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Final Technical Report Template

Final Technical Report

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Epidemiology of Septoria Tritici Blotch in the low and medium rainfall zones of Southern region to inform IDM strategies

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REPORT SENSITIVITY

Does the report have any of the following sensitivities?

Intended for journal publication	YES ☒ NO ☐
Results are incomplete	YES ☐ NO ☒
Commercial/IP concerns	YES ☐ NO ☒
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ABSTRACT

Septoria tritici blotch (STB), caused by *Zymoseptoria tritici*, is a major wheat disease in the medium (MRZ) and low (LRZ) rainfall zones of the Southern region. Stubble retention and large-scale cropping of susceptible wheat varieties has contributed to its rising prevalence, leading to yield losses exceeding 20% in conducive seasons and economic losses of up to $459/ha in untreated susceptible varieties. This study, conducted over 48 field experiments from 2021–2024, examined STB epidemiology, inoculum survival, spore dispersal using spore traps, and the effectiveness of integrated disease management (IDM) strategies in MRZ and LRZ.

Spore trap data revealed that stubble is a critical source of early-season inoculum, with peak spore release occurring in winter. However, disease severity in-crop was primarily driven by spores released within crop canopy. In-crop disease risk was influenced by early sowing, variety susceptibility, and seasonal conditions, with wetter years facilitating higher disease pressure and economic losses. Stubble management (baling, burning, cultivation) reduced early-season inoculum levels, but its effect on final disease severity was limited due to airborne spore dispersal from surrounding paddocks. Variety resistance was the most cost-effective management strategy, with resistant cultivars reducing disease severity, yield loss, and fungicide dependence. Fungicide applications were profitable in high-disease seasons, particularly in susceptible varieties and where yield potential is greater than 3t/ha, providing up to $459/ha in economic benefits, but were less effective in resistant varieties and in low-disease years, where financial returns were inconsistent. Crop rotation with non-host species reduced STB risk, while delayed sowing lowered early-season infection rates and disease progression.

These findings underscore the need for region-specific IDM strategies that integrate variety resistance, fungicide application, stubble management, and crop rotation to minimise STB risk, optimise economic returns, and improve wheat productivity in the MRZ and LRZ.

EXECUTIVE SUMMARY

Background and objectives

Septoria tritici blotch (STB), caused by *Zymoseptoria tritici*, is a major disease challenge in the MRZ and LRZ of Southern Australia, particularly in high-rainfall seasons and intensive wheat production systems. Widespread adoption of stubble retention, early sowing, and susceptible wheat varieties has contributed to rising disease prevalence, leading to yield losses of 20–43% and economic losses of up to $459/ha in untreated susceptible varieties.

This project, conducted from 2021 to 2024 across 48 field experiments, aimed to:

- ❖ Investigate STB epidemiology, including spore dispersal patterns, inoculum survival, and the impact of rainfall on disease development.
- ❖ Evaluate the economic viability of integrated disease management (IDM) strategies, including fungicide applications, variety resistance, stubble management, and crop rotation.
- ❖ Provide region-specific recommendations to improve grower decision-making, maximizing profitability while reducing disease risk.

Key findings and achievements

1. **STB epidemiology and disease risk factors**

- ❖ The lifecycle of *Zymoseptoria tritici* is polycyclic and involves both sexual (ascospores) and asexual (pycnidiospores) reproduction phases in Southern Australia.
- ❖ Spore trap data confirmed that wheat stubble is a major source of early-season STB infection, with peak spore release occurring in winter months where average temperatures are low (10-15°C).
- ❖ Rainfall is a key driver of in-crop STB risk, with higher spring rainfall increasing spore dispersal and disease severity.
- ❖ Late-season disease pressure is primarily driven by spores traveling from neighbouring fields, limiting the long-term effectiveness of localized stubble management alone.
- ❖ Early sowing significantly increases disease risk, particularly in susceptible (S, SVS) wheat varieties, due to prolonged exposure to early inoculum under wet conditions.

2. **Economic analysis of integrated disease management (IDM) strategies**

A combination of variety resistance, targeted fungicide use, stubble management, and crop rotation provided the best economic and disease control outcomes.

Variety resistance: the most cost-effective STB management tool

- ❖ Less susceptible wheat varieties consistently reduced disease severity and minimized yield loss, offering an economic advantage of up to $433/ha compared to susceptible varieties in MRZ.

- ❖ Growing susceptible varieties (S, SVS) in high-risk seasons such as 2022 resulted in substantial yield losses (up to 43%) and required greater fungicide inputs, reducing profitability.

Fungicide applications: effective in high-risk seasons but not always profitable

- ❖ Fungicide profitability varied depending on disease pressure and yield potential:
    - In high-disease years (e.g., 2022), fungicide applications increased gross margins by up to $459/ha in MRZ.
    - In low-disease years (e.g., 2021), fungicides resulted in financial losses, reinforcing the importance of seasonal disease monitoring.
    - In crops with <3 t/ha yield potential (low-rainfall regions and dry seasons), fungicide applications often failed to provide a positive return on investment.
- ❖ The most effective fungicide strategy was two foliar sprays at Z31 and Z39, but profitability was highly dependent on seasonal conditions and variety selection.

Stubble management: reduces early-season risk but not late-season disease

- ❖ Higher stubble loads were associated with increased early-season STB risk**.**
- ❖ Baling, burning, and cultivation significantly reduced early inoculum levels, but due to long-distance spore movement from neighbouring paddocks, stubble management had minimal impact on late-season disease.
- ❖ Economic benefits from stubble reduction were site-specific, as growers in high-risk areas benefited more from variety selection and fungicide strategies than from stubble management alone.

Crop rotation and sowing time: reducing disease risk and maximizing economic returns

- ❖ Rotating wheat with non-host crops (e.g., canola, pulses) effectively reduced inoculum loads, resulting in lower STB risk and improved profitability.
- ❖ A minimum one-year break between consecutive wheat crops is recommended to effectively reduce STB risk. However, since the stubble source is not a limiting factor, infection can still occur from spores dispersed from neighbouring fields during the season.
- ❖ Early-sown wheat (April) had up to 21% greater yield loss due to STB, while delaying sowing (May) reduced disease pressure and minimized fungicide dependence.

Industry impact and recommendations

When and how industry can benefit

This research provides practical, data-driven management strategies that can be immediately adopted to enhance disease control, reduce input costs, and maximize farm profitability:

- Variety resistance should be the primary strategy for STB management, with MSS or better-rated varieties offering significant cost savings and reduced reliance on fungicides.
- Fungicide applications should be targeted based on seasonal disease risk and yield potential:
    - For crops with >3 t/ha yield potential, two foliar sprays at Z31 and Z39 provided the highest economic returns in high-disease years.
    - For crops with <3 t/ha yield potential, fungicide use should be carefully evaluated, as returns were often minimal.
- Stubble management reduces early-season risk but does not eliminate late-season disease, so a combination of variety resistance and fungicide application remains essential in high-risk regions.
- Crop rotation with non-host crops reduces STB inoculum loads, improving wheat productivity.
- Delaying sowing to May in the MRZ and LRZ can significantly lower early STB pressure and fungicide reliance, leading to higher economic returns.

Who can benefit

- Growers in MRZ and LRZ looking to maximize economic returns through variety selection, strategic fungicide use, and crop rotation.
- Advisors and agronomists developing seasonally adaptive STB management plans tailored to regional disease risk and economic conditions.
- Breeders and seed companies working on improving STB resistance in wheat varieties to reduce the reliance on fungicides.

Conclusion

This project highlights the importance of IDM strategies that combine variety resistance, targeted fungicide use, stubble management, and crop rotation. Implementing these findings will enable growers to reduce unnecessary fungicide applications, optimize input costs, and sustain wheat productivity across MRZ and LRZ, particularly in high-rainfall seasons and variable-yield environments.

BACKGROUND

Septoria tritici blotch (STB) is a foliar fungal disease of wheat that can cause yield losses of up to 50% in susceptible varieties in conducive years. Annual surveillance and grower/adviser reports have identified STB as one of the most prevalent foliar diseases impacting on wheat productivity in the Southern Region. The increased incidence and distribution of the disease is largely due to current intensive farming practices, including no-till and stubble retention, which have led to inoculum build-up. Additionally, the STB pathogen has the potential to rapidly evolve with recent reports of fungicide resistance/insensitivity development in its populations both in Australia and internationally.

Through GRDC investments, extensive research has been conducted into the disease lifecycle and epidemiology in the high rainfall zone (HRZ). The knowledge gained from the investments have been used to develop integrated disease management (IDM) strategies for STB in the HRZ. While the epidemiology of STB is well-understood in the HRZ, information on the disease lifecycle and factors leading to epidemics in the medium and low rainfall zones (MRZ & LRZ) is limited. This fundamental information is required to allow for the development of IDM that is specific for the regions. Currently, growers in the MRZ and LRZ are using the IDM strategies that were developed for the HRZ by applying pre-emptive fungicides prophylactically to manage STB. Given the differences in the environmental conditions and farming systems, this practice is unlikely to be effective and economical.

To determine the best management practices suited to LRZ and MRZ for STB control, Agriculture Victoria in partnership with the South Australia Research and Development Institute (SARDI) – with supporting investment from GRDC – conducted 48 field experiments over four seasons during 2021-24. This report presents findings from this research, examining the epidemiological conditions required for STB development and its impacts in the MRZ and LRZ of Victoria and South Australia. The results will help refine disease management strategies and support informed decision-making for growers in these regions.

OUTPUT 1

Output	By June 2024, a technical report detailing the epidemiology of Septoria tritici blotch in wheat grown in conditions of the medium and low rainfall zones of the Southern Region.
Description	Research will determine • the impact of inoculum loads present in stubble, volunteers and other host plants, • stubble management, including pathogen survival periods, pathogen dispersal in standing and slashed stubble, • environmental conditions that lead to spore maturation and release • temperature, moisture, rainfall events impacting on the pathogenicity, • effect of plant growth stages on susceptibility, • pycnidia spore and ascospore development and latent periods.

OBJECTIVES

To study the epidemiology of Septoria tritici blotch in wheat grown in the medium and low rainfall zones of the Southern region.

METHODOLOGY

OVERVIEW

The epidemiology of septoria tritici blotch (STB) in the medium (MRZ) and low rainfall zones (LRZ) was analysed by examining the timing of inoculum release and its survival in relation to climatic conditions. Burkard spore traps were installed across different rainfall regions in both states over 4 seasons, establishing the relationship between spore release trends and prevailing weather conditions. Inoculum survival on stubble was monitored through a field experiment at Longerenong, MRZ, Victoria.

The seasonal risk of STB in the Southern region was assessed through 18 field experiments conducted over four years (2021–2024) across three locations in Victoria (LRZ, MRZ, and high rainfall zone (HRZ)) and two in South Australia (HRZ and MRZ).

Spore release from stubble

To investigate the seasonal conditions influencing spore release from stubble across HRZ, MRZ, and LRZ, six solar-powered Burkard spore traps were deployed—one in each of the HRZ, MRZ, and LRZ regions of Victoria and South Australia (Figure 1). Each trap was placed away from wheat paddocks and positioned above STB-infected stubble spread over a 2.5 m^2 area, secured with wire mesh. Every 36 days, spore-laden tapes from the traps were collected and analysed at SARDI using qPCR technology to identify and quantify DNA derived from spores. Spore release was measured every two days throughout the monitoring period from May to November.

Inoculum survival on stubble

A three-year field experiment was conducted at Longerenong, MRZ, Victoria, to assess STB inoculum survival in standing stubble compared to various stubble management strategies. In 2021, an area of stubble infected with STB was established by growing the susceptible wheat variety Scepter, which was inoculated with infected wheat stubble. The wheat was then harvested at maturity, leaving the stubble standing.

In April 2022, seven stubble management treatments were applied (see below) and STB inoculum levels (expressed as KDNA copies/g of sample) were measured using PREDICTA B technology and a Burkard spore liberator. For PREDICTA B, 500 g soil samples, including wheat stubble, were collected monthly from May to October using an Accucore sampler (150 mm deep and 15 mm diameter). Spore release was quantified using a Burkard spore liberator. Stubble samples from each plot was pre-conditioned at 100% humidity for 24 hours, submerged in water to trigger spore release, and placed into the liberator which trapped spores on microscope slides coated with Tangle-Trap®sticky glue. Both soil samples and spore-laden slides were sent to SARDI for *Zymoseptoria tritici* DNA quantification via qPCR. The qPCR data was natural log transformed [ln(*Z.tritici* +1)] to linearize relationships between dependent and independent variables.

In 2023, the susceptible wheat variety Razor CL Plus (SVS) was sown across all treatments. The effectiveness of each strategy was then assessed by quantifying inoculum levels using PREDICTA B and visually evaluating disease severity, followed by analysis using ANOVA in Genstat (23rd edition). Fisher's protected least significance of difference (l.s.d.) test at 5% significance level was then used to perform possible pairwise comparisons between means.

The following seven stubble management treatments were applied in 2022, with six replicates arranged in a completely randomized block design:

1. Standing stubble
2. Slash and leave stubble
3. Slash and bale stubble
4. Burn stubble
5. Cultivate
6. Lentil sown into standing stubble
7. Canola sown into standing stubble

In-crop risk from STB

Eighteen field experiments were conducted to assess the seasonal conditions that contribute to STB risk in wheat production across the Southern region. Annually from 2021 to 2023, one experiment was conducted in each of the LRZ, MRZ, and HRZ regions of Victoria, as well as the MRZ and HRZ regions of South Australia (Figure 1). In 2024, three additional experiments were conducted in the LRZ, MRZ, and HRZ regions of Victoria. At each site, the susceptible wheat variety Razor CL Plus (SVS), inoculated with STB-infected stubble, was grown and monitored every two weeks for disease progression by assessing the percentage of leaf area affected on the top four leaves.

Climate data

Meteorological data were obtained from iMetos stations (Pessl Instruments, supplied by ADAMA) set up in experiment fields to measure temperature, rainfall quantity, relative humidity (RH), and leaf wetness period. Data from local meteorological stations were used to supplement any missing or inconsistent data.

Statistical analysis

The statistical analysis for various experiments (Spore release from stubble, Inoculum survival on stubble and In-crop risk from STB) was conducted using linear mixed models (LMMs) to assess the variation in spore quantities and disease severity across different treatments and climatic conditions.

For the analysis of variation in spore quantities between different stubble management approaches, the model incorporated both fixed effects for treatment, sampling date, and their interaction, alongside random effects to account for block, range, and row variations. Spatial variation was modelled using the methodology outlined by Gilmour et al. (1997), and the significance of fixed effects was assessed with Conditional Wald tests.

For disease severity (In-crop risk from STB), the model included fixed effects for factors such as town, minimum temperature, relative humidity, rainfall, and number of rainy days, as well as interaction terms between town and each climatic variable. A nested random structure (Year/rainfall zone) was used to account for temporal and spatial dependencies in the data.

Restricted maximum likelihood (REML) estimation was used for parameter fitting, and model fit was evaluated through residual diagnostics and variance component examination. Both models were fitted using the ASReml-R package in R (Butler et al., 2017; R Core Team, 2023). Predictions of disease severity were generated to assess the influence of climatic variables, particularly RH, on disease progression across different locations, providing valuable insights for STB risk assessment and management strategies.

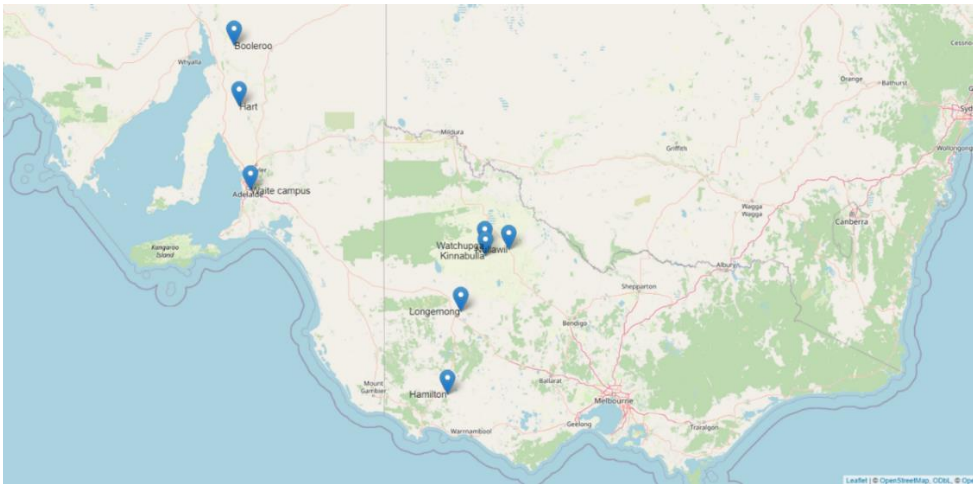

Figure 1: Burkard spore trap locations and experiment sites across South Australia and Victoria over four seasons (2021-2024).

LOCATION

The field experiments were conducted at the following locations, with details provided in the table below:

Site #	Latitude (decimal degrees)	Longitude (decimal degrees)	Nearest town
Experiment Site #1	-36.673004	142.2961	Longerenong, MRZ, Vic
Experiment Site #2*	-35.9833179	142.9145594	Birchip, LRZ, Vic
Experiment Site #3	-37.824019	142.0655	Hamilton, HRZ, Vic
Experiment Site #4	-33.7564	138.4391	Hart, MRZ, SA
Experiment Site #5	-32.8809	138.3505	Booleroo, LRZ, SA
Experiment Site #6	-34.9688	138.6339	Waite campus, HRZ, SA

**Experiment sites in the Low Rainfall Zone (LRZ) of Victoria varied each season (Watchupga – 2021; Nullawil – 2022; Kinnabulla – 2023; Nullawil – 2024) but were located near Birchip, which is used as a representative town for the region.*

If the research results are applicable to a specific GRDC region/s (e.g. North/South/West) or GRDC agro-ecological zone/s, indicate which in the table below:

Research	Benefiting GRDC region (select up to three)	Benefitting GRDC agro-ecological zone	
STB epidemiology	Southern Region Choose an item. Choose an item.	☐ Qld Central ☐ NSW NE/Qld SE ☒ NSW Vic Slopes ☐ Tas Grain ☒ SA Midnorth-Lower Yorke Eyre ☐ WA Northern ☐ WA Eastern ☐ WA Mallee	☐ NSW Central ☐ NSW NW/Qld SW ☒ Vic High Rainfall ☒ SA Vic Mallee ☒ SA Vic Bordertown-Wimmera ☐ WA Central ☐ WA Sandplain

RESULTS

Seasonal rainfall

Total and the frequency of growing season rainfall (April – November) varied between seasons and locations (Table 1). The year 2022 was the wettest year across all locations, with the highest total rainfall and most rainy days. In contrast, 2024 was the driest season, with a significant drop in rainfall, particularly in medium (MRZ) and low rainfall zones (LRZ) in Victoria.

High rainfall zones (HRZ), such as Hamilton and Waite, consistently recorded the highest total rainfall and the most rainy days across all seasons. Meanwhile, rainfall in MRZ and LRZ was more variable. Locations like Longerenong and Hart (MRZ) experienced considerable fluctuations, with 2022 being significantly wetter than other seasons. A similar trend was observed in LRZ locations such as Birchip and Booleroo, where rainfall peaked in 2022 but declined in subsequent years.

Rainy days did not always correlate with total rainfall. For example, Hamilton in 2024 recorded a similar number of rainy days as in previous years but had lower total rainfall, suggesting lighter or less intense rain events.

Table 1: Summary of seasonal conditions (total rainfall and mean number of rainy days) at six experiment sites in the Southern region across four seasons (2021 – 2024)**.**

Location	Total growing season rainfall (mm) and mean number of rainy days[#] (April to November)							
	2021		2022		2023		2024	
	Total rainfall (mm)	Mean number of rainy days	Total rainfall (mm)	Mean number of rainy days	Total rainfall (mm)	Mean number of rainy days	Total rainfall (mm)	Mean number of rainy days
Hamilton (HRZ, Vic)	444	18	636	20	436	18	387	19
Longerenong (MRZ, Vic)	296	14	547	16	331	11	184	10
Birchip (LRZ, Vic)	264	11	427	19	219	7	260	11
Waite (HRZ, Vic)	524	14	686	18	559	14	-	-
Hart (MRZ, Vic)	350	14	417	15	281	12	-	-
Booleroo (LRZ, Vic)	314	13	381	13	221	10	-	-

[#]A rainy day is defined as a day with at least 0.1 mm rainfall or more rainfall

Spore release from stubble

Spore release patterns varied by location and year, with notable fluctuations observed monthly and across seasons (Figures 2 and 3). Overall, spore release was generally higher during winter and declined noticeably in spring, except for late season surges detected at Hart (MRZ) in 2021 and at both Hart (MRZ) and Waite (HRZ) in 2022. Higher levels of spore release during winter period corresponds with the onset of disease epidemics in wheat grown in the Southern region.

In 2021, spore release peaked across all three rainfall regions in Vic, with an average frequency of 93% (defined as the percentage of days with inoculum detection). Similarly, in SA, spore release in 2023 reached higher levels at Hart (MRZ), with a 95% detection frequency, but such levels were not observed in other years. Surprisingly, 2022 measured the lowest spore release, with an average detection frequency of only 53% across all sites, despite being the wettest season compared to 2021 and 2023. Spore release was also lowest in high rainfall regions, such as Hamilton (Victoria) and Waite (SA), which are typically associated with greater in-crop disease severity. Overall, Booleroo (LRZ) measured lowest spore quantities with an average detection frequency of just 39% over the three years. This trend aligns with the lower disease levels commonly observed in the region.

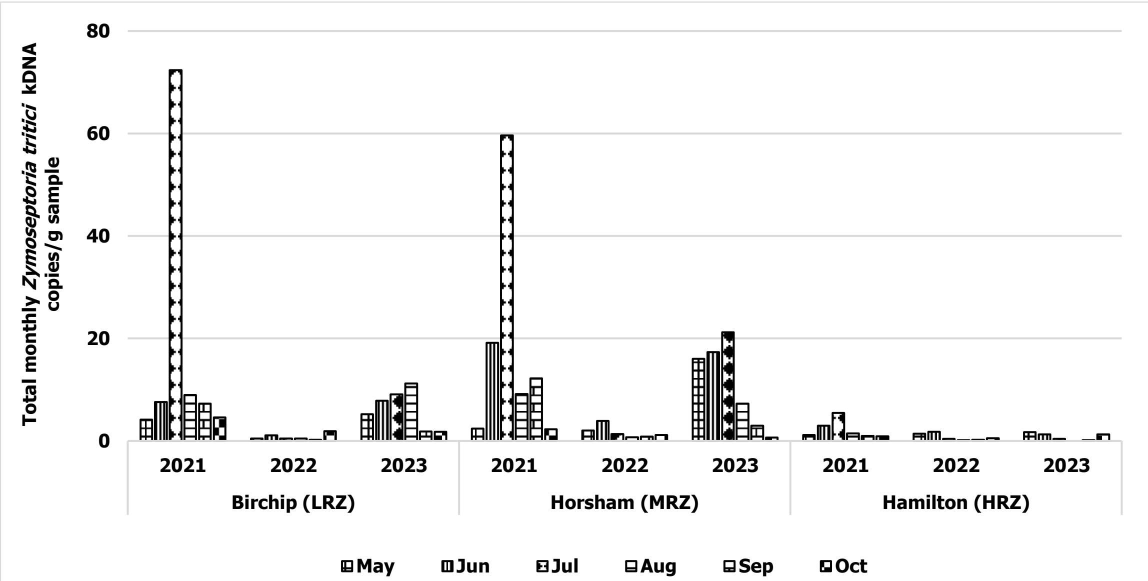

Figure 2: Abundance of *Zymoseptoria tritici* spores from May to October over three years (2021 – 2023) across three different rainfall zones in Victoria.

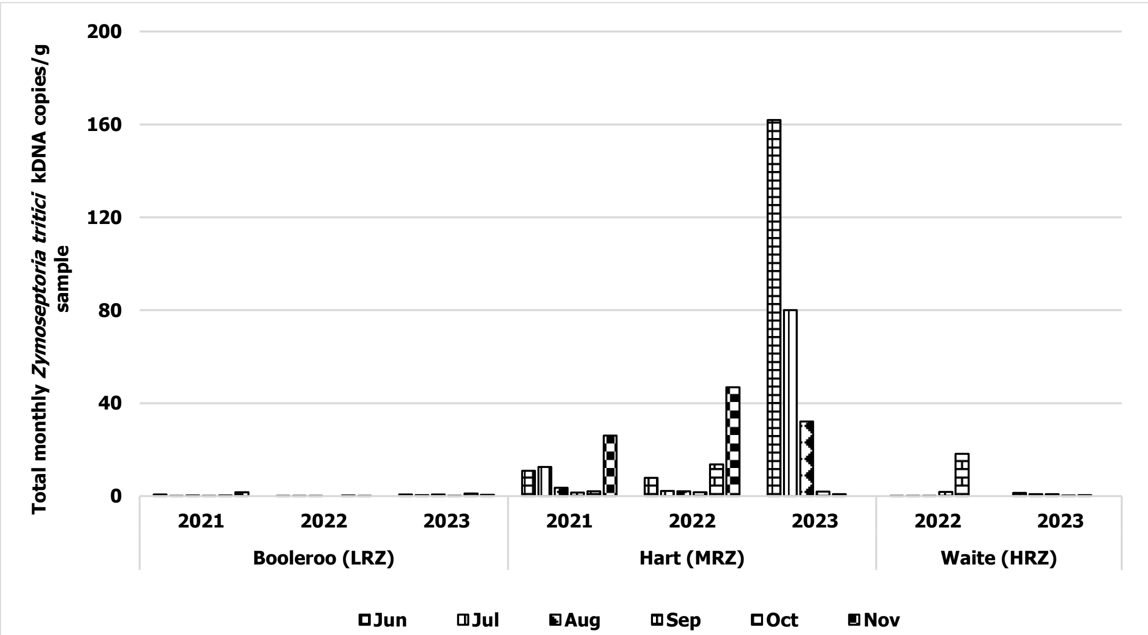

Figure 3: Abundance of *Zymoseptoria tritici* spores from June to November over three years (2021-2023) across three different rainfall zones in South Australia.

Linear mixed models (LMMs) were used to examine the relationship between spore release trends and climatic conditions. In brief, the results showed at most sites, warmer minimum temperatures (near 10°C) and lower maximum temperatures (near 15°C) dramatically increase spore counts whereas rainfall showed a strong but negative association with the inoculum discharge.

Inoculum survival on stubble

Susceptible wheat varieties grown in 2021 accumulated a substantial inoculum load, with *Zymoseptoria tritici* DNA levels averaging 1,759 KDNA copies per gram of sample following harvest. However, as the 2022 season progressed, *Z. tritici* DNA levels declined, mirroring with spore release trends observed in Burkard spore traps across the Southern region over three seasons (2021–2023).

Stubble management strategies played a crucial role in reducing inoculum loads, particularly during winter, leading to lower spore release compared to standing stubble (Figures 4 and 5). However, the effectiveness of these strategies depended on the method used. Stubble removal techniques such as burning, baling, or cultivation significantly reduced the inoculum source, leading to lower spore release and reduced in-crop disease risk. In contrast, leaving stubble on the ground maintained higher inoculum levels, promoting greater spore dispersal and increasing disease pressure.

In winter 2023, *Z. tritici* DNA levels remained high, averaging 1,950 KDNA copies/g in June and 448 KDNA copies/g in August from the same plots. No significant differences were observed between stubble management treatments for *Z. tritici* DNA levels during this period (data not shown).

The exact reasons for the increased inoculum levels remain unclear, but above-average rainfall likely played a major role. The site received 178 mm of rainfall in winter 2023 and 283 mm in spring 2022, creating favourable conditions for the rapid multiplication of *Z. tritici* colonies within the stubble, leading to higher inoculum loads.

The impact of higher inoculum levels was evident in elevated in-crop STB severity, particularly when the subsequently sown Razor CL Plus (SVS) crop was assessed early in the season (Table 2). Although stubble management treatments significantly influenced STB severity, the differences were minor, making it difficult to determine which strategy was the most effective in reducing disease. Additionally, no significant grain yield improvements were observed across treatments, likely due to widespread disease pressure.

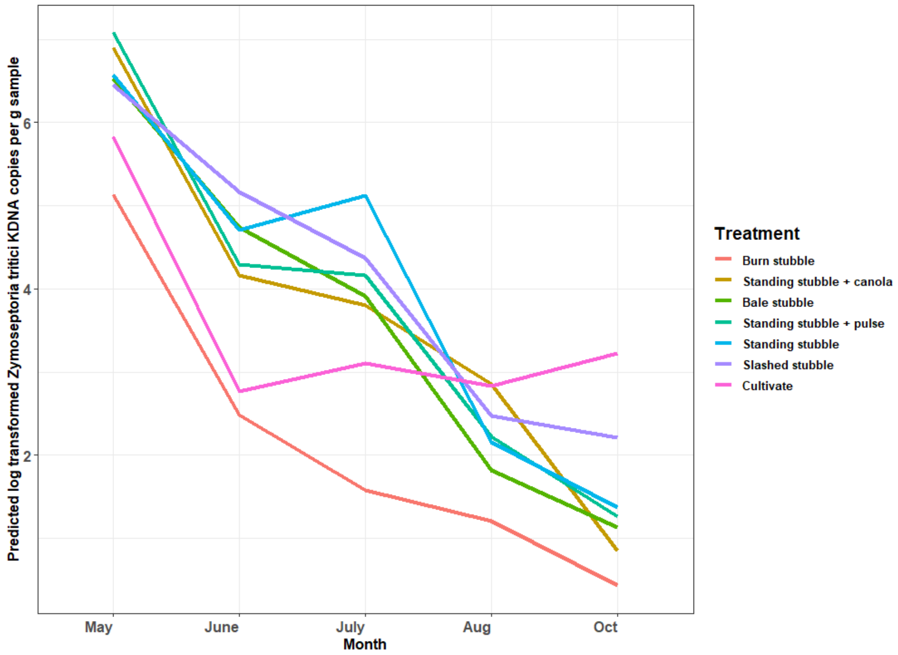

Figure 4: Effect of different stubble management strategies over *Zymoseptoria tritici* inoculum on stubble during 2022 at Longerenong (MRZ), Victoria. Predicted values are generated using a linear mixed model in ASRemlR with time and treatment interaction as fixed effects and experimental blocking structure (range and row) as the random effects.

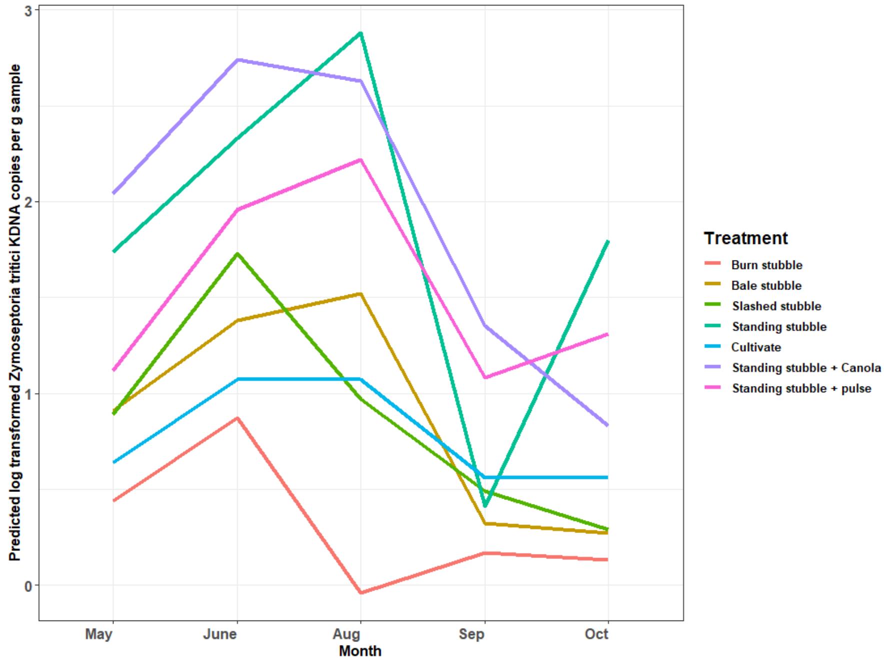

Figure 5: Effect of different stubble management strategies over *Zymoseptoria tritici* spore dispersal during 2022 at Longerenong (MRZ), Victoria. Predicted values are generated using a linear mixed model in ASRemlR with time and treatment interaction as fixed effects and experimental blocking structure (range and row) as the random effects.

Table 2: STB severity (%) and grain yield in wheat variety Razor CL Plus (SVS) in 2023 in response to different stubble application treatments applied during 2022 at Longerenong, Victoria.

Treatments	Disease severity (% leaf area affected)#			Grain yield (t/ha)
	6th July Z28	26th July Z33	5th Sep Z55	
Bale stubble	2[ab]	22[ab]	18[ab]	3.46
Burn stubble	1[a]	21[ab]	16[a]	3.53
Cultivate	2[ab]	19[a]	21[c]	3.48
Slashed stubble	2[bc]	24[bc]	18[ab]	3.52
Standing stubble	3[c]	26[c]	20[bc]	3.61
Standing stubble + Canola	2[abc]	20[ab]	17[ab]	3.66
Standing stubble + pulse	2[ab]	21[ab]	19[abc]	3.70
P	0.044	0.027	0.020	0.866
LSD (0.05)	0.9	4.26	2.9	*ns*

#Within a column, means with one letter in common are not significantly different at 0.05.

In-crop risk from STB

Septoria tritici blotch (STB) progression varied across years and locations, reflecting the influence of environmental conditions (Figures 6 and 7).

In Victoria, STB severity followed a consistent trend, with higher disease incidence observed in the HRZ compared to the MRZ and LRZ (Figure 6). Across all years, disease severity increased from early crop stages (May–June) and peaked around September–October, particularly in HRZ region and in MRZ during 2022 and 2023. Notably, the disease progression in LRZ consistently exhibited lower disease severity, likely due to drier conditions limiting pathogen development and spread.

Disease severity was greatest during 2022 and 2023 compared to other seasons. The 2022 season, one of the wettest in Victoria, received excessive spring rainfall that facilitated STB progression to the upper canopy, causing high disease severity with significant impacts on grain yield and quality. Despite below average spring rainfall in 2023, disease severity remained high, primarily due to the substantial inoculum load from retained stubble. The higher rainfall during 2022 resulted in increased biomass in wheat crops leaving greater stubble amounts on ground after harvest for *Z. tritici* to colonize.

A similar trend was observed in South Australia, where STB severity was generally higher in HRZ compared to MRZ (Figure 7). The disease showed a sharp increase from July onward, reaching peak severity in September–October. The 2021 and 2022 seasons exhibited the most severe disease progression in HRZ, with nearly 100% of the leaf area affected by the end of the season. In contrast, MRZ showed a relatively slower disease buildup, with a more fluctuating pattern, possibly influenced by variable rainfall conditions.

A regression analysis between environmental variables and disease severity showed relative humidity (RH), rainfall, and location were significant predictors of disease severity (Table 3). However, temperature showed a non-significant effect (p=0.84189), suggesting that its effect may be dependent on other factors. Rainfall distribution (number of rainy days in a month) had a weaker but still significant impact on disease severity (p=0.023).

The interaction effect between town and RH (p=0.012) was significant and negative, indicating that the effect of RH on disease severity varied by location and, in most cases, higher humidity was linked to reduced disease levels (Figure 8). Similarly, the interaction between town and rainfall was marginally significant (p=0.075), suggesting that rainfall's influence on disease progression might depend on regional factors such as microclimatic conditions. In contrast, the interaction between town and temperature was not significant (p=0.979), implying that the effect of temperature was relatively uniform across locations.

These findings highlight the critical role of RH and rainfall as key environmental drivers of disease severity, with their effects differing across locations. The significant negative location and RH interaction suggests that increased humidity may reduce disease severity, potentially due to changes in microclimate, pathogen dynamics and host response. This underscores the need for region specific disease management strategies that consider both environmental and agronomic factors.

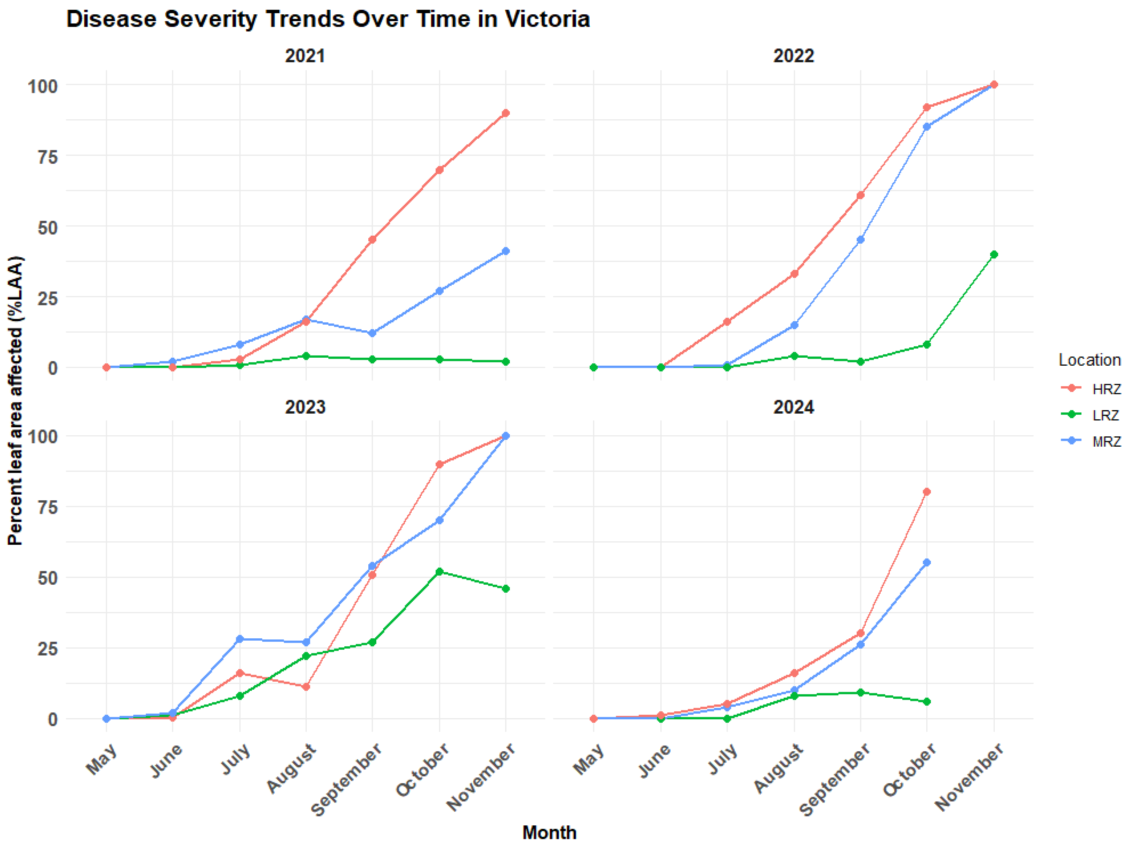

Figure 6: Septoria tritici blotch severity (% leaf area affected) trends over time in the highly susceptible variety Razor CL Plus (SVS) across different rainfall regions in Victoria over four years (2021-2024).

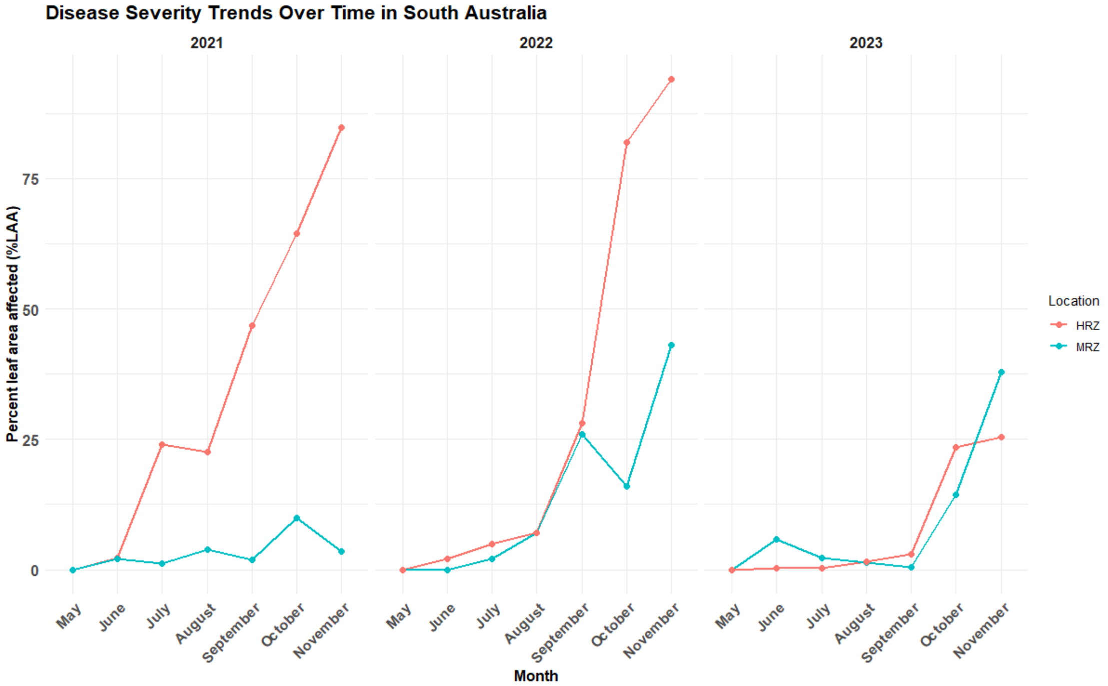

Figure 7: Septoria tritici blotch severity (% leaf area affected) trends over time in the highly susceptible variety Razor CL Plus (SVS) across different rainfall regions in South Australia over three years (2021-2023).

Table 3: Wald test results for environmental variables associated with disease severity.

Effect	Df	Wald (Inclusive)	Pr (Chisq)	Wald (Conditional)	Pr (Chisq)
Fixed Effects					
Intercept	1	31.770	<0.001	18.670	<0.001
Location	5	20.310	0.001	45.500	<0.001
Minimum Temperature	1	46.120	<0.001	0.040	0.841
Relative Humidity (RH)	1	17.850	<0.001	33.230	<0.001
Rainfall	1	11.580	0.00067	11.570	0.00067
Number of Rainy Days	1	1.313	0.252	5.147	0.023
Interaction Effects					
Location × Minimum Temperature	5	18.500	0.002	0.753	0.980
Location × RH	5	14.395	0.013	14.595	0.012
Location × Rainfall	5	10.270	0.068	9.995	0.075
Location × Number of Rainy Days	5	7.610	0.179	7.610	0.179

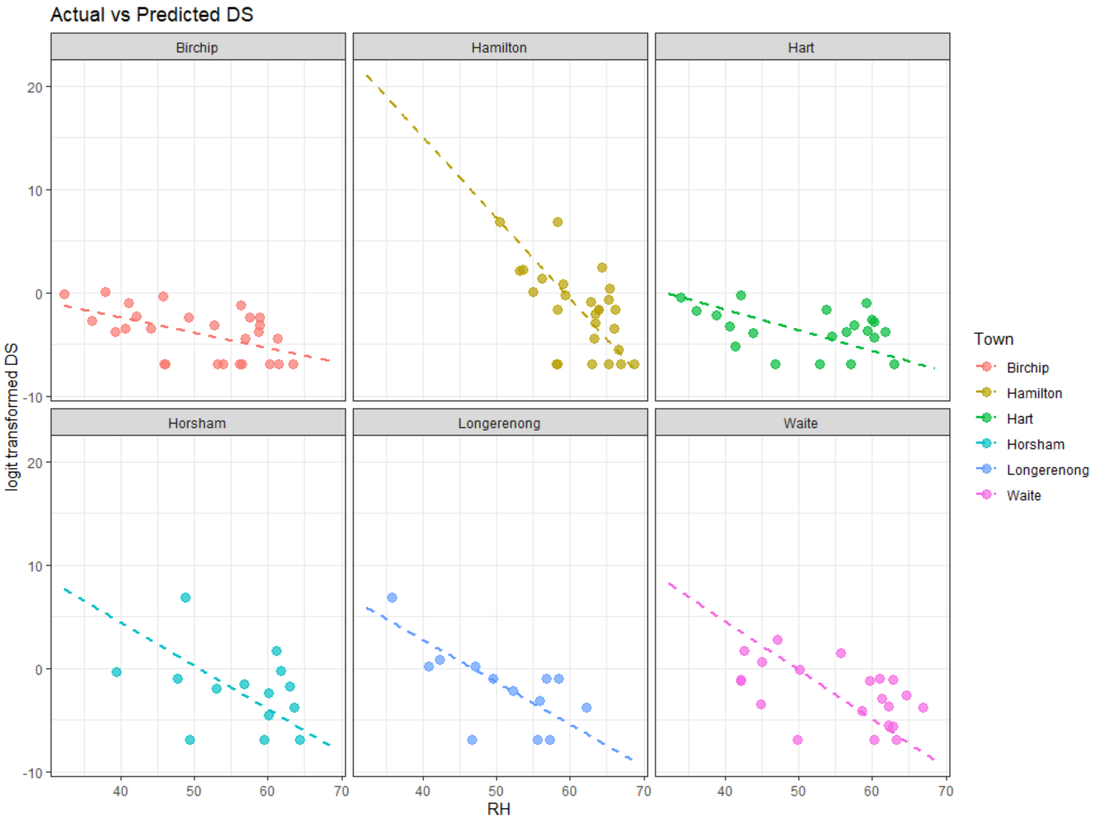

Figure 8: The relationship between logit-transformed disease severity measured in highly susceptible variety Razor CL Plus (SVS) and relative humidity between May and November over four seasons (2021-2024) across different locations in Victoria and South Australia. Dashed line represents the regression equation. Predicted values are generated using a multiple linear regression model in ASRemlR with environmental variables as fixed effects and year and location as random effects.

OUTPUT 2

Output	**By June 2024, practical and cost-effective integrated disease management strategies for STB in the LRZ and MRZ will be developed and made available to growers and advisers in the Southern Region.**
Description	STB IDM strategies will be developed for the Southern Region MRZ and LRZ. Experiments will be developed in consideration of current regional practices. STB IDM strategies will include as a minimum: • Fungicide application; timing, different mode of actions and with or without seed dressing • Stubble load management • STB resistant/tolerant varieties • Sowing time • Crop and variety rotations

OBJECTIVES

To assess the impact of Septoria tritici blotch (STB) in wheat and identify effective integrated disease management (IDM) strategies for its control in the MRZ and LRZ of the Southern region.

METHODOLOGY

OVERVIEW

A total of 28 field experiments were conducted between 2021 and 2024 to assess the effects of host plant resistance, fungicide application timing, inoculum loads, sowing time, and crop and variety rotations on STB in Wheat in the MRZ and LRZ of the Southern region (Table 4). These experiments also examined how location and seasonal variation influence the incidence and severity of STB.

To minimize the risk of soil-borne diseases, all experiment sites included at least a one-year break from cereals. Each experiment featured a minimum plot size of 20 m^2, with all experiment inputs managed using good farming practices. This ensured the experiments were influenced primarily by STB pressure and not by other factors.

Table 4: Overview of experiment sites and strategies investigated for Septoria tritici blotch (STB) management in the Southern region (2021 – 24).

Location	Rainfall zone	State	Harvest years	IDM strategies investigated				
				Variety selection	Fungicide timing	Inoculum loads	Crop and variety rotation	Sowing time
Hamilton	HRZ	Vic	2021	×	×	×	×	×
Hamilton	HRZ	Vic	2022	×	×	×	×	×
Hamilton	HRZ	Vic	2023	×	×	×	×	×
Hamilton	HRZ	Vic	2023	×	×	×	×	×
Waite	HRZ	SA	2021	×	×	×	×	×
Waite	HRZ	SA	2022	×	×	×	×	×
Waite	HRZ	SA	2023	×	×	×	×	×
Wallup	MRZ	Vic	2022	×	×	✓	×	×
Longerenong	MRZ	Vic	2021	✓	✓	×	✓	×
Longerenong	MRZ	Vic	2022	✓	✓	×	✓	×
Longerenong	MRZ	Vic	2023	✓	✓	✓	✓	×
Longerenong	MRZ	Vic	2024	×	✓	×	×	✓
Hart	MRZ	SA	2021	✓	✓	×	×	×
Hart	MRZ	SA	2022	✓	✓	×	×	×
Hart	MRZ	SA	2023	✓	✓	×	×	×
Watchupga	LRZ	Vic	2021	✓	✓	×	×	×
Nullawil	LRZ	Vic	2022	✓	✓	×	×	×
Kinnabulla	LRZ	Vic	2023	✓	✓	×	×	×
Nullawil	LRZ	Vic	2024	×	×	×	×	×
Booleroo	LRZ	SA	2021	✓	×	×	×	×
Booleroo	LRZ	SA	2022	✓	×	×	×	×
Booleroo	LRZ	SA	2023	✓	×	×	×	×

Variety selection

Between 2021 and 2023, twelve field experiments were conducted to evaluate yield and quality losses in wheat cultivars with varying resistance and susceptibility to STB. One experiment per year was carried out in the MRZ and LRZ regions of Victoria and South Australia, totalling three years of experiments in each region.

Each experiment included six commercial wheat varieties under two treatments:

1. Disease - No disease control with 1 Kg STB infected wheat stubble/plot or inoculated with spore inoculum at a concentration of > 10,000 spores/ml.
2. Fungicide – Seed + foliar applied fungicides at Z31 and Z39

The experiments were arranged in a split-plot design, with treatments assigned as the main plots and wheat varieties as subplots. Six replications were conducted for each treatment to ensure statistical robustness.

STB severity was visually assessed multiple times during the growing season. Plots were then harvested for grain yield, and sub-samples of the grain were tested for quality parameters, including protein percentage, screenings (percentage of grain <2.2 mm width), retention (percentage of grain >2.5 mm width), and grain weight.

Varieties:

Variety	Rating[A]
Sunlamb[#]	Moderately Resistant (MR)
Orion[#]	Moderately Resistant to Moderately Susceptible (MRMS)
LRPB Lancer	Moderately Susceptible (MS)
Hammer CL Plus	Moderately Susceptible to Susceptible (MSS)
Scepter	Susceptible (S)
Calibre	Susceptible (S)
Razor CL Plus	Susceptible to Very Susceptible (SVS)
LRPB Impala	Susceptible to Very Susceptible (SVS)

[#]Sunlamb and Orion were used only in 2021 and were replaced by Caliber and Razor CL Plus in 2022 and 2023.
[A]Hollaway, McLean and Dadu (2023) Cereal Disease Guide 2023.

Chemical applications*:

Fungicide application timing	*Product*	*Active ingredient (gai/L)[#]*	*Rate*
Seed	Jockey Stayer®	Fluquinconazole 167g/L	300 mL/100 Kg seed
Foliar at Z31	Soprano®	Epoxiconazole 500 g/L	125 mL/ha
Foliar at Z39	Elatus™ Ace®	Benzovindiflupyr 40g/L + Propiconazole 250g/L	500 mL/ha

*[#] gai = grams active ingredient *Tebuconazole applied at 145mL/ha to all plots and sites in Victoria to selectively control stripe rust.*

Fungicide timing

Over four years (2021–2024), ten experiments were conducted to determine the optimal fungicide timing for controlling STB. Between 2021 and 2023, one experiment each was conducted in the MRZ and LRZ of Victoria, as well as the MRZ of South Australia. An additional experiment was conducted at Longerenong, MRZ, Victoria, in 2024.

Each experiment included six fungicide treatments applied to the susceptible wheat variety Scepter. The treatments comprised single or combined applications of seed and foliar fungicides, a minimum disease control treatment, and an untreated control (UTC) (Table 5). For the first three seasons (2021–2023), foliar fungicide applications were timed to target conventional growth stages, specifically stem elongation (Z31) and flag leaf emergence (Z39), to maximize STB control on yield-contributing flag leaves. In 2024, however, foliar fungicides were applied based on symptomology observed in the canopy to determine the optimal timing for STB control (Table 6).

All experiments followed a completely randomized block design with six replicates per treatment. Disease severity was visually assessed, and the resulting data were analysed using the same methodology as the variety selection experiments.

Table 5: Treatment outline and details of fungicides used in the timing experiments (2021 – 2023) in the Southern region.

Treatments/Fungicide application timing*	Product	Fungicide active (gai/L)[#]	Rate
Seed treatment	Jockey Stayer®	Fluquinconazole 167g/L	300 mL/100kg seed
Foliar at Z31	Soprano® at Z31	Epoxiconazole 500g/L	125 mL/ha
Foliar at Z31 + Z39	Soprano® at Z31 and Elatus™ Ace® at Z39[a]	Epoxiconazole 500g/L and Benzovindiflupyr 40g/L + Propiconazole 250g/L	125 mL/ha + 500 mL/ha
Foliar at Z39	Elatus™ Ace® at Z39	Benzovindiflupyr 40g/L + Propiconazole 250g/L	500 mL/ha
Seed + Foliar at Z31 and Z39 (Minimum disease)	Jockey Stayer® + Soprano® at Z31 and Elatus™ Ace® at Z39	Fluquinconazole 167g/L + Epoxiconazole 125g/L and Benzovindiflupyr 40g/L + Propiconazole 250g/L	300 mL/100 kg seed + 125 mL/ha and 500 mL/ha
Untreated control (Maximum disease)	No disease control with STB infected wheat stubble and nil fungicide in season		

*[#] gai = grams active ingredient. *Tebuconazole applied at 145ml/ha to all plots and sites in Victoria to selectively control stripe rust.*

Table 6: Treatment outline and details of fungicides used in the timing experiment in 2024 at Longerenong, MRZ, Victoria.

Treatments/Fungicide application timing*	Product	Active ingredient (gai/L)[#]	Rate
Symptomless	Elatus™ Ace®	Benzovindiflupyr 40g/L + Propiconazole 250g/L	500mL/ha
First symptoms	Maxentis®	Azoxystrobin 133g/L + Prothioconazole 100g/L	600mL/ha
Secondary symptoms	Maxentis®	Azoxystrobin 133g/L + Prothioconazole 100g/L	600mL/ha

Symptomless + Secondary symptoms	Elatus™ Ace® + Maxentis®	Benzovindiflupyr 40g/L + Propiconazole 250g/L + Azoxystrobin 133g/L + Prothioconazole 100g/L	500 + 600mL/ha
Minimum disease	Jockey Stayer® + Elatus™ Ace® at Z31 + Maxentis® at Z39 and Soprano® at Z55	Fluquinconazole 167g/L + Benzovindiflupyr 40g/L + Propiconazole 250g/L + Azoxystrobin 133g/L + Prothioconazole 100g/L and Epoxiconazole 125g/L	300mL/100kg seed + 500 + 600 and 125mL/ha
Maximum disease	No disease control with STB infected wheat stubble and nil fungicide in season		

*# gai = grams active ingredient. * Triadimefon applied at 300ml/ha to all plots to selectively control stripe rust.*

Inoculum loads

Two field experiments were conducted in the MRZ at Longerenong, Victoria, one in 2022 and another in 2023, to assess the impact of increasing inoculum levels on disease severity and grain yield. Six treatments, including varying inoculum levels and a control with minimal disease, were applied to the highly susceptible wheat variety LRPB Impala (SVS) (Table 7). To minimize inter-plot disease spread, treatments were separated by double buffers of a non-host crop (barley). Disease severity was visually assessed throughout the season, and plots were harvested to measure grain yield.

Table 7: Impact of inoculum load on in crop disease risk from STB - treatment outline.

Treatments/Stubble load (Kg/plot)	Product	Fungicide active (gai/L)#	Rate
Zero stubble (0)			
Quarter kilo gram stubble (1/4 Kg)			
Half kilo gram stubble (1/2 Kg)			
One Kilogram stubble (1 Kg)			
Two-kilogram stubble (2 Kg)			
Minimum disease (no stubble applied)	Jockey stayer® + Soprano® at Z31 and Elatus ace® at Z39	Fluquinconazole 167g/L + Epoxiconazole 125 g/L and Benzovindiflupyr 40g/L + Propiconazole 250 g/L	300 mL/100 Kg seed + 125 and 500 mL/ha

 # gai = grams active ingredient

Crop and variety rotation

Crop rotation

The impact of crop and variety rotations including the effect of different intensity of wheat and non-wheat crops on inoculum levels and associated STB risk was studied through Agriculture Victoria's long term Sustainable Cropping Rotations in Mediterranean Environments (SCRIME) field experiment.

The long-term rotation experiment, SCRIME (Figure 9) was established by Agriculture Victoria in 1998 at Longerenong, Victoria to examine the effect of fundamental changes in crop types / rotation and tillage on crop productivity and grain quality in cropping systems of medium rainfall environments of Southern Australia. The experiment comprised of 9 treatments (rotations/tillage practice) arranged in a spatially replicated design with 3 replicates (Table 8). Each plot was 14 m wide by 36 m long.

Table 8: Treatment outline of SCRIME experiment at Longerenong (MRZ), Victoria

Treatments	**phases 1**	**phases 2**	**phases 3**	**phases 4**	**phases 5**	**phases 6**
1	wheat	wheat	wheat			
3	pulse	wheat	barley			
4	green manure	wheat	barley			
6	canola	wheat	pulse (pea)	*(reduced till)*		
7	canola	wheat	pulse (pea)	*(conventional till)*		
8	lucerne	lucerne	lucerne/fallow	canola	wheat	pulse (pea)
9	green manure	canola	pulse (pea)	medic	wheat	barley
11	canola	wheat	pulse (pea)	*(zero tillage)*		
12	fallow	wheat	pulse (pea)			

To measure the levels of inoculum, five treatments (with three different rotation options and stubble management practices; Table 20) were sampled annually pre-sowing in April by collecting 20 soil cores per plot. These samples, including stubble debris from three replicates, were analysed by SARDI using qPCR (PREDICTA B) to quantify STB inoculum.

Variety rotation

To determine the impact of variety selection on inoculum loads, disease treatment for all the varieties within variety selection experiments at Longerenong (MRZ), Hart (MRZ) and Booleroo (LRZ) were sampled for PREDICTA B post-harvest during April 2022 and 2023.

Figure 9: SCRIME experiment view at Longerenong, Victoria during 2021 (Image courtesy: Roger Perris, Agriculture Victoria).

Sowing time

During 2024, two field experiments with two time of sowings, one sown on 24 April (early) and one sown on 21 May (late), were compared in the MRZ at Longerenong, Victoria. Each experiment included three wheat varieties in six replicates and two treatments (inoculated with +/- disease) sown in a randomised block design (Table 9). Both experiments were assessed for disease severity, grain yield and quality.

Table 9: Sowing time experiment treatment outline for both early and late sown experiments*.

Variety (STB resistance rating)	Treatment[A]	Product	Active ingredient (gai/L)[#]	Rate
Hammer CL Plus (MSS)	Fungicide	Jockey Stayer® + Elatus™ Ace® at Z31 + Maxentis® at Z39 and Soprano® at Z55	Fluquinconazole 167g/L + Benzovindiflupyr 40g/L + Propiconazole 250g/L + Azoxystrobin 133g/L + Prothioconazole 100g/L and Epoxiconazole 125g/L	300mL/100kg seed + 500 + 600 and 125mL/ha
Scepter (S)	Disease	No disease control with STB infected wheat stubble and nil fungicide in season		
Razor CL Plus (SVS)				

*[#] gai = grams active ingredient *Triadimefon applied at 300mL/ha to all plots to selectively control stripe rust. Agriculture Victoria. [A]Both treatments, Fungicide and Disease were applied to each of the three wheat varieties.*

Statistical analysis

The statistical analysis for the variety selection and fungicide timing experiments was conducted using linear mixed models (LMMs) to assess variations in disease severity, variety performance, and fungicide treatments across different seasons and locations. Restricted maximum likelihood (REML) estimation was used for parameter fitting, and model fit was evaluated through residual diagnostics and variance component examination. All models were fitted using ASReml-R (Butler et al., 2017; R Core Team, 2023).

For the variety selection analysis, a LMM was used to examine disease severity at multiple occasions, grain yield and quality incorporating both fixed and random effects. Fixed effects included variety, treatment, and their interaction, allowing for an assessment of treatment efficacy across different varieties. Random effects accounted for block and main plot variations, ensuring that spatial and environmental influences were considered in the analysis. To model spatial correlation within the experimental layout, a first-order autoregressive process (AR1) in the row direction was applied. Conditional Wald tests were used to determine the significance of fixed terms.

For the fungicide timing analysis, another LMM was used to analyse disease severity, grain yield and quality in response to fungicide application timing. The model included treatment as a fixed effect, while random effects accounted for block and row variations to capture experimental variability. A first-order autoregressive process (AR1) in the row direction was also applied to account for spatial correlation between neighbouring plots.

Model assumptions, including normality and homoscedasticity, were assessed through diagnostic tests, and data transformations were applied if necessary. For possible pairwise comparisons between treatment means, Tukey's tests at 5% significance level were used.

The statistical analysis for the influence of inoculum loads on STB risk, crop and variety rotation, and sowing time was conducted using generalized analysis of variance (ANOVA) in Genstat (23rd Edition). This approach assessed the effects of various treatments on the response variable, incorporating both fixed and random effects to provide a robust evaluation of treatment differences while accounting for sources of variation across experimental designs. Fixed effects included the primary treatment factors and their interactions, while random effects were included to capture variability due to the experimental design, such as block and spatial effects.

The analysis assumed that residuals followed a normal distribution with constant variance (homoscedasticity), and assumptions were verified using Levene's test and residual plots. If necessary, data transformations (such as logarithmic or square-root transformations) were applied to meet the assumptions. F-tests were used to evaluate the significance of the main effects and interactions. For multiple comparisons between treatments, the Least Significant Difference (LSD) test was used to control for experimental error and ensure statistical reliability, providing insights into how inoculum loads, crop rotations, and sowing times influenced STB risk across the experimental conditions.

LOCATION

The field experiments were conducted at the following locations, with details provided in the table below:

Site #	Latitude (decimal degrees)	Longitude (decimal degrees)	Nearest town
Experimental Site #1	-36.673004	142.2961	Longerenong, MRZ, Vic
Experimental Site #2*	-35.9833179	142.9145594	Birchip, LRZ, Vic
Experimental Site #3	-37.824019	142.0655	Hamilton, HRZ, Vic
Experimental Site #4	-33.7564	138.4391	Hart, MRZ, SA
Experimental Site #5	-32.8809	138.3505	Booleroo, LRZ, SA
Experimental Site #6	-34.9688	138.6339	Waite campus, HRZ, SA

**Experimental sites in the Low Rainfall Zone (LRZ) of Victoria varied each season (Watchupga – 2021; Nullawil – 2022; Kinnabulla – 2023; Nullawil – 2024) but were located near Birchip, which is used as a representative town for the region.*

If the research results are applicable to a specific GRDC region/s (e.g. North/South/West) or GRDC agro-ecological zone/s, indicate which in the table below:

Research	Benefiting GRDC region (select up to three)	Benefitting GRDC agro-ecological zone	
Variety selection Fungicide timing Fungicide product comparison Inoculum loads Crop and Variety rotation Sowing time	Choose an item. Southern Region Northern Region	☐ Qld Central ☐ NSW NE/Qld SE ☒ NSW Vic Slopes ☐ Tas Grain ☒ SA Midnorth-Lower Yorke Eyre ☐ WA Northern ☐ WA Eastern ☐ WA Mallee	☐ NSW Central ☐ NSW NW/Qld SW ☐ Vic High Rainfall ☒ SA Vic Mallee ☒ SA Vic Bordertown-Wimmera ☐ WA Central ☐ WA Sandplain

RESULTS

Variety selection

Septoria tritici blotch (STB) resulted in yield losses of 8–43% or 0.26–1.73 t/ha in susceptible wheat varieties grown in the Southern region (Table 11 and 12). Additionally, STB infection led to notable reductions in grain quality, including increased screenings, reduced retentions, and lower seed weight. The severity of STB, along with its impact on yield and quality, varied depending on the season, location, and varietal resistance. The most significant losses occurred in 2022, with a 43% yield reduction driven by extreme disease pressure across all sites, affecting four of five locations. The exception was Birchip (LRZ, Vic), where a stripe rust outbreak prevented STB from causing yield losses (data not shown). In 2023, comparable disease pressure led to yield losses of 5–28% at both Victorian sites, but no losses were recorded in South Australia despite greater disease severity. Conversely, 2021 experienced the lowest disease pressure, with only an 8% yield loss observed at one of five locations, Longerenong (MRZ, Vic).

Disease development and yield loss also related to varietal resistance, demonstrating the benefits of avoiding highly susceptible cultivars in the management of STB (Figures 10 - 13). The most severely affected varieties, including Hammer CL Plus (MSS), Calibre (S), Scepter (S), LRPB Impala (SVS), and Razor CL Plus (SVS), experienced the greatest impact across most locations and seasons. Notably, Razor CL Plus suffered the highest yield loss (43%) in 2022 at Longerenong, Vic, while Scepter incurred losses ranging between 8-36% due to STB across all three seasons at one location (Longerenong, Vic) and in one season (2022) at four other sites. Similarly, Hammer CL Plus, Calibre, and LRPB Impala recorded losses in two (2022 and 2023) of the three seasons in Victoria and in one season (2022) at both South Australian locations. In comparison, the less susceptible variety LRPB Lancer (MS) measured a yield loss of 17% only in 2022 at Longerenong, Vic, where disease pressure was exceptionally high. However, no yield losses were observed in other locations or in different seasons due to less disease severity. Meanwhile, the resistant varieties Sunlamb (MR) and Orion (MRMS) measured no yield loss due to STB in 2021 across all sites in the Southern region.

Septoria tritici blotch caused minor reductions in grain quality for susceptible varieties during 2021 and 2023 (data not shown). However, the higher disease pressure during the 2022 season had a significant impact on grain quality across all varieties, regardless of their resistance to STB. At Longerenong, Vic, in particular, severe STB led to increased screenings and protein content while reducing grain weight (Table 10). Post-harvest retentions dropped by an average of 26%, ranging from 14% to 55%, effectively increasing yield losses to approximately 30–90% across all varieties.

In general, STB severity and the resulting yield losses were more prevalent in susceptible varieties, though they varied across seasons. The 2022 season was particularly conducive to disease development, resulting in extreme disease pressure and significant yield losses at all locations. Among the sites, Longerenong (MRZ, Vic) consistently experienced losses across all seasons whereas yield losses due to STB were less common in low rainfall zones.

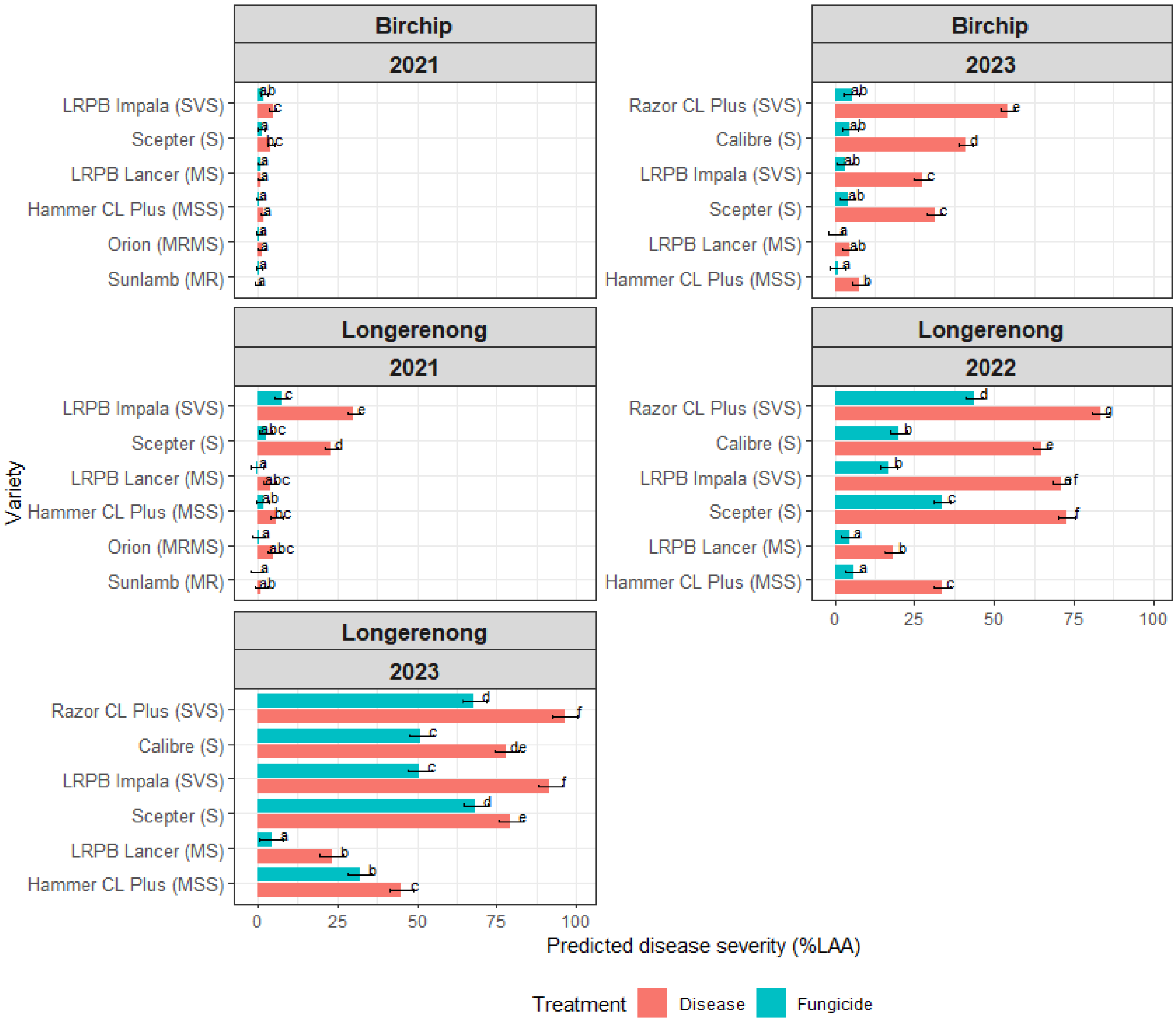

Figure 10: Predicted means for disease severity (% Leaf area affected) of eight wheat varieties in response to with and without disease at two different rainfall zones in Victoria during 2021 – 2023.

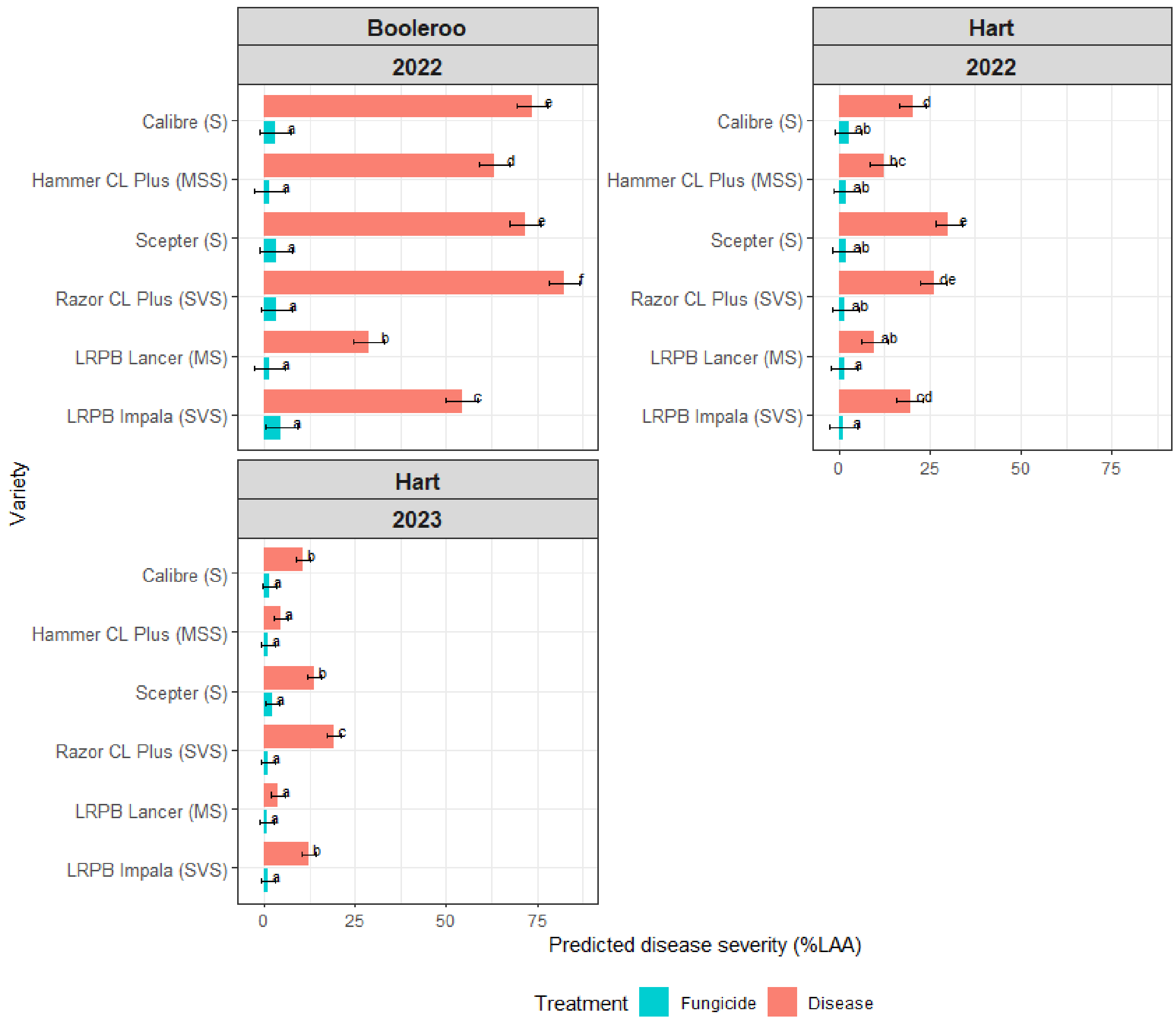

Figure 11: Predicted means for disease severity (% Leaf area affected) of eight wheat varieties in response to with and without disease at two different rainfall zones in South Australia during 2021 – 2023.

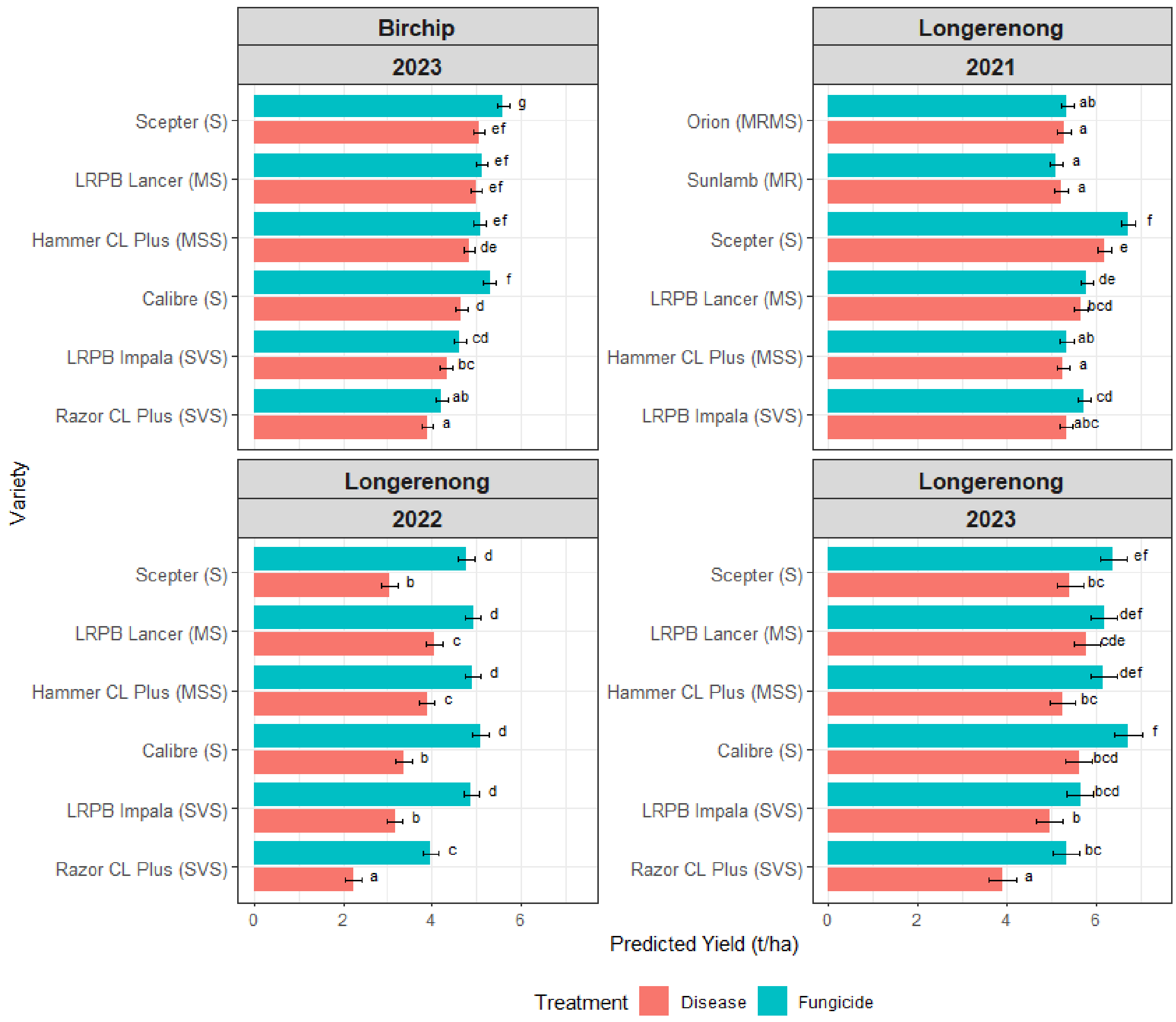

Figure 12: Predicted means for yield (t/ha) of eight wheat varieties in response to with and without disease at two different rainfall zones in Victoria over 3 years (2021 – 2023).

Table 10: Grain quality of six wheat varieties treated with low and high levels of STB at Longerenong (MRZ), VIC during 2022.

Variety	Rating	Protein (%)		Screenings (%)		Retention(%)		1000GW	
		Fungicide	Disease	Fungicide	Disease	Fungicide	Disease	Fungicide	Disease
LRPB Lancer	MS	12	13^{ns}	3.6	5.5**	87.8	75.5**	38.5	33.9**
Hammer CL Plus	MSS	12	12^{ns}	5.0	10.7**	78.1	59.3**	33.3	29.1^{ns}
Scepter	S	11	13**	5.5	15.8**	74.4	45.1**	35.3	27.0**
Calibre	S	11	13**	4.3	7.2**	84.7	70.8**	40.3	32.2**
Razor CL Plus	SVS	12	13**	6.6	11.8*	71.8	55.9**	29.8	27.1^{ns}
LRPB Impala	SVS	10	11**	10.1	32.8**	58.0	25.9**	26.8	20.2**

*** = statistically significant at 5% LSD; * = statistically significant at 1% LSD, ^{ns} = not significant at 5% LSD when the Disease and Fungicide treatments were compared.*

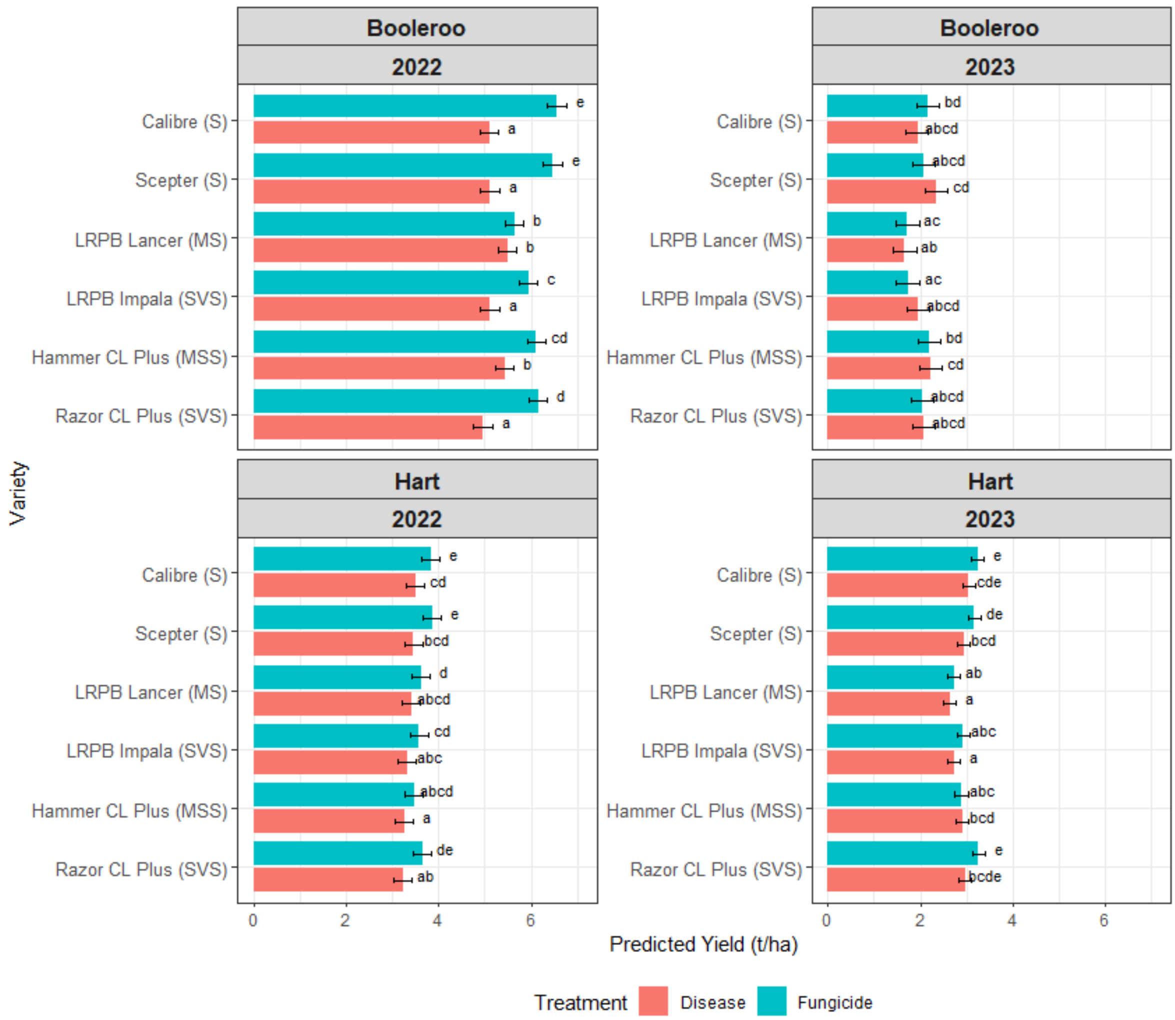

Figure 13: Predicted means for yield (t/ha) of eight wheat varieties in response to with and without disease at two different rainfall zones in South Australia over 3 years (2021 – 2023).

Table 11: Percentage yield reduction between disease and fungicide treatments in eight Wheat varieties at Longerenong (MRZ) and Birchip (LRZ) in Victoria during 2021 to 2023.

Variety	Rating	Yield loss (%)[A]					
		Longerenong (MRZ, Vic)			Birchip (LRZ, Vic)		
		2021	2022	2023	2021	2022	2023
Sunlamb	MR	-	-	-	-	-	-
Orion	MRMS	-	-	-	-	-	-
LRPB Lancer	MS	-	17	-	-	-	-
Hammer CL Plus	MSS	-	21	16	-	-	-
Scepter	S	8	36	17	-	-	10
Caibre	S	-	35	13	-	-	13
LRPB Impala	SVS	-	35	-	-	-	-
Razor CL Plus	SVS	-	43	28	-	-	-

[A] *Percentage yield reduction was estimated as percent yield decrease vs the minimum disease treatment.*

Table 12: Percentage yield reduction between disease and fungicide treatments in eight Wheat varieties at Hart (MRZ) and Booleroo (LRZ) in South Australia during 2021 to 2023.

Variety	Rating	Yield loss (%)[A]					
		Hart (MRZ, SA)			Booleroo (LRZ, SA)		
		2021	2022	2023	2021	2022	2023
Sunlamb	MR	-	-	-	-	-	-
Orion	MRMS	-	-	-	-	-	-
LRPB Lancer	MS	-	-	-	-	-	-
Hammer CL Plus	MSS	-	-	-	-	11	-
Scepter	S	-	12	-	-	21	-
Caibre	S	-	9	-	-	23	-
LRPB Impala	SVS	-	-	-	-	14	-
Razor CL Plus	SVS	-	11	-	-	20	-

[A]*Percentage yield reduction was estimated as percent yield decrease vs the minimum disease treatment.*

Fungicide timing

Fungicide applications demonstrated effective suppression of STB in all locations and seasons when compared to an untreated control (Figure 14). However, the need for a fungicide and the number of applications required varied depending on the season and location. Yield gains from fungicide applications also changed with the season and location.

Across all locations and seasons, the most effective strategy for reducing STB severity, as measured by the area under the disease progress curve (AUDPC), was the application of two foliar fungicides, one at stem elongation (Z31) and another at flag leaf emergence (Z39) with or without seed treatment (Figure 14). A single foliar application at Z31 also showed statistically similar reduction in AUDPC at most locations, particularly in 2021 and 2023, when spring conditions were less conducive for the disease development. However, in 2022, when seasonal conditions were highly conducive to STB, two foliar applications at Z31 and Z39 decreased AUDPC by ~50%. Single applications, either at seed or a foliar application at flag leaf emergence (Z39) were the least effective in reducing STB severity across all locations and seasons. Maximum reduction in disease severity was also found when foliar applications were applied after symptoms were detected in the crop compared to applications applied prior to symptom appearance (Table 15).

Despite significant reductions in STB severity, fungicide applications were not always economic (Figure 15). During 2022, fungicide applications increased grain yield by 7 – 39% at Longerenong, Vic and Hart, SA whereas during 2023, yield gains were limited to 7-16% at Victorian sites but not at Hart, SA despite greater disease severity (Tables 13 and 14). During 2021, fungicide applications did not resulted in yield increases at any location. Across all seasons, the two-spray strategy consistently provided the greatest yield benefit and improved grain quality of Scepter by reducing screenings, increasing retentions and improving grain weight (data not shown).

At Longerenong, in 2022 and 2023, despite two foliar applications effectively suppressing STB for longer periods, complete control was not achieved at grain ripening stage (Z71-Z75) as evident by residual AUDPC (Figure 14). This suggests a possible reduction in the efficacy of the fungicides applied (due to decreasing levels of sensitivity to fungicides in the STB population) or the need for a more intensive fungicide strategy. Fungicide resistance testing of samples at Centre for Crop and Disease Management (CCDM), Perth, WA demonstrated reduced sensitivity of *Z. tritici* populations to DMIs (Group 3) confirming the reduced efficacy of the fungicides applied (data not shown).

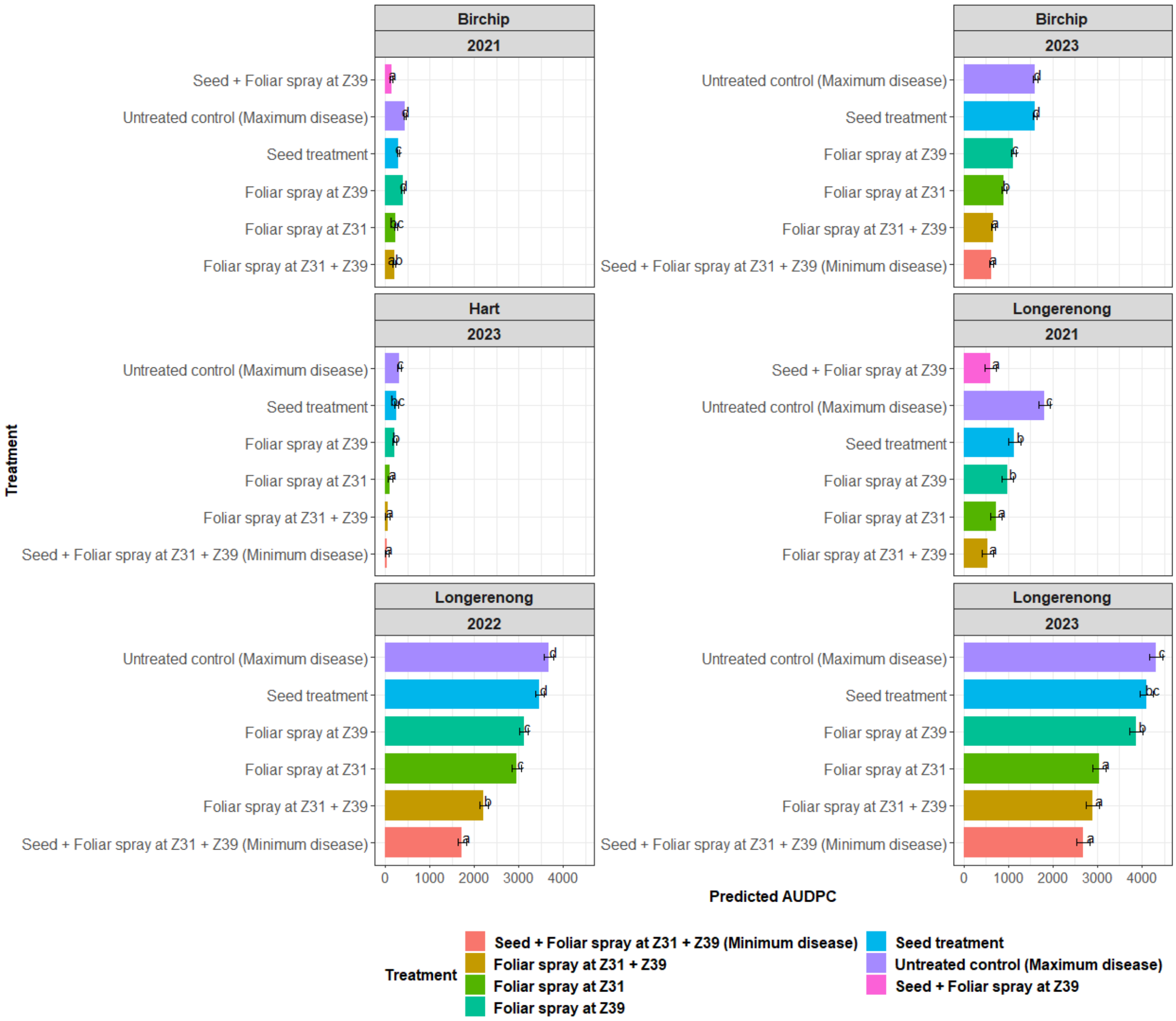

Figure 14: Predicted means for area under disease progress curve (AUDPC) of wheat variety Scepter (S) infected with Septoria tritici blotch (STB) in response to different fungicide treatments in Victoria and South Australia during 2021 – 2023.

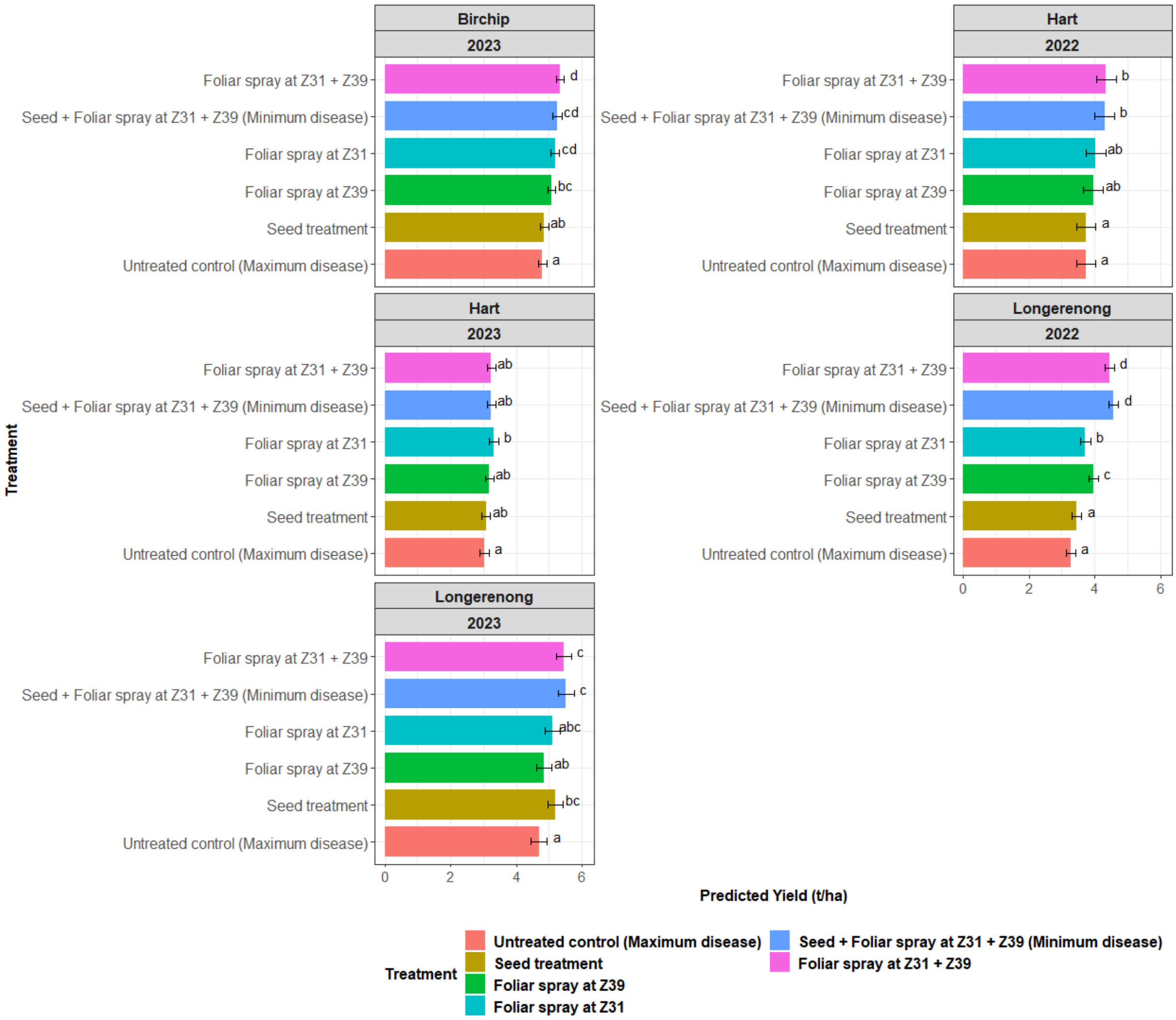

Figure 15: Predicted means for grain yield (t/ha) of wheat variety Scepter (S) infected with Septoria tritici blotch in response to different fungicide treatments in Victoria and South Australia during 2021 – 2023.

Table 13: Percentage yield increase of wheat variety Scepter (S) infected with Septoria tritici blotch in response to different fungicide treatments at Longerenong (MRZ) and Birchip (LRZ) in Victoria during 2021 to 2023.

Treatment	Yield gain (%)					
	Longerenong (MRZ, Vic)			Birchip (LRZ, Vic)		
	2021	2022	2023	2021	2022	2023
Untreated control (Maximum disease)	-	-	-	-	-	-
Seed	-	-	-	-	-	-
Foliar at Z31	-	14	-	-	-	7
Foliar at Z39	-	22	-	-	-	-
Seed + Foliar at Z39	-	-	-	-	-	-
Foliar at Z31 + Z39	-	37	14	-	-	10
Seed + Foliar at Z31 + Z39 (Minimum disease)	-	39	16	-	-	10

Table 14: Percentage yield increase of wheat variety Scepter (S) infected with Septoria tritici blotch in response to different fungicide treatments at Hart (MRZ) in South Australia during 2021 to 2023.

Treatment	Yield gain (%) Hart (MRZ, SA)		
	2021	2022	2023
Untreated control (Maximum disease)	-	-	-
Seed	-	-	-
Foliar at Z31	-	8	-
Foliar at Z39		9	-
Seed + Foliar at Z39	-	-	-
Foliar at Z31 + Z39	-	14	-
Seed + Foliar at Z31 + Z39 (Minimum disease)	-	14	-

Table 15: STB severity (%) in the wheat variety Scepter (S) in response to different fungicide treatments at Longerenong, Victoria during 2024.

Treatment	Disease severity (% leaf area affected) [A]		Grain yield (t/ha)
	19 Aug Z39 [B]	22 Sep Z65 [B]	
Maximum disease	9^{d}	45^{e}	5.2
Symptomless	4^{a}	25^{d}	5.7
First symptoms	5^{b}	8^{bc}	5.8
Secondary symptoms	7^{c}	12^{c}	5.9
Symptomless + Secondary symptoms	4^{a}	3^{ab}	5.8
Minimum disease	6^{b}	2^{a}	5.9
P	<0.001	<0.001	0.109
LSD (0.05)	1.2	5.8	*ns*

[A]Within column means with one letter in common are not significantly different (0.05). [B]Date of assessment and Zadoks growth stage.

Fungicide product comparison

The current project did not include an evaluation of fungicide products specifically for STB control. However, results from experiments conducted by Field Applied Research (FAR) Australia at Balldale, NSW, in 2023 and 2024 were presented here. These experiments primarily assessed the efficacy of various fungicide active ingredients for wheat powdery mildew control. However, STB infection was dominant in both seasons, allowing the identification of effective fungicides for STB management. The experiments consisted of 10 treatments (Tables 16 and 17) replicated four times.

In 2023, while significant differences in STB severity were observed between treatments, no yield differences were found between fungicide applications and the untreated control (Table 16). In contrast, in 2024, Radial (epoxiconazole + azoxystrobin) provided the best protection against STB and resulted in the highest yield, reaching 7.35 t/ha (Tables 17 and 18). Other products containing prothioconazole, either alone or in combination, offered comparable levels of disease control and yield performance to Radial. Compared to the untreated control, these treatments resulted in yield gains of up to 14%. However, fungicide treatments containing only epoxiconazole, tebuconazole, or a mildewcide did not provide significant STB control in either season or showed limited yield benefits over the untreated control in 2024 (Table 18).

Table 16: Effects of fungicide products on STB infection (% leaf area infected- LAI) on individual leaf layers of Scepter (S) variety at milk development stage (Z71) during 2023 at Balldale, NSW.

Treatment/product	Flag %LAI#		Flag-1 %LAI		Flag-2 %LAI	
Control	10.8	a	59.9	a	89.9	a
Vivando® (Group U8) + Opus125® (Group 3)	1.8	b	11.4	cd	51.3	b
Tolendo® (Group 13) + Opus125® (Group 3)	1.4	b	11.2	cd	59.4	b
Legend® (Group 13) + Opus125® (Group 3)	1.9	b	12.1	c	60.5	b
Orius® (Group 3)	9.1	a	41.8	b	86.9	a
Proviso® (Group 3)	0.5	b	3.8	cd	31.7	c
Opus125® (Group 3)	1.6	b	10.7	cd	57.1	b
Radial® (Group 11 + 3)	0.6	b	4.9	cd	32	c
Prosaro® (Group 3 + 3)	1.1	b	9.2	cd	48	b
Proviso® + Opus125® + Orius®	0.3	b	1.8	d	13.6	d
P	<0.001		<0.001		<0.001	
LSD (0.05)	4.3		10.03		13.96	

#*Within column, means with one letter in common are not significantly different.*

Table 17: Effects of fungicide products on STB infection (% leaf area infected- LAI) on individual leaf layers of Scepter (S) variety at grain fill stage (Z75) during 2024 at Balldale, NSW.

Treatment/product	Flag-1 %LAI#		Flag-2 %LAI	
Control	7.0	a	20.6	a
Vivando® (Group U8) + Opus125® (Group 3)	2.9	bcd	15.7	ab
Tolendo® (Group 13) + Opus125® (Group 3)	2.1	cde	9.8	bcd
Legend® (Group 13) + Opus125® (Group 3)	1.8	cde	14.0	abc
Orius® (Group 3)	4.7	ab	22.9	a
Proviso® (Group 3)	1.3	cde	7.4	bcd
Opus125® (Group 3)	2.0	cde	19.4	a
Radial® (Group 11 + 3)	0.6	de	1.9	d
Prosaro® (Group 3 + 3)	0.6	de	9.8	bcd
Proviso® + Opus125® + Orius®	0.4	e	4.7	cd
P	<0.001		<0.001	
LSD (0.05)	2.3		9.5	

#*Within column, means with one letter in common are not significantly different.*

Table 18: Influence of fungicide products on grain yield (t/ha) and quality (protein (%), test weight (kg/hL), and screenings (%)) at Balldale, NSW during 2024.

Treatment/product	Yield (t/ha)[#]		Yield loss (%)	Protein (%)		Test Weight (kg/hL)	
Control	6.36	d	14	13.7	ab	76.5	c
Vivando (Group U8) + Opus125 (Group 3)	7.07	bc	-	13.6	ab	77.5	bc
Tolendo (Group 13) + Opus125 (Group 3)	7.05	bc	-	13.7	ab	78.1	ab
Legend (Group 13) + Opus125 (Group 3)	7.11	abc	-	13.8	a	78.0	ab
Orius (Group 3)	6.90	c	-	13.8	a	78.0	ab
Proviso (Group 3)	7.17	ab	-	13.3	cd	78.2	ab
Opus125 (Group 3)	7.04	bc	-	13.6	ab	78.2	ab
Radial (Group 11 + 3)	7.35	a	-	13.5	bcd	78.5	a
Prosaro (Group 3 + 3)	7.14	abc	-	13.5	abc	78.1	ab
Proviso + Opus125 + Orius	7.20	ab	-	13.2	d	78.0	ab
P	<0.001			0.001		0.039	
LSD (0.05)	0.24			0.3		1.0	

[#]*Within column, means with one letter in common are not significantly different.*

Inoculum loads

Stubble application significantly increased STB severity in wheat variety LRPB Impala (SVS) at Longerenong and Wallup, Vic during 2022 and 2023 respectively (Table 19). Although decreasing inoculum loads did significantly vary disease severity very early in the season but did not at grain ripening stage. Hence there was no significant difference for grain yield or quality reductions between different stubble load treatments. However, when fungicides were used along with no stubble, significant control of STB was achieved in both the seasons leading to yield gains of up to ~30% and quality of grain improved.

Table 19: Septoria tritici blotch severity (% leaf area affected) and grain yield of wheat variety LRPB Impala (SVS) in response to variable loads of stubble inoculum at Longerenong (2022) and Wallup (2023) in Victoria.

Stubble Treatment	Stubble load (t/ha)	Z31-45[#]		Grain yield (t/ha)[#]	
		Longerenong, 2022	Wallup, 2023	Longerenong, 2022	Wallup, 2023
Minimum disease	-	5[a]	4[a]	4.01[a]	5.60[c]
Zero Stubble	0	11[b]	7[b]	2.69[c]	5.33[b]
Quarter kilogram stubble (0.25 kg)	0.14	20[c]	8[bc]	2.90[b]	5.40[b]
Half kilogram stubble (0.5 kg)	0.28	23[cd]	9[bc]	2.88[bc]	5.30[b]
One kilogram stubble (1 kg)	0.56	23[d]	8[bc]	2.82[bc]	5.30[ab]
Two-kilogram stubble (2 kg)	1.11	23[cd]	9[c]	2.86[bc]	5.03[a]
P		<0.001	0.002	<0.001	0.002
LSD (0.05)		3.4	2.36	0.2	0.25

[#]*Within column, means with one letter in common are not significantly different.*

Crop and variety rotation

Crop rotation

Zymoseptoria tritici inoculum levels significantly varied with the years since wheat is last sown at the AgVic's SCRIME experiment during 2022 and 2023 (Table 20). Inoculum levels were highest when wheat was repeatedly sown demonstrating significant STB risk to the subsequent wheat crop. Whereas *Z. tritici* levels decreased if wheat is rotated with either a cereal (not wheat) or canola or a pulse crop. No significant difference was found if the break between the two wheat crops is either one or two years. Thus, suggesting at least one year break between two wheat crops to reduce STB risk.

Between the two seasons, inoculum loads during 2023 were greater compared to 2022 likely due to the above average spring rainfall received during 2022 causing increased biomass/stubble loads and also opportunity for *Z. tritici* to rapidly colonize and produce greater inoculum loads. Build-up of high inoculum loads prior to the sowing season indicate significant risk to the incoming wheat crops.

Table 20: Pre-sowing *Zymoseptoria tritici* levels (kDNA copies/g sample) in soil following different crop rotations at Longerenong, Victoria during 2022 (year 1 and 2023 (year 2).

Treat #	Rotations	Cultivation	Years since wheat	Year 0	Year 1	Year 2	*Zymoseptoria tritici* (kDNA copies/g Sample)[AB] pre-sowing	
							Apr-22	Apr-23
1	Continuous Wheat		0	Wheat*	Wheat	Wheat	177[d]	362[c]
3	Cereal - Pulse - Cereal		0	Wheat	Peas	Barley	52[b]	1178[d]
			1	Barley	Wheat	Peas	1[a]	2[ab]
			2	Peas	Barley	Wheat	1[a]	2[ab]
6	Cereal - Oilseed - Pulse	Reduced tillage stubble burnt	0	Wheat	Canola	Peas	246[c]	895[cd]
			1	Peas	Wheat	Canola	4[a]	8[ab]
			2	Canola	Peas	Wheat	36[ab]	1[a]
7	Cereal - Oilseed - Pulse	Conventional tillage	0	Wheat	Canola	Peas	22[bc]	362[cd]
			1	Peas	Wheat	Canola	1[a]	3[ab]
			2	Canola	Peas	Wheat	1[a]	12[b]
11	Cereal - Oilseed - Pulse	Zero tillage stubble retained	0	Wheat	Canola	Peas	25[ab]	353[c]
			1	Peas	Wheat	Canola	1[a]	0[a]
			2	Canola	Peas	Wheat	1[a]	6[b]
P							<0.001	<0.001
LSD (0.05)							0.9	1

[*]Wheat Variety sown in 2021 (year 0) and 2022 (year 1): Hammer CL Plus (MSS); [A]Within a column, means with one letter in common are not significantly different at 0.05. [B]Analysis was conducted using log-transformed data to linearize the relationship between dependent and independent variables but non-transformed data is presented for reader benefit.

Variety rotation

Zymoseptoria tritici inoculum levels significantly varied with the varietal resistance/susceptibility to STB at three of four locations during 2022 (Longerenong, Vic) and 2023 (Hart and Booleroo, SA) (Tables 21 and 22). The inoculum levels following harvest were highest in the plots where a susceptible variety was sown compared to a resistant variety. The inoculum levels within a plot also reflected in-crop STB severity prior to harvest.

During 2023, at Longerenong, Victoria, *Z. tritici* inoculum levels did not vary with the varietal resistance/susceptibility to STB likely due to the above average rainfall received during spring 2022 assisting rapid colonisation of pathogen on the stubble irrespective of whether it's a resistant or susceptible stubble (Table 21).

Table 21: Pre-sowing *Zymoseptoria tritici* levels (kDNA copies/g sample) in eight wheat varieties at Longerenong, Victoria during 2022 and 2023.

Variety	Rating	*Zymoseptoria tritici* (kDNA copies/g sample)[AB]	
		January, 2022	*April, 2023*
Sunlamb	MR	102[a]	-
Orion	MRMS	227[ab]	-
LRPB Lancer	MS	86[a]	3,100
Hammer CL Plus	MSS	665[bc]	2,408
Scepter	S	1277[bc]	2,863
Calibre	S	-	3,215
LRPB Impala	SVS	817[c]	3,154
Rzor CL Plus	SVS	-	3,782
P		<0.001	0.598
LSD (0.05)		0.5	*ns*

[A]Within a column, means with one letter in common are not significantly different at 0.05. [B]Analysis was conducted using log-transformed data to linearize the relationship between dependent and independent variables but non-transformed data is presented for reader benefit.

Table 22: Pre-sowing *Zymoseptoria tritici* levels (kDNA copies/g sample) in six wheat varieties at Hart and Booleroo, South Australia during 2023.

Variety	Rating	*Zymoseptoria tritici* (kDNA copies/g sample)[AB]	
		Hart, April 2023	*Booleroo, April 2023*
LRPB Lancer	MS	1,958[a]	1,118[a]
Hammer CL Plus	MSS	1,793[a]	4,059[b]
Scepter	S	6,283[bc]	5,091[bc]
Calibre	S	4,468[b]	5,226[bcd]
Razor CL Plus	SVS	7,786[cd]	8,772[cd]
LRPB Impala	SVS	10,557[d]	9,295[d]
P		<0.001	<0.001
LSD (0.05)		0.2	0.3

[A]Within a column, means with one letter in common are not significantly different at 0.05. [B]Analysis was conducted using log-transformed data to linearize the relationship between dependent and independent variables but back-transformed data is presented for reader benefit.

Sowing time

Septoria tritici blotch severity significantly varied with sowing time, variety, and fungicide application. Early sowing in April demonstrated losses of up to 21 per cent (~1.2t/ha) in susceptible varieties because of higher STB infection levels of up to 33 per cent at late flowering stage (Table 23). However, when sowing was delayed by about a month and still within the optimal sowing window, the risk from disease significantly reduced and no yield was lost. Equally, by avoiding susceptible varieties yield loss was minimised even when sown early.

Higher STB severity in early (April) sown experiments also affected grain quality of Scepter (S) and Hammer CL Plus (MSS), with a small increase in screenings and reduction in 1000 grain weight but did not affect protein content (data not shown). Late sowing did not affect the grain quality of any of the three wheat varieties.

Table 23: Septoria tritici blotch (STB) severity (% leaf area affected) and grain yield (t/ha) of three wheat varieties with and without disease, sown in separate experiments on 24 April (early) and 20 May (late) at Longerenong (MRZ), Victoria, 2024.

Variety	Rating	Disease severity[A] (% leaf area affected) in disease treatment		Grain yield (t/ha)					
		Early sown	Late sown	Early sown			Late sown		
		22 Sep Z65[B]	14 Oct Z65	Disease	Fungicide	Loss (%)[C]	Disease	Fungicide	Loss (%)
Hammer CL Plus	MSS	12[a]	1[a]	5.5	5.93[ns]	0	6.01	6.03[ns]	0
Scepter	S	31[b]	5[c]	5.21	6.30*	17	6.09	6.57[ns]	0
Razor CL Plus	SVS	33[b]	3[b]	4.51	5.69**	21	5.69	5.72[ns]	0
P		0.001	<0.001						
LSD (0.05)		10.4	1.1						

*[A]Within column means with one letter in common are not significantly different (0.05). ** = statistically significant at 1% and * = 5%; ns = not statistically significant when the Disease and Fungicide treatments were compared. [B]Date of assessment and Zadoks growth stage. [C] Yield loss % for each variety was presented as % yield decrease vs the minimum disease treatment.*

DISCUSSION OF RESULTS

Septoria tritici blotch (STB), caused by the fungal pathogen *Zymoseptoria tritici,* is a significant foliar disease affecting wheat. It is now the second most common disease in the Southern region, particularly in Victoria (Figure 16). In high rainfall zones (HRZ), where the disease is most widespread, it frequently leads to yield losses of up to 50% and a decline in grain quality. Until five years ago, STB was not a primary concern for growers in the MRZ and LRZ, where yellow leaf spot (YLS), caused by *Pyrenophora teres f. repentis*, posed the dominant challenge. However, over the past decade, a notable shift toward varieties with greater resistance to YLS has occurred in the region. While this varietal change has successfully reduced YLS incidence, it has inadvertently increased STB prevalence, as these new varieties are more vulnerable to STB. This led to yield losses of up to 20% in conducive seasons particularly, in the MRZ, while in LRZ, yield losses are not common, but the prevalence of disease has increased. Through this study, we present the environmental conditions contributing to the rise in STB incidence and propose management strategies to enhance control in the MRZ and LRZ of the Southern region.

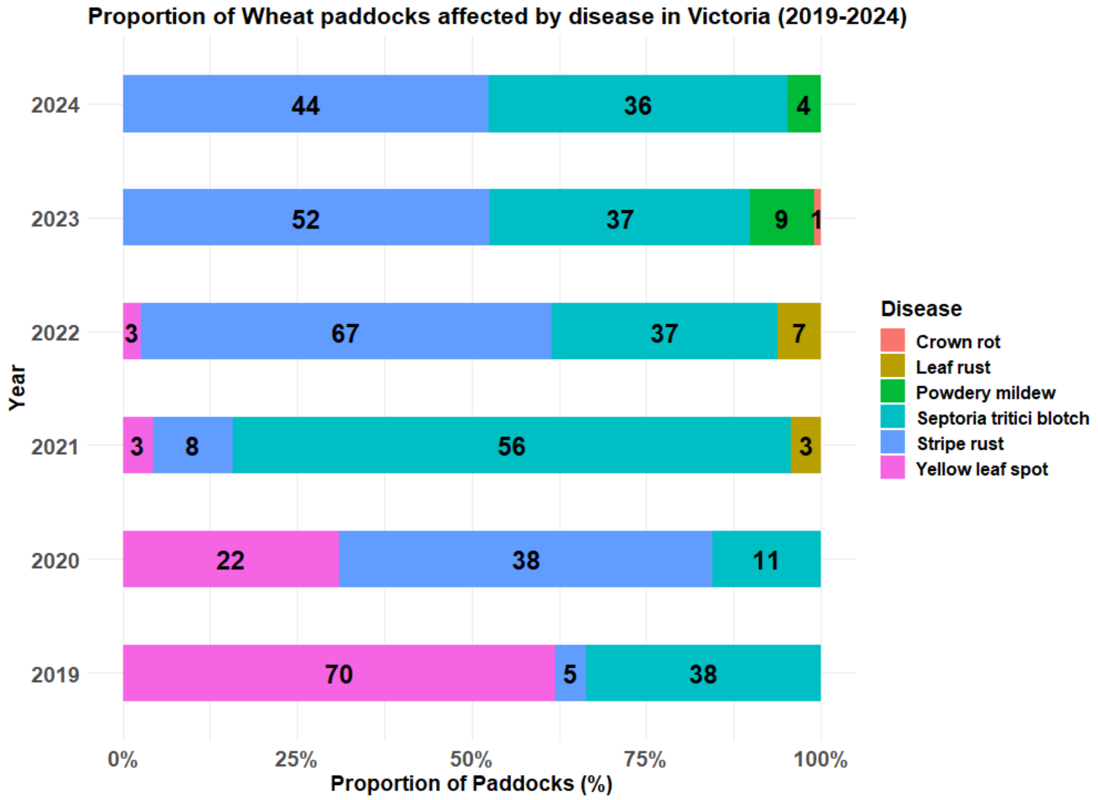

Figure 16: Prevalence of diseases in wheat paddocks in Victoria during 2019-2024. Data sourced from GRDC projects Disease surveillance and related diagnostics for the Australian grains industry (DJP2103_005RTX) and Seasonal status of pests and diseases delivered to growers (DEE2404-004RTX).

Output 1

Epidemiology of Septoria tritici blotch (STB) in the low and medium rainfall zones of Southern Australia

Lifecycle and symptoms

The lifecycle of *Zymoseptoria tritici* is polycyclic (Eyal et al. 1987) and involves both sexual and asexual reproduction phases in Australia (Brown, 1975; Figure 17). The fungus survives on wheat stubble and/or debris between growing seasons, forming pseudothecia (sexual fruiting bodies) with asci and ascospores. Ascospores produced sexually serve as primary source of inoculum. These are wind dispersed and initiate the primary infection in wheat seedlings early in the season. Visible symptoms emerge as small, water-soaked spots on the lower leaves, which develop into characteristic tan to greyish lesions with dark brown to black pycnidia (asexual fruiting bodies) embedded within (Figure 18). The disease progresses upward through the canopy, affecting older leaves first and potentially reaching the flag leaves in severe cases.

Within pycnidia, the fungus produces pycnidiospores, which are splashed onto adjacent leaves or plants by rain or irrigation, facilitating secondary infections within the crop. This polycyclic phase allows rapid disease spread during the growing season, especially in dense canopies where moisture is retained. As the season progresses and conditions become less favourable, the fungus shifts to sexual reproduction. This stage produces ascospores, which are released the following autumn, completing the cycle. The pathogen overwinters on stubble, surviving harsh conditions and serving as the inoculum source for the next crop cycle, particularly in stubble-retained farming systems.

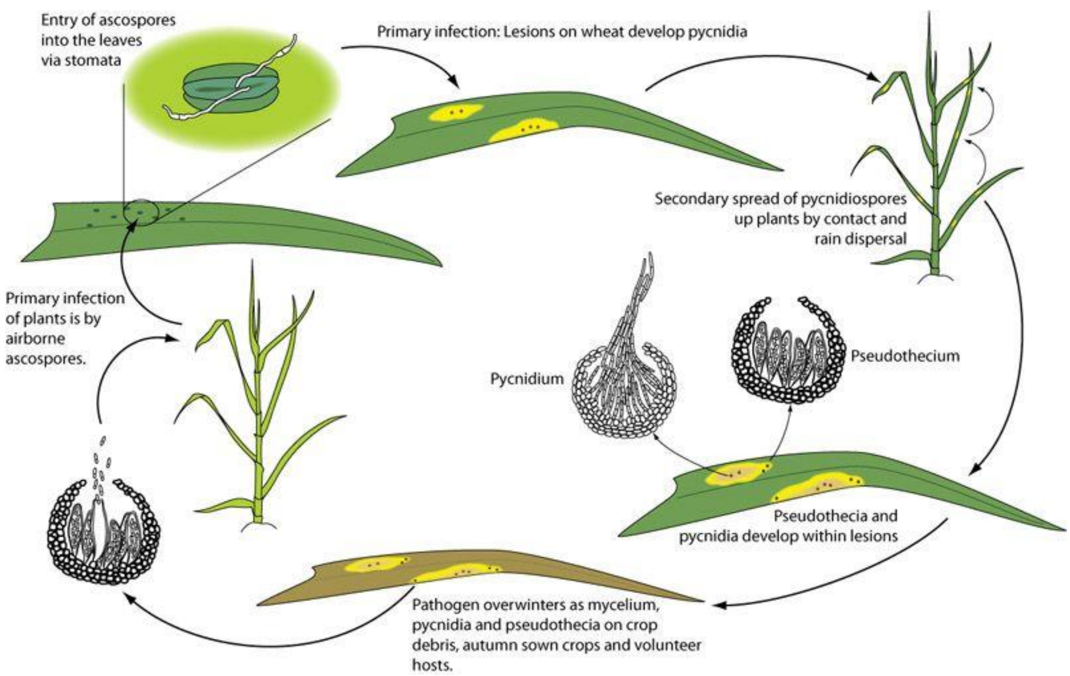

Figure 17: Lifecycle of *Zymoseptoria tritici* causing septoria tritici blotch (STB) in wheat. (Source: Ponomarenko et al., 2011).

Figure 18: Characteristic symptoms of Septoria tritici blotch (STB) on wheat leaves with dark brown necrotic blotches with black pycnidia and a wheat crop demonstrating severe STB symptoms at Hamilton, Victoria during 2022.

Significance of ascospores in disease epidemics in the MRZ and LRZ regions

Ascospores and pycnidiospores were detected in this study using a Burkard spore liberator confirming the presence of these stages and their role in driving epidemics in the MRZ and LRZ regions. However, the sequence of events in the disease development and spread need to be clarified to inform appropriate management strategies for control in these regions. Spore trap units were previously used successfully to track airborne inoculum of *Z. tritici* in Europe (Duvivier et al., 2013). These studies showed that ascospores were produced throughout the season but with a distinct seasonal pattern. Likewise, ascospore production in this study was tracked using Burkard spore traps, which detected ascospores throughout the growing season (May – Oct). Consistent with Brown et al., (1978), this study revealed that the ascospore discharge in Australia was at its peak during winter (May -July) with a gradual decline observed as the season progressed. The elevated detection rates during winter likely indicate the maturation of pseudothecia in this region, leading to increased release of ascospores (Figure 19). The peak detections also coincide with the early growth stages of wheat plants sown between late April and early May, potentially explaining the initial infections observed across the region, with ascospores serving as the source of primary infection. Conversely, wheat crops sown later (late May – June) in the region likely avoid this early surge of ascospores, which may account for their reduced symptom expression or disease severity through the season.

During 2021 and 2022 at Hart, and in 2022 at Waite in South Australia, spore release trends were noted to rise towards the end of the growing season in November, preceded by a decline through the earlier months. This upsurge in spore release in November at these sites suggests the formation of pseudothecia on senescing wheat leaves. Previous studies have documented ascospore discharge from infected wheat foliage, indicating that ascospores can serve not only as primary inoculum but also as secondary inoculum (Hunter et al., 1999; Duvivier et al., 2013). This additional inoculum, capable of travelling long distances, enables the pathogen to colonize wheat crops independently of pycnidiospores or to intensify STB damage by increasing the overall inoculum load.

The climatic factors influencing ascospore dispersal have been inconsistently reported in the literature. While many studies confirm higher ascospore release in autumn and winter, none have conclusively identified the key drivers (Duvivier et al. 2013; Hassine et al. 2019). This inconsistency is partly due to variations in spore release across locations at similar timeframes.

This study found that ascospore release varied significantly by location and season, suggesting specific environmental conditions influence dispersal. Analysis using LMMs revealed that ascospore release was promoted by warmer minimum temperatures (around 10°C) and lower maximum temperatures (around 15°C), while higher rainfall reduced spore activity, though some moisture was found necessary for release. These findings align with observations across different rainfall regions, where ascospore release was lower in high-rainfall zones (HRZ) and wetter seasons but greater in drier conditions. This suggests that in seasons with minimal rainfall before sowing, ascospore release is likely higher, provided there is sufficient stubble carryover from the previous season.

Figure 19: Ascospores of *Zymoseptoria tritici* emerging from a pseudothecia (dark colored overwintering structure). *Photo courtesy of Mary Burrows, Montana State University, Bugwood.org.*

Pycnidiospore development and conditions favourable for in-crop disease risk in the MRZ and LRZ regions

Pycnidiospores are found during the season on wheat leaves and play a key role in spreading the disease within the crop canopy (Figure 21). They are splash-dispersed over short distances and infect new leaves upon contact. As noted by Duvivier et al. (2013), air borne inoculum trapped in spore traps was determined to be ascospores since the spore trap units were placed at a considerable distance from wheat crops, making it unlikely for pycnidiospores due to their limited travel range. Conversely, a spore trap placed within the centre of a wheat crop tracked pycnidiospores, correlating with the observed in-crop disease severity. Unlike, ascospore release, which follows a different pattern, pycnidiospore release reached its peak between July and October during spring, confirming that pycnidiospores serve as the source for secondary infections (Figure 20).

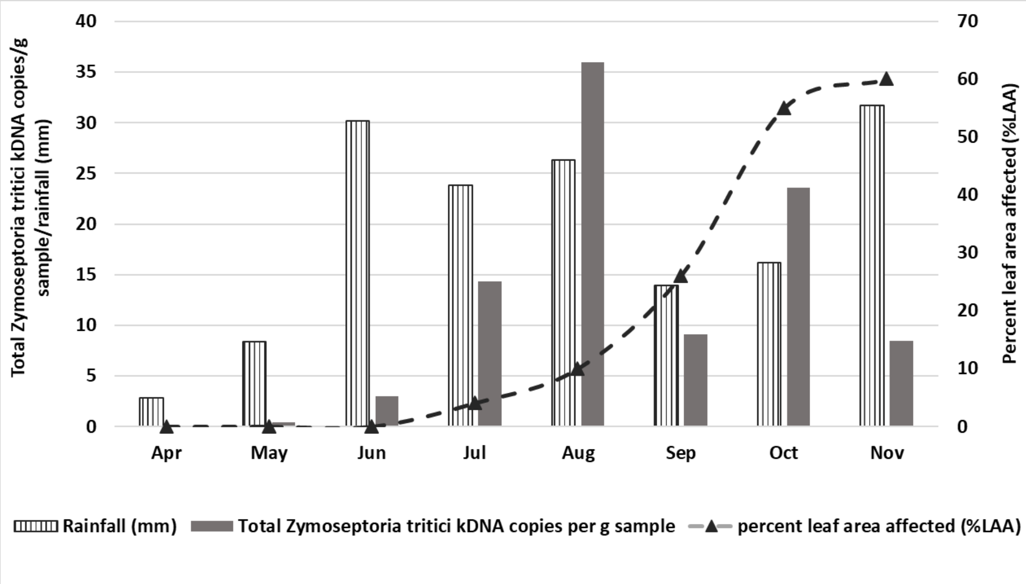

Figure 20: Relationship between rainfall, disease severity (%LAA) and *Zymoseptoria tritici* spore release (kDNA copies/g sample) at Horsham, Victoria during 2024.

Pycnidiospore discharge is known to be influenced by several climatic factors during season including frequent rain, cool temperatures, and high humidity (Mundt et al., 1999). When these conditions are present, the disease progresses rapidly, leading to elevated severity that impacts grain yield and quality. In the Southern Australia, in-crop disease severity varied with the rainfall and humidity across locations. The highest severity was observed in seasons and regions with abundant rainfall, particularly the HRZ and MRZ, where conditions are most conducive. In contrast, STB severity remained relatively low in the LRZ in both Victoria and South Australia, reflecting the limiting effect of reduced moisture on disease.

Figure 21: Asexual spores of *Zymoseptoria tritici*. *Photo courtesy of Paul Bachi, University of Kentucky Research and Education Center, Bugwood.org.*

Inoculum survival and consequent effects to in-crop disease

The extensive cultivation of high yielding but susceptible varieties, combined with the stubble retention systems in the MRZ and LRZ of the Southern region have increased the inoculum levels unprecedently through accumulation of large stubble loads. The elevated stubble loads increase disease prevalence and severity irrespective of seasonal conditions. Alongside higher inoculum loads, the ability of *Z. tritici* to sexually reproduce on stubble enhances the genetic diversity within *Z. tritici,* facilitating the emergence of virulent pathotypes. Research by Zhan et al. (2003) indicates that 84% of this diversity is observed within a single paddock. Therefore, effective local management strategies targeting the primary inoculum source, stubble are essential to control the extensive genetic diversity and limit the selection for virulence or fungicide resistance traits. Various stubble management strategies can be applied to reduce ascospore production or restrict their dispersal minimizing gene flow between neighbouring fields (McDonald and Mundt 2016). Traditional practices such as burning, baling, or cultivation applied in this study significantly reduced the inoculum source, leading to lower spore release and reduced in-crop disease risk. Additionally, net reduction of inoculum levels can also be achieved by manipulating harvest cut height to reduce the standing stubble available for the STB pathogen to colonise (Baxter et al. 2024). In contrast, retaining the stubble on the ground maintained higher inoculum levels, promoting greater spore dispersal and increasing disease risk. However, it is important to recognise that while these approaches can reduce the levels of *Z. tritici* airborne ascospores within a paddock, the substantial number of ascospores immigrating from neighbouring fields may still be sufficient to trigger epidemics (Suffert and Sache 2011). Thus, effective stubble management should be implemented on a community-wide scale to achieve its full potential benefits. Considering the increased yield loss risks, sowing wheat into wheat stubble should be avoided, with preference given to rotating wheat with other crops, which is likely to provide improved STB control.

Output 2

Management strategies for Septoria tritici blotch in the low and medium rainfall zones of Southern Australia

Variety selection

This study confirmed that the most effective long-term strategy for STB control, regardless of region and season, is the use of resistant varieties. However, resistant varieties are not yet available for growers in the main season wheats best suited to MRZ and LRZ of the Southern region (Victorian and Tasmanian Sowing Guide, 2025). This study showed that in most seasons, moderately susceptible (MS-MSS) varieties offered better yield and economic benefits compared to susceptible varieties when disease is present. Without fungicide use, the infection levels in less susceptible varieties can be 10–40% lower than in susceptible varieties, resulting only in marginal yield losses ranging from 20% to none, depending on the seasonal conditions. Similar trends were observed in New South Wales (NSW), where MS-rated varieties had 30% lower disease severity and 10–15% less yield loss (Baxter et al., 2025). Likewise, previous research from Agriculture Victoria reported yield losses of approximately 46% in highly susceptible varieties, whereas resistant varieties showed 30% less yield loss in comparison due to STB at Kaniva, Victoria during 2016 (DJP1907-001RTX, Integrated disease management strategies for Southern region cereal and pulse growers).

STB severity and yield losses were strongly influenced by seasonal conditions, particularly rainfall patterns. Disease severity and yield losses were highest in seasons with frequent and high rainfall. During 2022, extreme disease pressure was recorded due to both the amount and frequency of rainfall from August to November, which created ideal conditions for STB development and resulted in significant yield losses. In contrast, yield losses in 2021 were below 10%, highlighting the critical role of seasonal conditions in STB infection and the importance of proactive disease management in susceptible cultivars during wetter seasons. The correlation between rainfall and STB severity has been previously established, with positive associations found between disease development and the number of rainy days in the four weeks before and after heading, as well as the total rainfall during that period (Murray et al., 1990). Since *Z. tritici* requires a moist leaf surface for successful infection and spreads throughout the crop canopy via rain splash, both the amount and frequency of rainfall significantly impact disease severity and the resulting yield losses.

Yield losses also varied by location and largely reflected the amount of rainfall received at each site. However, Booleroo (LRZ) experienced greater STB severity and yield losses than Hart (MRZ), despite receiving higher total rainfall and more rainy days during the season. This inconsistency can be attributed to differences in yield potential between the two sites; Booleroo had a higher yield potential (5.2 t/ha) compared to Hart (3.4 t/ha) on average. Yield potential influenced the extent of yield losses across the Southern region. At Hart (MRZ), greater disease severity was recorded in 2023, yet no measurable yield losses occurred. This was likely due to the site's low grain yield potential (<3 t/ha), which did not allow for significant differences between minimum and maximum disease treatments. Similar trends were observed in other seasons, where yield losses were only recorded when yield potential exceeded 3 t/ha. This suggests that STB is unlikely to have an economic impact in environments where grain yields are below 3 t/ha.

Beyond its impact on yield, STB also adversely affected grain quality, leading to increased screenings and reduced grain weight. These findings are consistent with previous studies, which reported that higher disease pressure resulted in linear reductions in test weight, milling quality and increased screenings (McKendry et al., 1995; Castro et al., 2018). Additionally, STB infection was associated with higher protein content, while fungicide applications led to a decrease in protein levels. Castro et al. (2018) similarly observed that fungicide applications reduced grain protein content, likely due to a dilution effect caused by increased yields following fungicide use.

Fungicide timing, products and resistance

The findings from this study confirm that fungicide applications effectively suppress STB, but their effectiveness depends on seasonal conditions, application timing, and disease pressure. The two-spray strategy at stem elongation (Z31) and flag leaf emergence (Z39) provided the most consistent disease control, aligning with previous research that highlights the importance of these application timings for optimal disease suppression (Poole and Arnaudin, 2014). However, in high disease pressure years as 2022, two applications were insufficient to provide complete control, suggesting that a third application around flowering (Z55–Z61) may be beneficial for extended protection. Conversely, in years with lower disease pressure, such as 2021 and 2023, a single application at Z31 provided comparable control, reinforcing findings that fungicide efficacy is influenced by seasonal conditions (Torriani et al. 2015).

In contrast, single applications, either at sowing or at flag leaf emergence (Z39), were the least effective in reducing STB severity across all locations and seasons. The limited efficacy of seed treatments can be attributed to their protection expiring early in the season, leaving crops vulnerable to later infections. Similarly, fungicide applications at Z39 were less effective because disease levels were already too high at that stage, reducing the likelihood of an economic return from the spray. These results highlight the importance of well-timed fungicide applications that align with disease development stages to maximize control and economic benefits.

Fungicides were also more effective when applied after STB symptoms were detected in the crop. This finding contradicts the general consensus that preventative applications are more effective for STB control. The long latent period (~30 days), which is the time between infection and appearance of first symptoms, poses challenges for timely fungicide application. Delaying application could lead to underestimation of the disease risk and lead to yield loss, while applying too early may result in suboptimal control.

Therefore, monitoring symptoms in wheat crops for STB is critical to improve the efficacy of applied fungicides. Early season STB infections typically affect lower leaves in the canopy. As the canopy develops, disease progresses upwards to the yield-contributing flag leaves when there is sufficient rain to support epidemic progression. Application of fungicides upon detection of the first symptoms in the lower canopy can intercept latent infections early in the upper canopy, offering better control.

The effectiveness of fungicide active ingredients against STB varies, highlighting the importance of selecting the most effective chemistry for disease control. Group 3 (DMI) fungicides have shown differences in efficacy due to resistant mutations in the *Cyp51* gene within *Z. tritici* populations. Specifically, flutriafol, tebuconazole, and propiconazole have exhibited reduced performance, whereas epoxiconazole and prothioconazole have provided better disease control. An opportunistic comparison at Longerenong, Victoria, in 2023 further confirmed that prothioconazole offered superior STB suppression compared to epoxiconazole. These findings align with previous experiments conducted by FAR Australia in New South Wales, which demonstrated similar trends in DMI fungicide efficacy. Additionally, the newly permitted U8 and Group 13 fungicides, approved for wheat powdery mildew control, did not provide effective protection against STB, reinforcing the need for targeted fungicide selection.

The emergence of fungicide resistance continues to pose a challenge, with a 2024 sample from Hamilton, Victoria, confirming the presence of the G143A mutation, which confers resistance to strobilurin (QoI, Group 11) fungicides. This mutation, first detected in South Australia in 2020 and in Tasmania in 2022, is now widespread across the Southern region. Given this increasing resistance pressure, resistance management strategies to mitigate further resistance development in STB populations are urgently required.

Stubble load management

This study, through a stubble management experiment, demonstrated that stubble retention significantly increases in-crop STB risk. However, determining the threshold levels of stubble that contribute to disease development is crucial to balance residue retention benefits with disease control. To address this, different stubble loads were evaluated to assess their impact on STB severity and the associated yield losses in a susceptible variety LRPB Impala (SVS).

In this study, the absence of stubble application reduced early disease severity but increasing inoculum loads did not significantly influence final disease severity, grain yield, or quality. These findings align with previous stubble management experiments, where disease severity and yield losses in Razor CL Plus (SVS) did not significantly vary across different stubble management strategies. This suggests that while stubble management plays a role in early disease development, it may not be a critical factor in seasons with high disease pressure (Suffert and Sache 2011). Under such conditions, environmental factors in spring, including seasonal rainfall and humidity, may have a greater influence on disease progression than initial inoculum levels from stubble.

However, when fungicides were used in combination with no stubble, significant control of STB was achieved. This demonstrates that in systems where susceptible varieties are grown consecutively, managing stubble loads may be critical to help with the early STB risk. Additionally, fungicide applications proved beneficial in maintaining yield, however, optimal number of fungicide applications required for effective control remains an important consideration.

Crop and Variety rotation

Apart from assessing the influence of stubble loads on early disease risk, this study also evaluated *Z. tritici* inoculum levels on stubble based on varietal resistance or susceptibility to STB. Understanding how varietal resistance affects inoculum persistence on stubble can provide valuable insights for integrated disease management strategies, particularly in systems where stubble retention is practiced.

Results showed that inoculum levels significantly varied with varietal resistance at three of four locations during 2022 (Longerenong, Vic) and 2023 (Hart and Booleroo, SA). Plots sown with susceptible varieties carried the highest inoculum loads, whereas resistant varieties retained significantly lower pathogen levels. However, despite these differences, the levels of inoculum on stubble, regardless of varietal resistance, remained above thresholds, considered to pose an in-season disease risk.

At Longerenong in 2023, resistant varieties had lower in-crop disease severity but no statistically significant differences for inoculum levels on stubble between varieties with different resistance ratings. This suggests that a moderately resistant (MR) variety can release a similar number of *Z. tritici* ascospores in the following season as more susceptible varieties (MR–MS, MS, S, or S–VS). Thus, while varietal resistance is critical for in-season disease suppression, it does not necessarily reduce the long-term risk posed by infected stubble. These results agree with previous findings in NSW by Baxter et al. (2024) which concluded that any infected wheat stubble, regardless of the resistance rating of the previous crop, should be considered a potential inoculum source for the following wheat crop.

This study confirmed that continuous wheat cultivation without rotation increases the risk of STB development. However, introducing a break crop, such as canola, a pulse crop or a barley effectively reduced *Z. tritici* inoculum levels, which in turn lowered in-season disease risk. These findings reinforce crop rotation as a key management strategy for STB control, as non-host crops disrupt the pathogen's lifecycle and limit its carryover between growing seasons. Implementing at least a one-year break between wheat crops was found to significantly reduce inoculum buildup. These results align with NSW findings where crop rotation has been identified as an important strategy for reducing the *Z. tritici* inoculum levels. However, research in NSW also showed that *Z. tritici* can still produce ascospores even after a two-year break, suggesting that a single-year rotation may not always be sufficient for effective STB management. Additionally, the results of this study contrast with those of Bankina et al. (2021), who found no significant influence of crop rotation on STB severity in wheat crops. Such inconsistencies are found common in STB research, as long-distance dispersal of ascospores from neighbouring fields can contribute to new infections, even in well-managed crop rotation systems.

Sowing time

Our results demonstrated that STB severity varied with sowing time, suggesting that adjusting planting dates can be an effective cultural practice for disease management. Early sowing in April resulted in higher STB infection levels at the late flowering stage, leading to significant yield losses. This is likely because early sowing extends the crop's exposure to favourable conditions for *Z. tritici*, allowing for more infection cycles and greater pathogen spread throughout the season (Ponomarenko et al. 2011). In contrast, delaying sowing by approximately one month, while still remaining within the optimal sowing window and maintaining similar yield potential, significantly reduced STB risk, with no observed yield loss. Delayed sowing helps mitigate disease pressure by avoiding the early release of spores from stubble, delaying primary infection, and reducing the likelihood of severe disease development.

These findings also align with research by Almogdad et al. (2024), who reported that adjusting planting dates is a crucial strategy for reducing disease severity. Their study found that selective changes in sowing time successfully controlled STB by minimizing the overlap between crop susceptibility and peak pathogen activity. These results highlight the importance of integrating sowing time adjustments with other disease management strategies, such as selecting resistant varieties and applying fungicides strategically, to optimize wheat production while minimizing the risk of STB.

Economics of Septoria tritici blotch (STB) management in wheat in the low, medium and high rainfall regions of the Southern region

The economic analysis of STB management strategies revealed substantial differences in profitability across low (LRZ), medium (MRZ), and high rainfall zones (HRZ) (Tables 24 to 5). These findings highlight the importance of region-specific and seasonally adaptive disease management approaches that balance fungicide use and variety selection for maximum returns.

In the MRZ, STB pressure varied by season, with wetter years leading to moderate to high disease severity and greater economic impact. Fungicide applications provided strong financial benefits in high-disease seasons, increasing gross margins by up to $315/ha, particularly when two foliar sprays were applied at Z31 and Z39 (Table 24). However, in low-disease seasons like 2021, fungicide application often resulted in financial losses, confirming that routine fungicide use is not economically justified when disease pressure is low. In 2022, a high-disease year, susceptible (S, SVS) varieties showed the strongest economic responses to fungicides, with Longerenong's S-rated varieties gaining up to $459/ha (Table 25). Moderately resistant varieties (MS, MSS) also benefited from fungicides, but to a lesser extent, reinforcing their natural resistance advantage. In 2023, with moderate disease pressure driven by stubble inoculum, fungicide effectiveness varied by location, with Longerenong showing strong economic benefits from fungicides (S: $221/ha, SVS: $272/ha), whereas at Hart, fungicide benefits were low or even negative. Beyond fungicides, resistant wheat varieties in MRZ offered additional economic advantages, with gross margins improving by up to $433/ha over highly susceptible varieties, reinforcing variety selection as a cost-effective primary control strategy (Table 26).

In the LRZ, STB severity was generally lower due to drier conditions limiting disease progression, which greatly reduced the economic viability of fungicide applications. In low-disease seasons like 2021, fungicide applications resulted in negative net benefits across all varieties, further confirming that fungicides should not be applied routinely in LRZ (Table 24). Even in high-disease years like 2022, fungicide benefits were minimal, with only modest yield improvements observed. In 2023, fungicide applications provided mixed results, with some locations showing small benefits (up to $114/ha in S-rated varieties) but others showing little to no return on investment (Table 25). Overall, variety selection proved to be the most cost-effective strategy in LRZ, with resistant varieties improving gross margins by up to $291/ha compared to highly susceptible varieties, making genetic resistance the most financially viable STB control measure in low-rainfall environments (Table 26).

The HRZ exhibited the greatest economic benefits from both variety selection and fungicide applications, as STB pressure remained consistently high. Fungicide profitability followed a clear disease-pressure trend, with negative or low benefits in 2021 and strong returns in 2022, often exceeding $400/ha (Table 27). The strongest fungicide response was observed in S and SVS varieties, with Gnarwarre's S-rated varieties gaining up to $703/ha from fungicide use in 2022, while Hagley and Millicent showed similar trends with multiple fungicide applications providing over $800/ha in benefits in susceptible varieties (Table 28). However, RMR-rated varieties showed little to no benefit from fungicide applications, particularly at Hagley (-217/ha in 2021) and Millicent (-1/ha in 2021), demonstrating that genetic resistance alone can effectively withstand disease pressure, significantly reducing the need for fungicides (Table 27). The most effective fungicide programs in HRZ involved multiple applications at key growth stages, but in RMR varieties, fungicide responses diminished as variety resistance offset the need for chemical control. This highlights that resistant varieties in HRZ not only improve gross margins (up to $1539/ha over highly susceptible varieties) but also reduce reliance on fungicides, making them a critical tool in STB management (Table 28).

Overall, the economic analysis highlights that STB management should be tailored to regional conditions. In MRZ and HRZ, fungicides can provide economic benefits in high-disease seasons but must be used strategically to maximize return on investment. In LRZ, genetic resistance offers the most cost-effective solution. The findings emphasize the importance of an integrated approach that combines resistant varieties and targeted fungicide applications to optimize farm profitability while minimizing disease risks.

Table 24: Mean gross margin ($/ha) comparison between fungicide and untreated control treatments for Scepter (S) in medium and low rainfall zones of the Southern region.

Location/Treatment	2021		2022#		2023	
Birchip, Vic, LRZ	**Gross margin ($/ha)**	**Benefit ($/ha) from fungicides over untreated control**	**Gross margin ($/ha)**	**Benefit ($/ha) from fungicides over untreated control**	**Gross margin ($/ha)**	**Benefit ($/ha) from fungicides over untreated control**
Foliar spray at Z31	678	-45	-	-	1536	94
Foliar spray at Z31 + Z39	689	-33	-	-	1540	97
Foliar spray at Z39	729	6	-	-	1483	40
Seed + Foliar spray at Z31 + Z39 (Minimum disease)	-	-	-	-	1526	83
Seed + Foliar spray at Z39	724	2	-	-	-	-
Seed treatment	703	-19	-	-	1436	-7
Untreated control (Maximum disease)	722	0	-	-	1443	0
Hart, SA, MRZ						
Foliar spray at Z31	547	-8	1174	53	979	57
Foliar spray at Z31 + Z39	518	-37	1240	120	917	-5
Foliar spray at Z39	497	-58	1202	82	925	3
Seed + Foliar spray at Z31 + Z39 (Minimum disease)	-	-	1224	104	908	-14
Seed + Foliar spray at Z39	532	-23	-	-	-	-
Seed treatment	558	3	1089	-31	895	-27
Untreated control (Maximum disease)	555	0	1121	0	922	0
Longerenong, Vic, MRZ						
Foliar spray at Z31	1792	-24	1077	101	1530	96
Foliar spray at Z31 + Z39	1797	-19	1292	**315**	1584	150
Foliar spray at Z39	1803	-13	1174	197	1447	12
Seed + Foliar spray at Z31 + Z39 (Minimum disease)	-	-	1295	**318**	1596	162
Seed + Foliar spray at Z39	1821	5	-	-	-	-
Seed treatment	1782	-34	1030	53	1508	73
Untreated control (Maximum disease)	1816	0	977	0	1434	0

#A severe stripe rust infection at Birchip in 2022 compromised the ability to assess the impact of septoria tritici blotch (STB) on wheat yield, so the data was excluded. Across all locations and seasons, wheat value per hectare ($/ha) was calculated using an assumed farm gate price of $300 per tonne, multiplied by plot yield. Gross margins ($/ha) were determined by subtracting fungicide application costs from the wheat value. The benefit ($/ha) of fungicide applications was calculated as the difference between the gross margin of treated plots and the untreated control.

Table 25: Benefit from fungicides applications over untreated in the medium and low rainfall zones of the Southern region for different resistance/susceptibility ratings to septoria tritici blotch (STB).

Location/Treatment	2021			2022#			2023		
	Disease	Fungicide	Benefit ($/ha) from fungicides	Disease	Fungicide	Benefit ($/ha) from fungicides	Disease	Fungicide	Benefit ($/ha) from fungicides
Birchip, Vic, LRZ									
MS	748	621	-127	-	-	-	1520	1453	-67
MSS	787	745	-42	-	-	-	1461	1472	10
S	844	817	-27	-	-	-	1451	1566	**114**
SVS	807	711	-96	-	-	-	1229	1271	41
Booleroo, SA, LRZ									
MS	200	150	-50	1645	1627	-19	488	464	-24
MSS	487	442	-45	1626	1766	140	678	572	-106
S	457	423	-34	1539	1894	355	638	572	-67
SVS	504	415	-90	1499	1739	240	604	498	-106
Hart, SA, MRZ									
MS	506	505	-1	1022	1001	-21	801	759	-42
MSS	642	632	-10	971	987	16	851	793	-59
S	662	683	21	1039	1089	50	898	895	-2
SVS	672	655	-17	983	1005	22	854	857	2
Longerenong, Vic, MRZ									
MS	1695	1659	-35	1228	1410	182	1760	1780	21
MSS	1592	1527	-65	1162	1395	233	1564	1788	224
S	1857	1958	101	960	1419	**459**	1667	1888	**221**
SVS	1610	1667	57	807	1254	**447**	1326	1598	**272**

#A severe stripe rust infection at Birchip in 2022 compromised the ability to assess the impact of septoria tritici blotch (STB) on wheat yield, so the data was excluded. Across all locations and seasons, wheat value per hectare ($/ha) was calculated using an assumed farm gate price of $300 per tonne, multiplied by plot yield. Gross margins ($/ha) were determined by subtracting fungicide application costs from the wheat value. The benefit ($/ha) of fungicide applications was calculated as the difference between the gross margin of treated plots and the untreated control.

Table 26: Mean Gross margin ($/ha) comparison between Variety resistance to septoria tritici blotch (STB) over a susceptible or a highly susceptible variety in the presence of disease in medium and low rainfall zones of the Southern region.

Location/Rating	2021			2022#			2023		
Birchip, Vic, LRZ	Gross margin ($/ha)	Benefit ($/ha) over a SVS rated variety	Benefit ($/ha) over a S rated variety	Gross margin ($/ha)	Benefit ($/ha) over a SVS rated variety	Benefit ($/ha) over a S rated variety	Gross margin ($/ha)	Benefit ($/ha) over a SVS rated variety	Benefit ($/ha) over a S rated variety
MS	748	-59	-96	-	-	-	1520	**291**	69
MSS	787	-20	-57	-	-	-	1461	232	10
S	844	37	0	-	-	-	1451	222	0
SVS	807	0	-37	-	-	-	1229	0	-222
Booleroo, SA, LRZ									
MS	200	-304	-257	1645	146	106	488	-116	-150
MSS	487	-17	30	1626	127	87	678	74	40
S	457	-47	0	1539	40	0	638	35	0
SVS	504	0	47	1499	0	-40	604	0	-35
Hart, SA, MRZ									
MS	506	-166	-156	1022	39	-17	801	-53	-97
MSS	642	-31	-20	971	-12	-68	851	-3	-46
S	662	-10	0	1039	56	0	898	43	0
SVS	672	0	10	983	0	-56	854	0	-43
Longerenong, Vic, MRZ									
MS	1695	84	-162	1228	**421**	268	1760	**433**	93
MSS	1592	-18	-264	1162	355	203	1564	238	-102
S	1857	246	0	960	152	0	1667	341	0
SVS	1610	0	-246	807	0	-152	1326	0	-341

#A severe stripe rust infection at Birchip in 2022 compromised the ability to assess the impact of septoria tritici blotch (STB) on wheat yield, so the data was excluded. Across all locations and seasons, wheat value per hectare ($/ha) was calculated using an assumed farm gate price of $300 per tonne, multiplied by plot yield of disease only treatments. The benefit ($/ha) of using an MS or MSS variety was determined by calculating the difference in gross margin between MS or MSS varieties and S or SVS varieties.

Table 27: Benefit from fungicides applications over untreated in high rainfall zones of the Southern region for different resistance/susceptibility ratings to Septoria tritici blotch (STB).

Location/Treatment	2021			2022		
	1 Fungicide	**2 Fungicide**	**4 Fungicide**	**1 Fungicide**	**2 Fungicide**	**4 Fungicide**
Gnarwarre, Vic						
RMR	-76	216	142	221	51	175
MRMS	230	174	-14	566	387	571
MS	38	501	586	512	252	613
S	110	549	595	362	225	703
Hagley, TAS						
RMR	-217	441	124	221	618	607
MRMS	644	591	928	584	999	748
MS	548	480	781	467	1440	742
S	527	792	**1144**	569	1176	859
Millicent, SA						
RMR	-1	72	-104	-28	-90	-146
MRMS	287	345	382	41	165	310
MS	500	822	907	275	510	445
S	758	969	**1120**	197	462	448

Raw data for high rainfall region was obtained from GRDC -FAR'S co-investment, "Integrated disease management (IDM) strategies for septoria tritici blotch (STB) in the Southern region" (FAR2004-002SAX). Across all locations and seasons, wheat value per hectare ($/ha) was calculated using an assumed farm gate price of $300 per tonne, multiplied by plot yield. Gross margins ($/ha) were determined by subtracting fungicide application costs from the wheat value. The benefit ($/ha) of fungicide applications was calculated as the difference between the gross margin of treated plots and the untreated control.

Table 28: Mean Gross margin ($/ha) comparison between Variety resistance to Septoria tritici blotch (STB) over a susceptible variety in the presence of disease in high rainfall zones of the Southern region.

Location/Treatment	2021		2022	
	Gross margin ($/ha)	Benefit ($/ha) over a S rated variety	Gross margin ($/ha)	Benefit ($/ha) over a S rated variety
Gnarwarre, Vic				
RMR	2058	696	1422	948
MRMS	1494	132	1251	777
MS	1422	60	1176	702
S	1362	0	474	0
Hagley, Tas				
RMR	3771	**1410**	2289	918
MRMS	2940	579	2175	804
MS	3279	918	1659	288
S	2361	0	1371	0
Millicent, SA				
RMR	3141	**1539**	1860	888
MRMS	2673	1071	1557	585
MS	2181	579	990	18
S	1602	0	972	0

Raw data for high rainfall region was obtained from GRDC -FAR'S co-investment, "Integrated disease management (IDM) strategies for septoria tritici blotch (STB) in the Southern region" (FAR2004-002SAX). Across all locations and seasons, wheat value per hectare ($/ha) was calculated using an assumed farm gate price of $300 per tonne, multiplied by plot yield of disease only treatments. The benefit ($/ha) of using a resistant variety was determined by comparing the gross margin of resistant varieties to that of an S variety.

Table 29: Product costs of each fungicide used in this, and FAR Australia's projects and the wheat yield (Kg/ha) return required to break even.

Product	Application rate	Fungicide costs ($/ha)	Additional yield required (Kg/ha)
Elatus ace ®	500 mL/ha	22.35	75
Opus 125 ®	500 mL/ha	8.75	29
Soprano ®	125 mL/ha	8.65	29
Maxentis ®	600 mL/ha	16.53	55
Jockey stayer ®	300 mL/100 Kg seed	17.15	57
Flutriafol 500 ®	400 mL/ha	5.20	17
Systiva®	150 mL/100 Kg seed	30.00	100
Revystar®	750 mL/ha	96.00	320
Prosaro®	300 mL/ha	9.60	32
Aviator® Xpro®	500 mL/ha	31.35	105

Fungicide product costs were obtained from local resellers at Horsham, Victoria on 1st March 2025.

CONCLUSION

This project provided valuable insights into the epidemiology of STB in Southern Australia. The lifecycle of *Zymoseptoria tritici* is polycyclic, involving both sexual (ascospores) and asexual (pycnidiospores) reproduction phases. Spore dispersal is primarily influenced by low winter temperatures (10-15°C), while in spring, it is driven by frequent rainfall events and low relative humidity conditions. Wheat stubble was identified as a significant source of early-season infection, and early sowing of wheat exacerbated disease risk, particularly in susceptible varieties, due to prolonged exposure to inoculum. Notably, disease risk and yield reduction were higher in the MRZ, where frequent rainfall events favoured spore dispersal, resulting in more severe disease pressure and significant yield losses (up to 43%) in susceptible varieties. In contrast, the LRZ experienced lower disease pressure, and yield reductions were generally less pronounced, especially in dry seasons with limited rainfall.

In terms of management strategies, the combination of variety resistance, targeted fungicide applications, stubble management, and crop rotation proved most effective in controlling STB and maximizing profitability. Growing less susceptible wheat varieties resulted in lower disease severity and up to $433/ha in economic advantages compared to susceptible varieties. Fungicide applications were most beneficial in high-disease years, with gross margins increasing by up to $459/ha in high-risk seasons, particularly in the MRZ. However, fungicide applications were not always profitable in low-disease years or crops with low yield potential, especially in the LRZ. Stubble management reduced early-season inoculum levels but had limited impact on late-season disease, as spores could still travel long distances. Crop rotation with non-host crops such as canola and pulses significantly reduced inoculum loads, while delaying sowing (e.g., to May) reduced disease pressure and minimized fungicide dependence, ultimately leading to higher economic returns. These findings offer actionable, data-driven recommendations that help mitigate disease risks while optimizing economic outcomes for wheat growers in both the MRZ and LRZ of Southern Australia.

IMPLICATIONS

The outcomes of this project have significant implications for the Australian wheat industry, particularly for growers in the MRZ and LRZ, where STB remains a major threat to wheat production. The findings provide valuable, region-specific recommendations for disease management strategies that can improve yield stability, reduce input costs, and enhance profitability.

The adoption of variety resistance strategies offers the most cost-effective STB management tool, with less susceptible wheat varieties consistently reducing disease severity and minimizing yield loss. In high-risk areas, such as the MRZ, growing resistant varieties can lead to an economic advantage of up to $433/ha compared to susceptible varieties. In contrast, using susceptible varieties in high-risk areas leads to significant yield losses of up to 43%, necessitating costly fungicide applications, which can reduce profitability. Fungicide applications proved to be effective in high-disease years, particularly in the MRZ, where the application of fungicides increased gross margins by up to $459/ha during high-disease seasons like 2022. However, fungicide applications in low-disease years (such as in the LRZ during dry seasons) were less profitable and often resulted in financial losses, reinforcing the importance of seasonal disease monitoring to determine when fungicide use is most economical.

While the upfront cost of transitioning to resistant wheat varieties may be higher, the reduction in fungicide use and improved yields offer a clear return on investment. In contrast, the cost of fungicide applications in high-disease years can be offset by increased gross margins, but in low-disease years, these costs may not be justified. Crop rotation and stubble management may require some initial investment in terms of practice change or infrastructure (e.g., baling and burning stubble), but the long-term benefits in terms of disease control and sustainability are likely substantial.

In conclusion, the integration of these disease management strategies can help wheat growers in Southern Australia enhance their productivity, reduce disease risks, and optimize profitability. By adopting a combination of resistant varieties, targeted fungicide use, stubble management, and crop rotation, growers can make informed decisions that will lead to better disease control, improved yields, and enhanced long-term sustainability.

RECOMMENDATIONS

The findings of this project underscore the importance of adopting IDM strategies to combat STB and enhance wheat production in Southern Australia. Based on the results, the following recommendations are made:

- **Communication of proven IDM strategies:**
  Showcase the effectiveness of beneficial IDM strategies in real-world conditions, helping growers adopt best practices with confidence.
- **Integrating STB IDM strategies with other disease management in wheat:**
  IDM strategies for STB should be compatible with those for other wheat diseases (ex. Stripe rust), ensuring effective management across multiple pathogens. Using shared strategies, allows for coordinated disease control.
- **Use of spore trapping technology to track and forecast disease risk spatially and temporally:**
  Tracking spore release, provides real-time data on disease risk. This data can inform disease forecasting models, allowing growers to make more accurate decisions and reduce unnecessary fungicide use.
- **Development of predictive model-based Apps:**
  A predictive model app, integrating environmental data and spore release trends, could help forecast disease risk and guide fungicide use. Such an app would allow growers to make informed decisions and reduce reliance on fungicides.
- **Monitoring virulence in STB pathogen populations:**
  Continuously track virulence shifts in STB pathogen populations to identify emerging risks. This information should be shared with breeders and growers to guide resistance breeding and disease management.
- **Implement effective stubble management practices on a regional scale:**
  Implement effective stubble management practices on a regional scale to reduce airborne ascospores locally and minimize the spread of STB.
- **Deploying wheat cultivars with diverse resistance sources:**
  Avoid large-scale cropping of susceptible varieties and dynamically deploy wheat cultivars with diverse resistance sources across regions and seasons to disrupt pathogen evolution and slow virulence development.
- **Disease management in a fungicide resistance environment:**
  With resistance increasing in STB populations, particularly to DMIs (Group 3) and Strobilurins (Group 11), future IDM strategies should prioritize non-chemical approaches and reduce reliance on fungicides.
- **Breeding for more resistant varieties:**
  Develop and adopt wheat varieties with improved STB resistance to lower fungicide dependence, enhance disease control, and improve long-term profitability.

GLOSSARY AND ACRONYMS

Below is an abbreviations and acronyms list that appear in this report.

DEECA	Department of Energy, Environment, and Climate Action
SARDI	South Australia Research and Development Institute
STB	Septoria tritici blotch
IDM	Integrated disease management
HRZ	High rainfall zone
MRZ	Medium rainfall zone
LRZ	Low rainfall zone
LMM	Linear mixed model
REML	Restricted maximum likelihood
ANOVA	Analysis of variance
LSD	Least significant difference
SCRIME	Sustainable Cropping Rotations in Mediterranean Environments
RH	Relative humidity
DNA	Deoxyribonucleic acid
MR	Moderately resistant
MRMS	Moderately resistant to moderately susceptible
MS	Moderately susceptible
MSS	Moderately susceptible to susceptible
S	Susceptible
SVS	Susceptible to very susceptible
AUDPC	Area under the disease progress curve
AR1	Autoregressive process
FAR Australia	Field Applied Research
UTC	Untreated control
LAI/A	Leaf area infected/affected

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APPENDIX