Cereal diseases - an autopsy of 2022 and management considerations for the 2023 season

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GRDC codes

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DPI2207-004RTX: Integrated management if Fusarium crown rot in the Northern and Southern Regions
DAN1907: NVT Services Agreement 2019-2023

Take home messages

- Favourable climatic conditions in 2022 resulted in the increased prevalence of a range of cereal diseases across NSW, in particular: Fusarium head blight (FHB), stripe rust and Septoria tritici blotch
- In combination with increased cereal stubble loads produced in 2022, pathogen levels are likely to be elevated again in 2023
- Conditions led to a Fusarium head blight (FHB) epidemic which has not been seen since 2016 but was considerably more widespread across NSW than ever before
- Multiple stripe rust pathotypes were prevalent across NSW in 2022 including a new mutation. Keep up to date with latest varietal resistance ratings
- Assess your risk. Commercial and industry providers are available to assess germination and vigour of seed being retained for sowing; and presence of pathogen loads in soil, stubble, and seed
- Source clean seed free of pathogens or with as low a level as possible
- NSW DPI plant pathologists can assist with correct diagnosis, cereal stubble and seed testing and advice on appropriate management options.

Introduction

A diagnostic service for cereal growers and their advisers in New South Wales is provided at no cost through project code DPI2207-002RTX (previously BLG207 and BLG208). This service uses evidence-based methods, including visual symptoms and the identification of pathogens, to confirm a diagnosis. Any samples that are suspected to be viruses are confirmed using ELISA testing at the NSW DPI Elizabeth Macarthur Agricultural Institute. This no cost diagnostic service is part of a partnership between the NSW Department of Primary Industries (DPI) and the Grains Research and Development Corporation (GRDC).

Samples of wheat, barley, and oat rusts (such as stripe, leaf, and stem rust) are sent to the Australian Cereal Rust Control Program (ACRCP). This helps track the spread of rust pathotypes across New South Wales and Australia. The ACRCP regularly updates an interactive map, which shows which pathotypes are dominant in different regions, enabling growers and advisors to be aware of what is happening during the growing season.

The project also keeps track of disease enquiries received from growers and advisers throughout the season. This information is used to support cereal producers in obtaining correct diagnoses of diseases and independent management advice. Getting the right diagnosis can help limit the economic impact of diseases by reducing the unnecessary use of in-crop fungicides.

Collation of this data across NSW provides an annual 'snapshot' of the key biotic and abiotic constraints to cereal production (Table 1).

Table 1. Cereal diagnostics and enquiries processed across NSW between 2019 and 2022. Disease/issues are ranked in order of frequency in 2022

Disease/ Issue	**2022**	**2021**	**2020**	**2019**
Fusarium head blight	389	18	10	0
Stripe rust (wheat)	379	343	194	13
Septoria tritici blotch (wheat)	104	56	17	13
Fusarium crown rot	89	99	61	14
Physiological/melanism	68	20	65	10
Wheat powdery mildew	53	17	53	1
Yellow leaf spot (wheat)	49	56	10	4
Other non-disease (e.g., soil constraint, leaf blotching/mottling)	42	53	34	24
Spot form of net blotch (barley)	30	50	65	32
Herbicide	27	7	28	6
Leaf rust (wheat)	21	37	35	2
Rusts crown and stem (oats)	21	24	29	4
White grain disorder (Eutiarosporella spp.)	21	1	1	0
Environmental (e.g., frost damage, waterlogging)	16	24	45	4
Net form of net blotch (barley)	11	20	23	0
Nutrition	11	18	16	2
Barley powdery mildew	9	8	12	0
Scald (barley)	9	7	65	4
Loose smut	8	11	9	1
Bacterial blight (other cereals)	8	4	30	0
Leaf rust (barley)	8	3	0	0
Take-all	6	33	16	1
Seedling root disease complex (Pythium, crown rot, Rhizoctonia, take-all)	6	13	8	2
Barley grass stripe rust	6	2	20	1
Ring spot	5	2	0	1
Other oat foliar diseases (red leather leaf, septoria blotch, bacterial blight)	4	9	26	12
Common root rot	3	26	2	3
Wheat streak mosaic virus	3	23	3	1
Rhizoctonia	3	9	12	7
Barley yellow dwarf virus	3	4	19	1
Other minor diseases	1	1	4	2
Total	**1416**	**998**	**912**	**165**

Individual seasons have a strong influence on the demand for cereal diagnostic support provided to NSW growers/advisers. Table 1 clearly shows the increased demand for diagnostic activities during 2022 with a 42% increase in demand compared to the 2021, which was also a highly conducive year for cereal diseases. The increase was primarily due to a third consecutive season conducive to the development of a range of cereal leaf and head diseases.

Fusarium head blight (FHB) replaced wheat stripe rust as the most diagnosed and queried cereal disease in 2022, with 28% of the total activities. Stripe rust had been the most queried disease during 2020 and 2021 but was the second most queried disease during 2022 with 27% of activities. Septoria tritici blotch (STB) remained the third most queried disease for the second year running. In fourth spot was Fusarium crown rot (FCR), this is not surprising considering it is one of the main sources of inoculum for FHB infections in 2022. It also reinforces the fact that root and stem diseases such as FCR do not disappear during wet seasons.

Observations and learnings from the 2022 cropping season

Is it disease?

Importantly, 11% of activities in 2022, 13% in 2021, 21% in 2020 and 28% in 2019 were not related to disease. In 2022, 164 samples were submitted as suspected of having disease issues, however, these were either diagnosed as being plant physiological responses to stress, frost damage, herbicide injury, related to crop nutritional issues or other non-disease issues (Table 1).

For example, during 2022, weather conditions were ideal for the expression of physiological issues including melanism in certain wheat varieties, with 68 individual queries received. Melanism, which also known as pseudo black chaff, is a physiological response in wheat associated with carrying a stem rust resistance gene Sr2. Not all wheat varieties carry Sr2, so expression is variety specific. This response results in the overproduction of a pigment called a melanoid, which can cause browning of the stem or glumes in wheat heads. Melanism is favoured by high humidity and ultraviolet light (UV) and can be mistaken for Fusarium crown rot (FCR) if it is found on the stem, or for Fusarium head blight (FHB) if it is found on or below the head or on glumes. The defining diagnostic feature of melanism is that it causes browning from a node downwards, which differs from FCR which results in stem browning from a node upwards.

This highlights the ongoing importance of the diagnostic service provided by these projects to NSW growers and their advisers to support correct identification and implementation of appropriate management strategies. A second opinion from a plant pathologist can ensure the correct diagnosis – (see contact details below).

Environmental and disease interactions associated with yield loss and pinched grain

In southern New South Wales (sNSW) many wheat crops did not meet their predicted yield potential. This yield reduction was mainly due to pinched or aborted grains in heads. It is unclear whether the cause was more due to management decisions and environmental factors or diseases, but it is certain that all contributed to the yield loss to varying degrees. Yield potential of a cereal crop is set early with any number of factors influencing or reducing top end yield. Many factors occurred during 2022 to reduce crop yield and increase pinched grain.

Heavy rainfall and trafficability issues delayed sowing in many areas, resulting in seed germination in cold, wet and waterlogged soils. These conditions are not favourable for quick root development to depth, which enables the root systems to move below the bands of *Pythium* and *Rhizoctonia* in the soil. Early infections of these diseases, along with take-all and Fusarium crown rot (FCR), compromised root systems, limiting growth above and below ground. This was more evident in cereal-on-cereal rotations and disc seeding systems.

The series of disease conducive cropping seasons and wet summers enabled the build-up of inoculum of many diseases to very high levels by sowing in 2022. In some cases, to levels which have not been seen before, such as with wheat stripe rust. Inoculum loads combined with prolonged cooler temperatures, rainfall, and humidity, placed the 2022 cereal crop under enormous early disease pressure, particularly from foliar diseases. Paddock trafficability issues with ground application or availability of aerial application, delayed or prevented fungicide applications in some regions. This generally resulted in increased disease levels in unprotected susceptible varieties with significant loss of green leaf area on vital yield contributing leaves (Flag (F), F-1 and F-2). This compromised the ability of affected plants to physically transport the required nutrients and water to the heads to fill plump grain.

The combination of potential factors such as waterlogging (shut down plants), compromised root systems (*Pythium* and *Rhizoctonia*), partially or fully blocked vascular systems (FCR and take-all), caused significant loss of green leaf area (foliar diseases) and head diseases (FHB) and lower than average solar radiation for sNSW (reduced carbohydrate and protein transportation). All of these factors potentially influenced abortion and pinching of grains to varying degrees. This led to reduced yield, high screenings, and quality downgrades.

Fusarium head blight (FHB)

During 2022, Fusarium head blight (FHB), a fungal disease that affects wheat and other cereal crops, was the most queried disease with 28% of activities (Table 1). The disease was common at varying levels across southern Queensland (sQld), New South Wales (NSW), Victoria (Vic) and South Australia (SA) in 2022. The last major outbreak of FHB in NSW was in 2016, which was a year with high late season rainfall much like 2022.

FHB is caused by several species of the fungus Fusarium, with *F. pseudograminearum (Fp)* and *F. graminearum (Fg)* being the most common. Both species can produce toxins known as mycotoxins that can contaminate the grain and make it unsafe for human and stock consumption. FHB can reduce crop yield and quality and can also affect the germination and vigour of retained seed. Infection is favoured by prolonged periods of moisture (36-72 hours of greater than 80% humidity) and temperatures between 20-30°C. The infections occur through the anthers during flowering.

FHB appears as bleached spikelets or partial or whole head bleaching. The defining diagnostic characteristic of FHB is the browning of the rachis (stem of head). Any spikelets above this browning point will die or have shrivelled grain. Other characteristics include white or pink grains or orange spore masses around the glumes.

It is important to identify which species of Fusarium is causing the FHB infection because this will determine the best management strategy and provide information about the potential risk of mycotoxins. If the infection is caused by *Fp*, it is likely to come from basal tiller infection from FCR. Under humid conditions, macroconidia form around the nodes on the stem and are then splashed dispersed onto leaves and eventually into the head during rainfall. *Fp* does not have an airborne dispersal mechanism, so the underlying FCR levels must be addressed prior to sowing future cereal crops through an integrated disease management (IDM) plan to minimise the inoculum for FCR and FHB reinfection.

The second *Fusarium spp.*, *Fg*, as opposed to *Fp*, has an airborne dispersal mechanism and hosted on grass species, cereal crops, maize and sorghum stubbles. The ascospores produced by *Fg* are highly wind dispersed. Crop rotation, stubble management and green bridge control is key to reducing *Fg* risk.

Causal *Fusarium spp.* produce a range of mycotoxins, including deoxynivalenol (DON) and nivalenol (NIV). The toxicity of these mycotoxins can vary depending on the species of Fusarium. NIV is generally considered to be around 10 times more toxic than DON. There are two different forms of

DON, with 3ADON being half as toxic as the 15ADON form. *Fp*, produces 3ADON, while *Fg*, produces the more toxic 15ADON and NIV mycotoxins.

Care must be taken when feeding Fusarium infected grain to stock. There are no specific Australian stock feed guidelines for mycotoxins. The US Food and drug Administration (FDA) have guidelines that state: for the DON toxin, advisory levels for food products consumed by humans is 1 part per million (ppm); 10 ppm for ruminating beef and feedlot cattle older than 4 months (cannot exceed 50% of diet); 10 ppm for poultry (cannot exceed 50% of diet); 5 ppm for swine (cannot exceed 20% of diet); and 5 ppm for all other animals (cannot exceed 40% of diet) (FDA, 2010).

Species identification work, via quantitative PCR, has been undertaken from diagnostic samples submitted during 2022. To date, three *Fusarium spp.* have been identified as the cause of FHB, being *Fp, Fg* and *Fusarium culmorum (Fc)*, with *Fp* being the most common. This indicates that a large portion of NSW cropping regions have an underlying FCR issue which must be addressed via an IDM plan. *Eutiarosporella spp.,* the causal pathogen of white grain disorder (WGD), has also been identified from infected heads. Unlike FHB, WGD does not produce a mycotoxin, but can reduce vigour and germination of seed the following year. Both FHB and WGD can cause acceptance issues at grain receival if white grain numbers exceed delivery limits.

Wheat stripe rust

Wheat stripe rust made up 27% of activities in 2022 (Table 1). High inoculum levels combined with early opportunity for sowing grazing wheat kickstarted the epidemic for the 2022 cropping season. The first reported stripe infection in NSW was in mid-May 2022, being the second earliest report on record.

The situation with wheat stripe rust in eastern states cropping regions has never been more complex, with several pathotypes present in our environment. During 2021, two new mutations were identified by Professor Robert Park, Sydney University Australian Cereal Rust Survey, being 238 E191 A+ 17+ 33+ and 238 E191 A+ J+ T+ 17+. These mutations are thought to have come from a hybrid of the 198 E16 A+ J+ T+ 17+ (198) and 239 E237 A- 17+ 33+ (239) pathotypes. Many of these pathotypes in our environment occurred in minor frequencies, with only three deemed predominate in NSW during 2022. These being 198, 238 E191 A+ 17+ 33+ (238) and 239.

Each of these pathotypes may affect a particular variety (host) differently. This is due to the genetic makeup of the host plant i.e., the resistance genes within the plant and the individual pathotypes virulence or avirulence status on those genes. It is important to stay up to date with the latest variety resistance ratings, as they can change from year to year. These ratings are developed through the National Variety Trial (NVT) pathology screening project and are released annually on the GRDC website and in state-based sowing guides, such as the NSW DPI Sowing Guide. See Robert Parks paper for full details on pathotype distribution and variety implications.

Septoria tritici blotch (STB)

Septoria tritici blotch (STB) was ranked third for activities during 2022 (Table 1). STB was particularly devastating to wheat crops that were not protected by fungicide in the high to medium rainfall zone of sNSW during 2022. Due to the inoculum build up experienced in previous seasons and the optimal environmental conditions, STB became a serious issue in regions where it does not usually pose a threat to yield. In these areas, varieties that were rated as more resistant to stripe rust, were adversely affected by STB, due to reduced fungicide use in these crops targeted at stripe rust management. In some cases, STB still reduced yield in crops that were protected by one to two sprays, further outlining that fungicide choice and timing is important in STB control.

STB has a fungal structure produced on wheat stubble (pseudothecia) which releases airborne spores (ascospores) under ideal environmental conditions. The ascospores produced can spread long distances (>km's) to infect susceptible wheat, durum and triticale crops. Even after a non-host break crop (e.g., canola) is sown in a paddock, any remaining stubble residues from preceding wheat crops can still be a source of inoculum and infect a newly emerging wheat crop. This risk can remain for at least two years.

Stubble spore release experiments conducted at Wagga Wagga Agricultural Institute (WWAI) have shown that the resistance rating of the wheat variety grown has little influence on the ability of the pathogen to colonise senescent stubble and the inoculum levels produced off retained stubble, i.e., the number of spores released, in the following season. Therefore, any infected stubble must be considered a risk for the proceeding wheat crop or crops nearby. However, the resistance rating of the variety is effective during the growing season in limiting STB infection within the canopy. Further experiments also found that between 20% and 45% yield loss from STB is possible in a susceptible wheat variety.

Stubble management experiments have shown that a net reduction in inoculum levels can be achieved by manipulating harvest cut height to reduce the standing straw available for the STB pathogen to colonise. These experiments had three cut height treatments, being 32 cm (high), 24 cm (medium) and 14 cm (low). Cut heights were selected to lower straw length by one node on the mainstem. Using the 32 cm cut height as a base level, lowering cut height to 24 cm reduced the number of ascospores produced by 84%. When comparing the 32 cm cut height to the 14 cm cut height, there was a 97% reduction in the number of ascospores released from the stubble.

The excess material must be removed from the paddock to result in a net reduction. Otherwise, the inoculum from the standing stubble is only relocated to the ground, which maintains the same inoculum levels within the paddock. Removal can be by bailing or burning (narrow windrow or blanket burn) the straw. Some methods are less labour intensive than others, however the cost benefit risks of each method and other system impacts, must be weighed before being undertaken.

Ramularia leaf spot of barley

Ramularia leaf spot (RLS) of barley is caused by the pathogen *Ramularia collo-cygni.* It is a relatively new incursion into the NSW grain growing belt. RLS was first detected in Australia in 2016 in Tasmania, followed by Western Australian in 2018. Further surveys have confirmed the presence of RLS in New South Wales, Victoria and South Australia.

RLS can be seed dispersed or wind borne. The pathogen grows for at least the start of its lifecycle as an endophyte, which means the fungus lives within the barley plant without causing disease symptoms or leaf damage. At some point after flowering, the pathogen can express toxins (Rubellins) in the plant that cause characteristic rectangular lesions on the leaves and stems. These lesions lead to loss of green leaf area, and subsequent loss of yield due to reduced grain filling. The exact triggers that cause the change from endophyte to pathogen are not well understood, however the disease is likely to be more prevalent in the high rainfall cropping areas and more severe in years with higher rainfall at the end of the cropping season.

RLS can be difficult to differentiate from other barley diseases such as the net-blotches and other physiological plant responses. RLS appears as small rectangular red-brown lesions surrounded by a yellow chlorotic margin, often in a speckled or chequer plate pattern. Differing from the net-blotches, RLS lesions are restricted between the leaf venations, giving them a square or rectangular shape.

Very little is known about the resistance levels of current barley varieties, fungicide resistance status and potential yield losses incurred in Australian environments from Ramularia. Internationally, yield losses have been recorded up to 30%, a figure that is consistent with the impacts other barley necrotrophic diseases. Fungicide resistance has evolved to some fungicide chemistries internationally (GRDC, 2021). However, limited testing in Australia suggests all three major fungicide groups, Group 3, 7 and 11, are effective against RLS. International research suggests that application time should be between GS31-GS49 (GRDC, 2021). There are currently two fungicides registered for RLS control in Australia.

Disease risk in 2023

Climatic conditions (rainfall, temperature and humidity) play a significant role in initiating and driving disease epidemics. If 2023 has even close to our mean annual in-crop rainfall, this will result in elevated leaf disease risk. This is due to the extreme inoculum levels of many diseases which have built off the back of the disease conducive 2020-2022 seasons.

If 2023 is mild and wet, there is a higher risk of foliar disease epidemics. These include biotrophic diseases such as rusts and necrotrophic diseases such as STB and YLS in wheat and Ramularia, spot-form of net-blotch, net-form of net-blotch and scald in barley. These conditions will also favour soil borne diseases such as take-all and *Pythium*.

If the 2023 season is drier, there will likely be a reduction of foliar diseases and increase in root diseases, such as Fusarium crown rot (FCR) and *Rhizoctonia,* where disease expression is favoured by the drier conditions.

The final inoculum consideration is from seed borne diseases and virus such as bacterial blight, smuts, bunts, Fusarium infected grain and wheat streak mosaic virus. Where possible, sourcing clean seed for sowing in 2023, that is, not from crops with moderate to high levels of infection in 2022, is important to reduce risk of these diseases. However, for the 2023 cropping year, this may not be easily done considering the widespread occurrence of FHB and poor-quality wheat grain i.e., pinched grain. Fusarium infected grain will potentially be an issue for sowing 2023.

Disease management for 2023

Managing diseases separately, stripe rust and septoria tritici blotch (STB)

One observation from 2022 was differences in fungicide management between varieties with more or less stripe rust resistance and the impact the level of fungicide use had on Septoria tritici blotch (STB) control. Most varieties grown in sNSW are moderately susceptible to susceptible (MSS) or worse to STB. So, under the right conditions, most varieties can be yield limited by STB infection.

STB caught a lot of growers and agronomist by surprise in the medium to low rainfall zones last year where this disease is not normally an issue. This contrasts with the higher rainfall regions in sNSW which are at risk of STB infections in most seasons and where management strategies are generally already planned for STB.

During 2022, varieties that are more susceptible to stripe rust often had better STB control than varieties with high resistance ratings for stripe rust. This was as a result of the use of fungicides targeted to control stripe rust. Stripe rust susceptible varieties likely had between two to four or more fungicide units applied targeted to manage stripe rust. These would have had some efficacy on STB and helped keep it under control. However, four fungicide units is not a sustainable way to control stripe rust. It promotes both on and off target resistance development in diseases such as STB and wheat powdery mildew (WPM). New research conducted by Professor Robert Park at Sydney University has proven that individual pathotypes of both wheat and barley leaf rust within Australia have acquired resistance to Group 3 fungicides (DMI, triazoles). Hence the need to judiciously apply fungicides in susceptible varieties, as there is no reason why stripe rust cannot develop the same resistance.

On the other hand, varieties with improved levels of stripe rust resistance (moderately resistant-moderately susceptible, MRMS, and better) were generally more affected by STB as they only required one or maybe two fungicide units, generally early, around late tillering or the start of stem elongation to manage stripe rust. Once these early fungicides had run out, by GS39 at the latest, STB infection was well underway in some crops which had not been diagnosed. This later STB infection is what then caused yield loss and pinched grain in many situations. A single further fungicide application between GS39-GS49, solely for STB, would have helped reduce the severity of late STB infection, protecting yield and reducing screenings.

So… what can we do better for 2023?

Firstly, grow more stripe rust resistant varieties as there is a big difference in fungicide stewardship between one or two fungicide units on a less susceptible rated stripe rust variety and four units on a susceptible (S) variety in conducive seasons. It also reduces the risk of yield loss if trafficability within season becomes an issue. For example, in 2022, many growers and advisors reported delayed foliar fungicide applications by ~10 days, related to trafficability or access to aerial application. In more susceptible varieties and under the high inoculum loads of 2022, this delay resulted in up to 40%+ yield loss. This is a significant economic impact. Growing more stripe rust susceptible varieties may have a yield benefit in some regions but this needs to be balanced against the increased disease risk of yield loss and reliance on critical timing of fungicide applications.

All varieties, unless rated resistant (R), do have susceptibility to stripe rust infection at the seedling stage. Hence, more resistant varieties only need fungicide protection early until adult plant resistant (APR) genes become active. APR is temperature and growth stage sensitive, and the timing of full expression can vary from year to year. Generally, a resistant to moderately resistant (RMR) or moderately resistant (MR) variety has full expression around GS31 or GS32, MRMS around GS39 and moderately susceptible (MS) around GS59. After these growth stages, the APR genes can be relied on to control further stripe rust development. MSS or S varieties have little APR and by the time it expresses after grain fill, severe yield loss has been incurred if not controlled using in-crop fungicides. Hence, the need to fully manage these varieties throughout the season with multiple fungicide applications.

If a S rated variety is to be sown and the seasonal outlook is conducive to foliar diseases, the planned fungicide regime for an S or worse rated variety to stripe rust should consider including an up-front fungicide such as flutriafol on starter fertiliser at sowing, followed by a GS31 and GS39 in-crop fungicide application. If the conducive conditions persist later into the season, a later GS59 fungicide application could be needed. A reduction in the time between applications to no more than 3-4 weeks may also need to be considered, as under high inoculum pressure the protective component of fungicides will be running out leaving the plants unprotected. We saw this happen in 2022.

Alternatively, if an up-front fungicide is not used, a minimum of two in-crop fungicide applications should be planned, timed at GS31 and GS39. With the likelihood of GS59 application. Earlier in-crop intervention may be needed if stripe rust appears prior to GS31. These control programs, combined with fungicide choice, will also help protect against STB infection. This is a high input strategy that will inevitably increase selection for fungicide resistance within the stripe rust population, but which will also select for resistance in other fungal pathogens such as STB and WPM which will also be present at the time of application.

For varieties with better levels of stripe rust resistance (RMR-MRMS), early protection up front from flutriafol on the fertiliser, pending season, maybe enough to protect the plants from stripe rust until APR becomes active. Alternatively, if flutriafol is not an option, apply fungicide around early stem elongation to control early stripe rust infections. If the season is conducive, apply fungicide again around GS39-49 to protect against STB. If the STB season is severe like 2022, a third application around GS59 may be necessary. However, in most seasons it will not be needed.

The intermediate rated varieties, MS and MSS to stripe rust, depending on season, are likely going to need a management package meshing components from each management plan discussed above. At a minimum, plan on two fungicide applications.

It should be noted that even in high stripe rust pressure years, there is very little data showing a yield benefit from using fungicides prior to the commencement of stem elongation. That said, any sprays applied before the commencement of stem elongation will at best only have a suppressive effect on inoculum load, as none of the leaves that contribute significantly to grain yield emerge until after this growth stage. Therefore, crops which include a fungicide with the herbicide application during tillering (GS25) still require a dedicated stripe rust fungicide spray at GS31-32 to protect the Flag-2 leaf. In susceptible varieties the gap is simply too long between GS25 and the flag leaf (GS39) second application timing which can result in significant stripe development on the unprotected Flag-2 and Flag-1 leaves during this period.

Fungicide applications can be altered to suit another key growth stage such as flowering, seasonal conditions and outlook along with yield potential. Fungicide resistance management through rotation of MOA and individual triazole actives within season should also be considered. (Refer AFREN website).

Lastly, not all fungicide active ingredients are the same when it comes to controlling STB and fungicide choice is becoming increasingly important. Group 3 (DMI, triazoles) actives such as Tebuconazole and Propiconazole will readily control stripe rust, but have poorer activity against STB. Prothioconazole and Epoxiconazole are more robust and better options for straight STB control. They will also have good activity on stripe rust.

Group 7 (SDHI) and Group 11 (Qols, Strobilurins) fungicides are mainly protectants, with some of the Group 3 actives they are paired with being poorer curatively on STB, so they should be applied to plants with minimal infection. Do not spray the same Group 3 active ingredient more than twice in one season and once for Group 7 and Group 11. Use mixtures with multiple active ingredients to minimise the development of resistance, rotate actives and groups (especially between consecutive applications) and be mindful of label instructions and withholding periods.

Fusarium head blight

Fusarium head blight (FHB) was prevalent across the northern and southern grain regions during 2022. The carryover of *Fusarium spp.* in seed from crops infected with FHB in 2022, which have been retained for sowing this season, is a concern. Using seed that has moderate Fusarium infection levels can firstly affect germination and vigour of the seed. Secondly, it can cause seedling blight of young wheat plants, stunting their growth and causing death. Thirdly, it can introduce Fusarium crown rot (FCR) into otherwise FCR free paddocks.

It is critical that seed retained from any crop known to have FHB or detection of white grains at harvest should be tested for the level of Fusarium infection well in advance of sowing. Testing will allow a cleaner seed source to be identified if required or a fungicide seed treatment to be implemented. NSW DPI Tamworth is offering a free seed testing service to determine Fusarium infection levels. It is important to get seed sources tested, as infection may be higher than the visual number of white/pink grains in the sample. This is due to later infections of FHB which may not have discoloured the seed.

If you have a known Fusarium infected seed source, it should be tested for germination and vigour as Fusarium can affect these traits. There are commercial providers available to do so. This will allow you to adjust your seeding rates at sowing accordingly or find a different seed source.

In high-risk situations such as conducive weather conditions (prolonged high >80% humidity during flowering and early grain fill), overhead irrigation, presence of maize or sorghum stubbles, high underlying FCR levels or high-risk durum wheat paddocks, the application of Prosaro® at the start of flowering is an option to reduce FHB levels.

The application of Prosaro® at the start of flowering is required as the anthers are the primary infection site for FHB. There is a big distinction between an FHB and stripe rust fungicide timing to limit head infections. An effective stripe rust control needs to be carried out at least 2-3 weeks prior to flowering to give time for the spores to die so they are not blown into the head at flowering. Whereas with FHB, the fungicide needs to be timed specifically at flowering to protect the anthers. Note, in North America, strobilurin fungicides (also known as Group 11 or QoIs in Australia) are not recommended from booting (GS45) onwards in paddocks with FHB risk, as this can increase mycotoxin accumulation in infected grain (Chilvers et al. 2016). The risk of mycotoxin accumulation and the need to control other diseases will need to considered.

Fungicide application for FHB is a dedicated spray set-up differently than for stripe rust, as coverage of heads is critical. Timing (start of flowering, GS61), high water rates (minimum 100 L/ha) by ground rig and twin angled nozzles to allow coverage on both sides of the head is required. Prosaro® is the only registered product in Australia. Efficacy is considerably reduced with aerial application.

At harvest, it is best to separate out grain from infected and uninfected paddocks to maximise market opportunities, harvest least infected paddocks first, open header sieves and increase fan speed to blow out heavily infected grains if they are pinched and lighter to reduce the number of white/pink grains in the sample. This is only an option if the other grain is full, otherwise non-infected grain will also be blown out the back of the header.

FHB requires extended periods (>36 h) of high humidity (>80%) at a very specific growth stage (flowering) to initiate infections so is heavily reliant on these conditions coming together. Considerable differences in FHB levels between varieties within a location that flowered 2 weeks apart were common in 2022 even though under the same inoculum pressure. Hence, the risk of FHB again in 2023 needs to be kept in perspective and the key underlying message that in many regions, the FHB infection in 2022 was related to basal infections from FCR. A hot and dry seasonal finish in 2022 would have prevented FHB infection but would likely have led to widespread yield loss from FCR which is exacerbated by stress during grain filling. FCR risk across much of NSW is at all-time highs following three consecutive wet seasons as moisture favours infection, but simply limits expression and yield loss from whiteheads. Do **NOT** ignore the signs from FHB in 2022. Test paddocks with any level of FHB for their level of FCR inoculum in retained stubble, especially if considering another cereal crop in 2023.

Powdery mildew

Blumeria graminis f. sp. *tritici* (*Bgt*), the causal agent of wheat powdery mildew (WPM), is favoured by prolonged warm and moist weather conditions, 15° to 22°C, relative humidity > 70%, dense crops facilitated by high levels of nitrogen in the soil, which facilitate long periods of green leaf retention, moisture, and humidity in the canopy. The addition of irrigation water promotes these ideal conditions and often drives WPM epidemics; hence the irrigation areas and Murray River border region tend to see WPM in higher frequency than other growing areas of sNSW.

The pathogen is at high-risk for developing fungicide insensitivity and resistance. This is primarily due to the fast life cycle and the inherent genetic diversity of the pathogen. . As such, for 2023, an integrated disease management plan (IDM) should be implemented to reduce the risk of WPM infection if growing susceptible wheat varieties.

Firstly, destroy the green bridge. WPM can host on volunteer wheat plants and removing them, reduces the inoculum level in the environment

Where possible select varieties with improved resistance to WPM. Table 2 shows that commonly grown varieties in sNSW have susceptibility to WPM. However, it does also show that there are less susceptible options available, but the suitability of these varieties to your environment would have to considered. Avoid susceptible (S) or worse rated varieties in high-risk situations such as irrigated crops.

Table 2. Popular varieties grown in sNSW and their resistance ratings to WPM (GRDC, 2023). Note: these are the 2022 ratings, 2023 ratings have not been released at time of writing.

Variety	WPM rating	Variety	WPM rating
Beckom	S	Illabo	R
Boree	SVS	LRPB Flanker	MR (P)
Brumby	R#	LRPB Lancer	R
Catapult	S	LRBP Mustang	MSS
Condo	MR	LRPB Raider	MSS
Coolah	S	LRPB Scotch	R
Coota	S	Reilly	MSS
DS Bennett	R	RockStar	SVS
EGA Gregory	RMR	Scepter	SVS
EGA Wedgetail	MRMS	Vixen	SVS

R= resistant, MR= moderately resistant, MRMS= moderately resistant to moderately susceptible, MSS= moderately susceptible to susceptible, S= susceptible, SVS= susceptible to very susceptible.

Early sowing and high nitrogen levels promote repeated exposure to early WPM infection events, longer green leaf retention and dense bulky canopies. All these factors help promote initial infection from WPM and drive the epidemic throughout the season which needs to be considered within management strategies.

Fungicide advice to NSW and Victorian wheat growers includes (Simpfendorfer et al, 2022):

- Avoid using Group 11 fungicides in areas where resistance to QoIs has been reported
- Minimise use of the Group 3 fungicides that are known to have compromised resistance
- Monitor Group 3 fungicides closely, especially where the gateway mutation has been detected
- Rotate Group 3 fungicide actives within and across seasons. In other words, do not use the same Group 3 product twice in succession
- Avoid more than three applications of fungicides containing a Group 3 active in a growing season
- Group 11 fungicides should be used as a preventive, rather than for curative control and should be rotated with effective Group 3 products
- Avoid applying Group 7 and Group 11 products more than once per growing season, either alone or in mixtures. This includes in-furrow or seed treatments that have substantial activity on foliar diseases, as well as subsequent foliar sprays. Combined seed and in-furrow treatments count as one application.

Further information of fungicide resistance status in sNSW WPM population can be found in the useful links below.

Cereal root diseases

With the risk of cereal root disease elevated for 2023, consider the risk associated with cereal-on-cereal rotations. Root diseases are difficult to control as you cannot apply fungicides once they appear to limit further development. An IDM plan must be implemented to address the underlying pathogen loads which may take more than one season.

Rhizoctonia, Pythium, take-all and Fusarium crown rot (FCR) were all prevalent during 2022. If you must sow a cereal-on-cereal, be proactive instead of reactive. Consult paddock notes, management plans and rotation sequences from previous years to identify known and potential disease issues. Gain an understanding of your underlying inoculum levels through PreDicta®B DNA based testing which quantifies a wide range of pathogen levels in your paddock and provides an associated risk level. Alternatively, 2022 cereal stubble can be submitted to the NSW DPI Tamworth laboratory for free plating of FCR, common root rot and take-all risk (contact Steven Simpfendorfer, details below or sampling bags available from Local Lands Service offices across NSW).

Management of FCR

If moderate to high Fusarium levels are identified in cereal stubble or PreDicta®B testing, consider growing a non-host break crop (i.e., pulses, canola or grass free pasture legumes such as lucerne). This will allow time for the decomposition of infected cereal stubble, reducing survival of the FCR fungus. Solid rotations with non-consecutive cereals and diverse break crops create an environment that will reduce the likelihood of significant root diseases including FCR.

Varieties and crop species can differ in their resistance and tolerance to FCR. So, crop and variety choice can be used as a 'band aid' solution if you are forced to grow a cereal under moderate FCR risk. For FCR, in the order of most susceptible to least susceptible, is durum wheat>triticale>bread wheat>barley>oats. Under moderate FCR risk, consider barley or oats instead of bread wheat and avoid durum. Barley tends to suffer less yield loss from FCR as it generally fills grain earlier in the season compared with wheat. This provides some escape from heat and moisture stress which exacerbates disease expression. However, barley is still a very good host of the FCR fungus. Growing a cereal crop will still build or maintain FCR inoculum within paddocks, so you are just buying time and not addressing the underlying FCR issue.

There are other management options at sowing that can reduce the level of FCR infection and expression during grain filling. These include inter-row sowing, fungicide seed treatments, sowing at the start of the recommended window for each variety in your area to reduce heat/water stress at flowering, matching nitrogen fertiliser applications to stored soil water at sowing and predicted seasonal conditions.

Control of grass weeds and volunteer cereal plants is vital especially in break crops, as most grass weeds are alternate hosts of winter cereal pathogens, including the FCR fungus. Controlling weeds and cereal volunteers over summer also maximises soil moisture storage and reduces the carryover of other pathogens including rust and insect virus vectors.

Conclusions

2022, was a challenging cropping year for many in the face of high rainfall, devastating floods and high sustained cereal disease pressure. The authors thoughts and wishes are with those who were affected and wish them a quick recovery. However, for many, the season was still very successful with good grain yields. The 2023 season is already shaping as another favourable year for crop production with high soil moisture levels already accumulated in many areas. Cereal disease risk is likely to be higher due to pathogen build-up between 2020-2022. Well-planned integrated management strategies in the face of higher input costs and potentially tight fungicide availability again in 2023, will assist minimisation of disease levels whilst maximising profit. If 2022 has taught us anything, it is that we cannot control the weather. However, growers still need to focus on managing the controllable in 2023. This starts with ensuring the quality of seed for sowing and committing added attention to identifying and managing cereal disease risk such as FCR within individual paddocks. NSW DPI is here to support growers with seed and cereal stubble testing, correct diagnosis and discussion of management options prior to sowing and as required throughout the season.

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Useful links

NSW DPI research result booklets: https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides

NSW DPI Sowing Guide: https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/winter-crop-variety-sowing-guide

Wheat powdery mildew: https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2022/02/fungicide-resistance-in-wheat-powdery-mildew-in-nsw-and-northern-victoria-in-2020-2021

NVT Online: https://nvt.grdc.com.au/nvt-disease-ratings

Australian Cereal Rust Survey: https://www.sydney.edu.au/science/our-research/research-areas/life-and-environmental-sciences/cereal-rust-research/rust-reports.html

AFREN website: https://afren.com.au/

PreDicta®B website: https://pir.sa.gov.au/research/services/molecular_diagnostics/predicta_b

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