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1ST JULY 2020

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GRAINS RESEARCH UPDATE

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ONLINE DELIVERY

Campbell Town, Tasmania

1st July 2020

#GRDCUpdates

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- Charcoal rot
- Ascochyta blight of chickpea
- White grain disorder
- Sclerotinia stem rot

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Tasmanians are on the frontline of fungicide resistance – what options are available to 'slow the train'?

Nick Poole, Tracey Wylie and Katherine Fuhrmann.

FAR Australia.

GRDC project codes: FAR 00003 Hyperyielding Cereals – A feed grain initiative, CUR1905-001SAX Australian Fungicide Resistance Extension Network (AFREN): fungicide resistance management targeted at regional level

Keywords

- Fungicide resistance, reduced sensitivity, Septoria tritici blotch (STB) *Zymoseptoria tritici*, powdery mildew *Blumeria graminis f. sp. tritici*, Integrated Disease Management (IDM), Group 11 Quinone outside Inhibitors (QoIs), Strobilurins, Group 7 Succinate Dehydrogenase Inhibitors (SDHIs), Group 3 DeMethylation Inhibitors (DMIs), Triazoles.

Take home messages

- Tasmanian growers are on the frontline of fungicide resistance issues in Australia as a result of a growing season that is typically longer, wetter and more disease prone than the mainland.
- The typically longer growing season confers large benefits in terms of productivity however this means Tasmanian crops require more fungicide applications to control disease compared to mainland Australia.
- The number of fungicide applications over time is a key driver fuelling the shift (the selection of more resistant strains) in pathogen populations towards fungicide resistance.
- Reduced sensitivity of the Septoria tritici blotch (STB) pathogen, *Zymoseptoria tritici*, to Group 3 DeMethylation Inhibitors (DMI) fungicides (e.g. triazoles – Folicur®, Tilt®) is already evident in the field in Tasmania, following the discovery of more resistant strains (R8 strain or Isoform 11) back in 2016.
- In addition, wheat powdery mildew (WPM) strains resistant to strobilurin fungicides are widespread in Tasmania, Victoria and SA following their discovery in 2017.
- Other disease pathogens are known to be at high risk of resistance developing in the future, particularly in the Tasmanian environment, for example, STB pathogen resistance to strobilurins, which is common in Europe and New Zealand.
- The Net blotch pathogens, *Pyrenophora teres* f. *maculata* and *P. teres* f. *teres* in barley have shown reductions in sensitivity and increases in field resistance to Group 3 DMIs in SA and WA.
- For the first time in 2019 resistance to Group 7 Succinate Dehydrogenase Inhibitors (SDHI) fungicides on the Yorke Peninsula in SA.
- Ramularia in barley overseas has overcome all three fungicide groups; Group 3 DMIs, Group 7 SDHIs e.g. fluxapyroxad (Systiva®)and Group 11 Quinone outside Inhibitors (QoIs) e.g. azoxystrobin (Amistar®), but there is no evidence of this in Tasmania at this stage.
- The presence of resistant pathogen strains and their proportion in the population will increasingly influence our ability to control disease in Tasmanian crops, making it imperative that we adopt disease management strategies that will slow down resistance development.
- To 'slow the train', growers and advisers need to adopt anti resistance measures when using fungicides that avoid repeating the same active ingredients, and wherever possible, in an integrated disease management (IDM) approach.

What is the difference between resistance and reduced sensitivity?

When fungal disease is termed as ***sensitive*** to fungicide it is considered that the fungicide will control the disease pathogen at specified label rates.

Reduced sensitivity means that the fungicide does not work optimally to control the fungal pathogen, but does not completely fail. In most cases, this is related to small changes in the pathogen at the target site where the fungicide binds to the fungus. It typically results in small reductions in product performance, which may not be noticeable at the field level. In some cases, for example with Group 3 DMIs against STB, growers may find that they need to use increased rates of the fungicide to obtain the previous level of control. Reduced sensitivity must be confirmed by laboratory analysis.

Resistant means the fungicide fails to provide an acceptable level of control of the specified pathogen in the field at full label rates. Resistance must be confirmed with laboratory testing, and be clearly linked with an unacceptable loss of disease control when using the fungicide in the field at full label rates under the correct application conditions.

What is the current status of fungicide resistance and reduced sensitivity in Tasmania and Australia?

Over the last eight years the Fungicide Resistance Group (FRG) (Centre for Crop and Disease Management, (CCDM at Curtin University) has been working with industry and other researchers to

Table 1. Fungicide resistance and reduced sensitivity cases identified in Australian broad acre grains crops.

Disease	Pathogen	Fungicide Group	Compounds affected	Region	Industry implications
Barley powdery mildew	*Blumeria graminis* f.sp. *hordei*	3 (DMI)	tebuconazole, propiconazole, flutriafol	Qld, NSW, Vic, **Tas**, WA	Field resistance to some Group 3 DMI fungicides
Wheat powdery mildew	*Blumeria graminis* f.sp. *tritici*	3 (DMI)	None	NSW, Vic, **Tas**	This is a gateway mutation. It does not reduce the efficacy of the fungicide but is the first step towards resistance evolving.
		11 (QoI)	All group 11	Vic, **Tas**, SA	Field resistance to all Group 11 fungicides
Barley net form net blotch	*Pyrenophora teres* f. *teres*	3	tebuconazole, propiconazole, prothioconazole	WA, SA	Reduced sensitivity and field resistance
		7	fluxapyroxad bixafen	SA (Yorke Peninsula)	Reduced sensitivity or resistance depending on the frequency population.
Barley spot form net blotch	*Pyrenophora teres* f. *maculata*	3 (DMI)	tebuconazole, epoxiconazole	WA	Field resistance to old generation Group 3 fungicides
Canola blackleg Sclerotinia,	*Leptosphaeria maculans*	2 (MAP-Kinase)	iprodione	WA	Field implication unclear. Registered to target not Blackleg in Canola.
		3	fluquinconazole	NSW, Vic, SA, WA	Field implication unclear. High likelihood of reduced sensitivity and/or resistance developing.
Wheat septoria tritici blotch (STB)	*Zymoseptoria tritici*	3	tebuconazole, flutriafol, propiconazole, cyproconazole, triadimenol	NSW, Vic, SA, **Tas (100%)**	Reduced sensitivity that does not cause complete field failure
Botrytis grey mould of chickpeas	***Botrytis cinerea***	1 (MBC)	carbendazim	SA	Field implication unclear. While not registered or considered efficacious for control of Ascochyta blight, cross-resistance is common amongst Group 1 fungicides. Indicative of increased risk of resistance developing to other Group 1 fungicides.
Ascochyta blight	***Didymella lentis***	1	carbendazim	SA	Field implication unclear. Only one isolate ever found, most likely originating from vineyards adjacent to crop.

establish a fast and cost-effective monitoring system for fungicide resistance of common diseases of broad acre grain crops. Current cases of fungicide resistance and reduced sensitivity in Australian broadacre grain crops are outlined in Table 1. At present the key pathogens of concern to Tasmania are wheat and barley powdery mildew (WPM, BPM), and Septoria tritici blotch (STB). For the near future the development of resistance in the net blotch and Ramularia pathogens are of primary concern, in addition to the potential for QoI resistance in the STB pathogen.

Risk of resistance development within the different fungicide groups (example pathogens at high risk of developing resistance in the future)

Of the three principal fungicide modes of action used regularly for cereal disease control;

Group 11 QoIs (strobilurins) are at the highest risk of pathogen resistance development, particularly the pathogens responsible for STB in wheat, Ramularia in barley and powdery mildew in barley.

Group 7 SDHIs are at moderate – high risk of pathogen resistance development, with evidence in New Zealand and Europe of pathogen shifts in sensitivity and resistance to this fungicide group in Ramularia leaf spot in barley and STB populations in Europe.

Group 3 DMIs Demethylase Inhibitors (DMIs – triazoles) are generally considered at low-moderate risk, however recent developments in WA have challenged this view with regard to the two net blotch forms.. In these cases pathogen mutations have resulted in the DMI fungicide target site gene (*Cyp51A* gene) "over producing (expressing)", resulting in multiple copies of the mutated gene, leading to highly resistant strains of net blotch.

Septoria tritici blotch (STB) reduced sensitivity to fungicide application in wheat

In Tasmania where the use of fungicides is more intensive, the field performance of commonly used Group 3 fungicides, such as flutriafol and tebuconazole, has been compromised by more resistant strains of the STB pathogen. Despite the dominance of the R8 or Isoform 11 strain, other triazole fungicides still appear to be effective in the field, although it is understood that their effectiveness may decline over time. Recent work at the Hyper Yielding Cereals (HYC) research site (Hagley, Tasmania) based on seed treatment and three fungicide applications have shown good levels of disease control when fungicide programs were applied, indicating that fungicides are still effective in the Tasmanian environment (Figure 1). Even though this disease management program was based on a seed treatment and three foliar fungicides, no more than one SDHI and one QoI application were

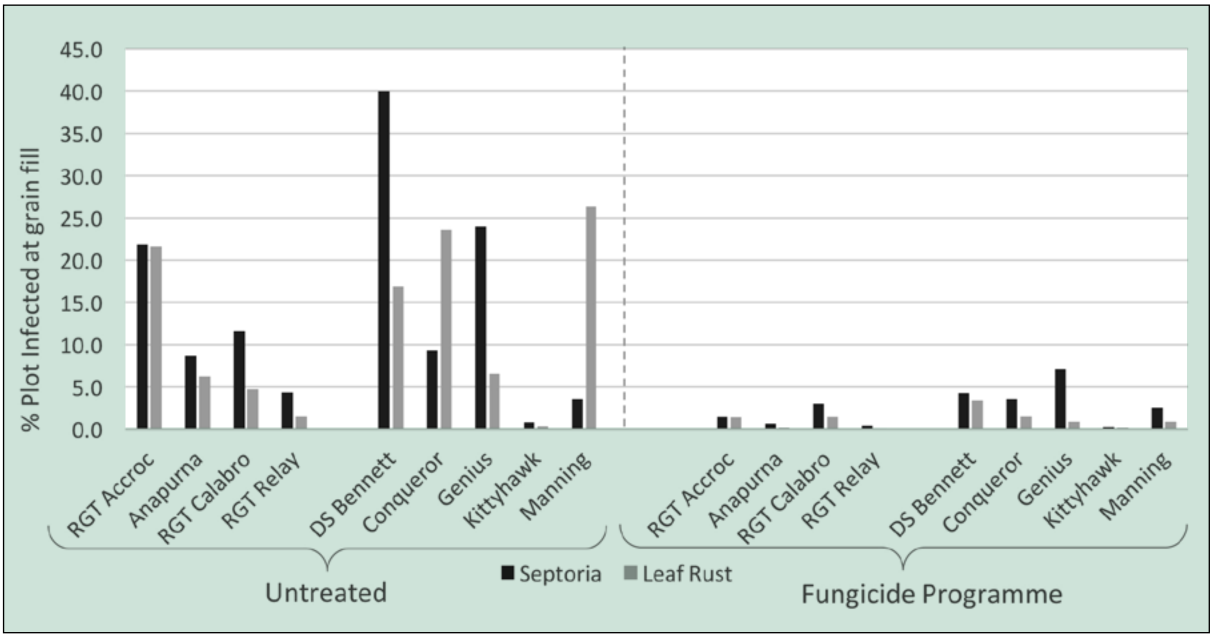

Figure 1. Control of STB and leaf rust in a range of wheat cultivars with a full program of fungicide (seed treatment and three foliar sprays) application under supplementary irrigation – Hyper Yielding Research Centre, Hagley, Tasmania 2019

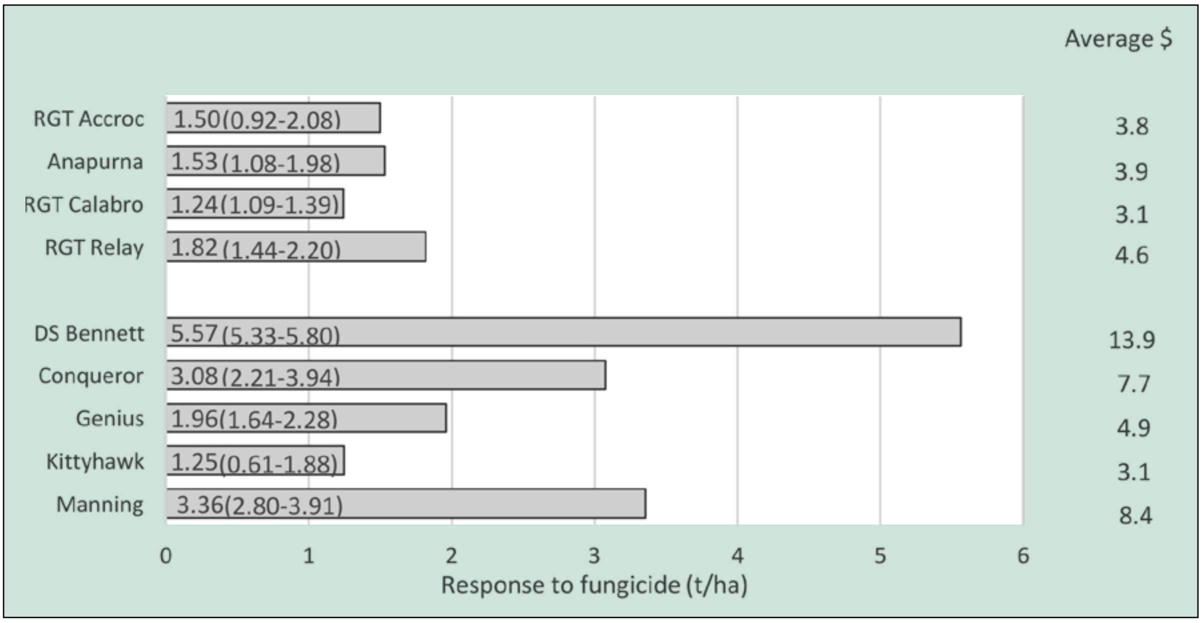

Figure 2. Yield (t/ha) and economic response to fungicide in nine cultivars of wheat under supplementary irrigation ($ return for $ spent) – mean of 2018 & 2019 Hyper Yielding Cereals research site, Hagley, Tasmania

n.b. Economic return from fungicide (two-year average of dollar back for every dollar spent) calculated based on $350/t price for feed wheat and total costs of fungicide at $95/ha and 3 applications at $15/ha totalling $45/ha.

applied. Over the last two years in Tasmania this HYC trial series has shown that fungicides are still effective if used correctly and their use has given good economic returns (Figure 2). This illustrates that if we can protect our fungicides by adopting anti resistance guidelines they can still be profitably applied.

Fungicide activity against powdery mildew and strobilurin resistance

Product performance against powdery mildew – Blumeria graminis

Early in 2017 researchers at the Centre for Crop & Disease Management led by Dr Fran Lopez discovered strobilurin (Quinone outside Inhibitors (QoI) – Group 11) resistance in WPM *Blumeria graminis f. sp. tritici.* The resistance was discovered in samples from susceptible varieties grown in southern Victoria and Tasmania. This was the first case of QoI resistance in broad acre cereal crops in Australia. The single point mutation that confers this resistance (G143A mutation) is the same mutation that exists in the WPM pathogen populations in Europe, discovered two years after these products were introduced in 1996. It is a single step to resistance and means that QoI or strobilurins, irrespective of active ingredient, won't give control. In the states of Tasmania, Victoria and SA, we know that in paddocks dominated by strobilurin resistant strains, WPM will no longer be effectively controlled by Group 11 QoIs (azoxystrobin (e.g. Radial®, Tazer Xpert™, Amistar Xtra®) and pyraclostrobin (Opera®)). However, with the triazoles there is a further complication in that, in Victoria, NSW and Tasmania the 'gateway' mutation Y136F has also been discovered in WPM populations. This is a mutation that whilst it is unlikely to affect the field performance of triazole fungicides against WPM, it will enable the population to develop more serious mutations (hence the term 'gateway'). As a result, reduced sensitivity in the WPM population to triazoles is likely to develop, albeit quite slowly in comparison to QoI resistance, since it is a multistep resistance, based on accumulating multiple mutations (multi-step resistance).

In BPM, resistance to Group 3 DMIs is based on mutations that would have more effect than the gateway mutations in wheat, however at present Group 11 QoI resistance in the BPM pathogen has not yet been discovered.

Anti-resistance measures when using fungicides as part of an Integrated Disease Management (IDM) strategy

Clearly, the best way to avoid fungicide resistance is not to use fungicides! However, in high disease pressure regions such as Tasmania, this is easier said than done. When a cultivar's genetic resistance breaks down or is incomplete, it is imperative that growers and advisers have access to a diverse range of effective fungicides (in terms of mode of action) for controlling the disease. With wheat and barley crops, multiple applications of fungicide are commonplace in Tasmania, so it's important that we adopt anti-resistance measures in cereal crops to preserve the life of our fungicides for as long as possible into the future. ***So, what can we do to 'slow down the resistance train'?***:

- To minimise the number of fungicide applications using the same mode of action use other **Integrated Disease Management** (IDM) measures to control disease:
    - o Rotations – avoid high risk rotations for disease, for example, barley on barley or wheat on wheat.
    - o Seed hygiene – minimise the use of seed from paddocks where there were high levels of disease that could be seedborne (e.g. Ramularia, net form net blotch).
    - o Less susceptible cultivars, and where this is not possible delay the sowing of the most susceptible cultivars.
    - o Cultural control such as stubble management, where disease risks are high and the penalties for stubble removal are not as high.
    - o Grazing early sown cereal crops up to GS30 to reduce disease pressure.
- With wheat and barley crops, two to three applications of fungicide is commonplace in Tasmania so avoid repeat applications of the same product and where possible the same mode of action in the same crop. This is particularly important when using Group 11 QoI (strobilurins) and Group 7 SDHIs, which preferably would only be used once in a growing season.
- Avoid using the seed treatment fluxapyroxad (Systiva®) year after year in barley without rotating with foliar fungicides of a different mode of action during the season.
- Never apply the same DMI (triazole) Group 3 fungicide twice in a row, irrespective of whether the DMI is applied alone or as a mixture with another mode of action.
- In Tasmania avoid the use of tebuconazole alone and flutriafol for STB control, as these Group 3 DMIs are more affected by reduced sensitivity than other DMIs.
- Group 3 DMIs (Triazoles e.g. epoxiconazole (Opus®) or triazole mixtures (e.g. prothioconazole and tebuconazole (Prosaro®)) used alone are best reserved for less important spray timings, or in situations where disease pressure is low.
- With SDHI seed treatments such as fluxapyroxad (Systiva®) or QoI fungicides used in-furrow such as Uniform® containing azoxystrobin, consider foliar fungicide follow ups which have a different mode of action, and therefore, avoiding if possible a second application of SDHI or QoI fungicides.

Influence of fungicide rate

Growers and agronomists frequently ask the question whether dose rates have an impact on how likely fungicide resistance is to evolve. Resistance comes in many forms and trying to manipulate rates with fungicides should not be seen as the core resistance management strategy.

The reality is that using the most appropriate rate for effective disease control is the best strategy for managing resistance. Label rates have been developed to provide robust and reliable control of the target disease.

In many cases the full label rate is the most appropriate rate for control. However, for some diseases, the lower rate from the label range of a fungicide can be used in conjunction with a crop variety that has a good disease resistance rating because disease pressure will be lower. Contrary to what might be the case with other agrichemicals, there is evidence that by using a higher rate than necessary this increases the risk of resistance, as removing all of the sensitive individuals provides more opportunity for resistant individuals to dominate the population and hence be the strain colonising the plant. This is particularly the case with Group 11 QoIs and Group 7 SDHIs fungicides.

AFREN (Australian Fungicide Resistance Extension Network)

The Australian Fungicide Resistance Extension Network (AFREN) was established to develop and deliver fungicide resistance resources for grains growers and advisers across the country. It brings together regional plant pathologists, fungicide resistance experts and communications and extension specialists.

AFREN wants to equip growers with the knowledge and understanding that they need to reduce the emergence and manage the impacts of fungicide resistance in Australian grains crops.

As members of AFREN, the authors of this paper are keen to hear if you believe you are encountering reduced sensitivity or resistance in your broad acre crops in Tasmania.

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.

We would also like to acknowledge the work of our co-workers and collaborators in AFREN, in particular, Dr Kylie Ireland and Dr Fran Lopez from the Centre for Crop and Disease Management (CCDM). For more information on AFREN and fungicide resistance – Contact: Dr Kylie Ireland

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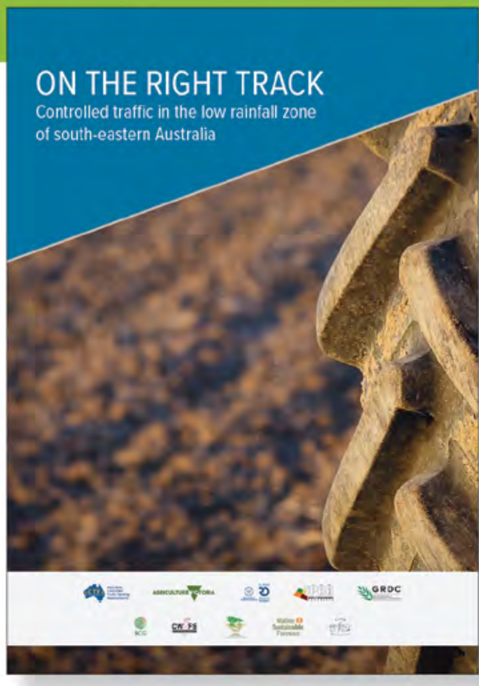

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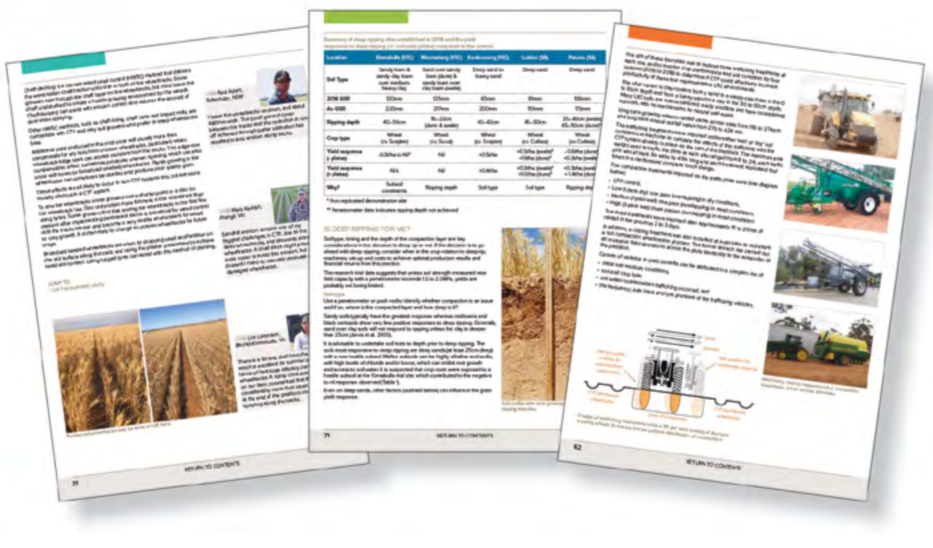

Australian global imports – factors impacting the domestic supply chain

Paul Lomax.

Agrichem.

Keywords

- supply chain, agricultural products, importation, logistics

Take home messages

- Many factors are at play in getting agricultural products to our farms in a timely manner.
- Being prepared and forecasting product requirements three to four months in advance reduces risk of shortfall in product supply.

Importation and the domestic supply chain

The perfect storm for grower supply shortages (2019 – 2020)

Demand stretches the supply elastic band beyond its limits:

- 2017 – 2018 - 2019 – Significant drought conditions experienced across many areas of Eastern Australia, with geographical climatic differences between and within Australian states.
- Little or no demand from growers to farm input providers in many areas.
- Little or no demand from farm input providers to suppliers/manufacturers.
- Devastating capital losses in all levels of the agricultural industry.
- Towards the end of 2019 – conservatism becomes the 'new norm' with little or no forecasting for inputs for 2020.
- Dec 2019 - COVID 19 is announced globally from Wuhan, China.
- It takes time to realise the seriousness of this situation, but by late January/early February 2020 the world is heading towards total shutdown in all facets of global manufacturing and supply chain.
- Good drought breaking rains occur in many regions during January 2020, spiking exponential input demand.
- International Freight Price Index increases 15.3% from Oct 2019 – April 2020 (Figure 1).
- Global freight movements drop 32% from Oct 2019 to Feb 2020 (Figure 1).
- Sharp imbalance in global shipping trade lanes and shipping container number equilibrium at all main ports
- Transhipping increases by 20 – 30%.

Table 1 illustrates the importation process and timelines from start to end and the many factors that contribute to the timeliness of product supply on-farm.

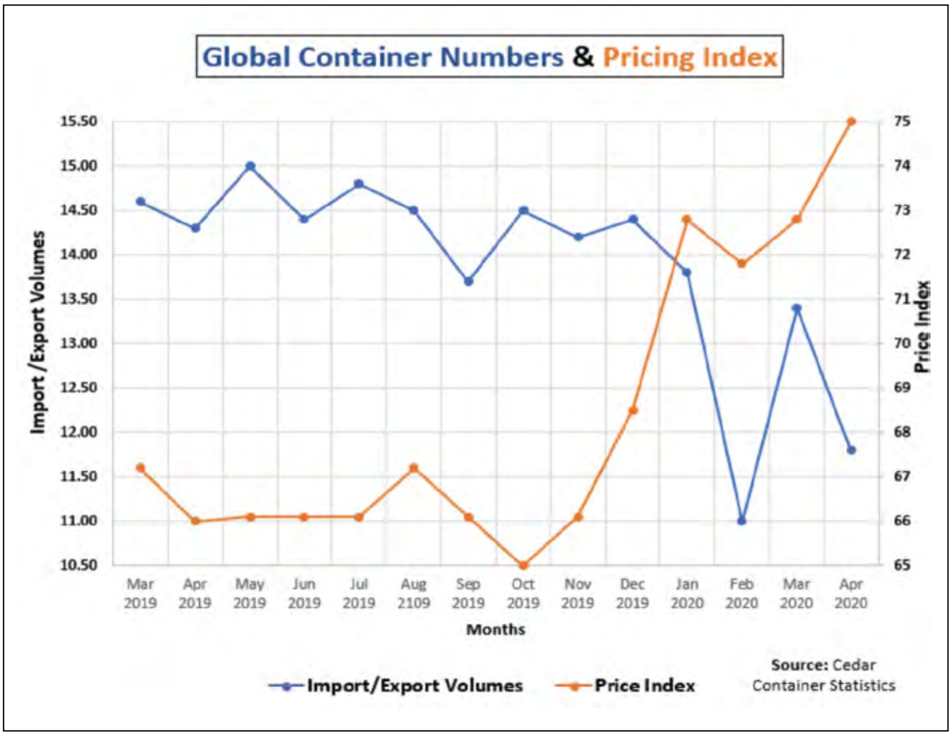

Figure 1. Global freight movements (import/export volumes) and international freight price index (%) from March 2019 to April 2020 (Source: Cedar Container Statistics).

Table 1. Diagrammatic representation of the domestic supply process via import, end to end.

IMPORTATION PROCESS & TIMELINE START TO END = 3 - 4 MONTHS ON AVERAGE, DEPENDING ON PORT OF ORIGIN OVERSEAS FOR DISPATCHED GOODS			
FARMER	FARM INPUT PROVIDER	SUPPLIER/MANUFACTURER	SUPPLIER/MANUFACTURER DOEMSTIC GOODS ARRIVAL
Farm Plan?	Farmer customer orders inputs	Forecasts from Farm Input Provider?	Vessel arrival
Input Needs Assessment?	from Farm Input Provider	Scheduling into manufactuing program	Vessel berth booking slot
		Are sufficient manufacturing incipients available?	Vessel customs clearance
FARM INPUTS	MINDSET & PROCESS	Country of origin - Manufacture & logistics to port	Container unload from vessel @ Port
Seed	Planning?	Palletising, Wrap/Strap, Containerisation	Customs inspections of contents
Crop Protection	Proactivity?	Booking transport container slots on sea vessels	Offical quarantine clearing to exit port area
Plant Nutrition	Seasonality?	Cost of sea freight increases with high demand low supply?	Tailgate to container handler for unpack
Animal Health	Risk profile? Price & Inventory loading?	Sailing Period?	Container unpack
General Merchandise	Working capital efficiency?	Transhipping? (Container dropped enroute at a	Storage & handling @ third party or owned storage site
Fuel/Lubricants	Back to back ordering across supply chain?	different port, to wait to be loaded onto another ship,	Dispatch to Farm Input Providers Store
Machinery	Storage space at port and up country?	to finally end up at the desired destination)	Dispatch to Farm
	Just In Time - Delivery mentality		
High %'s Are Imported	Currency Volatility?	Currency Volatility?	Currency Volatility?
DO YOU PROVIDE A MONTHLY GOODS NEEDED FORECAST TO YOUR FARM INPUT PROVIDER 3 - 4 MONTHS IN ADVANCE?	HOW DOES YOUR FARM INPUT PROVIDER KNOW HOW MUCH OF EACH ARTICLE TO PROCURE FOR ALL OF THEIR CUSTOMERS x MONTH?	HOW DOES THE SUPPLIER/MANUFACTURER KNOW HOW MUCH OF EACH ARTICLE TO PRODUCE FOR EACH FARM INPUT PROVIDER x MONTH?	DO THE GOODS ARRIVAL DOMESTICALLY MATCH THE ORIGINAL FORECASTS, PRICING AND TIMING EXPECTIONS FOR ALL PARTIES?

In summary:

- Conservatism in forecasting or no forecasting at all combined with periods of low demand that are reversed quickly, whilst being connected to a 'Just In Time' domestic delivery mentality, do not work within the framework of an import (indent) market timeline!
- It becomes very understandable why significant shortages of all farming inputs occurred across the nation when you also add in the global impacts from COVID 19 on manufacturing, supply and logistics of products, including agricultural products.

Reducing the risk of being caught short on supply?

Break key inputs into (i) commodity use known (for example, glyphosate) versus (ii) specific use unknown (for example, post-emergent selective herbicides).

For commodity products which a grower will always use:

- Forecast well before the products are required (3 – 4 months prior).
- Take a conservative approach of 60 – 70% of prior year usage.
- Understand that having all or some of the key products on-farm well prior to the expected use period, will provide security on-farm and smooth out the logistics and supply chain.
- The same issues felt by farm input providers are also felt at the farm level around timing and decision making;
    - Who should own the risk on forecast, inventory, price, working capital efficiency and supply across the various segments of the supply chain within Australia?
    - Should there be a greater level of understanding between all parties domestically, in relation to shared risk, to avoid the 2020 shortages?

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Notes

LOOK AROUND YOU.

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

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

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

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

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

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

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

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

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

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

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

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

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

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Crops that perform well in waterlogged conditions – will that become a reality?

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GRDC project codes: 9176582

Keywords

- barley, waterlogging tolerance, genetic solution.

Take home messages

- Waterlogging can cause losses in barley production worth over $20 million per annum in the high rainfall zone (HRZ) of Australia.
- Natural variation in waterlogging tolerance was shown by barley varieties and a tolerance gene has been discovered in a wild-type barley.
- The effectiveness of the gene and its impact on yield and quality are currently being tested.
- An agreement has been reached with a breeding company to introgress the gene into their commercial varieties so it can be tested in well adapted backgrounds.

Background

The total cropping area in the high rainfall zone (HRZ) of Australia is around 4 million hectares (Zhang et al. 2006), and on average, two thirds of this cropping zone is sown to cereals, with barley occupying 25 percent of this area. It is estimated that in one out of every five years waterlogging will have a major impact on crop production in the HRZ. Assuming waterlogging causes a 20 per cent yield loss to barley and a grain price of $220/ton, this corresponds to an economic loss of $23.6 million (Manik et al. 2019).

In previous work, natural variation in the waterlogging tolerance was found among barley varieties and a tolerance gene was discovered in a wild-type barley (TAM407227). The gene allows barley to develop aerenchyma tissue in its roots under waterlogged conditions, which acts like a snorkel to bring oxygen to the barley roots.

How much production is lost due to waterlogging?

Controlled environment experiments were conducted using a number of barley genotypes including four commercial varieties. Seeds were sown in five rows in stainless steel tanks (200cm x•100cm x 45cm) filled with a uniform sandy loam soil with the bottom of each tank containing 50mm coarse gravel overlaid with drainage matting. A water tray was used to supply water to the bottom of each tank. The water level of each container was maintained at 75mm depth by fitting a float valve to a reservoir. Excess water from rainfall flowed back to the reservoir and out an overflow. Any water lost from the tanks through evapotranspiration was resupplied by the reservoir to maintain the water level. Control plots were watered near to field capacity until grain filling. Waterlogging was achieved by raising the reservoir above the soil surface such that the water level increased to 400mm (roughly levelling with soil surface) thus the soil was completely saturated. These genotypes were exposed to four waterlogging treatments, shown in Figure 1. The middle three rows were harvested for measuring yield and yield components.

The waterlogging treatments WL1, WL2 and WL3 during the first four months after seedling emergence are most relevant to Tasmania and other high rainfall zones of Australia, and further discussion will concentrate on these treatments. The WL2 was also conducted in a laser levelled field site with a similar water controlling system.

Figure 2 shows the impact of the waterlogging treatments on the commercial varieties Westminster⦶ and RGT Planet⦶. Waterlogging treatments 1-3 caused severe damage to plants and yield was reduced by around 50%. There was no significant difference in yield response between each of the waterlogging treatments. Although not

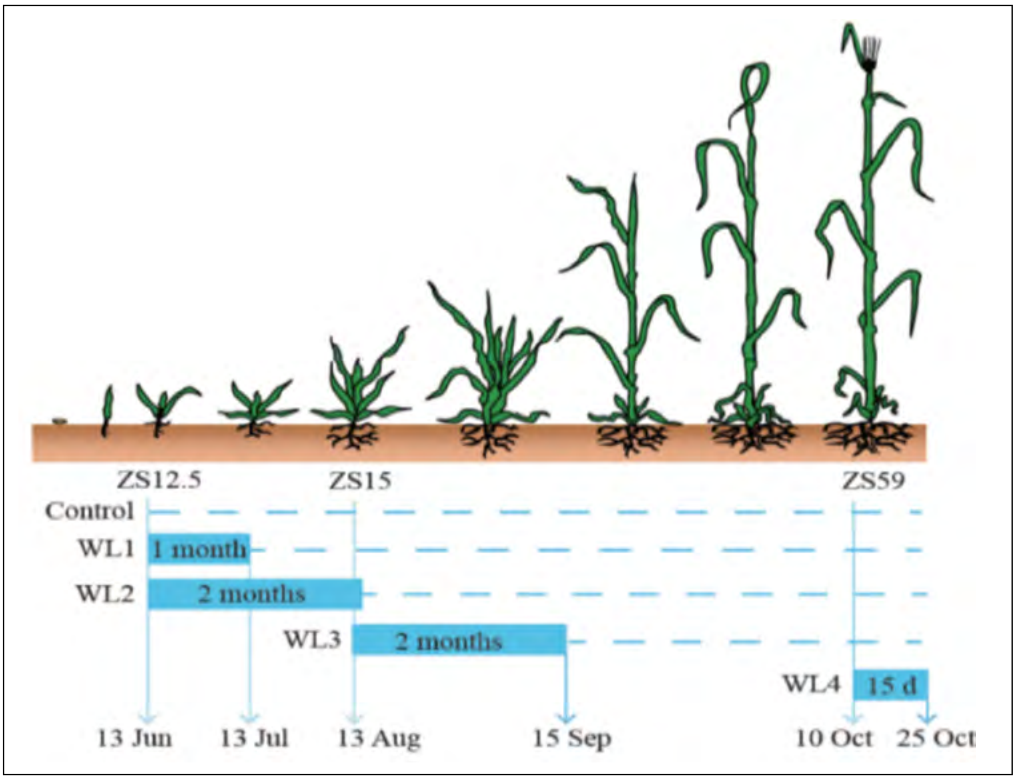

Figure 1. Diagram indicating the four waterlogging treatments with start and end dates; WL1: waterlogging exposed at Zadoks growth scale (ZS) 12.5 for one month; WL2: waterlogging exposed at ZS12.5 for two months; WL3: waterlogging exposed at ZS15 for two months; WL4: waterlogging exposed at ZS59 for 15 days.

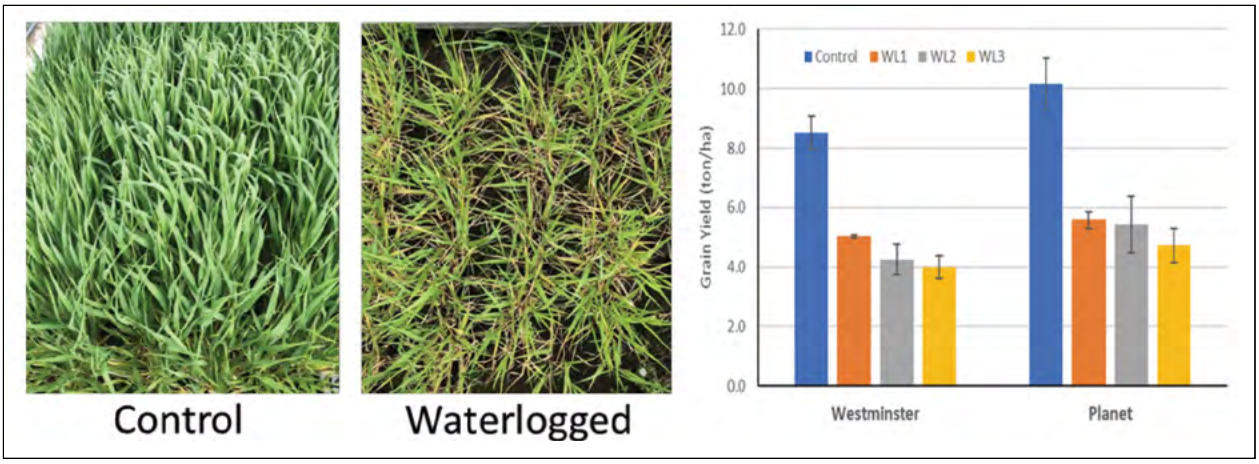

Figure 2. The impact of waterlogging treatments on Westminster⦶ and RGT Planet⦶.

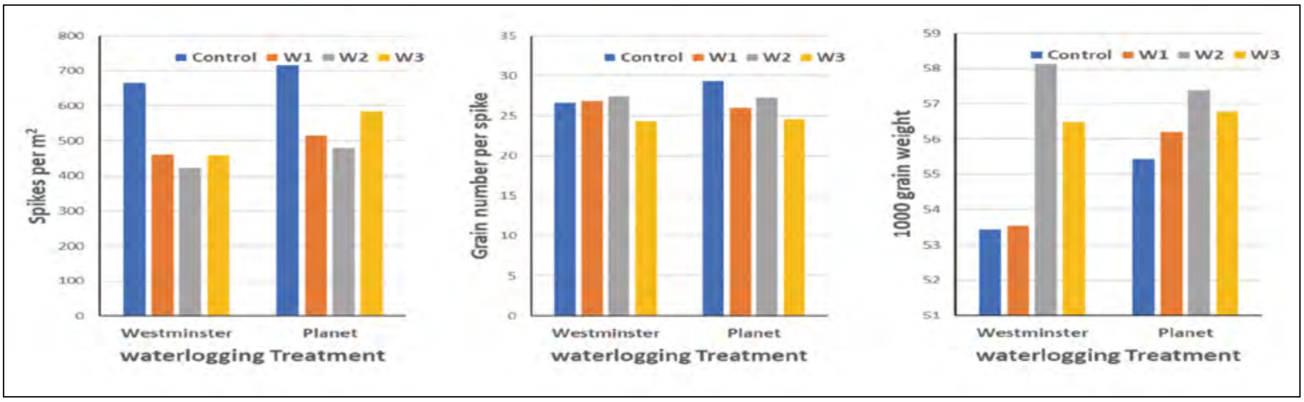

Figure 3. Effect of waterlogging treatments on yield components of Westminster⁽ᵇ⁾ and RGT Planet⁽ᵇ⁾.

significant, there was a trend for greater yield loss with increased length of waterlogging and later stage of treatment (i.e. WL3).

Figure 3 shows that the yield loss was mainly influenced by reduced tiller numbers and to a lesser extent reduced grain numbers per spike, whereas see size (1,000 grain weight) was not affected significantly.

How to manage waterlogging?

There are a few approaches that can be utilised to reduce the impact of waterlogging on crop growth. These include:

- nitrogen application,
- crop type,
- sowing time,
- engineering solutions (i.e. drainage), and;
- genetic solutions (i.e. breeding for tolerance).

Waterlogging impairs the uptake of nitrogen so increasing fertiliser nitrogen applications after the waterlogging has passed can mitigate the damage and encourage crop recovery. Similarly, choosing a tolerant crop type and delaying its sowing time until spring can minimise crop yield losses due to waterlogging. Different engineering solutions to improve drainage, including the use of raised beds, surface drainage, controlled traffic farming, strategic deep tillage and sub-soil manuring have been used by many growers to reduce the occurrence of waterlogging. However, these are generally expensive approaches only suitable to areas that become waterlogged frequently. Genetic solutions and the development of tolerant varieties is possibly the cheapest way of reducing waterlogging damage and provides a solution that can be readily adopted by all growers.

A genetic solution – does waterlogging tolerance exist?

Previous research identified many genotypes which exhibited waterlogging tolerance. A wild barley accession (TAM407227) showed improved tolerance to waterlogging compared to other genotypes (Zhang et al. 2016).

Further studies of the wild barley accession identified a major gene which contributed to its waterlogging tolerance via the gene's control of aerenchyma formation in roots under waterlogging stress (Zhang et al. 2017; Zhang et al. 2016). Aerenchyma are air-filled spaces that help transport air from the above-ground shoots to supply the roots of waterlogged plants, much like a snorkel. Once the value of this gene under waterlogging has been quantified and any 'yield drag' under non-waterlogged conditions is identified, the gene will be available for adoption in commercial breeding programs.

How effective is the waterlogging tolerance gene?

In this GRDC project, the tolerance gene from TAM407227 has been introgressed into Macquarie and the yield of the resulting plant type (Macquarie^{WL}) has been tested in this experiment. Results showed that the insertion of the gene led to improved plant growth and about a 20% increase in grain yield under waterlogging conditions, which corresponded to a 1-2 t/ha yield increase compared with Macquarie (Figure 4). More barley lines will be tested under field conditions in Western Australia, Victoria and potentially South Australia in coming seasons.

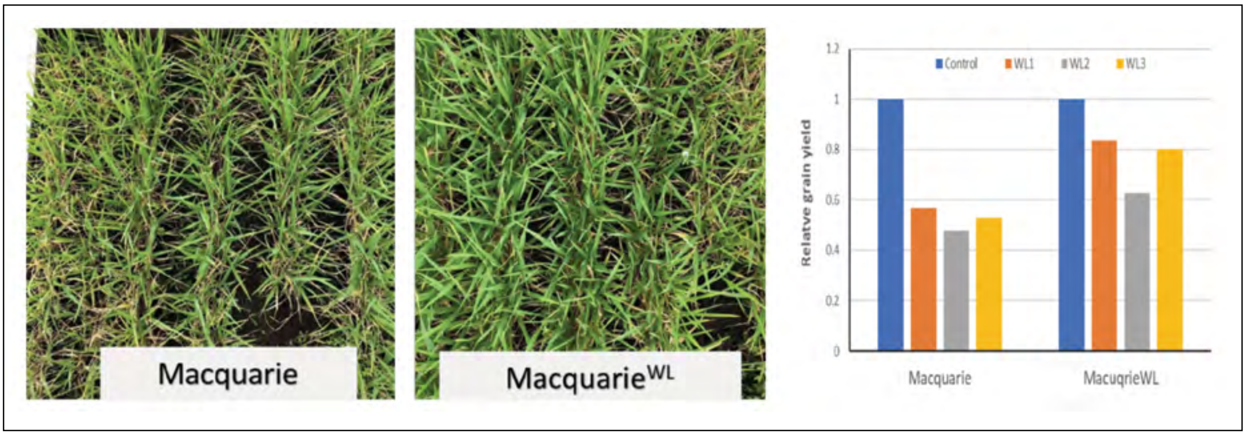

Figure 4. Waterlogging tolerant lines (Macquarie^{WL}) performed much better after two months of waterlogging (WL3 in Figure 1) compared with control lines (Macquarie).

When can growers access tolerant varieties?

Talks have been started with different seed and breeding companies regarding interest in introgressing the waterlogging tolerance gene into commercial varieties. An agreement has been signed between UTAS and Seed Force Pty Ltd, which makes it possible to add the gene to the current commercial variety, RGT Planet⁽ᵈ⁾ and potentially any future releases. The aim is for the new variety to behave the same as RGT Planet⁽ᵈ⁾ under non-waterlogged conditions with no 'yield drag', while performing much better under waterlogging stress. A rapid backcrossing program has been developed which accesses a world class screening facility, enabling growers to access the new varieties in 2-3 years.

Conclusion

A new gene for waterlogging tolerance has been discovered in a barley wild type. The addition of the tolerance gene into a commercial variety improved grain yield by more than 20% compared to the original variety under waterlogging conditions in both the tank and field, which correlated to a 1-2 t/ha yield increase. The addition of the gene influencing waterlogging tolerance into current commercial barley varieties may have huge benefits for growers in the high rainfall zones of Australia and may also have application in medium rainfall zones where waterlogging is less frequent. Collaboration with seed and breeding companies and assistance with a rapid backcrossing program will enable growers to benefit from new waterlogging tolerant varieties within 2-3 years.

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 also like to thank the staff and students in our research group, and the national and international collaborators for their continued support.

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Notes

SPRAY APPLICATION MANUAL FOR GRAIN GROWERS

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

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

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

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

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

How best to tackle herbicide resistance with new and old chemistries in Tasmanian farming systems?

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GRDC project codes: UCS00024

Keywords

- herbicide resistance, annual ryegrass, pre-emergent herbicide.

Take home messages

- Resistance to the Group A herbicides is increasing in annual ryegrass in Tasmania.
- New pre-emergent herbicides are becoming available; however, it is vital that these are used appropriately to get the best results.
- Rotating pre-emergent herbicide modes of action and using other weed management practices will be essential to managing resistance to these new herbicides.

Herbicide resistant weeds in Tasmania

Tasmania has several weed species with herbicide resistance: barley grass with resistance to paraquat and diquat, mainly from lucerne paddocks; wild radish with resistance to the Group B herbicides including the imidazolinone herbicides; and annual ryegrass resistant to Group A and Group B herbicides.

A recent survey of crop paddocks in Tasmania conducted by Charles Sturt University found resistant populations to the Group A herbicides diclofop-methyl and clethodim, but no populations resistant to glyphosate (Table 1). There has been a substantial increase in resistance to the Group A fop herbicides since 2014 in Tasmania. There has also been a reduction in the number of populations with complete susceptibility to all three herbicides tested (Table 1).

New pre-emergent grass herbicides for annual ryegrass and their fit for Tasmania

There are several new pre-emergent herbicides that have been released or will be released in the next few years. It is important to understand their behaviour to get the best use out of these herbicides. Not all products will be as suitable for high rainfall environments like Tasmania. For Tasmania, the key characteristics to look for in a pre-emergent herbicide for ryegrass control will be lower water solubility and longer persistence.

Table 1. Extent of resistance in annual ryegrass populations to diclofop-methyl, clethodim and glyphosate from Tasmania in 2014 and 2019.

	Diclofop-methyl		Clethodim		Glyphosate	
	2014	2019	2014	2019	2014	2019
Resistant (>20%)	42	63	4	7	0	0
Developing Resistance (10-20%)	4	6	4	8	0	0
Survivors (<10%)	8	12	6	16	0	13
Susceptible (0%)	46	18	86	69	100	87

Devrinol-C®

Devrinol-C®, active ingredient napropamide, is a Group K herbicide from UPL registered in 2019. Devrinol-C® is registered for annual grass weed control in canola.

Its active ingredient, napropamide, is not as water soluble as metazachlor (Butisan®) and has less movement through the soil. Canola has much greater tolerance to napropamide compared to metazachlor making it much safer in the high rainfall zone. Devrinol-C® offers an alternative pre-emergent herbicide to propyzamide or trifluralin for canola.

Luximax®

Luximax®, active ingredient cinmethylin, is a new mode of action herbicide (Group Z) from BASF registered in 2020. Luximax® is a pre-emergent herbicide for annual ryegrass control in wheat, but not durum. It will also provide some suppression of brome grass and wild oats. In our trials, control of ryegrass is as good as with Sakura®.

Its active ingredient, cinmethylin, has higher water solubility than many other wheat pre-emergent herbicides. This means cinmethylin will move readily into the soil with rainfall events. Less rainfall will be required to activate the herbicide similar to Boxer Gold® (prosulfocarb + S-metolachlor). Persistence of Luximax® is generally good.

Cinmethylin has quite high binding capacity to soil organic matter and this is important in achieving crop safety. Wheat is not inherently tolerant of cinmethylin, so positional selectivity (keeping the herbicide and the crop seed separate) is crucial. Knife-points with press-wheels is the only safe seeding system and the crop seed needs to be sown 3cm or deeper. Heavy rainfall in the first few days after application can also result in the herbicide causing crop damage. Mixtures with trifluralin, triallate and prosulfocarb are good and can provide some additional ryegrass control; however, mixtures with Sakura®, Boxer Gold® or Dual Gold® are likely to cause crop damage and need to be avoided.

Overwatch®

Overwatch®, active ingredient bixlozone, from FMC is a Group Q herbicide that will be available for sowing in 2021. Overwatch® controls annual ryegrass and some broadleaf weeds and will be registered in wheat, barley and canola. Some suppression of barley grass, brome grass and wild oats may occur.

Wheat is most tolerant to bixlozone, followed by barley and then canola. The safest use pattern will be incorporation by sowing (IBS) with knife-points and press wheels to maximise positional selectivity, particularly with canola. Some bleaching of the emerging crop occurs often, but in our trials, this has never resulted in yield loss. In situations where the crop grows poorly, for example, water logging, high root disease, etc., the crop may have more difficulty growing away from the initial bleaching effect.

Overwatch® has a little more water solubility than Sakura®. The level of ryegrass control in our trials has been just behind Sakura®. Mixtures with other herbicides can increase control levels and in our trials in the high rainfall zones, the mixture of Overwatch® plus Sakura® has been very good.

Ultro®

Ultro®, active ingredient carbetamide, from Adama is a Group E herbicide that will be available from 2021. Ultro® will be registered for the control of annual ryegrass, barley grass and brome grass in all pulse crops.

Pulses have reasonable tolerance to Ultro®, so crop damage should be rare. Ultro® provides the best control of annual ryegrass when used pre-emergent. Ultro® has relatively high water solubility, so is more effective on weeds like brome grass that tend to bury themselves in the soil. Persistence of Ultro® is shorter than Sakura®.

Mateno® Complete (BAY167)

Mateno® Complete is a new product from Bayer containing the active ingredient aclonifen. It will be a new mode of action pre-emergent and early post-emergent herbicide for the control of grass and some broadleaf weeds in wheat and barley. Registration is expected in 2022.

The behaviour of this herbicide in the soil will be more similar to Sakura® than Boxer Gold®. It will require more rainfall to activate and will have similar persistence to Sakura®. It will most likely work best for annual ryegrass as a pre-emergent IBS herbicide. The timing of the early post-emergent application will be similar to Boxer Gold®, at the 1 to 2-leaf stage of annual ryegrass. The post-emergent timing will require more rainfall after application than what Boxer Gold® does, so will suit higher rainfall regions like Tasmania.

Managing resistance to pre-emergent herbicides

To date, weed resistance surveys have not identified resistance to any of the main ryegrass pre-emergent herbicides in Tasmania. However, annual ryegrass with resistance to the Group D, Group J and Group K herbicides is present in Victoria and South Australia. One of the keys to slowing the evolution of herbicide resistance is to rotate herbicide modes of action. In Tasmania, a common choice will be to mix pre-emergent herbicides to obtain better annual ryegrass control. This will make rotating modes of action more challenging, but it is important to reduce reliance on any one mode of action. Additional weed control activities, such as crop competition, harvest weed seed control and crop topping, will have to be included wherever they are practical.

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 author would like to thank them for their continued support.

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Notes

TOP 10 TIPS

FOR REDUCING SPRAY DRIFT

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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.

THE 2017-2020 GRDC SOUTHERN REGIONAL PANEL

JANUARY 2020

GRDC
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CHAIR - JOHN BENNETT

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

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

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

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

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

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

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

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MICHAEL CHILVERS

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

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KATE WILSON

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

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ANDREW RUSSELL

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

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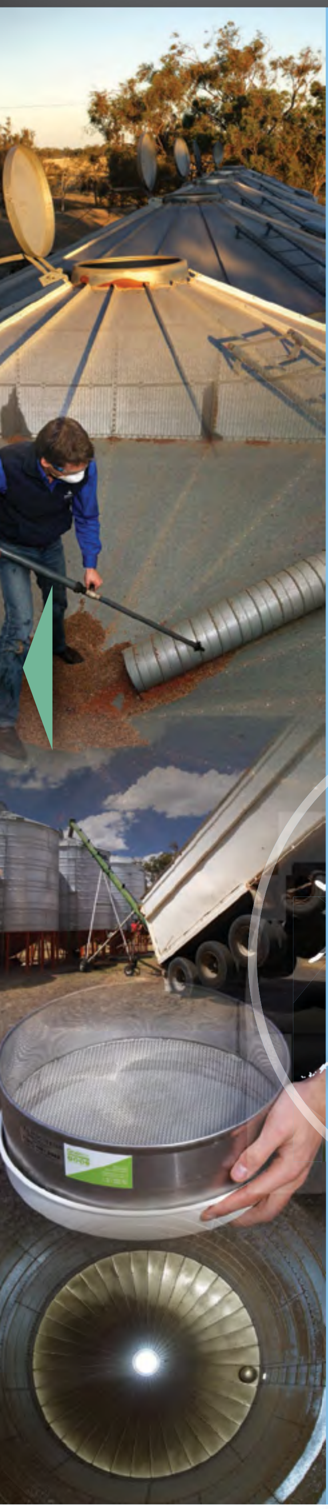

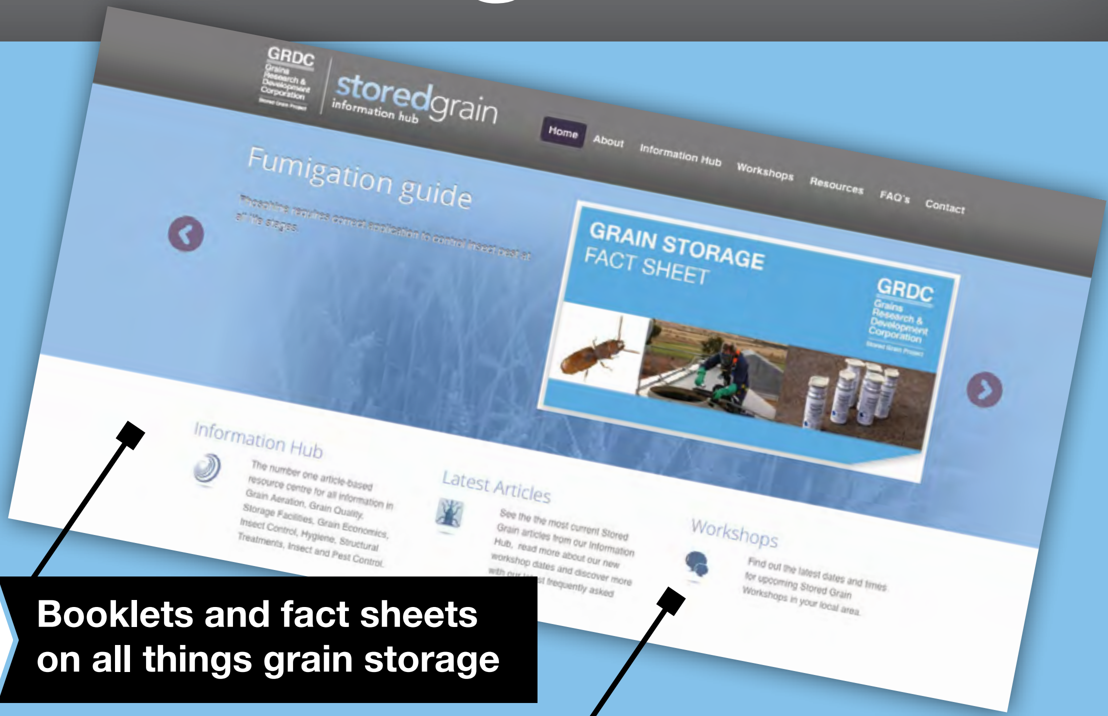

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