Cereal Disease Management
(Revised 2014)

Key fungicide timings for disease management strategies in:

• Autumn sown barley
• Spring sown barley
• Autumn sown wheat
Photos courtesy of:
Ian Harvey (PLANTwise)
Nick Poole (FAR)
Introduction

The Foundation for Arable Research’s Cropping Strategies were introduced in 2011 with the aim of summarising FAR’s research results over the last three to five years, and asking what those results meant for crop management. Farmers and advisers have consistently asked for concise summaries of “what this research means for me”. Each section of the strategy documents begins with a summary and is followed by examples of consolidated trials research which form the basis of the management strategies presented.

This Cropping Strategies booklet, Cereal Disease Management, focuses on key fungicide products, rates and timings for disease management strategies in autumn sown barley, spring sown barley and autumn sown wheat. It presents a range of management options for disease control in cereals that have performed well in trials over a number of years.

Disease management in wheat

This season’s Cereal Disease Management Cropping Strategy booklet is particularly important as the spectrum of diseases in New Zealand wheat crops has changed and as a result, the strategies for combating disease have also altered. Since 2011, wet weather necrotrophic diseases such as Septoria tritici blotch (STB) caused by the fungal pathogen Zymoseptoria tritici, have become the dominant disease issue, taking over from the cereal rusts which were dominant from 2002 – 2009.

Disease management strategies focused on cereal rusts do not work as well against wet weather diseases such as STB. There are three principal reasons for this:

• STB has developed resistance to the commonly used strobilurin fungicides

• STB is showing reduced sensitivity to triazoles (Demethylase inhibitors (DMI) Group 3 fungicides).

• STB is more difficult to control than cereal rusts, so generally requires higher rates of fungicide to achieve control.

The wheat strategies outlined in this book are primarily aimed at STB control, but they will also control rusts.

The Cereal Disease Management Cropping Strategies booklet outlines the disease management options that have provided better economic returns from trials over the last two years and takes account of recent changes in the resistance of key pathogens to fungicide application. It is important that strategy documents produced prior to the advent of resistance are not used as reference for crops grown now, because of the advent of resistance and newer product availability.

We hope that you find the information presented in this strategy document both interesting and economically rewarding in the management of your crops.

Nick Poole

Director of Research and Extension

Other Cropping Strategies available:

Issue 1: Nitrogen Application in Wheat (2011)

Issue 2: Nitrogen in Perennial Ryegrass Seed Crops and Canopy Management Strategy for Autumn Sown Oilseed Rape (2011)


NB Issue 3: Cereal Disease Management (2012) is now outdated. Replace with this book.
Key fungicide timings for disease management strategies in autumn sown barley

**Summary**

**Disease susceptible scenarios**
Generally autumn sown barley tends to be more disease prone than spring sown barley. This is due to the longer growing season and the tendency for wet weather diseases such as scald (Rhynchosporium) to build up over winter. FAR research trials have found that under these conditions autumn sown barley benefits from at least two foliar fungicides.

Therefore consider two spray applications for autumn sown barley starting at the start of stem elongation GS30–31.

**Seed Treatment – Systiva based on the new SDHI fungicide fluxapyroxad**
The first main year of Systiva seed treatment trials has shown an economic advantage in an irrigated crop but not dryland. Initial data show that foliar fungicide programmes should not be reduced through the use of Systiva. However, if Systiva has been used, remember it counts toward the two SDHI applications allowed per season, thus limiting you to one SDHI based foliar fungicide application in-crop. If SDHI seed treatment has been used, FAR would envisage GS39–49 as the optimum timing window for a foliar SDHI spray, due to the strengths of these fungicides against Ramularia leaf spot.

**GS30 – GS31 (pseudo stem erect – first node)**
At this first timing, tank mixtures of Proline (prothioconazole) with the strobilurin Acanto (picoxystrobin) or Adexar (epoxiconazole and fluxapyroxad) or Aviator Xpro (prothioconazole and bixafen) have been very effective on both wet weather diseases such as scald, and warmer weather diseases such as leaf rust. Consider Proline 0.4 l/ha + Acanto 0.25 l/ha or select from the pre-formulated SDHIs and triazole mixes such as Aviator Xpro 0.7 l/ha or Adexar 1.0 l/ha. Aviator Xpro and Adexar mixtures have performed well over the last three seasons in trials, but unlike the Acanto option, have not been tested against severe scald infections in autumn sown barley.

A lower cost option that has performed well at this timing and which may be more suitable for dryland or more disease resistant cultivars (provided there is no leaf rust present) is a mixture of Proline (prothioconazole) and Protek (carbendazim) or Proline formulated with low rates of Mogul (fluoxastrobin). In these scald situations consider Proline 0.4 l/ha + Protek 0.5 or Mogul 1.0 l/ha.
Follow the first application (applied at GS30–31) 3–4 weeks later with a second fungicide application, ideally as the flag leaf sheath is extending and when the first awns show. If the crop has not reached this stage do not let the spray interval exceed four weeks and spray earlier in the GS39–49 window.

**GS39 – GS49 (flag leaf fully emerged to first awns emerging)**

At this second timing consider an SDHI plus triazole where both Ramularia leaf spot and leaf rust are the principal disease threats. Consider Proline 0.2–0.4 l/ha + Seguris Flexi 0.3 – 0.6 l/ha or Aviator Xpro 0.7 l/ha or Adexar 1.0 l/ha.

Where a lower cost spray option is required, for example in dryland crops, consider Proline 0.2 l/ha + Protek 0.5. Remember this option will be less effective against leaf rust than Proline mixed with Seguris Flexi, but should control scald and Ramularia leaf spot.

**When are three sprays necessary?**

When high scald pressure is present early in the spring at the late tillering stage (pre GS30), consider applying a lower cost “holding” spray prior to the two sprays at GS30–31 and 39–49 timings. Options would include Proline 0.2 l/ha + Protek 0.5 l/ha. Do not omit the other two sprays if the pre GS30 is applied. This holding spray has tended to be most important in dryland crops on lighter soils where early leaf loss is relatively more important than in irrigated crops (as dryland crops have less green leaf retention later in the season). The two most likely scenarios for needing an early tillering spray are where barley is grown following barley or where barley is sown early.

Where crops are irrigated, the grain fill period is extended. In these situations, increasing the rate of fungicide at the second timing or applying a third spray at ear emergence (GS59) has increased yield by 2–3% in FAR trials (Ramularia leaf spot/leaf rust situations). To date, the margin returns have been slightly more reliable with a higher rate of fungicide applied at flag-awn emergence (when using Acanto 2010–2012). However since Seguris Flexi with Proline at GS39–49 is more effective against Ramularia leaf spot than Acanto, there has been less need to apply a third spray at ear emergence.

**Notes:**

Above rates assume optimum timing of application. Late sprays where disease is at high pressure may require higher rates.

In some situations in wetter seasons, dryland sites may be more equivalent to irrigated sites. In dryland situations, monitor rainfall between the key application timings at GS30, 49 and 59 (early stem elongation – ear emergence). If rainfall is more frequent and higher than average, consider implementing irrigated strategy options.

**Use of rates lower than the full label rate is done at the grower’s own risk.**
Background supporting data 2010–2012

The following table shows the mean yield and margin response from 10 fungicide treatments tested at the South Canterbury FAR Arable Site from three irrigated trials with cultivars Retriever in 2010 and 2011 and Tavern in 2012. Both cultivars are relatively susceptible to leaf rust and Ramularia leaf spot, and Tavern is also moderately susceptible to scald.

Influence of fungicide on yield and margin after chemical cost relative to the untreated ($/ha, grain price $400/t, application cost of $18/ha per pass) in irrigated autumn sown barley – 3 year mean, (Retriever 2010-11 and Tavern 2012).

<table>
<thead>
<tr>
<th>Trt. No.</th>
<th>GS30-31 (l/ha)</th>
<th>GS49 (l/ha)</th>
<th>GS59 (l/ha)</th>
<th>Yield (t/ha)</th>
<th>% Yield gain over nil fungicide</th>
<th>Margin over fungicide cost ($/ha)</th>
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<tbody>
<tr>
<td>1</td>
<td>Adexar 1.0</td>
<td>Adexar 1.0</td>
<td></td>
<td>11.9</td>
<td>37</td>
<td>1072</td>
</tr>
<tr>
<td>2</td>
<td>Aviator Xpro 0.7</td>
<td>Aviator Xpro 0.7</td>
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<td>11.7</td>
<td>35</td>
<td>1020</td>
</tr>
<tr>
<td>3</td>
<td>Proline 0.4 + Seguris Flexi 0.3</td>
<td>Proline 0.2 + Seguris Flexi 0.3</td>
<td></td>
<td>11.5</td>
<td>33</td>
<td>970</td>
</tr>
<tr>
<td>4</td>
<td>Proline 0.4 + Acanto 0.25</td>
<td>Proline 0.2 + Seguris Flexi 0.6</td>
<td></td>
<td>11.5</td>
<td>32</td>
<td>909</td>
</tr>
<tr>
<td>5</td>
<td>Proline 0.4 + Acanto 0.25</td>
<td>Proline 0.2 + Seguris Flexi 0.3</td>
<td></td>
<td>11.4</td>
<td>31</td>
<td>898</td>
</tr>
<tr>
<td>6</td>
<td>Proline 0.4 + Acanto 0.25</td>
<td>Proline 0.4 + Acanto 0.5</td>
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<td>28</td>
<td>733</td>
</tr>
<tr>
<td>7</td>
<td>Proline 0.4 + Acanto 0.25</td>
<td>Proline 0.2 + Acanto 0.25</td>
<td>Proline 0.2 + Acanto 0.25</td>
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<td>Proline 0.2 + Acanto 0.25</td>
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</tr>
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<td>Proline 0.2</td>
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<td>23</td>
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</tr>
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<td>nil</td>
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<td>8.7</td>
<td>0</td>
<td>0</td>
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</table>

LSD

Over the three years the main disease in the trials was Ramularia leaf spot which appeared later in the season. Scald was also a problem in 2012. The trials investigated the efficacy of Proline and Acanto compared with triazole plus SDHI. SDHIs are not a new group of fungicides but more an extension to an earlier discovered family of chemistry (FRAC Group 7). The site of activity for these fungicides is the mitochondria, the same part of the cell that strobilurins affect (provided the disease strain is not resistant). There is no cross resistance between the strobilurins and the SDHIs, so any fungal resistance that renders strobilurins ineffective has no effect on the SDHIs and vice versa. These SDHI products have performed well in the last three seasons of trials, particularly when Ramularia leaf spot has been the main disease.

The three SDHI molecules tested against barley disease are:

- Isopyrazam (IZM) – Seguris Flexi (available alone to be mixed with DMI triazoles)
- Fluoxaproxad - Adexar (co-formulated with epoxiconazole (Opus))
- Bixafen – Aviator Xpro (co-formulated with prothioconazole (Proline))

In Europe the barley disease net blotch is already showing resistance to SDHIs, so it is important to make sure that when we use these products, we do not exceed two applications per season and do so in mixtures with fungicides that have a different mode of action.

Ramularia leaf spot – a common late-season disease in autumn and spring sown barley.
Systiva seed treatment in autumn sown barley

The following table shows the mean yield from eight foliar fungicide treatments superimposed on two seed treatments, from three trials, dryland and irrigated at the Chertsey FAR Arable Site and dryland South Canterbury in 2013, with autumn sown cultivar Tavern.

**Influence of Systiva seed treatment on yield in autumn sown barley cultivar Tavern, Chertsey FAR Arable Site and South Canterbury 2013–14.**

<table>
<thead>
<tr>
<th>Foliar fungicide Trt. No.</th>
<th>GS26 (late tillering period)</th>
<th>GS30–31 (rows closed, leaf 3–4 emergence)</th>
<th>GS33</th>
<th>GS39</th>
<th>GS49 (awn emergence)</th>
<th>GS59</th>
<th>Dryland Yield</th>
<th>Irrigated Yield</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>No Systiva*</td>
<td>Systiva†</td>
</tr>
<tr>
<td>1</td>
<td>nil</td>
<td>nil</td>
<td></td>
<td></td>
<td>nil</td>
<td></td>
<td>7.4</td>
<td>8.1</td>
</tr>
<tr>
<td>2</td>
<td>Proline 0.2 + Acanto 0.25</td>
<td>Proline 0.2 + S.F. 0.3</td>
<td>8.6</td>
<td>8.9</td>
<td>8.7</td>
<td>9.6</td>
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<td></td>
</tr>
<tr>
<td>3</td>
<td>Proline 0.4 + Acanto 0.25</td>
<td>Proline 0.2 + S.F. 0.3</td>
<td>9.1</td>
<td>9.3</td>
<td>10.1</td>
<td>10.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Proline 0.4 + Acanto 0.25</td>
<td>Proline 0.4 + S.F. 0.3</td>
<td>9.1</td>
<td>9.2</td>
<td>10.3</td>
<td>10.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Proline 0.4 + Acanto 0.25</td>
<td>Proline 0.4 + S.F. 0.6</td>
<td>9.3</td>
<td>9.6</td>
<td>10.5</td>
<td>10.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Proline 0.4 + Acanto 0.25</td>
<td>Proline 0.2 + S.F. 0.3</td>
<td>9.1</td>
<td>9.4</td>
<td>9.8</td>
<td>10.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Proline 0.2 + Protek 0.5</td>
<td>Proline 0.2 + S.F. 0.3</td>
<td>9.4</td>
<td>9.5</td>
<td>10.4</td>
<td>10.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Proline 0.4 + Acanto 0.25</td>
<td>Proline 0.2 + Protek 0.5</td>
<td>9.3</td>
<td>9.3</td>
<td>10.4</td>
<td>10.7</td>
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</tr>
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<td>Mean</td>
<td>8.9</td>
<td>9.1</td>
<td>9.6</td>
<td>10.1</td>
<td></td>
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</tbody>
</table>

*Seed Raxil treated. 1. Systiva treated seed at 1.25 L/T seed. 2. Seguris Flexi.

The trials investigated the new barley SDHI seed treatment Systiva. The main diseases in the crop at Chertsey (irrigated) were scald and leaf rust, whereas in South Canterbury (dryland), net blotch and Ramularia leaf spot were the main problems. In the South Canterbury trial the best fungicide treatment gave a 13% yield increase over the untreated, compared with a 67% yield increase in the irrigated Chertsey trial. Yields with Systiva seed treatment were on average 0.2 and 0.5 t/ha higher on dryland and irrigated crops respectively compared with no Systiva seed treatment. The highest yield for the irrigated trial was treatment no. 7 – Systiva seed treatment followed by a three foliar fungicide spray programme producing 10.9 t/ha. With a grain price of $400/t it takes a yield increase of about 0.28 t/ha to pay for the Systiva seed treatment. Therefore Systiva seed treatment was cost effective in most of the fungicide programmes in the irrigated crop, but generally not the dryland (assuming a seed rate of 105 kg/ha).

On average across the three trials the disease control provided by the Systiva seed treatment increased grain yield by 0.68 t/ha compared with Raxil seed treatment when no follow up foliar fungicide was applied. The yield response to Systiva seed treatment decreased to less than 0.3 t/ha when the foliar fungicide follow ups were applied and fungicide timing was brought forward to standard timings for a two spray programme at GS30-31 and GS49.
Comparison to autumn sown barley:
Optimum fungicide timings in spring sown barley have generally mirrored those observed in FAR trials on autumn sown barley. However, three key differences have been observed:

- Spring sowing naturally reduces disease pressure allowing lower rates of fungicide to be employed.
- Later sown crops (October) develop much quicker with a short grain fill period reducing the need for fungicide persistence.
- Where dryland crops are sown later, particularly on the east coast of New Zealand (e.g. Hawke’s Bay), fungicides produce relatively small gains in profitability and therefore fungicide cost needs to be tailored accordingly.

Therefore consider two spray programmes for spring sown barley starting at the start of stem elongation GS30 or as the rows close over at GS23–30.

Spring barley

GS23–GS30 – Row closure (T1)
Similar products to those used in autumn sown barley have performed well in spring sown barley. At the first timing, tank mixtures of Proline (prothioconazole) with the strobilurins Acanto (picoxystrobin) or with fluoxastrobin in the formulated products Mogul or Fandango have performed well. Seguris Flexi the SDHi (isopyryzam) has also been effective when mixed with Proline as has the pre-formulated SDHi mixture Aviator Xpro (prothioconazole and bixafen). Therefore, for irrigated crops or early sown dryland crops consider:

Proline 0.2 l/ha + Acanto 0.25 l/ha or Proline 0.2 l/ha + Seguris Flexi 0.3–0.45 l/ha or Fandango 0.5 l/ha or Mogul 0.5 l/ha or Aviator Xpro 0.7 l/ha
For dryland crops, where disease pressure has been historically low, consider Proline mixed with Protek, Proline 0.2 l/ha + Protek 0.5 or Mogul 0.5 which has the same Proline component as Fandango but half the strobilurin component.

**GS39–GS49 – flag leaf fully emerged to awns emerging (T2)**
For irrigated crops or early sown disease prone dryland crops consider:
Aviator Xpro 0.7 l/ha or Proline 0.2 l/ha + Seguris Flexi 0.3–0.45 l/ha or Fandango 0.5 l/ha or Mogul 0.5 l/ha

The SDHI option Seguris Flexi would be stronger if the key target diseases were leaf rust and Ramularia leaf spot, whilst the SDHI option based on Aviator Xpro, would be stronger on scald and Ramularia leaf spot. Good leaf rust resistance and/or very dry conditions may reduce the value of adding a strobilurin or SDHI with the Proline.

The later GS49 timing has the advantage of applying fungicide to the flag leaf sheath, which is un-emerged at GS39. However this benefit has to be considered against ensuring that the gap between the two sprays does not exceed four weeks.

**Dryland crops with lower disease pressure**
Trials in the Manawatu and Hawke’s Bay over three years (and drier inland parts of Southland in previous FAR trials) have shown lower cost fungicide programmes to be more cost effective. In the Manawatu and Hawke’s Bay trials there has been no increase in yield from adding other fungicides to a two spray Proline programme in dryland situations.

**Notes:**
Above rates assume optimum timing of application. Late sprays where disease is at high pressure may require higher rates.

In some situations in wetter seasons, dryland sites may be more equivalent to irrigated sites. In dryland situations, monitor rainfall between the key application timings at GS30, 49 and 59 (early stem elongation – ear emergence). If rainfall is more frequent and higher than average, consider implementing irrigated strategy options.

**Use of rates lower than the full label rate is done at the grower’s own risk.**
The following table shows the mean yield and $ margin response from 11 fungicide treatments tested at the Chertsey FAR Arable Site from three irrigated trials with cultivars Booma in 2011 and Tavern in 2012 and 2013. Over the three seasons leaf rust was the main disease with Ramularia leaf spot as well in the 2012 season. The highest yielding treatment was Aviator Xpro 0.7 l/ha which yielded significantly higher than Aviator Xpro 0.5 l/ha. Aviator Xpro at 0.7 l/ha is a formulation with the SDHI bixafen and 0.4 l/ha Proline. The second highest yielding treatment had half the quantity of Proline and the SDHI Seguris Flexi at the second application timing.

**Influence of fungicide on yield and margin after chemical cost relative to the untreated ($/ha, grain price $400/t, application cost of $18/ha per pass) in irrigated spring sown barley – 3 year mean, (Booma 2011 and Tavern 2012-13).**

<table>
<thead>
<tr>
<th>Trt. No.</th>
<th>GS30-31 (l/ha)</th>
<th>GS49 (l/ha)</th>
<th>Yield (t/ha)</th>
<th>% Yield gain over nil fungicide</th>
<th>Margin over fungicide cost ($/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Aviator Xpro 0.7</td>
<td>Aviator Xpro 0.7</td>
<td>10.0</td>
<td>38.5</td>
<td>908</td>
</tr>
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<td>2</td>
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<td>Proline 0.2 + S.F. 0.45</td>
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<td>Proline 0.2 + S.F. 0.3</td>
<td>Proline 0.2 + S.F. 0.3</td>
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<td>0</td>
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</tbody>
</table>

**S.F. = Seguris Flexi**

The following graph shows the mean yield and $ margin response from four fungicide treatments tested in the Manawatu from 2009 to 2011 for cultivars Fairview, County and Bumpa. The main diseases present were net blotch and Ramularia leaf spot. The yield response was low in this trial series and adding a second fungicide to Proline was not economic.

**Influence of fungicide on yield (% relative to untreated) and margin over fungicide cost ($/ha) in dryland spring sown barley for three cultivars 2009–2011, Manawatu. Yield: 100 = 6.64 t/ha.**
Disease control in wheat

Background

Be aware the landscape has changed!

The spectrum of wheat disease in New Zealand has changed and as a result, the strategies for combating disease have also altered. Since 2011, wet weather necrotrophic diseases, such as Septoria tritici blotch (STB) caused by the fungal pathogen *Zymoseptoria tritici*, have become the dominant disease issue, taking over from the cereal rusts which were dominant from 2002 – 2009.

Disease management strategies focused on cereal rusts do not work as well against wet weather diseases such as STB. There are three principal reasons for this:

- STB has developed resistance to the commonly used strobilurin fungicides
- STB is showing reduced sensitivity to triazoles (Demethylase inhibitors (DMI) Group 3 fungicides).
- STB is more difficult to control than cereal rusts, so generally requires higher rates of fungicide to achieve control.

In addition, the last two seasons have seen a greater incidence of the wet weather disease tan spot (or yellow leaf spot) caused by the fungal pathogen *Pyrenophora tritici-repentis* in Canterbury wheat crops. Like STB, tan spot is a stubble borne disease of wheat, though unlike STB it tends to be more problematic in wheat on wheat crops (second or continuous wheat).

The strategies outlined in this book are primarily aimed at STB, but will also control rusts.

*Zymoseptoria tritici* (Septoria tritici blotch) in wheat.
Key fungicide timings for disease in autumn sown wheat

Summary

GS30 – T0 (Pre T1) fungicide applications
This should not be a routine spray, as the resulting yield increases are usually small and can be uneconomic. It is a spray that gives flexibility in management approach particularly if the T1 spray is delayed. This T0 spray is often mixed with the PGR.

Where STB pressure is very high, as a result of early sowing and a more susceptible cultivar, consider 75% doses of triazole formulations. If eyespot is present consider adding prochloraz for early disease control (FAR has no New Zealand generated data on prochloraz for this purpose). In Europe, STB populations have shown less reduction in sensitivity to prochloraz than to other triazoles.

GS31-32 – Leaf 3 emergence (T1)
The nodal growth stages GS31-32 traditionally coincide with leaf 3 emergence (the leaf two leaves below the flag). This is the first of the important top three leaves to emerge in the crop canopy and it is critical to keep all three leaves as disease free as possible.

Consider basing T1 applications on at least 75% dose rates of triazole e.g. Opus (epoxiconazole) 0.75 l/ha or Proline (prothioconazole) 0.6 l/ha. Proline has been more effective toward the 75% end of the 75–100% (0.6–0.8 l/ha) dose than Opus in FAR trials against STB. Note that with Proline the reference is to the highest rate on the label for wheat which is 0.8 l/ha, i.e. 75% of the 0.8 l/ha rate. Epxiconazole is available as a number of branded formulations, e.g. Accuro, Calibre, Fortify, Opus, Stellar.

Where cultivars are more resistant and/or late sowing has reduced STB pressure, consider applying the triazole alone, or in mixture with a second triazole to give greater efficacy.

Where disease pressure is high as a result of early sowing or susceptible cultivars, mix the triazole (Proline or Opus) with SDHI fungicide e.g. Seguris Flexi (isopyrazam) (0.8 –1.0 l/ha) or use the pre-formulated mixtures of SDHI and triazole such as Aviator Xpro 0.7–1.0 l/ha (prothioconazole and bixafen) or Adexar 1.0–1.25 l/ha (epoxiconazole and fluxapyroxad). Use the full label rate for early sown, susceptible cultivars. Since the dose rate of the triazole in these pre-formulated mixtures is less than a full label rate for the triazole alone, (Aviator Xpro at 0.7 l/ha contains the equivalent of 0.4 Proline and Adexar at 1.0 l/ha contains approximately 0.5 Opus) consider topping up the triazole component in order to better compliment the SDHI (e.g. add Proline at 0.2 l/ha to the lower label rate of Aviator Xpro or add Opus at 0.4–0.5 l/ha to the Adexar depending on whether 1.0 or 1.25 l/ha are used).

In general, where rusts have been absent and the principal disease is STB, Proline has performed better than Opus, particularly in South Canterbury and Southland.
GS39 – flag leaf emergence on main stem (T2)
This is an important growth stage for fungicide application in all wheat crops as the top three leaves have emerged on the main stem. Note that at this growth stage, flag leaves on the tillers are not fully emerged.

It is important to make sure that the time interval between the T1 spray and the flag leaf emergence spray does not exceed four weeks and that flag leaf applications are applied when the flag leaf has emerged on the main stem. Again consider 75–100% dose rates of triazole (for Opus full label rate 1.0 l/ha or Proline 0.6–0.8 l/ha) as the base component for this spray. Consider alternating your triazoles at the different application timings. i.e. if you used Proline at T1, consider Opus at T2 or vice versa.

In irrigated, or high rainfall, scenarios
Consider mixing the triazole (Opus or Proline) with Seguris Flexi (isopyrazam) (0.6–1.0 l/ha) or use the formulated mixtures of SDHI and triazole Aviator Xpro 0.7–1.0 l/ha (prothioconazole and bixafen) or Adexar 1.0–1.25 l/ha (epoxiconazole and fluxapyroxad). Use the higher rates of the SDHI with the susceptible cultivars and earlier sown crops and lower rates with more disease resistant cultivars or later sowings. Consider mixing more triazole (as outlined under T1 approach) if the period between the first spray and flag leaf has been punctuated with regular rainfall events.

Where the weather patterns are drier between T1 and T2, or the crop is under lower disease pressure, then consider lower rates of SDHI mixed with triazole dose rates of 75–100%.

In dryland scenarios in Mid and North Canterbury
Based on Mid Canterbury trials the use of more expensive fungicides is not cost effective in dryland. However, anti-resistance strategies are based on mixtures, so using lower rate mixtures of triazole and SDHI may be more appropriate than using triazole only strategies.

GS59-61 – ear emergence – first flowering (T3)
In irrigated scenarios, FAR research suggests that higher fungicide rates provide better protection against disease, particularly leaf rust, at T3.

Where one SDHI application has been applied
Where only one SDHI has been applied, wet weather has favoured STB, and leaf rust is also present, consider similar applications to those outlined for flag leaf, with rates adjusted for cultivar susceptibility.

Where two SDHI applications have been applied
Do not apply three SDHIs. Where two SDHI’s have been applied and cultivars are susceptible to both leaf
Summary

rust and STB. Consider Prosaro 0.6 l/ha or Opus 0.75–1.0 l/ha + Comet 0.4–0.6 l/ha. Comet is particularly effective against leaf rust when applied at ear emergence (GS59). Remember that Proline is weaker on leaf rust, hence the use of Prosaro (prothioconazole and tebuconazole), which has been slightly more effective than other mixtures at this timing applied at similar rates. Where STB has been encouraged by wet weather post flag leaf, ensure that Opus rates are at least 0.75 l/ha.

Where STB and Fusarium sp head infection are the key target diseases, then consider Proline (mixed with tebuconazole e.g. Prosaro for Fusarium spp) as a key ingredient for this spray. Effective control of Fusarium is difficult to achieve, even when the fungicide is applied at the most effective timing (early flowering).

In dryland scenarios
Consider T3 timing as an optional spray, dependent on rainfall, from flag leaf up until the end of flowering GS69 (anthers visible up the length of the ear). Consider applying fungicide if higher rainfall occurs in this period. Opus alone (0.25 - 0.5 l/ha) or low rate mixtures such as Amistar (0.25 l/ha) + Opus (0.25 l/ha) have been particularly effective to control rusts. Azoxystrobin is available as a number of branded formulations, e.g. Amistar, Atlantis Flo, Inspire, Salute, Tazer.

GS69-72 – Post flowering (T4)

Irrigated crops only – optional
For irrigated leaf rust-susceptible wheat crops on soils with good water holding capacity, mixtures based on Opus 0.25 l/ha + Amistar 0.25 l/ha (which have withholding periods of 42 and 35 days respectively) have delivered small but consistent yield benefits when applied following a similar application at ear emergence, but results were no better than increased rates of Comet/Opus applied at ear emergence when leaf rust was the primary disease. Be extremely mindful of withholding periods when considering late fungicides.

Tan spot scenarios
Where tan spot has been diagnosed in the crop at flag or ear emergence consider a strategy based on Proline (prothioconazole) mixed with the SDHI bixafen (as the preformulated mixture Aviator Xpro) or mixed with the strobilurin Comet (pyraclostrobin). The older triazole fungicide Tilt (propiconazole) is also an option for tan spot control. Tan spot is most likely to be found in second and continuous wheat crops.

Notes:
Above rates assume optimum timing of application. Late sprays, where disease pressure is high, may require higher rates.

In some situations in wetter seasons, dryland sites may be more equivalent to irrigated sites. In dryland situations, monitor rainfall between the key application timings at GS30, 49 and 59 (early stem elongation – ear emergence). If rainfall is more frequent and higher than average, consider implementing irrigated strategy options.

Use of rates lower than the full label rate is done at the grower’s own risk.
Tan spot

Tan spot was problematic in a small number of crops in 2013, principally where wheat was sown into wheat stubble (second or more continuous rotation positions). Like STB, tan spot is a stubble borne disease, however since its primary ascospores travel only short distances from the previous infected wheat stubble, infections tend to occur earlier and be more severe in wheat sown into wheat stubble. Cultural control by crop rotation and stubble management tends to be more effective in controlling this disease than in STB. Work being conducted by FAR Australia in 2014 in the Riverine Plains has found very low levels of disease at the initial assessments where stubble management has been carried out.

Fungicide management for tan spot

In 2013 FAR generated the first New Zealand data on the influence of fungicide product and rate on tan spot infection levels and yield. This data illustrated yield responses of up to 25% from the control of tan spot, and suggested that prothioconazole should be a key component in control strategies for the disease. In trials where different fungicide products and rates were applied following an initial standard spray at GS33, prothioconazole mixed with pyraclostrobin (strobilurin Comet) or the SDHI bixafen gave the best disease control and yield response.

Influence of fungicide on yield and margin after chemical cost relative to the untreated ($/ha, grain price $350/t, application cost of $15/ha per pass) on cv. Saracen, 2013-14.

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Septoria tritici blotch (STB)

Where Septoria tritici blotch (STB) is the principal disease threat

Cultural control measures should be used in conjunction with fungicides.

Stubble management

Although STB is a stubble borne disease it is unlikely that the method of crop establishment or presence of stubble in the paddock will have a marked impact on incidence. This is because the primary inoculum (ascospores) can travel several kilometres on the wind from the other stubble paddocks. If ascospores travelled only a few centimetres, as is the case with Tan spot, stubble management could be more important for disease control.

Influence of cultivar, sowing dates and weather pattern

When considering fungicide products, timing and rate, it is important to consider the effect of cultivar, sowing date and weather patterns:

<table>
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<th>High disease pressure is likely to result from:</th>
<th>Low disease pressure is likely to result from:</th>
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<tbody>
<tr>
<td>Early sowing (late March – early May)</td>
<td>Later sowing (late May or Spring)</td>
</tr>
<tr>
<td>More susceptible cultivars</td>
<td>More resistant cultivars</td>
</tr>
<tr>
<td>Wet weather GS31-39</td>
<td>Dry weather GS31-39</td>
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</table>

These effects combine to mean that the lowest disease incidence will occur where more resistant cultivars are sown later and subject to drier conditions during stem elongation. More susceptible cultivars which are sown earlier and which have been subject to wetter conditions during stem elongation are likely to have a higher incidence of disease.

Fungicide choice, rates, mixtures and timings

Strobilurin fungicides such as azoxystrobin e.g. Amistar, fluoxastrobin e.g. Mogul, picoxystrobin: Acanto or pyraclostrobin: Comet and trifloxystrobin: Twist no longer provide reliable control of STB following the discovery of resistance in the STB population in both South and North Island wheat crops.

Conditions which encourage STB

Septoria tritici blotch is a wet weather disease that spreads from the stubble of the previous crop. Unlike tan spot, where the initial ascospore release is only a few centimetres, primary STB ascospores can travel kilometres from the stubble where they mature. This means there is the potential for all wheat crops in a region to be infected from relatively few paddocks, or small areas of infected wheat stubble.

The life cycle of Zymoseptoria tritici (STB)
Fungicide resistance to Septoria tritici blotch (STB)

Key Points:
- STB resistance to strobilurins means these fungicides will be ineffective against STB in 2014.
- STB is also becoming less sensitive to triazoles, the other major fungicide group, meaning that higher triazole dose rates are required to control this disease.
- Disease control and yield responses from strobilurins to other diseases, such as rusts, will not be affected by resistance development in the STB populations.

The 2012/13 and 2013/14 seasons saw the development of widespread resistance of STB to some foliar fungicides. This change has resulted in poorer disease control from some fungicide programmes applied to manage this disease in wheat.

Reduced sensitivity to triazole fungicides

A 2012 survey of wheat crops in New Zealand, conducted by Syngenta in conjunction with FAR found that STB had developed reduced sensitivity to the triazole fungicides. Triazoles include products such as tebuconazole (Folicur), epoxiconazole (e.g Opus) and prothioconazole (Proline). This is not total fungicide resistance, but reduced sensitivity of the fungus to the triazoles. This reduced sensitivity means that higher rates of fungicide are required to obtain the same level of control as was experienced before the resistance mutation(s) occurred.

There are three key points to remember with this mechanism of resistance:

1. The shift in sensitivity of the fungal population develops over a number of years (and selection events).
2. It is a complex form of resistance governed by more than one gene which has meant that not all triazoles are affected in the same way.
3. Because of the genetic diversity that exists in a Septoria population, mutations conferring reduced sensitivity maybe different in different regions, different crops and different parts of crops. This in turn means that a triazole affected by reduced sensitivity in one crop may still be effective in another.

Studies at Massey University and Plant & Food Research (PFR) in Lincoln have indicated that in 2013, some Septoria populations had become 10–100 times less sensitive to some fungicides than sensitive isolates collected in the early 2000’s.

FAR Crop Action carried warnings of this reduced sensitivity at the start of the 2013 season and FAR established a series of trials to assess the rate response of epoxiconazole and prothioconazole. These trials in Southland and Canterbury established that the optimum dose was 75–100% label rate, and that prothioconazole was slightly more effective than epoxiconazole rate for rate.

In recent studies conducted by PFR, reduced sensitivity to STB was more pronounced with tebuconazole than the other three triazole fungicides tested. This finding is common with other diseases, where tebuconazole is one of the first triazoles affected by reduced sensitivity. It is associated with a common mutation Y136F which is an enabling mutation, allowing the fungus to develop reduced sensitivity to other triazoles.
Strobilurin resistance

In 2013 strobilurins failed to control STB in FAR trials and in paddocks elsewhere around the country. This was evident whether strobilurin fungicides were used alone or in mixture. Note, although FAR trials used Comet (pyraclostrobin), this resistance affects all strobilurins (see list in adjacent column).

In Southland the yield response to the strobilurin mixtures was still good, but control of STB was relatively poor.

Testing conducted by Plant & Food Research and Massey University and verified at Rothamsted Research in the UK, has found that this resistance is due to the mutation G143A which renders strobilurins completely ineffective against STB. Unlike reduced sensitivity in triazoles, this is a single point mutation which confers complete resistance. The same mutation and resultant resistance has been selected for in European STB populations through the use of strobilurin fungicides.

Strobilurin fungicides that will no longer be effective against resistant STB populations

Strobilurin QoI fungicides (and trade names) registered for use in cereals in New Zealand:
- Azoxystrobin: AgroPro Azoxystrobin 250 SC, Amistar, Atlantis Flo, Inspire, Orbit, Radial (also contains epoxiconazole), Salute, Tazer.
- Fluoxastrobin: Fandango, Mogul – both also contain prothioconazole
- Picloxystrobin: Acanto
- Pyraclostrobin: Comet
- Trifloxystrobin: Twist®

Non chemical (cultural) strategies for STB control

Future control of this disease is unlikely to be achieved with fungicides alone.

There are two key cultural factors to take into account when making decisions on foliar fungicides.

Wheat sowing date: has a strong influence on the amount of disease pressure evident in early spring. Earlier sown crops become infected earlier in the autumn, and the disease has more opportunities to complete a cycle of infection by the time spring application inputs are made.

Cultivar resistance: greater genetic resistance means that there is less disease in those cultivars tested. FAR Cultivar Evaluation booklets outline the latest STB (and other disease) resistance ratings by cultivar.

Septoria tritici blotch - note black speckles, which are fungal pycnidia.
Chemical control strategies for STB

As the strobilurins are no longer effective against resistant strains of this disease, replacements must be found. FAR work has revolved around: assessing the efficacy of the SDHI fungicides; examining the role of chlorothalonil (which is not currently registered for use against this disease) for its effect on STB; the use of more than one triazole and GS30 fungicide applications.

Efficacy of SDHI fungicides

SDHIs are not a new group of fungicides, rather, they are an extension to an earlier discovered family of chemistry. The site of activity for these fungicides is the mitochondria, the same part of the cell that strobilurins affect (provided the disease strain is not resistant). There is no cross resistance between the strobilurins and the SDHIs, so the resistance that renders the strobilurins ineffective has no effect on the SDHIs. These products have performed well in the last three seasons of trials, particularly when STB has been the main disease.

The three SDHI molecules tested against STB are:

- Isopyrazam (IZM) – Seguris Flexi (available alone to be mixed with DMI triazoles)
- Fluxapyroxad – Adexar (co-formulated with epoxiconazole (Opus))
- Bixafen – Aviator Xpro (co-formulated with prothioconazole (Proline))

These SDHIs were tested at five FAR sites in the 2013-14 season to assess their performance against STB. The summary of disease control and yield gains reveal that all three products are strong against STB. There is a slight advantage to Adexar, but it was not statistically superior to Aviator Xpro or Seguris Flexi. Adexar and Aviator Xpro were tested at two rates, and again there was no significant difference, but a trend to indicate that higher rates were slightly more effective.

Influence of SDHI/triazole fungicide mixtures against STB applied as two applications at GS31 and GS39 in two spray programmes or as two applications at GS39 and 59 in three spray programmes on moderately – fully susceptible cultivars – FAR 5 site mean 2013.
Should we use SDHIs early or late in our fungicide strategies?
To avoid the development of resistance, SDHI fungicides should not be used more than twice per season, so it is important to use them at timings which will achieve the best results. Trials were conducted on moderate to susceptible cultivars in mid-Canterbury, South Canterbury and Southland in order to determine the best response to SDHI fungicides applied at different timings at different sites.

- Where STB disease pressure is high as a result of earlier sowing and susceptible cultivars then it is advisable to use the SDHI applications at GS31 (T1) and GS39 (T2) timings.
- Where STB disease pressure is lower as a result of later sowing and more resistant cultivars then it may be better to use the SDHIs at GS39 (T2) and GS59 (T3), or just once at flag leaf.

Higher STB disease pressure early in spring will require the use of SDHI fungicides which are more effective in controlling STB before GS39 flag leaf and before we know how the season will shape up in terms of weather conditions.

Preventing SDHI resistance
There is a moderate to high risk of STB developing resistance to SDHI fungicides so it is important to avoid overusing them. There are no new fungicides in development that are likely to replace SDHIs for many years, so if we lose them we will only have the triazoles which are already partially compromised.

- Restrict use of SDHIs to a maximum of two applications in any wheat crop.
- Always mix SDHIs with a triazole to control foliar disease in cereal crops.
- When SDHI mixtures are used curatively under high disease pressure there is a greater risk of resistance development and product failure.

Is there a role for chlorothalonil?
No. Chlorothalonil should not be used to control STB. It has no label recommendation for use against this disease and no part of a treated crop can be fed to livestock.

Chlorothalonil is used widely in Europe to control STB but New Zealand formulations have no label claim for this disease (although it does have a label claim for Septoria nodorum (glume blotch) control). The lack of a label claim in New Zealand is further complicated by label restrictions which do not allow any part of the crop to be fed to livestock, including poultry. This restriction is based on the presence of a production contaminant called HCB which can accumulate in livestock (e.g. meats).

Triazole mixing or stacking
Mixing triazole fungicides together can have two principal effects. First, it allows the strengths and weaknesses of individual triazoles to be covered in a fungicide mixture, and second, in some cases it is a way of increasing the overall dose of triazole beyond the full label rate loading of the individual components. Where the disease is difficult to control or triazole fungicides are compromised, increasing triazole loading can boost disease control.

However, it is less easy to conclude that mixing two triazoles together is a sound anti-resistance strategy, as triazole resistance mechanisms are complicated. There is evidence that some triazoles are more effective against some strains of STB than others, but it is not clear that all triazole resistance mechanisms affect triazoles differently. Therefore putting yet more triazole to work may be good for efficacy, but not necessarily for staving off resistance.

In Europe there is evidence that STB is not developing reduced sensitivity to the older triazole, prochloraz. FAR research will evaluate mixing triazoles such as Opus and Proline with prochloraz this season, but at present there is no data on its benefits. Prochloraz is effective against eyespot and STB, but offers no rust or mildew control.

GS30 (T0 or Pre T1 fungicide)
This T0 application can control disease on leaves lower down the crop canopy than the top three leaves (typically Leaf 4 (or flag-3) and Leaf 5 or (flag-4)). The yield response from early sprays is usually small (based on European literature). There is little New Zealand data, but what we do have appears similar to Europe. FAR trial results were limited to March sown crops. In this case the response was 0.4 t/ha. A GS30 spray provides management flexibility should weather conditions delay the T1 fungicide.

The dilemma
Adopting a T0 spray timing will increase the number of triazole fungicides used in a growing season from three to four, which exacerbates the risk of resistance developing. This would not be an issue if the triazole was mixed with a fungicide with another mode of action. However T0 or Pre-T1 is not an optimal time to apply SDHI fungicide with a triazole, and no alternative groups are available. The small yield responses relative to the main fungicide timings (applied to the top three leaves) means there may be no economic benefit.

In summary, limited data suggests that it is only sensible to use T0 sprays when disease risk is very high, for example early sown susceptible cultivars.
## Chemical guide

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<td>Proline is a registered trademark of Bayer Crop Science</td>
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<td>0.4-0.8</td>
</tr>
<tr>
<td>Prosaro is a registered trademark of Bayer Crop Science</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Protek is a registered trademark of Zelam Ltd</td>
<td>0.3-0.5</td>
<td>0.3-0.5</td>
</tr>
<tr>
<td>Radial is a registered trademark of Adama New Zealand</td>
<td>0.8-1.6</td>
<td>0.8-1.6</td>
</tr>
<tr>
<td>Raxil is a registered trademark of Bayer Crop Science</td>
<td>1.0 l/t seed</td>
<td>1.0 l/t seed</td>
</tr>
<tr>
<td>Salute is a registered trademark of Zelam</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>Seguris Flexi is a registered trademark of Syngenta Crop Protection</td>
<td>0.6</td>
<td>0.6 or 1.0 (STB)</td>
</tr>
<tr>
<td>Stellar is a registered trademark of Adama New Zealand</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Systiva is a registered trademark of BASF (NZ) Ltd</td>
<td>0.75-1.25 l/t seed</td>
<td>0.75-1.25 l/t seed</td>
</tr>
<tr>
<td>Tazer is a registered trademark of Nufarm Ltd</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>Tilt EC is a registered trademark of Syngenta Crop Protection</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Twist SC is a registered trademark of Bayer Crop Science</td>
<td>0.25</td>
<td>0.25</td>
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