better ryegrass control (https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2022/08/optimum-crop-topping-timing-getting-better-ryegrass-control)

Annual ryegrass weed management and paraquat resistance (https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2022/02/annual-ryegrass-weed-management-and-paraquat-resistance)

Combatting herbicide resistance in ryegrass and sowthistle (milkthistle) in the Wimmera (https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2025/08/combatting-herbicide-resistance-in-ryegrass-and-sowthistle-milkthistle-in-the-wimmera)

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Notes

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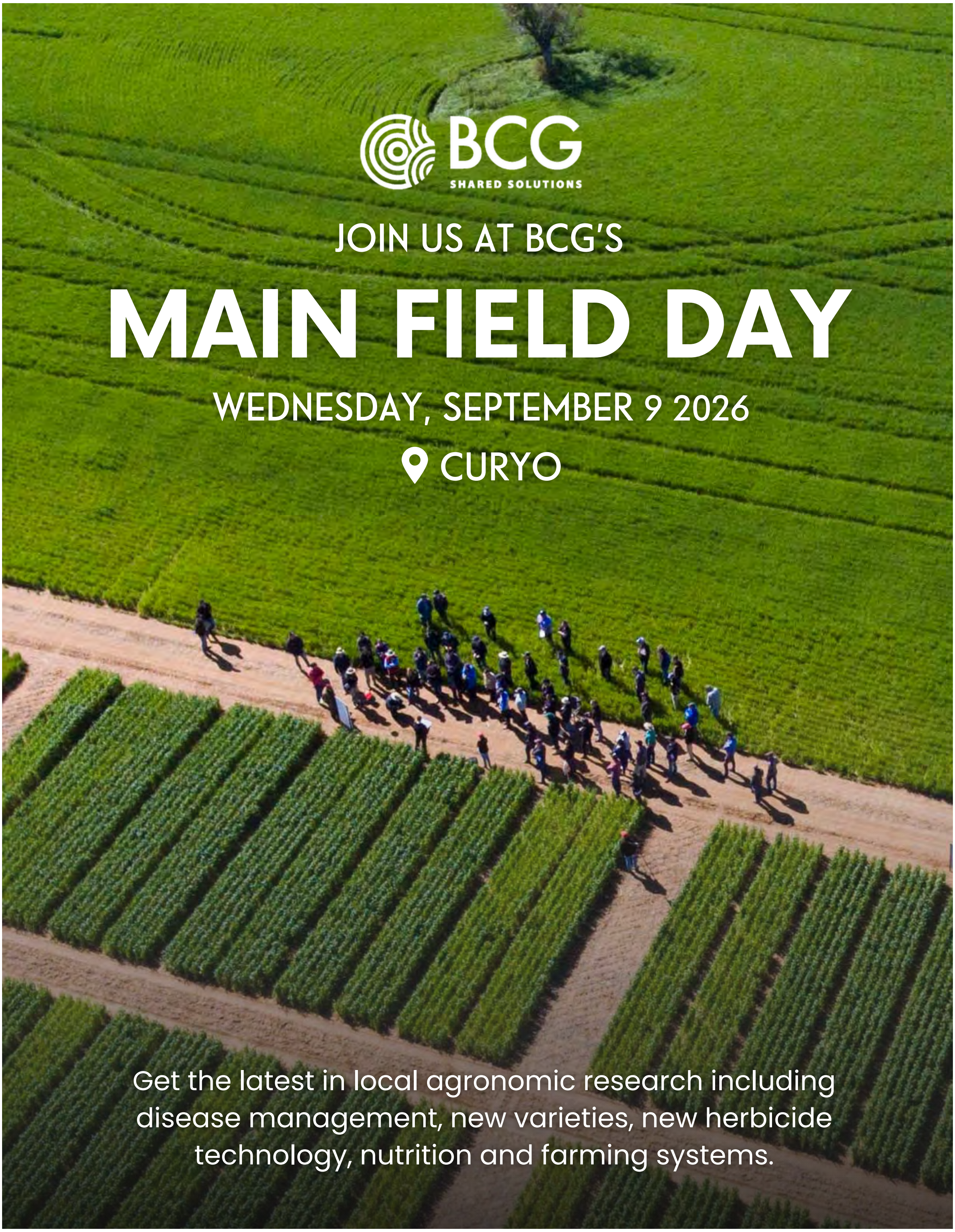

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JULY 28	SEP 9
GRAIN MARKETING IN VOLATILE TIMES Horsham Golf Club 9:30am - 1:30pm	**BCG MAIN FIELD DAY** Curyo 8:30am - 5pm

SEP 16	SEP 17
GRDC HARVESTER SET UP CLINIC Echuca 9:00am - 3:00pm	**GRDC HARVESTER SET UP CLINIC** Ultima 9:00am - 3:00pm

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Response to nitrogen fertiliser rate decisions at sites with high and low soil organic carbon

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GRDC project code: BWD2303-004BGX

Keywords

- fertiliser, nitrogen, risk, RiskWi$e.

Take home messages

- Nitrogen decisions are more likely to be profitable when they follow a consistent, evidence-based framework rather than seasonal guesswork.
- Soil organic carbon is a key driver of crop responsiveness to nitrogen and should influence fertiliser decisions.
- Assess nitrogen performance over multiple seasons using both gross margin and nitrogen balance to support long-term productivity and soil health.
- At the low organic carbon Curyo site, Yield Profit targeting a median (decile 5) season and nitrogen banking to 125kg/ha N delivered the best balance of profit, risk and long-term nitrogen sustainability.

Background

Nitrogen (N) supply is the primary limitation for achieving wheat water-limited potential yield in Australia (Hochman and Horan 2018). Nationally, addressing N deficiency in wheat could increase yield by 40% (Hochman and Horan 2018, Hunt et al. 2021). A recent survey of wheat growers and advisers conducted through RiskWi$e revealed a high proportion of growers experience low comfort when making N fertiliser decisions (Brown et al. 2026).

Decision Support Systems (DSS) such as Yield Prophet and N Banks support growers from a range of management styles to make evidence-based N fertiliser rate decisions. For growers who are more 'active' in their N management, Yield Prophet (and Yield Prophet Lite) help match N input to the water-limited potential yield for a given season. Yield Prophet is considered a better match for more 'active' N managers as there is a requirement for quality input data and set-up to ensure the accuracy of yield predictions. However, some growers may be uninterested, or unable, to collect the necessary data to ensure the quality of the tool's output. In these instances, a more 'passive' approach to N management can be employed, such as through the use of N Banks, a simpler, more 'passive' way of supporting N fertiliser rate decisions that capitalises on year-to-year soil N carry-over to support crop growth.

These decision systems, along with other N management strategies, are being studied intensively as part of the GRDC RiskWi$e project. The goal is to establish the risk and reward profiles of each strategy under a variety of environments, for example, sites with varying soil types, rainfall, and levels of soil organic carbon (SOC). BCG is currently conducting multiple multi-year experiments across western Victoria to compare long-term agronomic and financial performance of different N management strategies, including Yield Prophet and N banks. Findings for several of the N management strategies from 2018 to 2025 are summarised here for an experiment at Curyo in the southern Mallee, and Longerenong in the Wimmera.

Method

N management strategy set up

The methods of these trials are consistent with, and a continuation of, the trial outlined in Plowman et al. (2024a) with the following additional treatments described in Table 1 for the inclusion of treatments present at the Longerenong trial.

Table 1: Nitrogen management systems and treatments used in the experiments.

System	Treatment	Description
Nil	Nil	No N applied other than in starter fertiliser
Replacement (**Curyo**)	R	Amount of N removed in grain applied as fertiliser N
Yield Prophet Lite BOM (**Longerenong**)	YP_BOM	Matches the decile outlook for the season
National average	NA	National average N fertiliser (45kg/ha N) applied each season
Nitrogen banks	NB_CON	Soil mineral N + fertiliser = 100kg/ha N
(kg/ha N) (**Curyo**)	NB_PRF	Soil mineral N + fertiliser = 125kg/ha N
	NB_YLD	Soil mineral N + fertiliser = 150kg/ha N
Nitrogen banks	NB_CON	Soil mineral N + fertiliser = 150kg/ha N
(kg/ha N) (**Longerenong**)	NB_PRF	Soil mineral N + fertiliser = 175kg/ha N
	NB_YLD	Soil mineral N + fertiliser = 200kg/ha N
Yield Prophet probabilities based on seasonal finish	YP_D1	Lowest yielding finish on record (decile 1 in Yield Prophet Lite)
	YP_D3	Lower yielding quartile finish (decile 2–3 in Yield Prophet Lite)
	YP_D5	Median finish (decile 4–7 in Yield Prophet Lite)
	YP_D7	Higher yielding quartile finish (decile 8–9 in Yield Prophet Lite)

Table 2: Crop type and variety grown each year, alongside annual and growing season rainfall recorded for both trial sites.

Site, crop and rainfall	2018	2019	2020	2021	2022	2023	2024	2025
Annual rainfall mm Curyo (BOM station: 077008)	330	217	370	290	530	273	280	210
GSR (Apr–Oct) mm Curyo (BOM station: 077008)	107	181	240	196	406	187	139	162
Crop type, variety Curyo	Wheat, Scepter⍴	Canola, Hyola 350TT	Wheat, Scepter⍴	Barley, Spartacus CL⍴	Wheat, Razor CL Plus	Lentil, GIA Thunder	Barley, Maximus CL	Wheat, Shotgun⍴
Annual rainfall mm Longerenong (BOM station: 079028)					647	455	250[*]	340
GSR (Apr–Oct) mm Longerenong (BOM station: 079028)					467	264	149	238
Crop type, variety Longerenong					Wheat, Scepter⍴	Barley, Maximus CL	Lentil, GIA Thunder	Barley, Maximus CL

[*]Data unavailable for February and March.

Table 3: Soil type and soil organic carbon at both trial sites.

Soil type/organic carbon	Curyo	Longerenong
Soil type	Sandy clay loam	Grey cracking clay[^]
Organic carbon %	0.61%[*]	1.3%[^]

[*]Data are presented as the mean value averaged across multiple treatment plots.
[^]Data sourced from the APSoil database for the Horsham 1008 soil characterisation site.

Results and discussion

Average grain yvield over the long term

On average across the eight years at Curyo, the YP_D5 and YP_D7 treatments achieved the highest grain yields (3.67t/ha and 3.66t/ha, respectively), and both treatments were significantly higher than all others ($p<0.001$, Lsd = 0.26) (Figure 1). In contrast, yield data averaged over four trial years at Longerenong showed that this site is less responsive to N inputs as most treatments produced statistically equivalent yields: YP_D7 produced the highest average yield (4.1t/ha) but was not significantly different from YP_D5, NB_CON, YP_BOM, NB_PRF, NB_YLD, or NAT, with the only two exceptions being YP_D3 and NIL ($p<0.005$, Lsd = 0.22) (Figure 2).

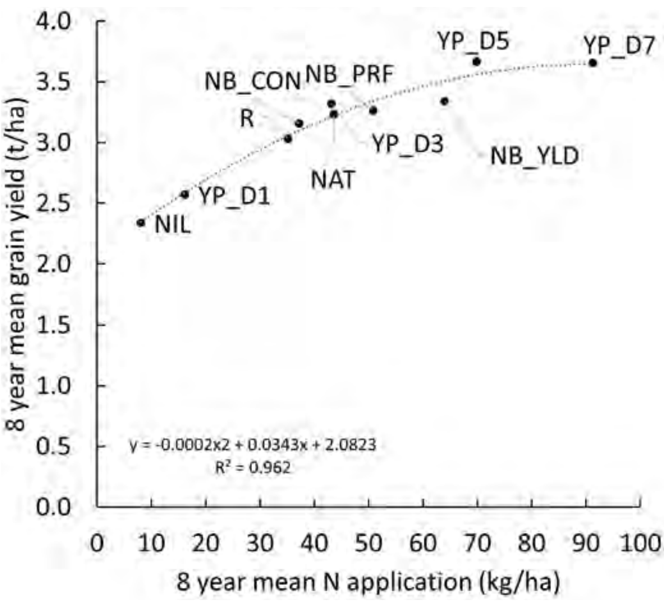

Figure 1. The relationship between mean eightyear fertiliser application and mean eight-year grain yield for the different treatments at the Curyo trial. The quadratic function fitted by least-squares regression is of the form y = -0.0002x2 + 0.0343x + 2.0823, R^2 = 0.962.

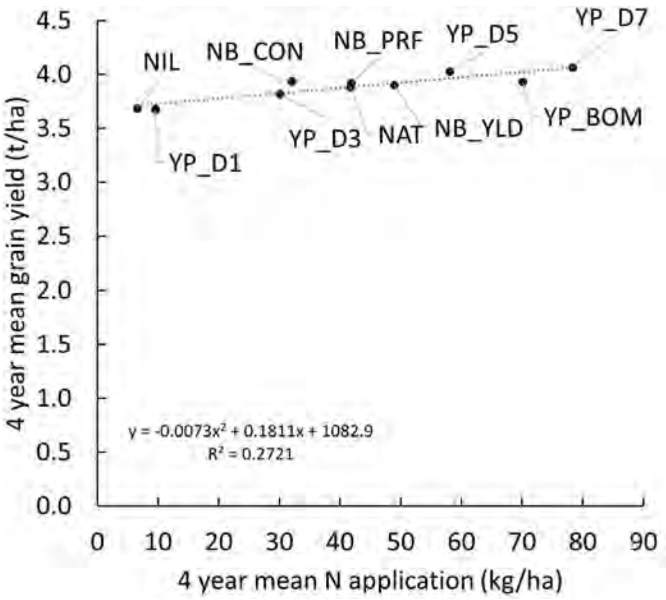

Figure 2. The relationship between mean four-year fertiliser application and mean four-year grain yield for the different treatments at the Longerenong trial. The linear function fitted by least-squares regression is of the form y = -0.0073x2 + 0.1811x + 1082.9, R^2 = 0.2721.

Average gross margin over the long term

At Curyo, the highest average gross margin across the eight years was achieved by YP_D5 ($883) which was significantly higher than all other treatments. The following treatments also achieved high margins, however were not significantly different from each other: YP_D7 ($836), YP_D3 ($817), NB_CON ($765), NB_PRF ($763), NAT ($756), and NB_YLD ($742) ($p<0.001$, Lsd $118), with no statistically significant differences between them. This is illustrated in Figure 3, where the relationship between mean N application and gross margin flattens out for this significance group. No significant differences were detected between gross margins for treatment alone at the Longerenong trial ($p=0.957$), however the interaction between year and treatment was significant ($p<0.05$, Lsd $197), and a weak relationship between long-term gross margin and mean N application rate was observed at this trial (Figure 4). Longerenong showed a yield to N rate in 2022 and 2023 (individual year data not shown). The lack of response observed in 2025 is possibly explained by soil water availability in 2025 following the lentil crop sown in 2024 for which a number of N treatments yielded higher than expected, and this is probably due to higher soil water availability in lower N treatments following the 2023 barley crop. Given the dry conditions in 2025 (Table 2), the higher N rate treatments in the 2025 barley crop may not have had the opportunity to respond to the higher N inputs, particularly following higher-than-expected lentil yields in 2024 which may have impacted soil available water.

Importantly, the percentage of SOC varies substantially at each site, as shown in Table 3. SOC and N are stored in consistent ratios (10–12 C to 1 N) in soil organic matter. Soils with lower SOC therefore have less organic N reserves and thus are more dependent on fertiliser N to achieve water-limited potential yields (Farrell et al. 2021). This was demonstrated as part of a recent sub-experiment conducted at the Curyo site by Plowman et al. (2024b) who reported that soil mineral N can be depleted in the short term (five years), negatively impacting yield, however it was possible to compensate for the impact on yield through the application of substantial rates of fertiliser N. Therefore, it is plausible to assume that the performance of N rate treatments varies depending on the growing environment, particularly soil organic carbon (SOC).

Nevertheless, the four highest average gross margins at the Longerenong trial were returned by NB_CON ($1108), NB_PRF ($1094), NIL ($1087), and NAT ($1087). The N rate for each treatment was 7kg/ha (NIL), 32kg/ha (NB_PRF), and 42kg/ha (NB_CON and NAT).

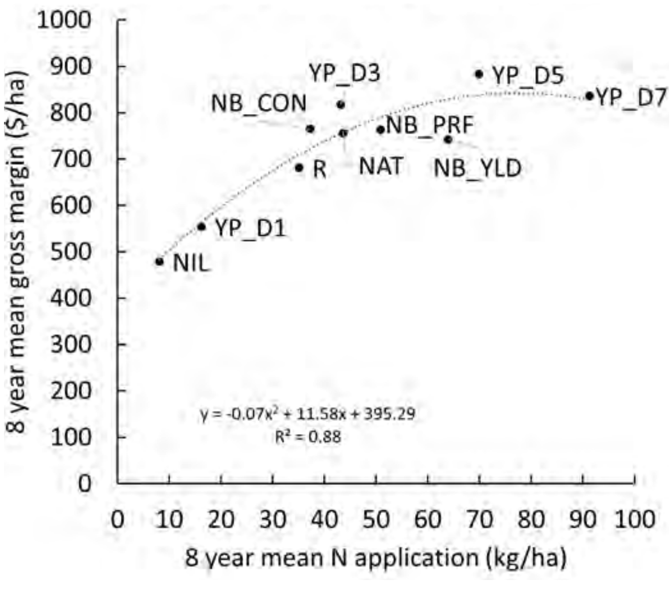

Figure 3. The relationship between mean eight-year fertiliser application and mean eight-year gross margin for the different treatments at the Curyo trial. The quadratic function fitted by least-squares regression is of the form y = -0.07x2 + 11.58x + 359.29, R^2 = 0.88.

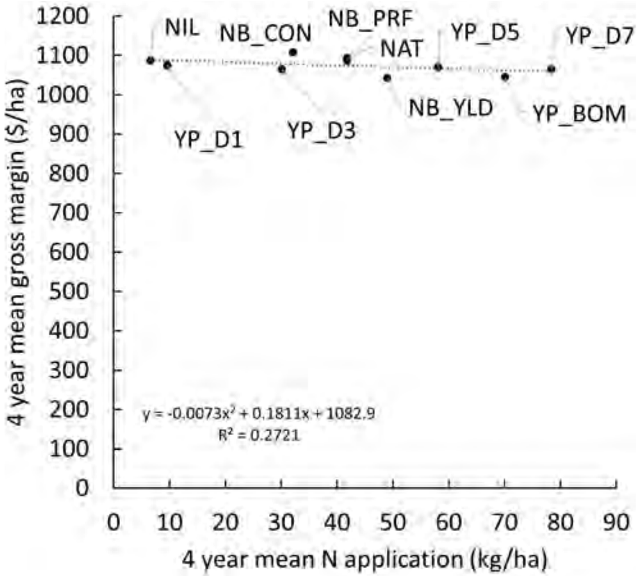

Figure 4. The relationship between mean four-year fertiliser application and mean four-year gross margin for the different treatments at the Longerenong trial. The linear function fitted by least-squares regression is of the form y = -0.073x2 + 0.1811x + 1082.9, R^2 = 0.2721.

Impacts on N carry-over and risks associated with different strategies

At the Curyo trial, negative gross margins were avoided by YP_D5, YP_D3, NB_CON, and NB_PRF over the eight-year period, illustrating a lower level of risk over the longer term, contrary to YP_D7 which recorded a negative gross margin, and thus demonstrates higher volatility (individual year data not shown). In comparison, the Longerenong trial showed there were no treatments which experienced a negative gross margin in any year, suggesting that N management in the lower rainfall Curyo environment is inherently riskier.

Regarding the assessment of risk in decision-making, growers should also consider the partial N balance, which is the relationship between N leaving a system through grain and environmental losses and N being replenished by fertiliser and legumes. Although a number of treatments achieved significantly higher gross margins over the eight-year average at Curyo, despite varying levels of volatility, YP_D5 was the optimal choice for growers choosing an 'active' style of N management, as its cumulative partial N balance sat at the low but positive value of 23kg/ha (Figure 5). For growers who prefer a more 'passive' style of N management, the NB_PRF management strategy achieved a cumulative partial N balance which was positive but still close to neutral (33kg/ha). At Longerenong, where treatment effects were weaker for gross margin, growers can be guided by the cumulative partial N balance where the NB_PRF strategy returned the lowest positive cumulative partial N balance (8kg/ha), whilst still achieving a higher average gross margin, albeit not significantly different from other treatments (Figure 6).

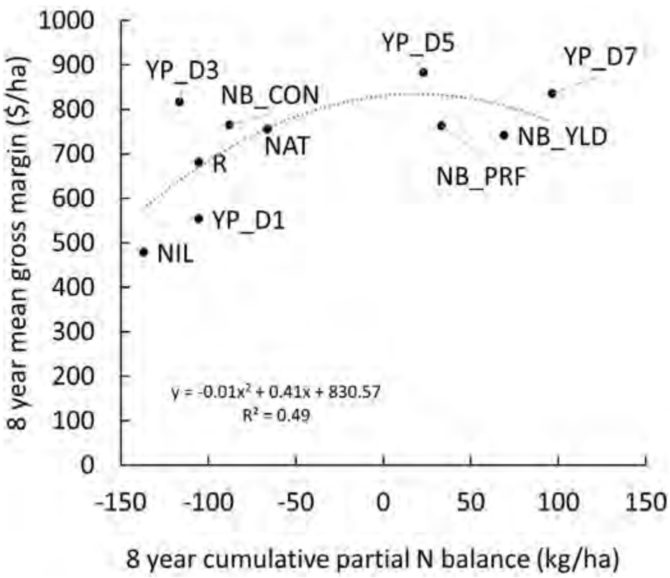

Figure 5. The relationship between eight-year nitrogen balance and eight-year mean gross margin for the different treatments. The quadratic function fitted by least-squares regression is of the form y = -0.01x2 + 0.41x + 830.57, R^2 = 0.49.

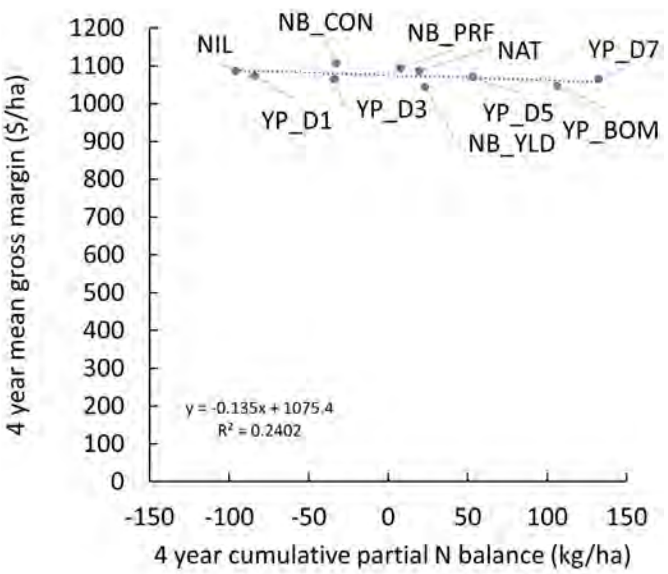

Figure 6. The relationship between four-year nitrogen balance and four-year mean gross margin for the different N management treatments at Longerenong. The linear function fitted by least-squares regression is of the form y = -0.135x + 1075.4, R^2 = 0.2402.

Conclusion

The difference in responsiveness between the Curyo and Longerenong trials is likely mostly driven by the SOC at each site. At the Curyo site, with lower overall rainfall and SOC, a clear advantage was illustrated through the employment of YP_D5 and NB_PRF – two different management strategies that resulted in good returns (though YP_D5 was significantly higher than NB_PRF) and N carry-over, whilst safeguarding N losses to the environment. At sites that are more responsive to N inputs, Yield Prophet® and N bank approaches are reliable decision-making systems to maximise returns on a short- and longer-term basis. The choice between a particular strategy is likely to be driven by grower preference for simplicity versus complexity in N management.

However, sites with higher SOC are less responsive to N fertiliser, and therefore growers are encouraged to be guided by a strategy that maximises profit whilst maintaining a low but positive partial N status, as well as one which suits their management style.

Acknowledgements

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From 2018 to 2019, the research was funded by La Trobe University funded through the Securing Food, Water and the Environment Research Focus Area. Funding was subsequently provided by the Mallee Catchment Management Authority from 2019 to 2022, through the Australian Government's National Landcare Program and GRDC, through the National Grower Network. We thank Paul Barclay for hosting the experiment.

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Protecting your most perishable asset – latest understanding on grain storage

Chris Warrick.

Primary Business

GRDC project code: PRB2412-001SAX

Keywords

- fumigant, grain storage, phosphine, silo.

Take home messages

- A storage must be gas-tight sealed to achieve a high enough concentration of fumigant for a long enough period to kill pests at all life cycle stages.
- Pressure test silos, and when buying a new silo, buy a quality, gas-tight sealable silo fitted with aeration and check it meets the Australian Standard.
- Phosphine is a highly toxic gas, so follow all product label statements when applying and venting.
- Phosphine gas concentration needs to reach 550 parts per million (ppm) and remain above this level for 7–10 days. Exposure periods vary with temperature and storage capacity.
- Powered air recirculation systems distribute the phosphine gas to achieve lethal concentration in all areas of the storage - particularly helpful in large silos.
- Fumigation meters are an essential part of best practice use of phosphine for measuring concentration during fumigation and post-venting.

Fumigation fundamentals

Poor fumigation techniques fail to kill pests at all life cycle stages, so while some adults may die, grain will soon be reinfested again as soon as larvae and eggs develop. What's worse, every time a poor fumigation is carried out, insects with some resistance survive, making the chemical less effective in the future.

The second challenge with fumigating is venting the gas to ensure it is safe and meets the delivery site requirements, with some delivery sites using 0.3 parts per million via a spear test as a clearance limit. New lower worker exposure limits, which come into effect in December 2026, could make venting prior to delivery even more challenging.

Gas-tight

Research shows that fumigating a storage that is anything less than gas-tight sealed doesn't achieve a high enough concentration of fumigant for a long enough period to kill pests at all life cycle stages. Pressure testing a silo ensures it can hold gas concentrations sufficient to kill all insects at all life stages. Just because a silo is sold as a sealed silo does not automatically mean it's suitable for fumigation. Even if a silo is sold as 'sealed', it is not sealed until it is proven gas-tight with a pressure test.

When a pressure test is undertaken, oil levels in the pressure relief valve must take a minimum of five minutes to fall from 25mm to a 12.5mm difference if the silo is sufficiently gas-tight. When buying a new silo, buy a quality, gas-tight sealable silo fitted with aeration and check with the manufacturer that it meets the Australian Standard for sealable silos (AS2628–2010).

Safety

Phosphine is a highly toxic gas with potentially fatal consequences if handled incorrectly. As a minimum requirement, product labels direct the use of elbow-length PVC gloves and a full-face breathing respirator with combined dust and gas cartridge, suitable for inorganic gas. Be aware that cartridges have a limited lifespan as they contain activated carbon. After use, store cartridges in a sealed container and follow manufacturer directions for replacement.

Working with phosphine in an open, well-ventilated area with the wind coming from the side will help carry the gas away from the body. When opening containers, take care and point container lids away from the face and body. When opened, use the entire contents — do not reseal left-over tablets.

Safe Work Australia has announced a change to worker exposure limits for phosphine. Affective from December 2026, the peak exposure limit will be 0.15 Parts per million (ppm) and the Time Weighted Average will be 0.05ppm.

Exposure period

To control pests at all life stages and prevent insect resistance, phosphine gas concentration needs to reach 550 parts per million (ppm) and remain above this level for 7–10 days. At this concentration, an exposure period of seven days is required when grain is above 25°C or 10 days if at 15–25°C. Insect activity and development slow down in cooler grain temperatures, which means a longer exposure time to fumigants is required to deliver a lethal dose to all life stages.

In gas-tight sealed silos larger than 300t capacity that don't have powered recirculation, the exposure period is extended to 20 days regardless of grain temperature. If the silo has powered recirculation, the exposure period can be shortened to 10 days. When grain temperatures fall below 15°C, insect pests become inactive and phosphine fumigation is no longer reliably effective.

Recirculation systems

Some silos are fitted with purpose-built chambers for applying phosphine from the bottom. This method of application carries a safety advantage, as the operator doesn't have to leave the ground to apply the phosphine.

Bottom-application chambers must have a passive or powered air recirculation system to carry the phosphine gas out of the confined space as it evolves. Without air movement, phosphine can reach explosive levels if it's left to evolve in a confined space.

Silos larger than 150t will benefit from a sealed, powered recirculation system to distribute gas throughout the storage and achieve consistent gas concentration sooner. Trials have found that, without powered recirculation, phosphine travels at approximately 6m per day through grain, in any direction.

In silos larger than 300t without powered recirculation, the phosphine label stipulates an extended exposure period of 20 days, referenced as 'surface only application'. Using powered recirculation enables the fumigation period to be shortened to 10 days.

An alternative to a dedicated, powered recirculation box with a phosphine chamber is to connect a small fan between the pluming from the silo headspace to the base and place the phosphine in the headspace and/or aeration ducts at the base. This option has two main advantages – it avoids the risk of explosion if the fans stops as the phosphine can safely continue liberating in the silo, and, being lower cost, there is also the option to buy multiple fans so more than one silo can be fumigated at a time.

Venting

Following fumigation, ventilate silos to allow phosphine gas to escape into the atmosphere, so grain can be delivered free of harmful gas residues. The same PPE required for applying the phosphine is required again to open the silo and remove the phosphine residue. After the removal of tablet residue or bag chains, the labels state that a silo without aeration fans fitted must be left open to ventilate for no less than five days. Silos with aeration fans fitted must be opened to ventilate with fans operating for no less than one day. Larger flat bottom silos, cool grain or extended fumigations are likely to require additional time to vent as the grain desorbs the phosphine.

A low-level phosphine meter is the safest way to ensure the grain is vented to the delivery limit set at the receival point. Grain should be spear tested at least a few hours after fans have been switched off and prior to moving in order to sample the air gaps into which grain may have been desorbing gas. The labels state that grain treated with phosphine should not be used for human consumption or for stock food for a minimum of two days after the ventilation period has finished.

Monitoring gas concentrations

Fumigation meters are an essential part of best practice use of phosphine, especially when fumigating storages that cannot be pressure tested, such as bunkers and bags. Meters are available in high range (0 to 2000ppm) for measuring concentration during fumigation, and low range (0 to 20ppm) for measuring concentration post-venting for clearance and safety.

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Northwest climate drivers – what, when and where

Dale Grey.

Agriculture Victoria, Bendigo.

Keywords

- climate, ENSO, IOD, predictions.

Take home messages

- An El Niño is gaining momentum, models predict it to be the real deal with a drier and warmer outcome, but it is early days as to whether this plays out.
- El Niño does not equal drought, and La Niña does not equal flood.
- The key climate drivers in the northwest have no, or variable, rainfall outcomes over summer and autumn.
- The key northwest climate drivers have their greatest influence over winter and spring.
- The Local Climate Tool is a good truth tester if you're interested in understanding the historic climate driver effects in your area.
- Monitor the climate situation from a trusted source that can tell you whether oceanic climate phenomena are coupling with the atmosphere.

Key climate drivers affecting northwest Victoria

Table 1 shows months of the year where the main climate drivers that affect rainfall across Victoria have statistically affected the rainfall, either positively or negatively. The peak months are in winter and spring, whereas in summer and, in particular, in autumn, the correlations are poorer.

Table 1: Key climate drivers and the months of the year that they have statistically affected rainfall somewhere in Victoria.

Victoria	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ENSO	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓
IOD					✓	✓	✓	✓	✓	✓		
SAM	✓	✓				✓	✓	✓	✓	✓	✓	✓
STR position					✓	✓	✓	✓	✓	✓	✓	✓
STR strength					✓	✓	✓	✓	✓	✓	✓	✓
MJO	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

ENSO = El Niño Southern Oscillation, IOD = Indian Ocean Dipole, SAM = Southern Annular Mode, STR = Sub-Tropical Ridge, MJO = Madden Julian Oscillation

Table 2 shows the same data but specifically for the Victorian Mallee. This analysis shows that winter and spring are the most reliable for a climate drivers' existence to affect rainfall, summer and autumn are particularly poor. No climate driver has had a strong effect in the critical early autumn months of March and April.

Table 2: Key climate drivers for the Mallee and the months of the year that they have statistically affected rainfall.

Mallee	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ENSO					✓	✓	✓	✓	✓	✓	✓	
IOD					✓	✓	✓	✓	✓	✓		
SAM												
STR position							✓	✓	✓			
STR strength					✓	✓	✓	✓	✓	✓		
MJO					✓	✓	✓	✓	✓	✓	✓	✓

It's worth noting that autumn is always a poor time for climate predictability. This is the autumn predictability barrier that exists because the tropical oceans are usually in reset mode during autumn. In autumn, tropical climate drivers are yet to show their hand as to what they might do in the coming winter and spring. In autumn, the undersea temperatures sometimes show signs as to the possibility of ENSO or IOD formation in the coming year but it's very uncertain as to whether those phenomena actually form. Autumn is a time to be concerned about the climate but not a time to put much faith in climate forecasts. Spend more time making decisions with known information: your soil moisture profile, has the break occurred yet, has optimal seeding time changed and the weed profiles of paddocks.

The Forecasts4Profit and Local Climate Tool web sites (originally funded by GRDC) are a great place to go to look at the historical effects of ENSO and the IOD across southeast Australia. Figures 1–3 are derived from this tool and show tercile distributions of the rainfall effects for varying seasons and ENSO and IOD phases. A tercile distribution is divided into thirds. The red colour shows the percentage of time rainfall was in the lowest third of the record, the yellow colour shows the percentage of time rainfall was in the middle or average third of the record, and the blue colour shows the percentage of time rainfall was in the highest third of the record. By definition, the historic record including all years shows a 33% chance each of low, average and high. In autumn, the climate driver response is varied, rainfall is close to the historic chance and perhaps some swayed a bit wetter, in the case of La Niña and -IOD. Winter behaviour shows the IOD and El Niño can play a more significant role earlier, where a La Niña in winter tends to show behaviour closer to the long-term average. The response to the ENSO and IOD climate drivers is greatest for spring with the likelihood of drier conditions moving up to 45–73%. The wetter climate drivers of La Niña and -IOD show the opposite effect, with the likelihood of wetter conditions increasing to 50-73%.

All of these pie charts show that the existence of a particular climate driver doesn't guarantee a certain outcome. El Niño doesn't 'equal' drought and La Niña doesn't 'equal' floods, occasionally the exact opposite has happened. What has historically happened is the odds substantially increase but don't guarantee anything. The Local Climate Tool is a good way of testing the historic outcomes for various climate drivers in your own area. In your mind, you might be thinking a drought is strongly on the cards but historically droughts in El Niño or +IOD years are only around 25% of all events rather than a 'lay down misère'.

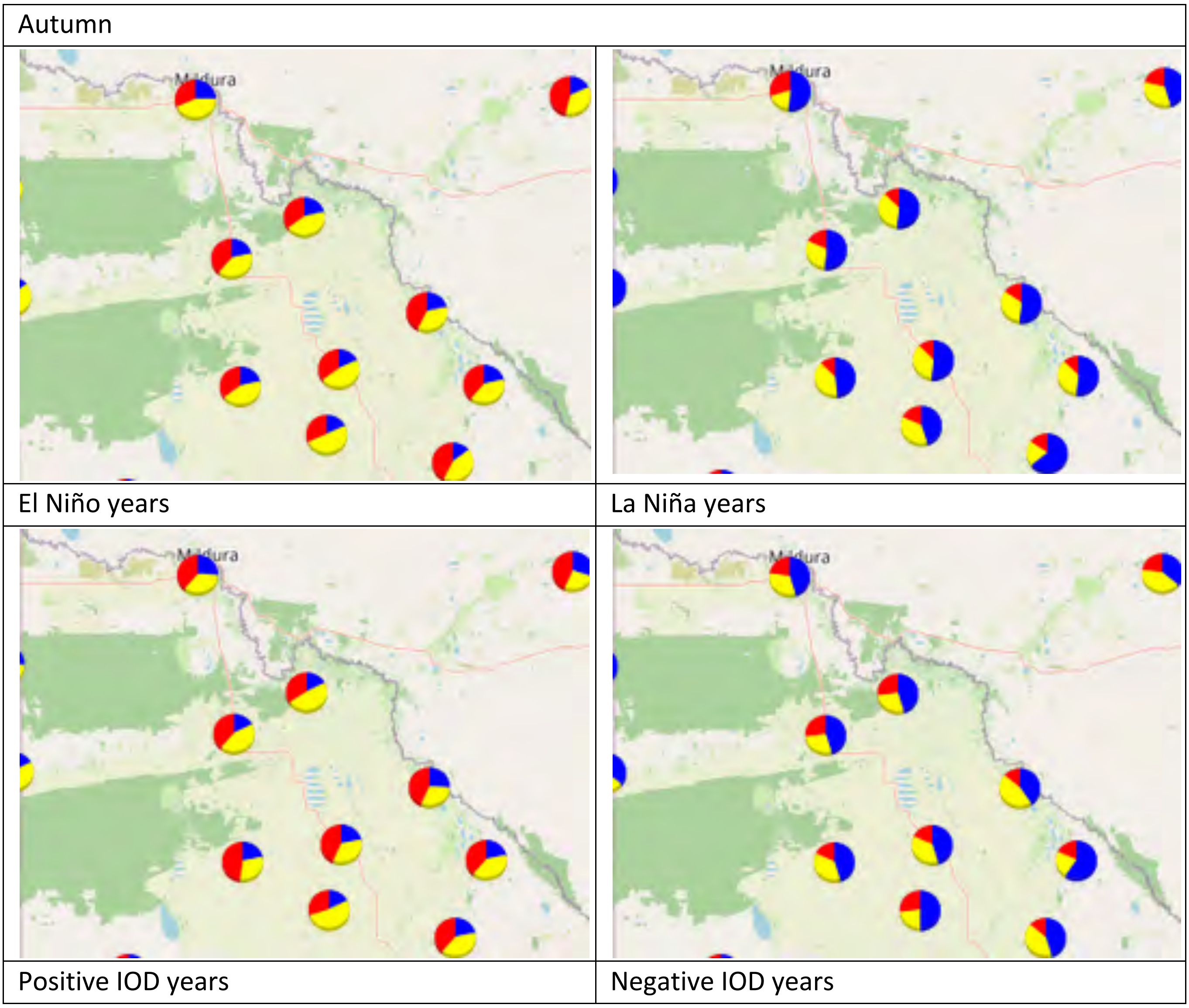
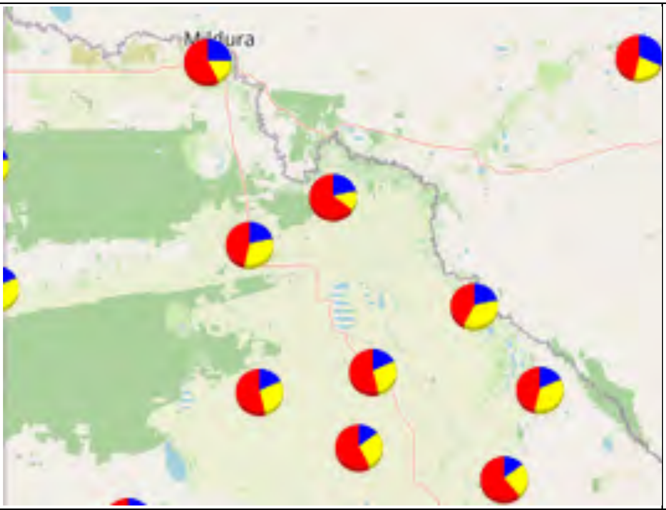
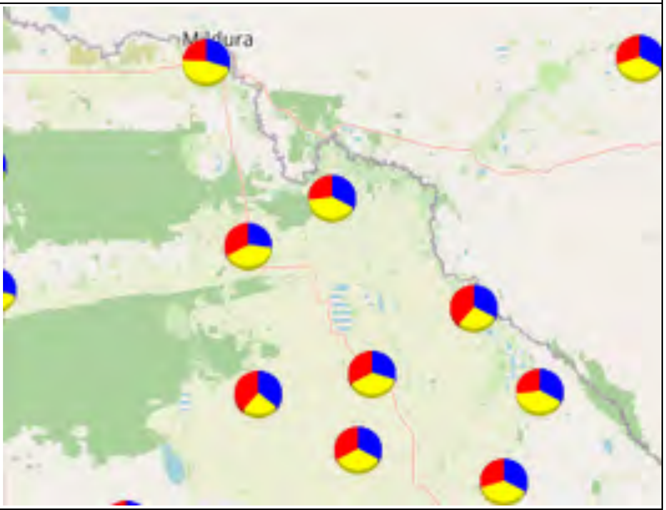


Figure 1. Autumn rainfall tercile graphs for the phases of ENSO and IOD.

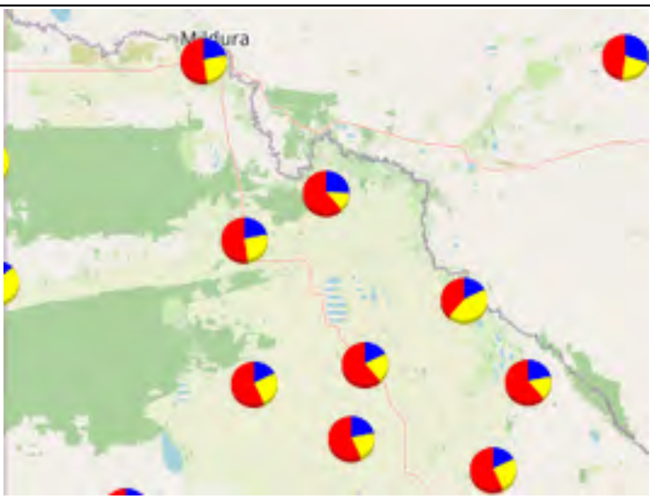
Winter



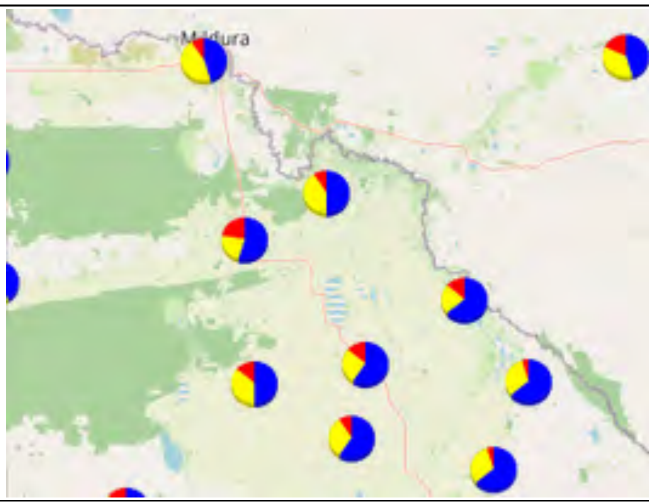
El Niño years



La Niña years



Positive IOD years



Negative IOD years

Figure 2. Winter rainfall tercile graphs for the phases of ENSO and IOD.

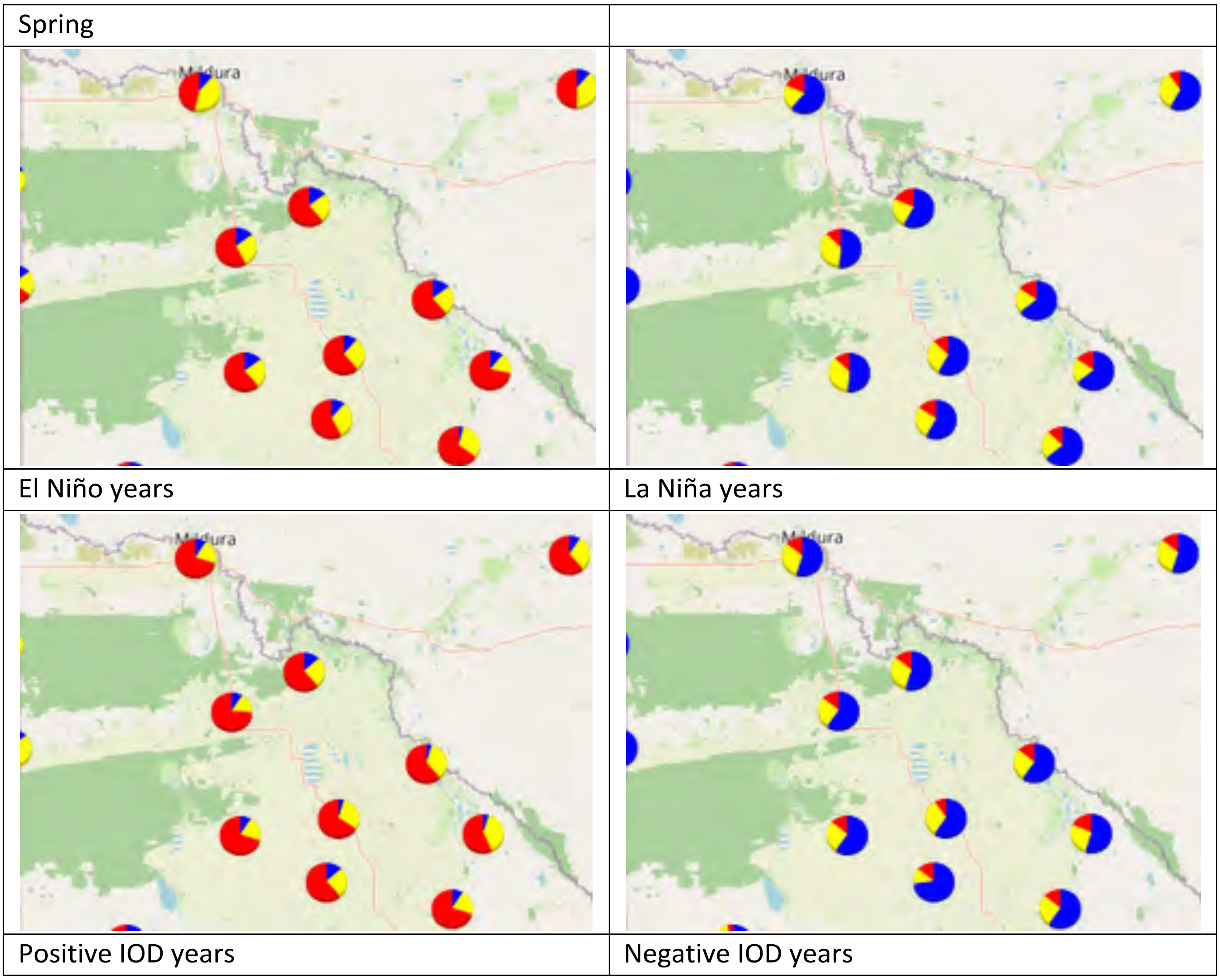


Figure 3. Spring rainfall tercile graphs for the phases of ENSO and IOD.

ENSO and IOD are called coupled ocean and atmosphere phenomena. These events are fully functioning when the ocean surface and depth combined with atmospheric wind, pressure and cloud patterns are all 'singing from the same hymn sheet'. All phenomena have these five key features that make up whether they are coupled or not.

In an El Niño, we would expect to see a warmer equatorial ocean surface from South America across to the International Date Line. We would expect to see warmer water to depth under this warm surface. Atmospherically, we would expect to see increased cloud at the Date Line and less to the north of Australia, westerly trade winds in the western Pacific and much higher air pressure at Darwin.

In a La Niña, we would expect to see a cooler equatorial ocean surface from South America across to the International Date Line. We would expect to see cooler water to depth under this cool surface. Atmospherically, we would expect to see decreased cloud at the Date Line and increased cloud north of Australia, stronger easterly trade winds in the western half of the Pacific and much lower air pressure at Darwin.

The IOD behaves similarly but with different geographic positioning. A +IOD is a large patch of cooler water off the island of Sumatra in Indonesia and warmer water off the coast of East Africa. There would be cooler water to depth in the eastern Indian Ocean and warmer water to depth in the west. Atmospherically, there would be less cloud off Sumatra and more off Africa, higher air pressure off Sumatra and lower off Africa, and stronger easterly trade winds blowing away from Indonesia.

A -IOD is a large patch of warmer water off the island of Sumatra in Indonesia and cooler water off the coast of East Africa. There would be warmer water to depth in the eastern Indian Ocean and cooler water to depth in the west. Atmospherically, there would be more cloud off Sumatra and less off Africa, lower air pressure off Sumatra and higher off Africa and stronger westerly trade winds blowing into Indonesia.

What happened 2023 to 2025

There are iconic years in climate history where the models and climate drivers get their acts together early and the outcome predicted turns out to be so. The years 2006, 2008, 2010, 2015, 2016 and 2022 spring to mind. In these years, the models successfully predicted the formation of climate drivers and what ended up occurring. The dry autumn in southwest Victoria in 2024 was also predicted by many models in the absence of a drier climate driver. The problem is many years don't have strong signals, or the climate drivers don't play ball, and this is more common than the years that nail it.

In 2023, as early as February, there was a high consensus among models for the formation of an El Niño and in March for a +IOD, with commensurate drier conditions. These signals primarily came from the undersea of the Pacific and Indian Oceans. As the season progressed, with drier conditions occurring, an El Niño weakly tried to form in the central Pacific. The problem was the Coral Sea never cooled off due to no reversals of the trade winds occurring in the western Pacific. Likewise, weak +IOD conditions also had a lack of atmospheric interest in forming, even though the ocean was vaguely interested. Coupling between ocean and atmosphere in the tropics is such a critical feature. A lack of coupling leads to a lack of confidence in the potential rainfall outcome. It's why it's important to monitor climate driver formation and the measurements of their coupling so that you aren't swayed by media reports of the formation of an El Niño's or a +IOD, when all this might be referring to is the temperature in the central Pacific or off Sumatra. In October 2023, a freakish rainfall event turned spring on its head and rainfall continued over summer for one of the best grazing spring-summer periods. No model predicted this change, but after October, many models got off the drier bandwagon, and a few were even predicting wetter. It was also important to understand that El Niños are historically not drier over summer, just warmer. This information seemed to be lacking in many media reports.

In 2024, as early as February, all the talk was about a potential La Niña. This prediction was grounded in the observations that the ocean was cooler at depth in the eastern Pacific and if this upwelled at the surface, a La Niña could occur. The problem with predictions in autumn is that they are notoriously inaccurate, as too much random and unpredictable weather needs to occur in the western Pacific, and this year was no different. Stronger trade winds in the central Pacific failed to fire up all year to get the cooler undersea water to outbreak at the surface. Pressure at Darwin also remained higher for much of the season, making it more difficult to get tropical moisture down. What became frustrating was that the majority of world models were fixated on the formation of a La Niña and the higher chances of wetter conditions that would emanate. The weather features needed to kickstart the climate of the Pacific literally didn't occur until January 2025, and even then, only for two weeks it would seem.

In the autumn of 2025, there was once again talk of a La Niña. The underlying coolness in the eastern Pacific and warmth in the western Pacific had not dissipated from the previous year and every model could see it. Despite predictions for a wetter winter and spring, once again the ocean and atmosphere didn't couple up classically. A -IOD formed in terms of the ocean in early spring, but this event didn't show any atmospheric response in terms of pressure or extra cloud off Sumatra; something about it was 'off'. A weak coupled La Niña finally formed in late spring but had left its run too late to affect the northern Victorian season. The La Niña finally broke down in mid-March of 2026 having strongly influenced the northern Australian summer wet season, but not much else. With so much talk about La Niña, it was important to concentrate on the five features that would indicate the event was potentially meaningful or whether it remained just 'talk'. The Fast Break newsletter and Very Fast Break YouTube clips provide monthly climate analysis during the growing season that hopes to cut through the hype that can abound in the media.

I have developed a list of things that I like to see to give me confidence in a forecast as opposed to 'that's interesting, but'.

In increasing confidence level:

- there is a consensus between models
- it's the time of year where there is model skill (accuracy)
- you can see from ocean and atmosphere observations where the forecast is derived from
- you can see ocean or atmosphere observations moving towards a climate driver formation
- you actually have a climate driver formed and coupled between the ocean and the atmosphere
- the models have good form between predictions and actual.

In 2023, 2024 and 2025, these six conditions were not met in autumn and failed to be met as the months ensued throughout the growing season.

What of 2026? In January this year, stronger westerly winds pushed warm water that had built up from the La Niña in the western Pacific over towards South America. This heated the Pacific undersea and in February, almost every model started predicting an El Niño. Based on the last 12 years of observations, it was probably a 50:50 chance of formation. Further westerly wind bursts in the western Pacific during autumn saw the undersea get very warm and the surface slowly warm. In June, the temperature reached the threshold above 0.8°C warmer than normal in the central Pacific and the Southern Oscillation Index was very negative. Westerly trade winds above the Solomon Islands and less cloud at the Date Line point to this event being in the early stages of a coupled El Niño. Unlike 2023–2025, this year is already different, we actually have the climate driver formed and starting to moderately couple with the atmosphere. Talk of it being 'super', 'mega', 'Godzilla', is unhelpful. These terms refer to a temperature of the central Pacific being above 2°C, where currently, it is 1.5°C. Historically, the connection between how hot the central Pacific gets has had a poor correlation with rainfall in Eastern Australia. Just the existence of any El Niño spins up the odds of drier, as we have also had droughts with weak El Niño's in the past, as well as with strongly warm ones. Pressure patterns have been favourable over the last two months which has led to average rainfall; nothing is really broken with the weather systems yet. Watch for stronger high-pressure systems over the Bight and cooler sea temperatures north of Australia as a sign that this El Niño is starting to exert some muscle.

Conclusion

It's important not to make farm decisions in autumn by placing too much emphasis on unreliable model forecasts at that time. The existence of any climate driver changes the odds of winter and spring rainfall but doesn't guarantee any outcome. During the season, don't get caught up in the climate hype and try to find information on whether any climate event is coupling the ocean and atmosphere. If you're ever wondering what the various climate drivers actually have meant for your location, the Local Climate Tool is a useful source of information.

Useful resources

GRDC South rainfall history and climate driver tool (https://climatetool.forecasts4profit.com.au/https://climatetool.forecasts4profit.com.au/)

The Break newsletters (https://agriculture.vic.gov.au/support-and-resources/newsletters/the-break)

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- Trade display supported by: Polytex and Spraytec

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Prefer to leave your feedback online? Scan the QR with your phone camera.

OR use the form on the next page – tear it out and drop at the registration desk as you leave. Thank you!

2026 Quambatook GRDC Grains Research Update Feedback

1. How would you describe your <u>main</u> role? *(choose one only)*

- ❑ Grower
- ❑ Agronomic adviser
- ❑ Farm business adviser
- ❑ Financial adviser
- ❑ Communications/extension
- ❑ Grain marketing
- ❑ Farm input/service provider
- ❑ Banking
- ❑ Accountant
- ❑ Researcher
- ❑ Student
- ❑ Other* (please specify)

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. Industry panel - pushing pulses for better crops in the southern Mallee
Audrey Delahunty (Agriculture Victoria), Claire Pickles (BCG), Matt Bissett (ExceedAg)
Ash Wallace (Agriculture Victoria), Josh Fanning (Agriculture Victoria)

Content relevance ☐ /10 Presentation quality ☐ /10

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

3. Evolution of clethodim resistance, what do we do?
Peter Boutsalis, University of Adelaide and Plant Science Consulting

Content relevance ☐ /10 Presentation quality ☐ /10

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

4. Risk and reward of N fertiliser decision-making strategies
– insights from a national network of RiskWi$e field experiments
Yolanda Plowman, BCG

Content relevance ☐ /10 Presentation quality ☐ /10

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

5. Protecting your most perishable asset - latest tips on grain storage
Chris Warrick, Primary Business

Content relevance [ ] /10 Presentation quality [ ] /10

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

6. Seasonal climate outlook: what is driving this season?
Dale Grey, Agriculture Victoria

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.