Fungicide Resistance Management Strategies

This document is a guide only and does not endorse particular products, groups of products or cultural methods in terms of their performance. With acknowledgement to CropLife Australia.
1. WHAT IS FUNGICIDE RESISTANCE?

Resistance by fungal pathogens to fungicides usually evolves following the intensive use of fungicides for disease control. In any fungal population there are likely to be individuals that have some degree of natural resistance and which are less susceptible to fungicides, even before the chemicals are used. Resistance arises through the incorrect use of fungicides by selection of the resistant forms of fungi. Continued use of a fungicide or fungicide chemical group can result in a significant build up of resistant individuals in the fungal population – to the point where that particular product, or other products from the same chemical group, is no longer effective. In some cases, removal of the selection pressure can result in the fungal population regaining its sensitivity to the fungicide group, but this is not always the case. The risk of fungicide resistance developing varies between different chemical groups and different fungal pathogens, such that specific strategies are recommended for those situations considered to carry the highest risk.
2. WHAT CAN BE DONE TO PREVENT OR DELAY RESISTANCE?

2.1 The most common approach to managing fungicide resistance is through responsible use of fungicides, of which the resistance management strategies presented in this document are good examples. In their most basic form, these strategies advocate rotation of fungicide products with a different chemical activity group to prevent over-use of any one product or activity group. More complex strategies safeguard against the development of cross-resistance or resistance to multiple chemical groups. All fungicide products are labelled to identify which activity group they belong to. The activity group is indicated by a number (or letter/number combination) code on the product label.
2.2 Selecting the most effective or appropriate way to apply fungicides will make them work better and assist in delaying the development of resistance. A good understanding of the pathogen’s life cycle and epidemiology will also help in the selection of the most appropriate application method. As a general rule, targeted applications to control a certain development stage or population level are most effective, whereas shotgun approaches like application of fungicides through irrigation systems could accelerate the development of resistance by exposing a large portion of the fungal population to sub-lethal rates. Particular attention should be given to label recommendations, rates and coverage. Adherence to suggested disease threshold levels is also good resistance management practice.
2. WHAT CAN BE DONE TO PREVENT OR DELAY RESISTANCE?

2.3 The use of cultural practices or growing varieties of crops with a high degree of natural resistance to diseases – requiring fewer or less frequent fungicide applications.

2.4 Working with industry bodies to establish resistance management strategies for minor crops and/or those crops for which no strategies exist. Of particular concern are permitted uses of fungicides, often in minor crops, where repeated use of a limited number of fungicide alternatives occurs. Although not explicitly stated on agricultural use permits, such permitted uses should also incorporate measures to prevent resistance.

2.5 In the event of tank mixing products and/or co-formulations, always follow the recommendation from the most recent Fungicide Resistance Management Strategies and apply the most stringent strategy applicable to the pathogen most at risk of developing resistance.
2. WHAT CAN BE DONE TO PREVENT OR DELAY RESISTANCE?

2.6 Certain environments are conducive to continuous infection and consistently high disease pressure. Examples of such environments are nurseries, tunnels, glasshouses and other structures of protected cultivation. Because protected cultivation usually requires multiple applications of fungicides at short intervals to control high disease incidence, these are often the origin of resistance to fungicides. Users of fungicides should be particularly mindful of the resistance risk under these conditions. Do not use a fungicide product to which resistance has been confirmed and stop using a product if resistance is suspected. When the fungicide in question no longer gives adequate control, stop using it temporarily and consult the supplier on its current resistance status.
2. WHAT CAN BE DONE TO PREVENT OR DELAY RESISTANCE?

2.7 In the absence of an established resistance management strategy for a particular crop/disease situation, it is recommended that the use of fungicides from any given activity group (excluding Group M) be limited to a maximum of one-third of the total number of fungicide applications. The use of consecutive applications of fungicides from the same activity group should also be limited by alternating between products from different activity groups. The use of Group M fungicides is not limited, as these fungicides carry an inherently low risk of fungicide resistance developing.
Resistance Management Strategies for Crops

Apples & Pears

Fruit: post-harvest treatment

Stone Fruit

Grape

Potato

Tomato
Resistance Management Strategy for:

**Group 3** (DMI);

**Group 9** (Anilinopyrimidine);

**Group 11** (Quinone outside Inhibitor) fungicides; and

**Combinations of Group 9** (Anilinopyrimidine) and Group 3 (DMI) fungicides; and Dodine.

1. To prevent or delay the onset of resistance to **Group 3** fungicides, **DO NOT** apply more than four **Group 3** sprays alone per season. If more sprays are required apply a tank mix of a **Group 3** with a **Group 9** or suitable product from **Groups M** or **M1** to **M9**, or apply a registered product containing a combination of a **Group 3** and a **Group 9** fungicide.

2. **DO NOT** apply more than four sprays per season of **Group 9** fungicides (solo products).

**DO NOT** apply more than five sprays per season of products containing a combination of a **Group 9** and a **Group 3** fungicide.

**DO NOT** apply more than three sprays per season of **Group 11** fungicides. If two or three consecutive applications of **Group 11** fungicides are used, then they must be followed by at least the same number of applications of fungicide(s) from a different group(s) before a **Group 11** fungicide is used again, either in the current or following season.

Where spray programs include both solo **Group 9** products and combination products, the maximum cumulative number of applications is five per season.

3. To prevent or delay the onset of resistance to Dodine, **DO NOT** apply more than three consecutive sprays of Dodine, and no more than a total of six Dodine sprays per season.

If more sprays are required, tank mix Dodine with a protectant product at the registered rate.
Crop(s): Fruit (post-harvest treatment)  
Pest(s): Post-harvest diseases

Resistance Management Strategy for:

**Group 3** (DMI);

**Group 2** (Dicarboximide); and other “systemic” fungicides; and

**Group 12** (Phenylpyrroles) fungicides

1. For the last pre-harvest spray, use a fungicide with a different activity group to the fungicide planned for use as a post-harvest treatment.

2. Where alternatives are available, rotate to use as many different activity groups as possible.

3. **DO NOT** dispose of unused dip solutions as a spray to crops or orchards.

4. **DO NOT** dispose of unused dip solutions within or near the crop or orchard area.
Crop(s): Stone Fruit  
Pest(s): Blossom Blight and Brown Rot

Resistance Management Strategy for:

Group 3 (DMI);  
Group 2 (Dicarboximide); and  
Group 9 (Anilinopyrimidine) fungicides

1. If applying Group 2 or 3 fungicides, **DO NOT** apply more than two consecutive sprays of fungicides from the same group before changing to another group.

2. **DO NOT** apply more than three sprays of a Group 9 fungicide per season. If two or three consecutive sprays are applied, they must be followed by at least the same number of sprays from an alternative chemical group, including from one season to the next.

3. A post-harvest treatment should also be counted as an application.

4. The last blossom blight spray and the first pre-harvest brown rot spray should be regarded as consecutive applications.

5. The spray program should be considered and the strategy applied on a whole-orchard basis.
Crop(s): Grape
Pest(s): Downy Mildew

Resistance Management Strategy for:

**Group 4** (Phenylamide);

**Group 11** (Quinone outside Inhibitor); and

**Group 40** (Carboxylic Acid Amides (CAA)) fungicides

1. Start disease control sprays when the vine shoots are approximately 20cm long and continue spraying at intervals of 7-21 days using a protectant or non-phenylamide fungicide.

2. When conditions favour disease development, apply two consecutive sprays of a **Group 4** product. **DO NOT** apply more than two consecutive sprays of a **Group 4** product. **DO NOT** apply more than four sprays of a **Group 4** product per season.

3. **DO NOT** apply more than three consecutive sprays of a **Group 40** fungicide, and no more than a total of six sprays per season.

4. **DO NOT** apply more than two sprays per season of **Group 11** fungicides. If two consecutive applications of **Group 11** fungicides are used, then they must be followed by at least the same number of applications of fungicide(s) from a different group(s) before a **Group 11** fungicide is used again, either in the current or following season.

5. Apply **Group 11** fungicides preventatively.

6. Apply a maximum of two consecutive applications in alternation with fungicides from a different MOA group with satisfactory efficacy against the target pathogen/s.
Crop(s): Grape  
Pest(s): Powdery Mildew

Resistance Management Strategy for:
Group 3 (DMI);  
Group 5 (Amine);  
Group 7 (SDI; carboxamides);  
Group 11 (Quinone outside Inhibitor);  
Group 13 (Quinoline) fungicides; and  
Group U8 (Actin Inhibitor) fungicides

1. **DO NOT** apply more than two consecutive sprays of a Group 3 fungicide.  
   **DO NOT** apply more than three Group 3 sprays per season.  
   **DO NOT** use Group 3 fungicides curatively.

2. **DO NOT** apply more than two consecutive sprays of a Group 5 fungicide.  
   **DO NOT** apply more than three Group 5 sprays per season.

3. **DO NOT** apply consecutive sprays of Group 7 fungicides, including from the end of one season to the start of the following season  
   **DO NOT** apply more than four Group 7 sprays per season.

4. **DO NOT** apply more than two sprays per season of Group 11 fungicides. If two consecutive applications of Group 11 fungicides are used, then they must be alternated with a fungicide from a different activity group.

5. Apply Group 11 fungicides preventatively.

6. Apply a maximum of two consecutive applications in alternation with fungicides from a different MOA group with satisfactory efficacy against the target pathogen/s.

7. **DO NOT** apply more than two consecutive sprays of a Group 13 fungicide.  
   **DO NOT** apply more than three Group 13 sprays per season.
Crop(s): Grape
Pest(s): Grey Mould (Bunch Rot)

Resistance Management Strategy for:

**Group 2** (Dicarboximide);

**Group 9** (Anilinopyrimidine) and combinations of **Group 9** (Anilinopyrimidine) and **Group 12** (Phenylpyrroles);

**Group 17** (Hydroxyanilide); and

**Group 7** (SDI; carboxamide) fungicides

1. If three or fewer bunch rot sprays are applied in a season, use no more than one spray from the same fungicide group during the season, for any **Group 2** or **9** (including combinations with **Group 12**), **Group 17** or **7** fungicides.

2. If four or more bunch rot sprays are applied in a season, use no more than two sprays from the same fungicide group during the season, for any **Group 2** or **9** (including combinations with **Group 12**), **Group 17** or **7** fungicides.

3. **DO NOT** apply more than two consecutive sprays from the same fungicide group, for any **Group 2** or **9** (including combinations with **Group 12**) or **Group 17** fungicide, including from the end of one season to the start of the following season.

4. **DO NOT** apply consecutive sprays of **Group 7** fungicides, including from the end of one season to the start of the following season.

5. Late season fungicide treatments should be applied before Botrytis infection reaches unacceptably high levels in the vineyard.
Crop(s): Potato  
Pest(s): Late Blight

Resistance Management Strategy for:

**Group 4** (Phenylamide);  
**Group 11** (Quinone outside Inhibitor); and  
**Group 40** *(Carboxylic Acid Amides (CAA))* fungicides

1. Start disease control early and maintain a regular program using a fungicide from groups other than **Group 4, 11 or 40**.

2. When conditions favour disease development, **DO NOT** wait for disease to appear, but apply two consecutive sprays of a **Group 4, 11 or 40** fungicide at the interval recommended on the label. Then resume the program of sprays using products from a different group to the **Group 4, 11 or 40** fungicides just applied.

3. **DO NOT** apply more than four sprays of a **Group 4 or 40** fungicide per season.

4. The total number of **Group 11** fungicide applications per season should not exceed one third of the total number of fungicide applications per crop. No more than two consecutive **Group 11** sprays should be applied. If consecutive applications of **Group 11** fungicides are used, then they must be followed by at least the same number of applications of fungicide(s) from a different group(s) before a **Group 11** fungicide is used again, either in the current or following season.
Crop(s): Potato  
Pest(s): Early Blight

Resistance Management Strategy for:

Group 2 (Dicarboximide);
Group 3 (DMI);
Group 7 (SBI; carboxamide);
Group 9 (Anilinopyrimidine); and
Group 11 (Quinone outside Inhibitor) fungicides.

1. Limit the use of Group 2, 3, 9 or 11 fungicides to periods when conditions favour disease development.

2. **DO NOT** apply more than six Group 2 sprays in one season. Apply no more than two consecutive sprays of a Group 2 fungicide.

3. **DO NOT** apply more than six Group 3 sprays in a season. Apply no more than two consecutive sprays of a Group 3 fungicide alone.

4. **DO NOT** apply more than four Group 7 sprays per season. Always tank mix Group 7 fungicides with a protectant such as mancozeb or metiram.

5. If three or fewer fungicide sprays for target spot are applied per crop, use only one spray containing a Group 9 fungicide. If four to six sprays are applied per crop, use a maximum of two sprays containing Group 9 fungicides. If seven or more sprays are applied per crop use a maximum of three sprays containing Group 9 fungicides.

   Apply no more than two consecutive sprays containing a Group 9 fungicide.

6. Apply Group 11 fungicides preventively. **DO NOT** apply more than three foliar applications of a Group 11 fungicide per crop, no more than two consecutive Group 11 sprays per crop. If consecutive applications of Group 11 fungicides are used, then they must be followed by at least the same number of applications of fungicide(s) from a different group(s) before a Group 11 fungicide is used again, either in the current or following season.

7. When using a Group 11 fungicide in-furrow at planting, use a fungicide from a different group as the first foliar spray.
Crop(s): Tomato  
Pest(s): Grey Mould

Resistance Management Strategy for:

**Group 2** (Dicarboximide) fungicides

1. Tank mix **Group 2** fungicides with a protectant such as chlorothalonil, or with each other. Avoid applying two **Group 2** fungicides in succession, unless tank mixed with a protectant.

2. **DO NOT** apply more than four **Group 2** sprays in a season.
Resistance Management Strategy for:
Group 2 (Dicarboximide);
Group 3 (DMI);
Group 7 (SDI, carboxamide);
Group 9 (Anilinopyrimidine); and
Group 11 (Quinone outside Inhibitor) fungicides

1. Limit the use of Group 2, 3, 9 or 11 fungicides to periods when conditions favour disease development.

2. DO NOT apply more than four Group 2 sprays in one season. Apply no more than two consecutive sprays of a Group 2 fungicide.

3. DO NOT apply more than six Group 3 sprays in a season. Apply no more than two consecutive sprays of a Group 3 fungicide alone.

4. DO NOT apply more than four Group 7 sprays in a season. Always tank mix Group 7 fungicides with a protectant such as mancozeb or metiram.

5. If three or fewer fungicide sprays for target spot are applied per crop, use only one spray containing a Group 9 fungicide. If four to six sprays are applied per crop, use a maximum of two sprays containing Group 9 fungicides. If seven or more sprays are applied per crop, use a maximum of three sprays containing Group 9 fungicides.

Apply no more than two consecutive sprays containing a Group 9 fungicide.

6. Apply Group 11 fungicides preventatively. DO NOT apply more than six sprays, or one third of total sprays (whichever is lower) from Group 11 fungicides. DO NOT apply more than two consecutive sprays of Group 11 fungicides. If consecutive applications of Group 11 fungicides are used, then they must be followed by at least the same number of applications of fungicide(s) from a different group(s) before a Group 11 fungicide is used again, either in the current or following season.
FRAC Code No. 9: **AnilinoPyrimidines (AP’s)**

<table>
<thead>
<tr>
<th>CODE</th>
<th>TARGET SITE OF ACTION</th>
<th>GROUP NAME</th>
<th>CHEMICAL GROUP</th>
<th>COMMON NAME</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>methionine biosynthesis (cgs gene, proposed)</td>
<td><strong>AP</strong> - fungicides (<strong>Anilino-Pyrimidines</strong>)</td>
<td>anilino-pyrimidines</td>
<td>cyprodinil mepanipyrim pyrimethalin</td>
<td>Resistance known in Botryis and Venturia, sporadically in Oculimacula. Medium risk. See FRAC Anilinopyrimidine guidelines for resistance management</td>
</tr>
</tbody>
</table>
FRAC Code No. 40: **Carboxylic Acid Amides (CAA)**

<table>
<thead>
<tr>
<th>CODE</th>
<th>TARGET SITE OF ACTION</th>
<th>GROUP NAME</th>
<th>CHEMICAL GROUP</th>
<th>COMMON NAME</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>Cellulose synthesis (updated Jan. 2011)</td>
<td>CAA -fungicides (Carboxylic acid amides)</td>
<td>cinnamic acid amides</td>
<td>dimethomorph, flumorph</td>
<td>Low to medium risk. Resistance management required.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>valinamide carbamates</td>
<td>benthialdicarb, iprovalicarb, valifenalate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>mandelic acid amides</td>
<td>mandipropamid</td>
<td></td>
</tr>
</tbody>
</table>
## Sterol Biosynthesis Inhibitors (SBI's)

<table>
<thead>
<tr>
<th>Sterol Biosynthesis Inhibitors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SBI Class:</strong></td>
</tr>
<tr>
<td><strong>FRAC serial code</strong></td>
</tr>
<tr>
<td><strong>FRAC target no.</strong></td>
</tr>
<tr>
<td><strong>Group name</strong></td>
</tr>
<tr>
<td><strong>Target in Sterol Biosynthesis</strong></td>
</tr>
<tr>
<td><strong>Chemistry</strong></td>
</tr>
<tr>
<td><strong>Uses</strong></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
### FRAC Code No. 7: Succinate Dehydrogenase Inhibitor

<table>
<thead>
<tr>
<th>CODE</th>
<th>TARGET SITE OF ACTION</th>
<th>GROUP NAME</th>
<th>CHEMICAL GROUP</th>
<th>COMMON NAME</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Complex II; succinate-dehydrogenase</td>
<td></td>
<td>Phenyl-benzamides</td>
<td>Benodanil, Fluolanil, Mepronil</td>
<td>Resistance known for several fungal species in field populations and lab mutants. Target site mutations in sdh gene, e.g. HY (or HIL) at 257, 267, 272 or P225L.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pyridinyl-ethyl-benzamide</td>
<td>Fluopyram</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Furan-carboxamides</td>
<td>Fenfuram</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Oxathiin-carboxamides</td>
<td>Carboxin, Oxycarboxin</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Thiazole-carboxamides</td>
<td>Thifluzamide</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pyrazole-carboxamides</td>
<td>Bixafen, Fluxapyroxad, Furarnetpyr, Isopyrazam, Penflufen, Penthiozyrad, Sedaxane</td>
<td>Medium-high risk. Resistance management required</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pyridine-carboxamides</td>
<td>Boscalid</td>
<td></td>
</tr>
</tbody>
</table>
## FRAC Code No. 11 - QoI fungicides:

<table>
<thead>
<tr>
<th>GROUP NAME</th>
<th>CHEMICAL GROUP</th>
<th>COMMON NAME</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>QoI-fungicides (Quinone outside Inhibitors)</td>
<td>methoxy-acrylates</td>
<td>azoxystrobin, coumoxystrobin, enoxastrobim, flufenoxystrobin, picoxytrobim, pyraoxystrobin</td>
<td>Resistance known in various fungal species. Target site mutations in cyt b gene (G143A, F129L) and additional mechanisms. Cross resistance shown between all members of the QoI group. High risk. See FRAC QoI Guidelines for resistance management.</td>
</tr>
<tr>
<td></td>
<td>methoxy-carbamates</td>
<td>pyraclostrobin, pyrametostrobin, triclopyricarb</td>
<td></td>
</tr>
<tr>
<td></td>
<td>oximino acetates</td>
<td>kresoxim-methyl, trifloxystrobin</td>
<td></td>
</tr>
<tr>
<td></td>
<td>oximino-acetamides</td>
<td>dimoxystrobin, fenaminostrobin, metominostrobin, orysastrobim</td>
<td></td>
</tr>
<tr>
<td></td>
<td>oxazolidine-diones</td>
<td>famoxadone</td>
<td></td>
</tr>
<tr>
<td></td>
<td>dihydro-dioxazines</td>
<td>fluoxastrobin</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Imidazolinones</td>
<td>fenamidone</td>
<td></td>
</tr>
<tr>
<td></td>
<td>benzyl-carbamates</td>
<td>pyflubencarb</td>
<td></td>
</tr>
</tbody>
</table>