Cereal Growth Stages
The link to disease management

IN ISSUE 2 OF FAR FOCUS:
• Cereal Growth Stages
• Disease Management in Cereals
Introduction

This edition of the FAR Focus has been produced in order to bring together work on disease management conducted in cereals over the last five years.

The booklet is designed to give growers greater confidence in identifying the important cereal growth stages and how they relate to the principles of disease management. The booklet is split into two sections: Cereal Growth Stages and Disease Management in Cereals.

The main emphasis of the first section is on growth stages illustrating the key stages for disease management decisions, and how these stages link to the emergence of the most important leaves for yield contribution. In the disease management section, the focus is on the use of foliar fungicides since these products were the principal products tested over the last five years. It should be emphasised that fungicides represent the last line of defence against disease after other measures such as stubble management, seed hygiene, crop rotation and cultivar resistance have been considered.

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1. Cereal Growth Stages

• Why are they important to cereal growers?

A growth stage key provides farmers, advisors and researchers with a common reference for describing the crop’s development. Management by growth stage is critical to optimise returns from inputs such as nitrogen, Plant Growth Regulators (PGRs), fungicides & water.

• Zadoks Cereal Growth Stage Key

This is the most commonly used growth stage key for cereals in which the development of the cereal plant is divided into 10 distinct development phases covering 100 individual growth stages. Individual growth stages are denoted by the prefix GS (growth stage) or Z (Zadoks), for example GS39 or Z39.

• Key growth stages in relation to disease control

The principal Zadoks growth stages used in relation to disease control and nitrogen management are those from the start of stem elongation through to early flowering: Zadoks GS30-GS61.

• Early stem elongation GS30-GS33 (pseudo stem erect - third node on the main stem)

This period is important for both nitrogen timing and protection of key leaves. In order to ensure the correct identification of these growth stages, plant stems are cut longitudinally, so that internal movement of the nodes (joints in the stem) and lengths of internodes (hollow cavities in the stem) can be measured.

• Leaf dissection at GS32

This is a method for determining which leaves are emerging from the main stem prior to the emergence of the flag leaf. Knowing which leaves are present is critical if fungicide use is to be optimised to protect leaves.

• How long does it take for the key leaves to emerge?

One of the most frequently asked questions in the field is how long does it take for the key leaves such as flag leaf, flag-1 and flag-2 to emerge?
Why are they important to cereal growers?

A growth stage key provides a common reference for describing the crop’s development, so that we can implement agronomic decisions based on a common understanding of which stage the crop has reached.

### Zadoks Cereal Growth Stage Key

The most commonly used growth stage key for cereals is the:

- **Zadoks Decimal Code** which splits the development of a cereal plant into 10 distinct phases of development and 100 individual growth stages.
- It allows the plant to be accurately described at every stage in its life cycle by a precise numbered growth stage (denoted with the prefix GS or Z e.g. GS39 or Z39)

Within each of the 10 development phases there are 10 individual growth stages, for example, in the seedling stage:

<table>
<thead>
<tr>
<th>Zadoks Growth Stage</th>
<th>Development phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>GS00-GS09</td>
<td>Germination</td>
</tr>
<tr>
<td>GS10-GS19</td>
<td>Seedling growth</td>
</tr>
<tr>
<td>GS20-GS29</td>
<td>Tillering</td>
</tr>
<tr>
<td>GS30-GS39</td>
<td>Stem elongation</td>
</tr>
<tr>
<td>GS40-GS49</td>
<td>Booting</td>
</tr>
<tr>
<td>GS50-GS59</td>
<td>Ear emergence</td>
</tr>
<tr>
<td>GS60-GS69</td>
<td>Flowering</td>
</tr>
<tr>
<td>GS70-GS79</td>
<td>Milk Development (grain fill period)</td>
</tr>
<tr>
<td>GS80-GS89</td>
<td>Dough Development (grain fill period)</td>
</tr>
<tr>
<td>GS90-GS99</td>
<td>Ripening</td>
</tr>
</tbody>
</table>
Cereal Growth Stages

**GS07** - Germinating seed with root (which forms first) and shoot

**GS11** - 1st unfolded leaf (deep sown on left, correctly sown on right)

**GS13** - Three unfolded leaves with first tiller emerging from first leaf axial

**GS24** - Main stem and 4 tillers (note: appears to be 3 tillers, however very small tiller on right)
Cereal Growth Stages

GS30 - Start of stem elongation (note: leaf sheath extending)

GS32 - Second node formed in main stem (approximates to leaf 3 emergence or Flag-2 or third last leaf)

GS39 - Flag leaf emergence (emergence of the most important leaf in wheat)

GS59+ Ear emergence complete
Key Points

- The Zadoks Cereal Growth Stage key does not run chronologically from GS00 to GS99, for example when the crop reaches 3 fully unfolded leaves (GS13) it begins to tiller (GS20), before it has completed 4, 5, 6 fully unfolded leaves (GS14, GS15, GS16).
- It is easier to assess main stem and number of tillers than it is the number of leaves (due to leaf senescence) during tillering. The plant growth stage is determined by main stem and number of tillers per plant e.g. GS22 is main stem plus 2 tillers up to GS29 main stem plus 9 or more tillers.
- Later autumn sown or spring sown crops will very rarely reach GS29 (main stem & 9 tillers or more under New Zealand conditions) before the main stem starts to elongate at GS30.
- As a consequence of growth stages overlapping it is possible to describe a plant with several growth stages at the same point in time. For example a cereal plant at GS32 (2nd node on the main stem) with 3 tillers and 7 leaves on the main stem would be at GS32, GS23, GS17, yet practically would be regarded as GS32, since this describes the most advanced stage of development.
- Note: after stem elongation (GS30) the growth stage describes the stage of the main stem, it is not an average of all the tillers. This is particularly important with fungicide timing e.g. GS39 is full flag leaf on the main stem, meaning that not all flag leaves in the crop will be fully emerged.
Key growth stages in relation to disease control

The key growth stages for both disease control and canopy management in cereals are those covered by the period from GS30 (the start of stem elongation) to GS61 (start of flowering). These growth stages are particularly important for management decisions related to disease control and will be referred to several times in this booklet.

Early stem elongation GS30-GS33 (pseudo stem erect - third node on the main stem)

The start of stem elongation is particularly important for decisions on fungicide and nitrogen inputs, since it marks the emergence of the first of the important yield contributing leaves and the point at which nitrogen uptake in the plant increases strongly. In order to correctly identify these growth stages more precisely, main stems of the cereal plants are cut longitudinally and the position of nodes (joints in the stem) and the length of internodes (cavity in the stem between nodes) are measured with a ruler.

Dimensions defining stem elongation with internal stem base dimensions.

GS30 - The tip of the developing ear is 1 cm or more from the base of the stem where the lowest leaves attach to the shoot apex.

GS31 - The first node can be seen 1 cm or more above the base of the shoot (with clear internode space below it) and the internode above it is less than 2 cm.

### Development Phase

<table>
<thead>
<tr>
<th>Development Phase</th>
<th>Decimal Growth Stage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stem Elongation GS30-GS39</td>
<td>GS30</td>
<td>Pseudo stem erect (Embryo ear at 1 cm) - start of stem elongation</td>
</tr>
<tr>
<td></td>
<td>GS31</td>
<td>1st node on main stem</td>
</tr>
<tr>
<td></td>
<td>GS32</td>
<td>2nd node on main stem - leaf 3 emerges on main stem - 2 leaves below the flag leaf this is referred to as Flag-2 or F-2</td>
</tr>
<tr>
<td></td>
<td>GS33</td>
<td>3rd node on main stem - leaf 2 (F-1) emerges on main stem</td>
</tr>
<tr>
<td></td>
<td>GS37</td>
<td>Flag leaf just visible on main stem</td>
</tr>
<tr>
<td></td>
<td>GS39</td>
<td>Flag leaf fully emerged on main stem with ligule showing</td>
</tr>
<tr>
<td>Booting GS40-GS49</td>
<td>GS41</td>
<td>Flag leaf - leaf sheath extending</td>
</tr>
<tr>
<td></td>
<td>GS45</td>
<td>Mid boot - ear swelling in top of main stem</td>
</tr>
<tr>
<td></td>
<td>GS49</td>
<td>1st awns emerging (barley/awned wheat)</td>
</tr>
<tr>
<td>Ear emergence GS50-GS59</td>
<td>GS59</td>
<td>Ear fully emerged on main stem</td>
</tr>
<tr>
<td>Flowering GS60-GS69</td>
<td>GS61</td>
<td>Start of flowering on main stem (first anthers appear approx 1/3 of the way up the ear)</td>
</tr>
</tbody>
</table>
GS32 - The second node can be detected and the internode below it exceeds 2 cm, however the internode space above the node has not yet reached 2 cm.

Third node (GS33) and all subsequent nodes e.g. GS34, GS35 and GS36 are defined in the same way as GS32; the node has to have a clear 2 cm space of internode space below it before it is distinguished as the next nodal growth stage.

**Leaf dissection at GS32**

Identifying the most important leaves (top 3 leaves) before the emergence of the final flag leaf can be done with reference to the nodal growth stage (see disease management section). However to be certain it is possible to dissect the un-emerged leaves from second node (GS32) onwards. Before GS32 the leaves yet to emerge are generally too small to properly identify. Note how small the flag leaf is at GS32.

**How long does it take for the key leaves to emerge?**

One of the most frequently asked questions in the field is how long does it take for the key leaves such as flag leaf, flag-1 and flag-2 to emerge?

The length of time taken for a leaf to emerge is called the phyllochron and is driven by temperature. It is measured in day degrees (°C days) meaning that the length of time for leaf emergence in calendar days depends on the temperature. Most wheat cultivars have phyllochrons of approximately 100-120 day °C.

For all crop models such as the Sirius Wheat Calculator it is essential to have the correct phyllochron as well as the precise climate and soil data.

Example: If the crop is at GS32 and flag-2 is emerged, how long will it take before the flag leaf is emerged?

A simple calculation of average daily temperature is to take the maximum and minimum daily temperature and divide by two (maximum daily temp + minimum daily temp ÷ 2). Therefore suppose that from GS32 to GS39 the average maximum temperature was 20°C and the average minimum temperature was 10°C. It would take approximately 16 days for the flag leaf to emerge on a variety with a phyllochron of 120 day °C.

- (Max daily temp 20°C + min daily temp 10°C/2) = 15 day °C
- Phyllochron 120 day °C divided by 15 day °C = 8 days per leaf
- Thus 8 days from flag-2 at GS32 to the emergence of flag-1, with another 8 days until flag leaf emergence = 16 days.

In reality since temperatures are warmer as spring progresses, it may be that there will be 9 days between flag-2 and flag-1 and only 7 days between flag-1 and flag leaf emergence on the main stem.
Key Points

- Use a ruler to measure node movement in the main stem to define early stem elongation growth stages.
- Take care not to confuse the basal node at the stem base with the first true node. Basal nodes are usually signified by a constriction of the stem below the node with an incompletely formed internode space, it is the point where the lowest leaves attach to the stem. Basal nodes will often grow small root tips. This is not the first node.
- Nodal growth stage can give an approximate guide to which leaf is emerging from the main stem; this can save time with leaf dissection when it comes to making decisions on fungicide application pre flag leaf (before all leaves are emerged).
- The rate of development influences the time between growth stages - later sowings spend less time in each development phase including grain fill, hence potentially have lower yield.
- Though it will vary between varieties and regions (due to temperature), during stem elongation leaves emerge approximately 5 - 10 days apart (10 under cooler temperatures at the start of stem elongation and nearer 5 - 7 days as the flag comes out).
- The period of time between leaf emergences is referred to as the phyllochron and is approximately 100-120 (°C days), though it can be longer or shorter depending on variety. Barley varieties tend to have shorter phyllochrons, so leaves tend to emerge quicker.
2. Disease Management in Cereals

• The major foliar diseases

What are the principal foliar and stem base diseases you are likely to encounter growing wheat and barley in New Zealand?

What are the conditions that are conducive to the disease developing?

• Why fungicides?

Fungicides do not create yield they only protect an inherent yield potential that the crop would have delivered free of disease. Economic response is related to the extra green leaf retention associated with fungicide use, particularly during grain fill. For a given level of disease, restriction in soil moisture, particularly during grain fill, reduces the difference in green leaf retention between fungicide treated and untreated crops and therefore the yield response.

• How do fungicides work?

All fungicides work more effectively when applied before disease becomes established in the leaves. Foliar applied fungicides do not properly protect leaves which are un-emerged at the time of application as they have limited systemic movement in the plant.

• Fungicide timing

For single-spray options, flag leaf emergence on the main stem is the key leaf to protect in wheat (GS39). In barley, the second to last leaf formed is the key leaf. This is the leaf below the flag and is termed flag minus1 (F-1). This leaf appears at approximately the third node stage (GS33).

• Disease management strategies

Foliar fungicides are insurance policies since their principal benefit is realised after application. Under New Zealand dryland conditions FAR results illustrate that the cost of this insurance policy should be kept at a minimum in order to make money from fungicides.

• Cereal powdery mildew resistance to strobilurin fungicides

Populations of powdery mildew that are resistant to strobilurin fungicide have been confirmed as present in New Zealand. The mutation that creates this resistance is identical to that found in Europe in 1998.
The major foliar diseases

What conditions encourage foliar diseases?

When making any decision on fungicide application one of the criteria to consider is the conditions, which could encourage disease development if present in the region or if on the older leaves of the crop. Though this booklet has not been designed to be a disease identification guide consider the following

- Cultivar - To start with make sure you know the disease strengths and weaknesses of your variety portfolio.
- Which disease - What disease does this mean you could potentially expect?
- Region - Is that disease noted to be prevalent in your region given the right development conditions?
- Symptoms - What does the disease look like on the leaf and what conditions are most suitable for the disease to develop?

(i) Foliar diseases of wheat

The following diseases are by no means a complete list of diseases for wheat and barley but have been the main diseases encountered in FAR trials over the last five years.

Stripe rust
(caused by *Puccinia graminis f.sp tritici*)

The fungus is an obligate parasite requiring volunteer cereal hosts between crops. The disease is favoured by higher temperatures than stripe rust, hence it is usually more problematic in the second half of the growing season. Orange brown pustules are larger than stripe rust and smaller than stem rust, randomly distributed on upper leaf surfaces and leaf sheaths predominately. On occasions it is easier to detect on lower leaves due to “green island effect”. Dying leaves at the base of the canopy can be a good indicator of whether the crop is under high spore pressure, since leaf rust pustule areas show up as green dots on the leaf where the fungus (obligate parasite) excretes sugars in order to keep the plant cells living for longer on senescing leaves.

Control:
- Resistant varieties.
- Grazing pre GS30 has been observed to reduce disease pressure in mild winters.
- Fungicide application - Most of the triazoles, strobilurins and morpholines offer some control of this disease (see management strategies for timings).

Leaf rust
(caused by *Puccinia triticana - wheat/P. hordei - barley*)

Spore dispersal: Air-borne spores

Leaf rust spores do not require free water to germinate unlike leaf rust and stem rust. Spores can germinate in as little as 6-8 hours when temperature is between 15-15°C. In winter spores tend to clump together restricting distribution giving rise to hot spots whilst in spring spores tend to disperse as single spores giving more uniform infection.

Spores are spread predominately by wind and

The following diseases are by no means a complete list of diseases for wheat and barley but have been the main diseases encountered in FAR trials over the last five years.

### Stripe rust

*caused by Puccinia graminis f.sp tritici*

- **Latent Period:** Approx 7-10 days at 20°C
- **Summer host:** Wheat & barley
- **Winter host:** Wheat & barley
- **Spore dispersal:** Air-borne spores
- **Leaf rust spores require free water to germinate.**

There are separate species for wheat and barley therefore no cross infection between the two crops.

The fungus is an obligate parasite requiring volunteer cereal hosts between crops. The disease is favoured by higher temperatures than stripe rust, hence it is usually more problematic in the second half of the growing season. Orange brown pustules are larger than stripe rust and smaller than stem rust, randomly distributed on upper leaf surfaces and leaf sheaths predominately. On occasions it is easier to detect on lower leaves due to “green island effect”. Dying leaves at the base of the canopy can be a good indicator of whether the crop is under high spore pressure, since leaf rust pustule areas show up as green dots on the leaf where the fungus (obligate parasite) excretes sugars in order to keep the plant cells living for longer on senescing leaves.

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### Stripe rust

*caused by Puccinia graminis f.sp tritici*

- **Latent Period:** Time between spore infection and symptoms being visible. Approx 10-14 days at 15°C but in July and August may be up to 25 days.
- **Summer host:** Wheat
- **Winter host:** Wheat & autumn wheat

Stripe rust spores do not require free water to germinate unlike leaf rust and stem rust. Spores can germinate in as little as 6-8 hours when temperature is between 5-15°C. In winter spores tend to clump together restricting distribution giving rise to hot spots whilst in spring spores tend to disperse as single spores giving more uniform infection.

Spores are spread predominately by wind and

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### Principal foliar cereals diseases and the optimum conditions for infection

<table>
<thead>
<tr>
<th>Disease</th>
<th>Heavy Rainfall</th>
<th>Higher Temp.</th>
<th>High Humidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stripe rust</td>
<td>=</td>
<td>–––</td>
<td>+++</td>
</tr>
<tr>
<td>Leaf rust</td>
<td>= (free water)</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>Stem rust</td>
<td>= (free water)</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>(unlikely to be a problem in NZ)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Powdery Mildew</td>
<td>–––</td>
<td>=</td>
<td>+++</td>
</tr>
<tr>
<td>Septoria leaf blotch</td>
<td>+++</td>
<td>=</td>
<td>+++</td>
</tr>
<tr>
<td>Septoria nодorum</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>Scald</td>
<td>+++</td>
<td>=</td>
<td>+++</td>
</tr>
<tr>
<td>Net Blotch</td>
<td>+++</td>
<td>=</td>
<td>+++</td>
</tr>
</tbody>
</table>

+++ Encourages

----- Discourages the disease

= Neutral effect on disease

Stem rust and leaf rust require free water on the leaf for the fungal spores to germinate.
Stem rust  
*(caused by *Puccinia graminis f.sp tritici)*

The fungus is an obligate parasite depending on cereal volunteers alone in Australia. The disease has dark brown pustules on leaves (both upper and lower surfaces), leaf sheaths, stems and heads. It is a later season disease usually developing most rapidly from ear emergence onwards. Germinating spores require temperatures of 18-25°C and the presence of free water on the leaf. The disease can infect both barley and wheat but there is a separate sub species for oats. Unlike the other rusts where water on the leaf. The disease can infect both barley and wheat but there is a separate sub species for oats. Unlike the other rusts where a single flag spray could be regarded as a good cover all spray, stem rust would require far later strategies for disease control to be effective.

**Latent Period:** Approx 7-10 days at 25°C  
**Summer host:** Volunteer wheat & barley (barley is susceptible at high temperatures)  
**Winter host:** Wheat & Triticale  
**Sporidispersal:** Air-borne spores  
**Stem rust spores require free water to germinate.**  
With lower temperatures this disease is unlikely to be a problem in New Zealand.

**Control:**  
- Resistant varieties.  
- Controlling volunteer cereals to avoid a green bridge.  
- Fungicide application - Most of the triazoles, strobilurins and morpholines would offer some control of this disease though most agrichemical labels in New Zealand would not have label claims for this disease. This disease should not be confused with the stem rust species that infects New Zealand grass seed crops.

Powdery mildew  
*(caused by *Blumeria graminis f.sp tritici)*

The disease tends to be more problematic in barley than in wheat particularly in the higher rainfall zones. Straw and stubble borne black fruiting bodies produce rain-splashed spores when it rains in the autumn, which infect volunteers, which in turn provide a source of wind blown spores to infect new crops. Cool 10-20°C, cloudy, and humid conditions favour development with maximum spore production at 20°C. Whilst rainfall can increase canopy humidity heavy rain can act as a fungicide by washing the spores (conidia) off the leaf.

**Latent Period:** Approx 7 days at 15°C  
**Summer host:** Volunteer wheat & barley/barley grass & resting spores on straw  
**In Crop:** Wheat & barley forms of the disease are almost identical but do not cross infect.  
**Sporidispersal:** Fruiting bodies give rise to rain-splashed spores initially, air-borne spores (conidia) give rise to main in-crop infection.

**Control:**  
- Resistant varieties.  
- Fungicide application - Most of the triazoles have an effect on powdery mildew but do not offer the control given by the morpholines (fenpropimorph, fenpropidin and spiroxamine). Since 2005 it has been shown that there are mildew strains present in New Zealand that show resistance to strobilurin fungicides. Since the basis of this resistance is the same mutation that has occurred in Europe it almost certain that its frequency in the population will increase, meaning that in the next 3-5 years it is unlikely that the strobilurin fungicides will offer any control of this disease.

Septoria leaf blotch  
*(caused by Mycosphaerella gramincola)*

A wet weather disease, which is readily identifiable due to the presence of the black fruiting bodies (pycnidia) in the leaf lesions (visible to the naked eye). Since the initial dispersal of spores from previous wheat stubbles is windborne this disease is not restricted to wheat on wheat rotation positions. The disease is favoured by earlier sowing and heavy rainfall during stem elongation. The longer latent period 21-42 days makes this disease particularly difficult to keep track of, since the top three leaves could be infected as a result of heavy rain but show few visual symptoms; a considerable disadvantage when considering fungicide application for control of this disease.

**Latent Period:** Approx 21-42 days (depending on temperature)  
**Sporidispersal:** Initial spore release from black fruiting bodies on the stubble which are wind blown and travel long distances.  
**In crop:** After initial infection in winter, secondary infection is by splash borne spores which move up through the crop canopy travelling short distances. Leaf to leaf contact also aids spore spread. Canopy architecture is an important component of disease spread (tips of older infected lower leaves being adjacent to newer more important leaves emerging further up the stem) when spores are splashed up the canopy.

**Control:**  
- Resistant varieties.  
- Later sowing can reduce disease pressure.  
- Fungicide application - most of the triazoles and strobilurins have an effect on speckled leaf blotch, though in general triazoles offer better curative activity with strobilurins providing better protection against the disease. There is now widespread Septoria leaf blotch resistance to strobilurin fungicides in Europe, but at this stage it has not yet been recorded in New Zealand. Though the development of resistance may be only a matter of time, it is unlikely to create the same problems as it has in Europe since the disease is not endemic in New Zealand wheat crops as it is in Europe.

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Disease Management in Cereals
Glume blotch/Stagonospora blotch  
*(caused by Phaeosphaeria nodorum)*

Purpling and burnt appearance on affected ears, lesions on leaf tissue have no distant black pycnidia, since they are tan brown in colour and far smaller than those of Septoria leaf blotch. Another wet weather disease similar to Septoria leaf blotch in life cycle and not restricted to wheat on wheat rotation positions. In contrast to Septoria leaf blotch, it is favoured by higher temperatures and has an ability to infect the ear causing seed borne infection. Again movement of spores from lower leaves to upper leaves is by means of rain splash or direct leaf-to-leaf contact caused by wind and rain. The latent period is shorter than Septoria leaf blotch and therefore disease cycles quicker under more ideal conditions.

**Control:**
- Resistant varieties.
- Fungicide application - Most of the triazoles and strobilurins have an effect on glume blotch, though there is little NZ data differentiating products against this disease. As was the case with Septoria leaf blotch triazoles offer better curative activity with strobilurins providing better protection against the disease (consult the manufacturers label for approval for control of this disease).

(ii) **Foliar diseases of Barley**

**Net blotch**  
*(caused by Pyrenophora teres)* - Spot Form (SFNB) & Net Form (NFNB)

**Spot Form**
Initial infection is from previous barley stubble, which can be a source of infection for two seasons. Secondary spread within the crop is usually evenly spread by virtue of wind blown conidia (which travel further) that are produced under high humidity at temperatures of 15-25°C. Unlike net form of net blotch it is not seed borne.

**Net Form**
The disease can be both seed borne and stubble borne with distinct net form lesions otherwise much as Spot form in terms of development conditions. Therefore barley on barley situations is highest risk but may still be a concern where stubble evident from two seasons e.g. failed break crop between two barley crops. The disease can affect the awns of the barley ear.

**Control:**
- Resistant varieties (note varieties can differ in their resistance to the two forms of the disease).
- Barley on barley will increase disease risk, particularly if early sown.
- Fungicide application - Most of the triazoles and strobilurins have an effect on the disease but the curative activity of strobilurins against this disease is limited (consult the manufacturers label for approval for control of this disease). Carbendazim also offers good control of the disease in New Zealand when used in mixtures with triazoles or in mixture with triazoles and strobilurins (see Management Strategy section).

**Scald**  
*(caused by Rhynchosporium secalis)*

This is a classic wet weather disease, which is most problematic in high rainfall seasons. Like Septoria leaf blotch the disease is favoured by early sowing both in the autumn and in the spring.

**Control:**
- Resistant varieties.
- Barley on barley will increase disease risk, particularly if early sown.
- Fungicide application - Most of the triazoles and strobilurins have an effect on the disease but the curative activity of strobilurins against this disease is limited (consult the manufacturers label for approval for control of this disease). Carbendazim also offers good control of the disease in New Zealand when used in mixtures with triazoles or in mixture with triazoles and strobilurins (see Management Strategy section).
**Ramularia leaf and awn spot** (caused by *Ramularia collo-cygni*)

Post flowering Ramularia leaf and awn spot can cause extensive damage to the upper leaves and awns in both spring and winter sown barley resulting in extensive losses in yield and quality. Leaf infection is most common where leaves remain wet for long periods of time, though infection can occur under dew as well as rainfall. Symptom expression on the leaves is not usually associated with early stem elongation growth stages pre flowering. In FAR trials it has often been observed 30 - 40 days after the second fungicide timing at GS49 (be aware of fungicide withholding periods). Crop stress induced by the crop flowering, or from poor crop nutrition will cause the fungus to produce a phytotoxin. This phytotoxin can produce ethylene under sunlight which will lead to early ripening of the crop. This series of events may lead to premature leaf senescence.

**Control:**
- Avoid high risk rotation positions if disease has been problematic - continuous cereals.
- Fungicide application - a number of triazoles carry an approval for eyespot control (consult the manufacturers label for approval for control of this disease).
- Higher water volume rates are very important in order to achieve canopy penetration.

**Other diseases of the stem base and ear of wheat and barley**

**Eyespot** (caused by *Psuedocercosporella herpotrichoides*)

This common stem base disease can create lodging in severe cases if the fungus penetrates through the leaf sheath and into the stem itself. The disease survives on residues of cereals and grasses and tends to be most severe in those circumstances where the soil surface stays wet and there is a high soil nitrogen reserve. This creates high humidity which encourages the disease to penetrate the stem.

**Control:**
- Avoid high risk rotation positions - wheat on wheat or wheat following maize.
- Establishment technique - the greater burial of previous cereal or maize residues the less the problem.
- Fungicide application - Specific triazoles such as tebuconazole and prothioconazole have activity against this disease. None of the currently approved strobilurins in the New Zealand market have label recommendations for Fusarium head blight control, but may have approval for an ear disease complex of diseases.

**Fusarium head blight - Head Scab** (caused by *Fusarium spp.*)

Symptoms are premature ripening of sections of the head. Pink or orange fungal growth may also be apparent on the bleached section of the head. This causes either sterility or shrivelling of the grain.

The fungi survive in the soil and on residues from cereals and grasses. The disease can be particularly prevalent following maize that has been minimally cultivated.

**Control:**
- Avoid high risk rotation positions if disease has been problematic - wheat on wheat or wheat following maize.
- Fungicide application - Specific triazoles such as tebuconazole and prothioconazole have activity against this disease. None of the currently approved strobilurins in the New Zealand market have label recommendations for Fusarium head blight control, but may have approval for an ear disease complex of diseases.
Why fungicides?

Why do we apply fungicides - what are we trying to achieve?
Fungicides are used to make money, therefore though disease may be present in a crop at many stages through the crop’s life it may not always be economic to control it. Therefore as an input, the economic response to fungicide relates to:
- which leaves of the plant are infected;
- extent of the disease pressure;
- the ability of the product to control that disease;
- water availability to the crop to express the benefit.

It is important to understand which plant structures (leaves, stem and ear) contribute most to yield and to determine when growing conditions (soil water) will allow any benefit to be expressed. Economic response from fungicides has two distinct but strongly related components, yield and quality.

What are we trying to protect?

![Diagram showing disease control on yield contributing leaves, disease free canopy during grain fill, improved grain fill, larger grain size, improved yield, improved quality characteristic.]

- Note that since the size of the final four leaves in wheat and barley differs, so does their contribution to grain yield. As a result fungicide strategies have slightly different emphases depending on the importance of the leaves being protected.
- Under dryland conditions the length of the grain fill period is reduced and therefore the contribution of the flag leaf and flag-1 in wheat is reduced relative to an irrigated crop. Under these conditions the activity of the stem and ear become relatively more important and the overall yield is reduced.

When do these important leaves emerge?
If the objective of a fungicide strategy is to protect the most important leaves, then it becomes important to identify when the top three leaves emerge. In terms of the Zadoks growth stage key the top three leaves and ear emergence are covered by GS32-GS59 i.e. second node to full ear emergence on the main stem. Thus for example at GS32 the leaf emerging from the main stem is likely to be F-2 or (leaf 3). F-1 or (leaf 2) emergence coincides with GS33.

Leaf tagging (red tag in photo) is a useful method of tracking which leaves are sprayed with fungicide at early stem elongation.

Keeping the canopy disease free during grain fill
Where disease is destroying the crop canopy during grain fill there are good correlations between green leaf retention due to earlier fungicide application and final yield.
Fungicide as an insurance
Fungicides should be applied before the top three leaves become infected and yet have their greatest impact during grain fill. As a consequence of this fungicide application is always likely to be an insurance-based input.

Constraint of water availability
As an insurance input it is difficult to take account of subsequent weather conditions during grain fill (other than from predictive models based on historical weather data). Under dryland conditions in New Zealand reduced water availability during grain fill can have a greater ability to reduce green leaf retention than disease.

FAR trial work studied the influence of different water availability in grain fill for a given stripe rust disease infection. Influence of water in early grain fill with and without fungicide application (Opus 0.25 l/ha + Amistar 0.25) in the presence of a stripe rust infection - cv Amarok, Canterbury Plain.
- As the water available for grain fill increased so did the impact of fungicide on green leaf retention in the presence of stripe rust.
- Where crops were untreated with fungicide, increasing water did not create the advantage in % green leaf retention, since the level of stripe rust increased and reduced the yield response to water.

Knowledge of soil water availability at flag leaf (GS39) and rainfall probabilities for your region during grain fill (historic average) will dictate:
- The need for further fungicide application at ear emergence in wheat.
- The level of expenditure for the fungicide (lower rates being used where less persistence is required).

Under dryland conditions soil water content (combined with regional rainfall) between flag leaf emergence and flowering strongly dictates the likelihood of a fungicide response from an ear wash application.
Key Points - Yield responses from fungicides

- Yield response from fungicides is linked to the differences achieved in green leaf retention, principally during grain fill.
- In order to achieve differences in green leaf retention during grain fill it is important to target the leaves that contribute most to yield: Flag leaf in wheat and F-1 or (leaf 2 - leaf below flag) in barley.
- Fungicides are insurance inputs: applied during stem elongation yet having their greatest impact during grain fill.
- In the presence of disease, link fungicide application and cost to historical/predicted rainfall during grain fill and current soil water availability.
- For a given disease infection, increased water availability is likely to increase disease pressure and generate greater green leaf retention, and thus yield, from fungicide application.

Key Points - Grain quality responses from fungicide

Grain size - much of the yield increase with a fungicide is achieved by increasing thousand seed weight. Therefore grain size is heavier and larger.

% Screenings - as a result of larger grains there are fewer screenings where fungicide generates yield responses.

% Grain protein - as a result of better grain fill grain protein content can be reduced.

Test weight kg/hl - where fungicides have a large influence on yield, test weights are strongly correlated.

Sample appearance - with particularly wet harvest periods later fungicide application can improve sample appearance purely through the control of late occurring saprophytic diseases such as sooty moulds.

Overall, the economics of fungicide application has to be assessed in terms of both yield and quality effects. However it is unusual to secure large quality benefits unless the fungicide has created a yield effect in the first place.

Influence of fungicide on grain quality

The influence of fungicide application on grain quality (test weight, screenings, protein, sample appearance etc.) is usually proportional to the yield increase generated by the fungicide. With resistant varieties where the yield increases from disease control are smaller, the effects on grain quality are proportionally smaller than the effects seen with more susceptible varieties.

Correlation between test weight and % yield response to fungicide

In FAR trials the influence of fungicide application on percentage screenings has tended to be greater with barley rather than wheat. An example of this relationship is outlined below with reference to a susceptible autumn sown barley crop.

Influence of leaf rust and scald control on test weight and screenings - FAR Arable Site (Dryland) Optic autumn sown 2005

Test weight kg/hl

<table>
<thead>
<tr>
<th>Test weight (kg/hl)</th>
<th>2 Sprays (triazole only)</th>
<th>2 Sprays (triazole + strobilurin)</th>
<th>3 Sprays (pre GS30 followed by Triazole + strobilurin)</th>
<th>Untreated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screenings (%)</td>
<td>67.6</td>
<td>68.5</td>
<td>70</td>
<td>19</td>
</tr>
<tr>
<td>Test weight kg/hl</td>
<td>6.2</td>
<td>4.1</td>
<td>2.3</td>
<td>62.8</td>
</tr>
</tbody>
</table>

Test weight vs. Screenings:

- Low disease pressure - cv Regency (Highbank - 2005)
  \[ R^2 = 0.7463 \]
  - Maximum yield increase 18%, 1.5 kg/hl range in test weight

- High disease pressure - cv Consort (Makikihi 2005)
  \[ R^2 = 0.8975 \]
  - Maximum yield increase 60%, 7.3 kg/hl range in test weight
How do fungicides work?

All fungicides work more effectively when applied before disease becomes established in the leaves to be protected.

In order to time foliar fungicides correctly we need to appreciate how these agrichemicals work in terms of movement and control of the pathogen. As a broad generalisation foliar fungicide activity can be described in one of two ways:

Protectant activity - is activity usually associated with the surface of the plant that confers protection against future spore infection, the length of the protection is termed the degree of persistence. Fungicides that are purely protectant, such as chlorothalonil, have no ability to control disease already present within the leaf i.e. it is not systemic.

Or

Curative activity - is the ability of a fungicide to destroy disease after infection has occurred (infection developing within the plant), it requires the fungicide to enter the plant tissue i.e. it exhibits a degree of systemic activity.

How do fungicides move?

When applied to the leaf tissue all of the systemic fungicides currently approved for cereals in New Zealand move in the same way.

• Cereal fungicides move towards the leaf tip. The fungicide diffuses into leaf surface and then travels via the water carrying vessels (xylem) towards the leaf tip (they are unable to travel downwards when inside the leaf and therefore do not protect the unemerged leaves).

• Different fungicide actives move at different rates and this determines how fast the products work and how quickly the product’s activity dissipates. The strobilurin fungicides such as Amistar, containing azoxystrobin, move very slowly compared to triazoles such as cyproconazole (triazole in Alto 100 SL) or flutriafol (see photo).

The movement of fungicide active ingredients can be seen with the use of radioactive droplets applied at the base of the leaf. This illustration shows the degree of movement three days after application of individual droplets at the base of the leaf. Red colouration denotes greatest concentration of labelled active ingredient and blue denotes no active present.

Curative activity - a false sense of security!

The ability of these products to provide curative activity can give growers and advisors a false sense of security with regard to controlling disease in the crop. The ability of these products to control disease after the date of infection (so called “kickback activity”) is limited to approximately 10 days maximum depending on temperature, rate and product. Where disease infection has been present in leaf tissue for longer than this, the fungicide will not be able to prevent visible leaf damage.

Fungicides work more effectively before disease becomes established in the leaf to be protected.

(Courtesy of D W Bartlett, Syngenta - Jeallot’s Hill International Research Centre)

Azoxystrobin = Amistar, Epoxiconazole = Opus, Tebuconazole = Folicur, Flutriafol (not used in NZ)
Currently available foliar fungicides used in New Zealand cereal crops

The two dominant chemical groups used in New Zealand for disease control in cereals are the **Group C DMI’s** (Demethylation inhibitors) and **Group K Strobilurins**. Group C DMI’s are often referred to as the triazole or azole group.

### Group C - DMI’s Azole Fungicides

<table>
<thead>
<tr>
<th>Chemical Name</th>
<th>Trade Name</th>
<th>Registered in New Zealand for use on Cereals</th>
<th>Other Crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difenoconazole</td>
<td>Score</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Epoxiconazole</td>
<td>Opus/Accuro/Stellar</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Cyproconazole</td>
<td>Alto</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Flusilazole</td>
<td>Nustar</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Fluquinconazole</td>
<td>Galmano (seed trt only)</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Propiconazole</td>
<td>Tilt/Bumper</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Tebuconazole</td>
<td>Folicur/Axis Gold</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Triadimefon</td>
<td>Milet</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Triadimenol</td>
<td>Cereous/Tribute</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Prothioconazole</td>
<td>Proline</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Prochloraz</td>
<td>Mirage/Sportak</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Spiroxamine</td>
<td>Impulse</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Fenpropidin</td>
<td>Tern</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Fenpropimorph</td>
<td>Opus Team*</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

* Mixture of fenpropimorph with epoxiconazole

### Group K - Strobilurin Fungicides

<table>
<thead>
<tr>
<th>Chemical Name</th>
<th>Trade Name</th>
<th>Registered in New Zealand for use on Cereals</th>
<th>Other Crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Azoxystrobin</td>
<td>Amistar</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Pyraclostrobin</td>
<td>Comet</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Trifloxystrobin</td>
<td>Twist</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Picoxystrobin</td>
<td>Acanto</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Kresoxim methyl*</td>
<td>Allegro</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Fluoxastrobin*</td>
<td>Fandango</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

* Available in cereals only in mixture with epoxiconazole
** Available in cereals only in mixture with prothioconazole

### Group A - Benzimidazole Fungicides

<table>
<thead>
<tr>
<th>Chemical Name</th>
<th>Trade Name</th>
<th>Registered in New Zealand for use on Cereals</th>
<th>Other Crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thiophanate methyl</td>
<td>Topsin</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Carbendazim</td>
<td>e.g. Protek</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Note that there are a number of formulated co-mixtures that contain products from different fungicide groups. It should also be noted that this list has not been included as a definitive list of all fungicides available in cereals, but to cover the common active ingredients used as foliar fungicides.
How does the fungicide kill the fungus?

Different fungicide groups have different modes of action to kill the fungus.

**Group C DMI**

Azoles or triazoles work by disrupting the manufacture (biosynthesis) of a fungal cell membrane component called ergosterol.

**Group K Strobilurin**

The strobilurins act on the fungal cell components called the Mitochondria, which are the cell organelles responsible for producing the chemical energy that drives the development of the fungus. The cellular process interrupted is called Respiration.

This difference affects the point at which germinating fungal spores are controlled.

Strobilurins are able to destroy the spore before it germinates, since germination is an extremely energy demanding process, whereas triazoles only start to work when the germinating spore requires ergosterol (initial spore germination is carried out using reserves of this compound). Strobilurins work most effectively on the surface of the leaf and make extremely good protectants but are relatively poor curative materials.

In contrast triazoles are better curative materials working well inside the leaf, however entry into the leaf also marks the gradual dissipation of the material as the active moves to the leaf tip, eventually leading to inadequate concentrations for protection.

**Key Points**

- Cereal foliar fungicides do not move down the plant, movement in the leaves and stem is upwards towards the leaf tip via the water carrying xylem vessels.
- Foliar fungicides applied to the leaves do not protect un-emerged leaves or the base of part emerged leaves, other than reducing inoculum levels on lower leaves for subsequent infection.
- Movement in these xylem vessels is the same for triazole fungicides applied to the leaf or applied as a seed treatment. However the movement of active ingredient from the stem base into new tissue i.e. from treated seed is less constrained than applying fungicide to the leaf (since product cannot move back down the leaf). However the amount of active supplied by a seed treatment is small in comparison to a foliar spray and is diluted with the growth of the plant.
- Fungicides are better employed before disease becomes established in the leaves to be protected. A delay in spraying increases the need for higher fungicide rates since there is more dependency on curative activity.
- Applying fungicide to a given leaf before infection becomes visible gives greater rate flexibility.
- Strobilurins are extremely effective protectants but poor curative fungicides.

They have the ability to control disease and keep the crop greener for longer, provided there is sufficient soil moisture and plants are not subjected to excessive temperatures. (Note for cereals: strobilurins are better applied mixed with a curative triazole fungicide).

- Triazoles are, in contrast better curative products with variable protection characteristics depending on how long sufficient concentration can be maintained within the leaves (remembering that once inside the leaf the fungicide starts to move away from the point of contact with the plant).
Fungicide timing

When should we employ foliar fungicides in cereals?

The optimum timing for foliar applied fungicides in cereals is from the start of stem elongation to ear emergence (GS30-GS59). This period coincides with the emergence of the four most important leaves in the crop and the ear. The optimum time for spraying a fungicide to protect a leaf is at the point of full emergence. Leaves un-emerged at the time of application will not be properly protected.

Leaves will usually be free from foliar disease on emergence!

The time between when the disease spores infect the leaf and when you can see a visible infection point is called the latent period or latent phase. This period is temperature driven and differs between diseases, yellow leaf spot/mildew being very short - seven days, whilst other diseases such as Septoria leaf blotch may take three times as long. It means that shortly after emergence whilst a leaf may look healthy, disease can already be developing within the newly emerged tissue.

The first signs of disease in a new leaf is usually at the tip since this part of the leaf has been exposed to disease for longer.

If the crop is under disease pressure, the longer the spray is delayed after leaf emergence the more difficult it will be to control disease in that leaf, since the curative activity of most systemic fungicides employed is little more than 7-10 days. Therefore the trigger for spraying should not be the level of disease in the leaf you wish to protect but the leaf below it, combined with knowledge of weather conditions favouring the disease.

Key Points

- Depending on the leaf you wish to protect the aim should be to spray at, or near, full emergence of the target leaf.
- For single spray options flag leaf emergence on the main stem is the key leaf to protect in wheat (GS39).
- In barley flag-1 is the key leaf - this is the leaf below the flag. This leaf appears at approximately the third node stage (GS33).

Fungicide timing for Wheat

Flag leaf emergence GS37-GS39 (flag leaf visible - flag leaf fully emerged on the main stem) is a pivotal growth stage for fungicide application, since fungicide applied at this stage means that all the top three leaves have been exposed to fungicide. Application before this growth stage means that there may be a need to consider a second application to protect leaves unemerged at application. Conversely, fungicide left until ear emergence (GS59) may result in significant damage as disease infects the top two most important leaves.

Thus spraying for disease:

- At second node (GS32) you will protect emerging flag minus2 (leaf 3) and lower leaves but not flag minus1 (leaf 2) and flag.
- At third node (GS33) you will protect emerging leaf 2 (flag minus1) and lower leaves but not the flag leaf
- At flag leaf emergence GS39 all leaves will be directly protected provided canopy density does not prevent coverage or that infection has become established before GS39.

A single early fungicide applied before flag leaf emergence will not control disease in wheat. This has been demonstrated in a number of FAR trials.
So what timings have the greatest impact on yield assuming a flag leaf spray is applied at GS39?

The size of the yield response with applications prior to flag leaf emergence is dependent on the type of disease and the onset of infection. For example in Savannah in 2007 where stripe rust infection occurred prior to flag leaf emergence the response to a GS32 (second node spray) over and above a flag spray was 0.3 t/ha. This compared to 0.11 t/ha from a GS32 application where leaf rust infection occurred post flag leaf emergence in the cultivar Consort.

Influence of irrigation on ear wash

Response to ear wash sprays at early-mid flower increase in importance with irrigation and or with higher rainfall later in the season. In 2005 under leaf rust pressure irrigation increased the value of the ear wash spray threefold.

Key Points - Wheat

- Flag leaf emergence sprays apply fungicide to the top three leaves of the cereal plant and produce the greatest yield responses from a single spray timing.
- Fungicide applied before flag leaf GS39 do not protect leaves that emerge later.
- Additional response from an earlier GS32 fungicide will depend on the nature of the disease and onset of infection.
- Stripe rust invariably infects susceptible crops at or before flag leaf emergence and so increase the value of the GS32 fungicide prior to flag leaf.
- Leaf rust infection tends to infect later in the season, since it has a higher optimum temperature requirement than stripe rust (the exception to this is after a very mild winter such as 2005, when the disease was seen early in the season). This disease tends to increase the value of fungicide applications made at ear emergence rather than the earlier GS32 spray.
**Fungicide timing for Barley - autumn sown**

With a small flag leaf and more important leaves produced earlier in the season, it is difficult to suggest a single spray timing for barley. In barley flag-1, the leaf below flag leaf is most correlated with yield. Unfortunately applications at this timing do not prevent disease infecting the flag leaf sheath which emerges after flag leaf emergence. In addition, sprays left until GS33 (when flag-1 emerges) are frequently too late to control early season infections of scald *Rhynchosporium secalis*. To counter these issues two key spray timings for this crop have been adopted in order to protect it. The GS30-GS31 spray at the start of stem elongation protects the crop from early infection on F-3 and F-4, whilst the GS49 1st awns showing spray protects flag, F-1 and F-2 along with the flag leaf sheath. This follow up spray is typically 3-4 weeks after the first application.

**Management Strategy**

*How can we use the knowledge of timing and fungicide activity in order to develop a management strategy that is economic?*

Foliar fungicides are insurance policies since the likelihood of response is related to subsequent grain fill conditions after application. In New Zealand cereal crops the cost of this “fungicide insurance policy” can be strongly linked to whether the crop is grown in a dryland or irrigated situation. Dryland trials over the last five years have shown that the drier conditions experienced during grain fill reduce the value of fungicide application, resulting in lower expenditure being more cost effective in this scenario compared to an equivalent irrigated crop. Dry conditions reduce not only the value of the ear emergence or “ear wash” application, but also the level of expenditure at key timings before ear emergence. Though dryland conditions vary with geographic region, invariably fungicide response will be lower than that of an equivalent irrigated situation.

**Dryland* versus Irrigated crops - influence on management strategy.**

**Susceptible Cultivars**

Three key features are noted when comparing dryland and irrigated fungicide response in cereals, firstly dryland crops give less overall yield response to fungicide. Secondly the yield and margin response to more expensive strobilurin fungicides (particularly in wheat) is difficult to justify in a dryland crop. Lastly, the economic response to an ear emergence fungicide application in wheat is very variable and more difficult to justify in dryland crops. In some regions dryland yield responses to fungicides can be greater due to higher rainfall e.g. Methven area of the Canterbury Plains, or in the case of South Canterbury and Southland, because grain fill conditions are generally cooler and longer.

The yield response to fungicide in susceptible dryland crops south of Timaru whilst not being as great as that experienced in Mid Canterbury irrigated equivalents, has exceeded Mid Canterbury dryland yield responses.

**Resistant Cultivars**

Fungicide management for resistant varieties is in many cases more difficult than for susceptible varieties. Knowledge that you are more certain to have to manage disease with a susceptible
variety enables you to plan strategies based on growth stages. With more resistant varieties, particularly those that are not stripe rust susceptible, disease epidemics are naturally delayed by the cultivar’s resistance and further curtailed by drier conditions in grain fill in a dryland scenario.

Growing resistant cultivars in dryland situations results in a far shorter window in which disease can develop and economic response be secured. In many cases such situations can be managed with a single spray applied at lower rates on the flag leaf (GS39), since neither persistence to cover a long grain fill or eradication for already established disease are required. This was noted in FAR trials between 2002 to 2005 when working with resistant cultivars there was no advantage splitting fungicides between flag leaf and ear emergence on dryland but there was an advantage on irrigated land.

**Key Points**

- Assuming disease develops in the crop, whether the wheat crop is dryland or irrigated has an enormous effect on the economic response to fungicide.
- Dryland wheat crops produce substantially lower returns from fungicides, dictating that in wheat, strobilurin fungicides are less economic even with more susceptible varieties.
- Where strobilurins are used in dryland scenarios, it is lower rates (below 50% doses) in combination with triazole that are most effective.
- Response to fungicide in dryland crops is very dependent upon regional rainfall. Responses to fungicide in South Canterbury, Southland and Methven dryland scenarios tend to be greater and justify more fungicide input than Mid Canterbury dryland crops.
- When resistant varieties are grown in dryland scenarios, opportunities for disease epidemics are reduced as natural resistance delays disease until well into stem elongation and drier conditions curtail disease development during grain fill.
- All of these factors combined means that there is less need for fungicide application to protect and maintain green leaf area in dryland scenarios.
Disease development

Of course whether the crop is dryland or irrigated may not in itself determine whether a crop is subject to disease infection, it more determines the likelihood of disease progression. So how can we determine our risk of disease infection in the first place?

How can we determine disease risk?

So far we can deduce that:

(i) Foliar fungicides are most effective when they are applied shortly after the emergence of the leaf you wish to protect (in practical terms this usually means long enough for leaf to fully or nearly fully emerge on the main stems but before the disease has expressed itself).

(ii) The top three - four leaves of the cereal canopy are the most important to protect along with the ear.

(iii) The first of the important leaves emerge at the start of stem elongation.

This information tells us when to start considering whether a fungicide is worthwhile and which leaf is most important. It does not tell us the degree of disease pressure and its likely rate of development.

To determine the likelihood of infection there are a number of factors to consider, but the following represent the practical starting points.

1) Variety resistance* - Timing by threshold or leaf emergence?
In more resistant cultivars disease epidemics are slower to establish and as a consequence will have less impact on yield. In such situations FAR funded work has shown less need for full rates of agrichemicals.

Where a cultivar has good resistance (MRR-mostly resistant, MR-moderately resistant and R-resistant) against the diseases prevalent in the region, it is more difficult to suggest a pre programmed approach to protect the top three leaves of the wheat canopy. Instead it is more appropriate to monitor from GS30-GS31 onwards, delaying until flag leaf if disease does not develop. Stripe rust is frequently the disease likely to require spraying prior to GS37-GS39 (flag leaf emergence).

Is your cultivar stripe rust susceptible? If not and it has generally good resistance to other diseases, then flag leaf emergence may represent the ideal timing for the first spray, with a second spray necessary on irrigated crops and possibly a single spray at flag for dryland resistant cultivars. Where varieties are more susceptible (S-susceptible, MSS-mostly susceptible and MS-moderately susceptible) disease can build up more rapidly and earlier in the season.

In these situations a pre-programmed approach is a better management strategy adjusting products and rates to take account of specific disease pressures at critical growth stages. With barley cultivars the diverse nature of disease and the increased importance of earlier timing makes it difficult to spray only once.

2) Presence of the disease in the crop/region and weather conditions for development

Though the length of the latent period (thermal time for disease expression to be visible to the naked eye) potentially distorts this factor, most advisors / growers use their crop as the threshold indicator for the need to spray a particular disease.

Therefore know what diseases to expect due to cultivar resistance and whether they are prevalent in your region. For example, the rusts, both leaf and stripe rust tend to be generally less prevalent further south (South Canterbury and Southland). Net Blotch is particularly prevalent in North Island spring barley. Septoria leaf blotch in wheat is not endemic in Canterbury crops (as it is in European crops) in early spring, but in Southland this disease is much more prevalent.

3) Sowing date of the crop

In general, earlier sowings of cereals tend to increase disease risk and as a consequence fungicide response. This is the case within both autumn and spring plantings and has been observed in many FAR trials.

* For more details on cultivar resistance ratings please see the latest FAR Cultivar Evaluation booklet
Disease management strategies for autumn sown wheat

i) Cultivar resistance profile*
First consider cultivar resistance remembering in general greater resistance will delay disease epidemics and the timing of the first application.

From a management strategy perspective cultivar resistance can be classed in 3 categories.

1. Susceptible - higher risk cultivars
2. More resistant varieties with one disease weakness
3. Resistant cultivars with no susceptible S and MSS ratings

1. Susceptible - higher risk cultivars
(susceptible to more than one disease prevalent for the region)

Eg. Savannah, Consort - consider using growth stage based spray programmes starting at GS30-GS32

2. More resistant varieties with one disease weakness

Stripe rust weakness
If the disease weakness is stripe rust it may still dictate starting the disease programme at GS30-GS32 as the category above, pre-programming to growth stage but catering for generally better resistance with lower rates at other timings.

Eg. Robigus

Leaf rust weakness
Since leaf rust is encouraged by warmer weather conditions than stripe rust, it usually becomes a major issue after flag leaf emergence (unless the winter is unduly mild as was the case in 2005). This still gives the opportunity for delaying the first spray beyond GS30-GS32, in some cases until flag leaf.

Eg. Phoenix

3. Resistant cultivars with no susceptible S and MSS ratings

These varieties are usually protected with lower rates of fungicides and one or two applications.

Note: MR-M5 intermediate ratings have not been considered susceptible. Obviously when the influence of irrigation and earlier sowing is superimposed over these different cultivar resistances risk status/potential response can be increased as indicated in the earlier section.

Influence of fungicide strategy on susceptible variety yield and margin cv Consort - Makikihi, South Canterbury, 3 year mean 2005 - 2007 (Dryland)

<table>
<thead>
<tr>
<th>Fungicide Programme/Growth stage</th>
<th>GS32</th>
<th>GS33</th>
<th>GS39</th>
<th>GS55-GS59</th>
<th>GS65</th>
<th>Yield %</th>
<th>$/ha Margin at $300/t</th>
<th>$450/t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Op+Cmt - Op+Cmt - Op+Cmt</td>
<td>126.7</td>
<td>513</td>
<td>897</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Opus - Opus - Opus</td>
<td>122.7</td>
<td>500</td>
<td>827</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proline - Proline - Op+Az</td>
<td>125.5</td>
<td>561</td>
<td>927</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fandango - Fandango - Op+Az</td>
<td>126.3</td>
<td>500</td>
<td>843</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Untreated</td>
<td>100</td>
<td>528</td>
<td>889</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Opus 0.25 GS30 Op+Az</td>
<td>126.1</td>
<td>526</td>
<td>901</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Untreated</td>
<td>100</td>
<td>526</td>
<td>901</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Op=Opus 0.5 l/ha/ Proline 0.4 l/ha / Cmt=Comet 0.4 l/ha
Fandango 1.0 l/ha GS65 Opus 0.25 l/ha + Az 0.25 l/ha * Opus applied GS30 not GS32

* For more details on cultivar resistance ratings please see the latest FAR Cultivar Evaluation booklet
1. Strategy for susceptible - higher risk cultivars  

Control of disease in these scenarios has been based on the typical “UK” 3 spray programme (T1, T2, T3), which accompanied these generally susceptible UK wheats when they were first grown in New Zealand.

Unlike the UK and northern Europe Septoria leaf blotch (Speckled leaf blotch) is not endemic in autumn sown New Zealand wheat crops. As a consequence the UK approach to T1 or Timing 1 sprays should not be adopted prophylactically here in New Zealand. Generally it has been found that the first spray for susceptible cultivars need not be expensive since it is frequently used to combat early rust rather than Septoria. Over the last three years incorporating a strobilurin at every timing (3 timings GS31-GS32, GS39 and GS65) has produced only small economic advantage in Mid Canterbury and no advantage in South Canterbury compared to programmes where purely triazole alone (Opus or Proline in trials was employed at GS32 and GS39).

**Strategy**

**GS30** - Where stripe rust is evident consider an early triazole application, such as Opus 0.25 l/ha (epoxiconazole), to act as holding spray until GS32 or GS33 if a straddle spray strategy is to be considered (see page 29 for details).

**GS31-GS32** - Base on at least half rate triazole (Opus 0.5 l/ha or Proline 0.4 l/ha). Consider Opus where stripe rust or leaf rust is evident and Proline where stem based diseases (eyespot, fusarium) and/or Septoria are considered more problematic. In general Proline has performed better than Opus where rusts have been absent at the first two timings (e.g. regions such as South Canterbury).

**GS39** - Main focal point for expenditure of the wheat programme, unless employing “Straddle Strategy” (see next section). Again consider at least half rate triazole (Opus 0.5 l/ha or Proline 0.4 l/ha) as the base for this spray.

**In irrigated scenarios** - consider mixing the triazole with 50% dose of strobilurin. Though Pyraclostrobin (Comet) has a slight edge over other strobilurins in Europe (leaf rust and sensitive isolates of Septoria), in New Zealand in three spray programmes it has performed similarly to other strobilurins such as Azoxystrobin (Amistar), Pyraclostrobin has been very consistent against leaf rust in FAR trials. Make sure that any premiums charged for co formulations does not unduly increase the cost of this spray relative to other alternative triazole/strobilurin mixtures. Conversely take advantage of subsidised formulated mixtures where active ingredients can be purchased more cheaply mixed, provided the level of active ingredient has not been reduced.

**In dryland scenarios** - Again consider at least half rate triazole (Opus 0.5 l/ha or Proline 0.4 l/ha) as the base for this spray.

In this scenario it has been difficult to illustrate the cost effectiveness of adding strobilurin chemistry (typically 30% dose rates) to Opus or Proline based on Mid Canterbury trials. It cannot be ruled out that lower doses of strobilurin (25% dose rates) would give an economic response, but these have not been tested in dryland situations. In irrigated scenarios 25% strobilurin dose rates have been inferior to 50% rates.

**GS59-GS61** - Low rate combinations of the triazoles and strobilurins are very effective at this timing, particularly in irrigated scenarios. A good standard has been Opus 0.25 l/ha + Amistar 0.25 l/ha, which is particularly effective against leaf rust. Initial work substituting Proline 0.2 l/ha for Opus has shown promise but in the presence of leaf rust Opus would be a stronger partner. On well irrigated soils with good water holding capacity (e.g. Wakanui clay) it is possible that further fungicide application during grain fill may be cost effective if the cultivar is under high leaf rust pressure. However, take care that the withholding period is not infringed (time between last permitted application and harvest).

Mid Canterbury dryland scenarios consider it as an optional spray waiting until GS69 (end of anthesis), based on rainfall since flag leaf. Consider applying ear wash should higher rainfall than the average fall in your region between GS39 and GS65.

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**Influence of fungicide strategy on susceptible variety yield and margin cv Savannah - FAR Arable Site, Mid Canterbury, 3 year mean 2005 - 2007 (Irrigated)**

<table>
<thead>
<tr>
<th>Fungicide Programme/Growth stage</th>
<th>Yield %</th>
<th>$300/t Margin at</th>
<th>$450/t Margin at</th>
</tr>
</thead>
<tbody>
<tr>
<td>Op+Cmt</td>
<td>133</td>
<td>460</td>
<td>817</td>
</tr>
<tr>
<td>Opus</td>
<td>129</td>
<td>478</td>
<td>793</td>
</tr>
<tr>
<td>Proline</td>
<td>126</td>
<td>409</td>
<td>700</td>
</tr>
<tr>
<td>Fandango</td>
<td>133</td>
<td>397</td>
<td>741</td>
</tr>
<tr>
<td>- Op+Cmt</td>
<td>132</td>
<td>477</td>
<td>812</td>
</tr>
<tr>
<td>Untreated</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Op=Opus 0.5 l/ha / Proline 0.4 l/ha / Cmt=Comet 0.4 l/ha  
Fandango 1.0 l/ha GS65 Opus 0.25 l/ha + Az 0.25 l/ha
2. Strategies for more resistant varieties with one disease weakness

More resistant varieties with a stripe rust weakness

Eg. Robigus, Raffles

With these cultivars, the weakness to stripe rust makes it difficult to reduce the number of spray timings, since stripe rust is generally an early season disease, (favoured by moist, humid conditions at optimum temperature of 15 °C). As a consequence this disease traditionally expresses itself before flag leaf.

However since these varieties are generally more resistant, the level of active ingredient employed, particularly at flag leaf and after can be reduced in comparison to the strategy for more susceptible varieties such as Savannah.

**Strategy**

**GS30-GS32** - Base spray timing on the appearance of stripe rust; consider Opus 0.5 l/ha with actual timing in this window depending on onset of infection. If infection coincides with GS33 one can consider using a straddle spray programme.

**GS39 onwards** - Considerations are similar to susceptible varieties, though the rates of the flag leaf sprays can be reduced. For example, base fungicide application on at least Opus 0.25 l/ha or Proline 0.2 l/ha plus a minimum of strobilurin Comet 0.2 l/ha (quarter rate) or Amistar 0.25 l/ha (third rate). If stripe rust is not controlled from first spray consider increasing the rate of Opus to 0.5 l/ha and drop the Proline option. Considerations for dryland and irrigated crops are the same as flag leaf options for susceptible crops.

**GS59-GS61** - See strategy for susceptible wheat. Since this application is not based on high rates, it is not possible to reduce suggested rates of active ingredients.
More resistant varieties with a leaf rust weakness

Leaf rust is less likely to be expressed until later in the season (flag leaf onwards). In these cases, the cultivar’s genetic resistance to other diseases may delay the build up of disease until GS33-GS39 (third node - flag leaf).

The only exception to this general guide is where the winter has been extremely mild and leaf rust development starts much earlier in the season (2005 season was the last time this happened). Therefore in these strategies the first fungicide can frequently be the flag leaf spray, saving on the application of an early spray. If the disease pressure does not allow the first spray to be delayed until flag leaf (GS39), then a first spray employed at 3rd node (GS33) will result in flag-1 being protected with fungicide but not the flag leaf. In these scenarios the follow up spray needs to be brought forward slightly to 50% - full ear emergence (GS55-GS59). This is termed the Straddle Approach, since fungicide is applied either side of flag leaf emergence but not at flag leaf emergence (see strategy section below).

Where disease programmes start at flag leaf emergence (GS39) the second spray need not be employed until full ear emergence to mid flower (GS59-GS65).

Again the considerations are similar to that for susceptible varieties:
- At flag leaf and ear emergence it is more appropriate to base triazole on Opus (epoxiconazole) since it is stronger on leaf rust than the other front running triazole Prolin (Prothioconazole).
- Pyraclostrobin and Azoxystrobin tend to be stronger strobilurins for leaf rust control, and therefore act as ideal mix partners with a triazole.
- In dryland scenarios, leaf rust susceptibility in a cultivar makes it more difficult to omit the ear emergence fungicide as this disease tends to predominate later in the season. However, the rates of the second spray can be reduced to reflect less need for persistence in low rainfall regions.

Comparison of a 2 spray straddle programme with a 3 spray programme (based on strobilurin) on susceptible variety yield and margin cv Consort - Makikih, South Canterbury, 3 year mean 2005 - 2007 (Dryland)

<table>
<thead>
<tr>
<th>Fungicide Programme/Growth stage</th>
<th>Yield %</th>
<th>$/ha Margin at $300/t</th>
<th>$/ha Margin at $450/t</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>3 spray</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Op+Cmt - Op+Cmt - Op+Az</td>
<td>126.7</td>
<td>513</td>
<td>897</td>
</tr>
<tr>
<td><strong>2 spray straddle</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Op+Cmt - Op+Cmt -</td>
<td>125</td>
<td>528</td>
<td>889</td>
</tr>
<tr>
<td>Untreated</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Op=Opus 0.5 l/ha/ Cmt=Comet 0.4 l/ha GS65 Opus 0.25 l/ha + Az 0.25 l/ha * Opus applied GS30 not GS32

Comparison of a 2 spray straddle programme with a 3 spray programme (based on strobilurin) on susceptible variety yield and margin cv Savannah - FAR Arable Site, Mid Canterbury, 3 year mean 2005 - 2007 (Irrigated)

<table>
<thead>
<tr>
<th>Fungicide Programme/Growth stage</th>
<th>Yield %</th>
<th>$/ha Margin at $300/t</th>
<th>$/ha Margin at $450/t</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>3 spray</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Op+Cmt - Op+Cmt - Op+Az</td>
<td>133</td>
<td>460</td>
<td>817</td>
</tr>
<tr>
<td><strong>2 spray straddle</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Op+Cmt - Op+Cmt -</td>
<td>132</td>
<td>477</td>
<td>812</td>
</tr>
<tr>
<td>Untreated</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Op=Opus 0.5 l/ha/ Cmt=Comet 0.4 l/ha GS65 Opus 0.25 l/ha + Az 0.25 l/ha

**Strategy**

Two Spray Straddle Approach - This two spray programme applies fungicide either side of flag leaf at 3rd node GS33 and early ear emergence GS55-GS59 (with no more than a 21 day gap between sprays). This approach uses slightly more fungicide than the alternative two spray outlined i.e. GS39 & GS59/65 as the programme starts and finishes earlier, so covers a wider window of protection. In work conducted in susceptible varieties, suffering from leaf rust and stripe rust, the two spray straddle has given yields 1-2% inferior to three sprays (all three sprays based on strobilurins). **GS33 and GS55 (2 spray straddle)** - For both sprays base active ingredient rates on Opus at a minimum of 0.5 l/ha mixed with strobilurins, either Comet (0.4 l/ha) or Amistar (0.5 l/ha) for irrigated scenarios.

In low rainfall dryland scenarios consider reducing, or omitting, the strobilurin, particularly with the second spray at GS55-GS59.

**GS39 and GS59/65 (2 spray starting at flag)** - As above for the first spray at GS39 but consider reducing the rates of active ingredient for the second spray for dryland since its persistence need not be as great if it starts at flowering.
3. Resistant varieties - with no susceptible ratings (S-susceptible and MSS-mostly susceptible)

These cultivars allow the lowest fungicide input in terms of fungicide rate and number of applications (e.g. Conquest).

**Dryland Strategy**

**GS39** - In many dryland scenarios it is possible that a single flag spray at GS39 based on Opus (0.5 l/ha) or Proline (0.4 l/ha) would be sufficient for disease control. This would need to be reviewed if the period up to flowering was very wet.

**Irrigated Strategy**

In irrigated scenarios where canopy duration is extended, it is usually better to employ two reduced rate sprays at GS39 and GS61-GS69 rather than a single flag spray.

**GS39 and GS61-GS69** - Consider low rate combinations of triazole and strobilurin, for example, Opus 0.25 l/ha + Amistar 0.25 l/ha at both timings or similarly using Proline 0.2 l/ha + Amistar 0.25 l/ha in very wet season.

**Disease management strategies for autumn sown barley**

It is difficult to adopt a single spray strategy for autumn sown barley for three principal reasons:

i) Autumn sown barley can suffer from a wider range of diseases than wheat, such as powdery mildew, scald, net blotch and leaf rust, thus if weather conditions prevent one disease developing, chances are that another will be elevated in importance.

ii) Lower leaves, particularly flag-3, that emerge earlier (GS30-GS31) are more important in barley than wheat. Thus spray programmes start earlier with this crop, though still need to cover disease that may develop when the flag leaf sheaf and awns emerge.

iii) Wet weather diseases, particularly scald (Rhynchosporium secalis), frequently build up over winter predominantly in early sown (late April / May) barley. In some cases this has been shown to make additional late tillering sprays economic, but does not remove the need to protect upper leaves that emerge during stem elongation. Recent adoption of Prothioconazole (Proline) as the main triazole for barley programmes has reduced the value of these early tillering sprays (pre GS30).
Prothioconazole (Proline) strengths:
Both in autumn and spring sown barley, Prothioconazole (Proline), released in 2005, has set a new standard of disease control and yield response in barley. This strength comes principally from better control of scald. Three years of trials on autumn sown barley (irrigated Tavern) in South Canterbury have shown key differences in product performance and the advantages of Proline (prothioconazole) against this disease.

From FARM trials Proline has also been noticeably better against barley leaf rust than it is against wheat leaf rust, resulting in greater applicability at the later spray timings in barley when this disease is a problem, along with scald. However the benefit of mixing a partner for leaf rust control, whether using Proline or Opus was also evident in FARM trials. This work also showed that control of leaf rust results in even greater returns from fungicide than treating crops for scald.

In many cases the strategies for barley can be simplified into two categories based on two sprays.

Treatments were evaluated as two sprays:

<table>
<thead>
<tr>
<th>Trt. No.</th>
<th>GS30-GS31 application (l/ha)</th>
<th>GS39-GS49 application (l/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Untreated</td>
<td>Untreated</td>
</tr>
<tr>
<td>2</td>
<td>Fandango 1.0</td>
<td>Fandango 0.5</td>
</tr>
<tr>
<td>3</td>
<td>Fandango 1.0 + Protek 0.5</td>
<td>Fandango 0.5 + Protek 0.5</td>
</tr>
<tr>
<td>4</td>
<td>Opus 0.5 + Twist 0.5</td>
<td>Opus 0.25 + Twist 0.5</td>
</tr>
<tr>
<td>5</td>
<td>Opus 0.5</td>
<td>Opus 0.25</td>
</tr>
<tr>
<td>6</td>
<td>Opus 0.5 + Twist 0.5 + Protek 0.5</td>
<td>Opus 0.5 + Twist 0.5 + Protek 0.5</td>
</tr>
<tr>
<td>7</td>
<td>Proline 0.4</td>
<td>Proline 0.2</td>
</tr>
<tr>
<td>8</td>
<td>Proline 0.4 + Acanto 0.25</td>
<td>Proline 0.2 + Acanto 0.25</td>
</tr>
</tbody>
</table>

*Note treatment numbers in this table relate to the following graphs.*
### 1. Disease susceptible scenarios

When early sowing and cultivar choice expose the grower to higher disease risk of a wider range of disease, particularly scald, Ramularia and leaf rust.

At risk varieties - susceptible to scald, or early sown, or susceptible to leaf rust.

#### Strategy

**GS30-GS31** - Timing 1 consider Proline 0.4 + Acanto 0.25 l/ha followed by **GS39-GS49** (flag-1st awns) Proline 0.2 l/ha + Acanto 0.25 l/ha at Timing 2. If only leaf rust is evident at GS39-GS49 Opus 0.25 l/ha or Proline 0.2 l/ha could be considered as a partner for Acanto.

**When are 3 sprays necessary?**

Where scald is evident pre GS30 at the late tillering stage, consider Proline 0.2 + Protek 0.5 l/ha as an additional early spray (do NOT omit the other two sprays if the pre GS30 is applied). This has tended to be more important in dryland crops where early leaf loss is relatively more important. The two most likely scenarios for needing an early tillering spray are where barley is grown on barley or where barley is sown early.

Where crops are irrigated it has been noted that increasing the rate of Acanto at the second timing has been beneficial to crops in this category.

### 2. More resistant scenarios

With autumn sown barley it is not always easy to identify more resistant scenarios as sowing in the autumn by its very nature increases disease pressure. Typically, where crops are more resistant to disease, they are invariably sown later in the autumn (late May/June).

In these situations it has been shown that Proline alone, or with a cheaper partner (two fungicide actives being better from a fungicide resistance stand point) such as carbendazim (Protek), can be sufficient. Increased leaf rust resistance of a cultivar generally reduces the need for the strobilurin partner. Thus, further south in South Island where leaf rust is less problematic, this approach may be valid, but it should be emphasised that early autumn sowing can increase scald pressure to such an extent that three way mixes of triazole/strobilurin/carbendazim can still be advantageous.

### Margins based on fungicide costs:

- Acanto $99.84/l
- Opus $60.98/l
- Fandango $100.00/l
- Twist $58.67/l
- Protek $18.58/l
- Proline $101.16/l

Application costs $15/ha, all chemical prices ex GST. 100 = 9.86 t/ha.

### Treatment numbers in this table relate to the yield and margin graph above.
Disease management strategies for spring sown barley

Many of the results generated for autumn sown barley have been mirrored in FAR trial results generated on spring sown barley. The two main differences are:

i) Spring sowings naturally reduce early disease pressure and provided first fungicide applications are not delayed beyond row closure (a factor that increases crop humidity and disease pressure) at late tillering GS23-GS30, lower rates of active ingredient can be successful.

ii) Spring sown crops, particularly October or later sown develop quicker, meaning that fungicide persistence does not have to be as great as with autumn sowings.

The other advantage of generally lower application rates is that spring barley (more so than autumn cereals), in some circumstances show no yield response to fungicide. This is usually as a result of spring droughts and later sowing reducing disease pressure and shortening grain fill periods. In these cases all fungicide programmes lose money, but the lower cost of the insurance programme prevents the loss being as great as it might be with full rates of fungicides. This was seen in trials in Southland in 2007. Proline (Prothiconazole) has again set a new standard for disease control in this crop, principally due to its activity on scald (Rhynchosporium secalis).

Mildew - role of mildewicides and strobilurin resistant strains

Spray only if the disease is threatening the key leaves, flag-1 and flag-2.

If powdery mildew is encountered at any stage in stem elongation on these key leaves, Proline or Opus alone will not be sufficient to control the disease. In these circumstances consider mixing with a designated mildewicide such as

- Fernpropimorph (only available in mixture with Opus as Opus Team)
- Spiroxamine (Impulse)
- Fenpropidin (Tern)

It should be emphasised that barley mildew is not as damaging as barley leaf rust infection. It should also be noted that the discovery of strobilurin resistant strains of mildew in New Zealand will mean that strobilurins will be less effective in the coming years against powdery mildew.

Strategy

**GS30-GS31** Proline 0.4 l/ha plus Protek 0.5 l/ha.

**GS49** Proline 0.2 - 0.4 l/ha rate depending on whether crop is irrigated or dryland plus Protek 0.5 l/ha.

Though two sprays is the preferred approach for disease protection in barley, if only one spray is to be used then application before GS32 (2nd node) will mean that the most important leaf (Flag-1) will be left unprotected from disease. If low disease pressure allows the grower to hold off until GS33 (3rd node) then one spray will at least cover flag-1.

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Key Points

- Proline at the rates tested has given on average at least 5% higher yield than Opus in susceptible spring sown barley.
- The strobilurin triazole mixtures incorporating Proline mixed with Picoxystrobin (Acanto) or Fluaxostrobin (Fandango) have produced the better yields and margin.
- The margins over chemical costs are greater under irrigation than dryland but the overall trend in product performance is the same.
- The most profitable treatment was the three way mix of Proline/Acanto and Protek, indicating that carbendazim (Protek) still has a place alongside triazoles and strobilurins, in particular for scald protection.

The following two graphs show the yield and margin response from the same nine fungicide treatments tested at the FAR Arable Site in Mid Canterbury from 2005 to 2007. The graphs show fungicide response in the disease susceptible cultivar Optic for both the irrigated and dryland crop, which over the three years suffered infection of scald, leaf rust and lower levels of powdery mildew.

<table>
<thead>
<tr>
<th>Trt. No.</th>
<th>GS30 application (/ha)</th>
<th>GS39-GS49 application (/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>nil</td>
<td>Nil</td>
</tr>
<tr>
<td>2</td>
<td>Proline 0.2</td>
<td>Proline 0.2</td>
</tr>
<tr>
<td>3</td>
<td>Opus 0.25</td>
<td>Opus 0.25</td>
</tr>
<tr>
<td>4</td>
<td>Proline 0.2 + Acanto 0.25</td>
<td>Proline 0.2 + Acanto 0.25</td>
</tr>
<tr>
<td>5</td>
<td>Proline 0.2 + Protek 0.5</td>
<td>Proline 0.2 + Protek 0.5</td>
</tr>
<tr>
<td>6</td>
<td>Opus 0.25 + Acanto 0.25</td>
<td>Opus 0.25 + Acanto 0.25</td>
</tr>
<tr>
<td>7</td>
<td>Opus 0.25 + Twist 0.5</td>
<td>Opus 0.25 + Twist 0.5</td>
</tr>
<tr>
<td>8</td>
<td>Fandango 0.5</td>
<td>Fandango 0.5</td>
</tr>
<tr>
<td>9</td>
<td>Proline 0.2 + Acanto 0.25 + Protek 0.5</td>
<td>Proline 0.2 + Acanto 0.25 + Protek 0.5</td>
</tr>
</tbody>
</table>

Note: Treatment numbers in this table relate to the yield and margin graphs below

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.

Strategy

**GS23-GS30** (row closure) - Proline 0.2 /ha + Acanto 0.25 /ha

**GS39-GS49** (flag leaf fully emerged - 1st awns) - Repeat Proline 0.2 /ha + Acanto 0.25 /ha

As already stated, very dry conditions combined with good leaf rust resistance may reduce value of the second spray. As weather conditions post awn emergence (post fungicide) are difficult to predict, it may be more appropriate to remove the strobilurin from the mix at the second timing rather than omit the application altogether.

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.
**Increased grain prices**

During the recent surge in grain prices the cost benefit ratios of fungicide application improved. Unlike fertiliser prices there was not a large increase in fungicide prices, meaning that any yield response associated with fungicide application has a greater value relative to the cost of the fungicides.

With higher grain prices it is potentially more economic to apply higher rates of active ingredient where a range of rates are suggested. However, if yield data has not revealed a yield benefit from a fungicide product or an application timing, higher grain prices will not influence this result.

**Cereal powdery mildew resistance to strobilurin fungicides**

When growers are considering their strategies for applying fungicides to their cereal crops it is important to remember that cereal powdery mildew has been confirmed in New Zealand. Whilst the extent of this resistance is not known it means that we can expect the incidence of resistance in this disease to increase since it is the same mutation that occurred in Europe.

**Background**

A resistance monitoring programme run by Crop & Food Research and commissioned by FAR, has identified strobilurin resistance in powdery mildew populations affecting cereals. The resistance was confirmed in both barley powdery mildew and wheat powdery mildew samples that had been collected across the Canterbury Plains.

Though the exact frequency of resistance in mildew populations cannot be determined from monitoring, it appeared that resistant isolates were more readily found in barley mildew.

The samples collected in spring 2004 were found to contain isolates that grew on plants treated with the strobilurin kresoxim-methyl (Stroby WG; also present in the broad spectrum mixture Allegro). In confirmatory testing carried out in 2005 suspected resistant isolates were again identified and sent to Germany (courtesy of BASF) for DNA analysis. This genetic analysis confirmed the presence of the G143A mutation, the same mutation which is the basis of resistance in powdery mildew and Septoria leaf blotch (speckled leaf blotch) in Europe.

**Which products are affected?**

Though the strobilurin, kresoxim methyl (Allegro) is the most effective product for mildew control, all six strobilurins (picoxystrobin - Acanto, azoxystrobin - Amistar, trifloxystrobin - Twist, pyraclostrobin - Comet, fluoxastrobins - Fandango (mixture with Proline) and kresoxim-methyl the strobilurin in the Allegro mixture with Opus) will be ineffective against mildew that is resistant. In addition the use of any strobilurin fungicides is likely to increase the proportion of resistance within the mildew populations present at spraying i.e. effectively selecting the resistant population by killing off the susceptible population. It is important to recognise that these resistant isolates carry no fitness penalty; therefore the population will not shift back to being strobilurin sensitive if we stop using these fungicides.

**What does this mean for mildew control in cereals?**

When wheat powdery mildew resistance was discovered in Europe (1998), its frequency increased such that after two seasons, strobilurins had little effect on this disease. Since it has been confirmed that the New Zealand mutation is identical to that found in Europe, it can be expected that mildew resistance will increase rapidly if strobilurins continue to be used.

This means that when considering mildew control, growers should be aware that strobilurin fungicides may not be fully effective and possibly ineffective in the long term.

**What products can we use for Mildew control that are not affected by strobilurin resistance?**

Since resistance was identified, agrichemical manufacturers have introduced specific mildewicide products for cereal crops. These active ingredients from the morpholine family can be purchased alone or in some cases only as mixtures. These active ingredients are:

- Spiroxamine (Impulse)
- Fenpropidin (Tern)
- Fenpropimorph (Opus Team - a mixture with Opus)

**How can we protect the activity of strobilurins against other cereal diseases?**

Recommendations given specifically for New Zealand conditions have been drawn up to avoid resistance development (Beresford 2005 - www.nzpps.org). It is very important that all New Zealand cereal growers follow these guidelines. Failure to do so by a minority of growers will result in the majority of growers being penalised.

Whilst these guidelines are likely to be of less value with mildew, they will help delay or avoid resistance developing in other diseases such as Septoria leaf blotch.

Whilst it is accepted that trial results have demonstrated that lower rates may be economic under some conditions, it is important to ensure that these rates are never used when the crop is under high disease pressure.

**Strobilurin Resistance Management**

**Current guidelines for cereal crops:**

1. **Apply a maximum of two strobilurin fungicide containing sprays per cereal crop.** Limiting the number of sprays is an important factor in delaying the build-up of resistant pathogen populations.
2. **Apply strobilurin fungicides in mixtures (usually with triazoles) to control cereal pathogens.** At the rate chosen each mixing partner on its own has to provide effective disease control. Refer to manufacturers recommendations for rates.
3. **Apply the strobilurin fungicides preventatively or as early as possible in the disease cycle.** Do not rely only on the curative potential of strobilurin fungicides.
4. **Split/reduced rate programmes, using repeated applications, which provide continuous selection pressure, should not be used.**

Note: In this booklet results have been presented as to how strobilurin application can be reduced from three applications to two in wheat.
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