CropLife Australia

Resistance Management Strategies

INSECTICIDES | FUNGICIDES | HERBICIDES

2022–2023

Locked Bag 4396 Kingston ACT 2604

w www.croplife.org.au

e info@croplife.org.au

t 02 6273 2733

Search the strategies online by keyword, crop, pest or type of product at:
croplife.org.au/resistance-management

Disclaimer

About CropLife Australia

CropLife Australia is the national peak industry organisation representing the best of the plant science sector in Australia. CropLife's members are the world-leading innovators, developers, manufacturers and formulators of crop protection and agricultural biotechnology products. The plant science industry, worth more than $20 billion a year to Australian agricultural production, provides products to protect crops against pests, weeds and diseases, as well as developing crop biotechnologies key to the nation's agricultural productivity, profitability and sustainability. CropLife Australia is part of the plant science industry's 91 country international federation.

CropLife member companies are committed to the stewardship of their products, contributing millions of dollars every year to ensure their products are sustainably managed for the benefit of users, consumers and the environment.

These world-leading resistance management strategies are part of CropLife's StewardshipFirst program, which is a comprehensive suite of whole-of-lifecycle stewardship initiatives and programs for the plant science industry's products.

The StewardshipFirst program includes CropLife's mandatory Code of Conduct for members, the spray drift and best practice management initiatives SprayBest and MyAgCHEMuse, and the Pollinator Protection Initiative, which includes BeeConnected and the *Seed Treatment Stewardship Strategy*.

It also includes programs run by CropLife's wholly owned stewardship and safety organisation, Agsafe, including ***drum****MUSTER*, ChemClear® and Agsafe Accreditation and Training, which complement the suite of stewardship initiatives and programs.

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Foreword

Climate change is escalating the frequency and intensity of extreme weather events and the insects, weeds and diseases that come with it. These pests are major threats to the productivity, profitability and sustainability of Australia's farming sector. Best practice management, incorporating appropriate strategies to minimise resistance, is crucial to ensure the longevity and viability of Australia's farming sector and the agricultural chemical products that enable it.

CropLife Australia's Resistance management strategies for fungicides, herbicides and insecticides assist farmers, agronomists and environmental land managers to ensure crop protection products remain viable and effective tools for the future. The freely available strategies provide the most up-to-date advice for the prevention and management of resistance to crop protection products. They are reviewed and updated by scientific, technical review committees in consultation with relevant national and international experts.

The plant science industry invests billions of dollars into research and development of new, effective and innovative agricultural chemical products each year, allowing farmers to access economically viable and environmentally sustainable crop protection solutions. The resistance management strategies are part of CropLife and our members' commitment to the responsible and ethical management of industry products throughout their lifecycle.

The strategies sit within CropLife's broader StewardshipFirst program, a suite of world-leading stewardship initiatives that assist all pesticide users in maintaining best-practice. Through these comprehensive product stewardship initiatives and programs, crop protection product users have all the information they need on preventing pesticide resistance and using products safely and correctly for human health and the environment.

Importantly, the resistance management strategies do not replace product labels, they simply supplement them. All pesticides, be they synthetic, organic or biological must be handled and applied as specified on the registered product label or approved permit.

It's crucial all farmers, spray applicators, agronomists and environmental land managers utilise these strategies to prevent resistance to crop protection products and maintain their viability as effective farming tools long into the future.

Matthew Cossey
Chief Executive Officer
CropLife Australia

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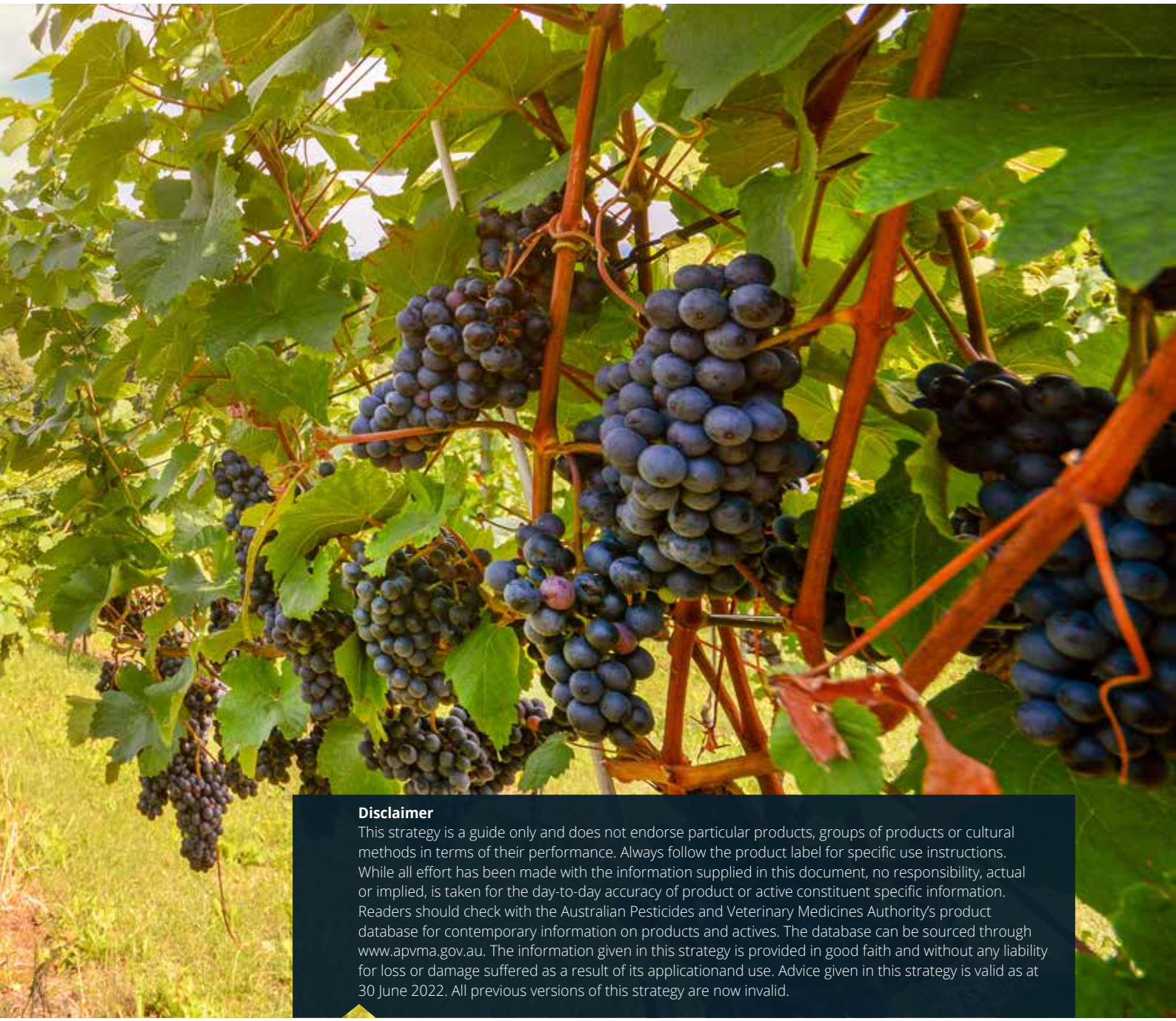
Acronyms and abbreviations

Acronym	Full title
APVMA	Australian Pesticides and Veterinary Medicines Authority
DBM	Diamondback moth
EPPO	European and Mediterranean Plant Protection Organisation
GRDC	Grains Research and Development Corporation
ECFR	Expert Committee on Fungicide Resistance
ECHR	Expert Committee on Herbicide Resistance
ECIR	Expert Committee on Insecticide Resistance
IMC	Integrated mite control
IPM	Integrated Pest Management
IRAC	Insecticide Resistance Action Committee
IRM	Insecticide resistance management
IWM	Integrated weed management
MoA	Mode of Action
NPV	Nuclear Polyhedrosis Virus
PPO	protoporphyrinogen oxidase
QoI	Quinone outside Inhibitors
RLEM	Red legged earth mite
RMS	Resistance management strategies
SDHI	Succinate Dehydrogenase Inhibitors
TIMS	Transgenic and Insect Management Strategies
UCI	upper canopy infection

Part 1 Insecticide resistance management strategies

DEVELOPED BY THE CROPLIFE AUSTRALIA EXPERT COMMITTEE ON INSECTICIDE RESISTANCE (ECIR) — VALID AT 30 JUNE 2022



Disclaimer

This strategy is a guide only and does not endorse particular products, groups of products or cultural methods in terms of their performance. Always follow the product label for specific use instructions. While all effort has been made with the information supplied in this document, no responsibility, actual or implied, is taken for the day-to-day accuracy of product or active constituent specific information. Readers should check with the Australian Pesticides and Veterinary Medicines Authority's product database for contemporary information on products and actives. The database can be sourced through www.apvma.gov.au. The information given in this strategy is provided in good faith and without any liability for loss or damage suffered as a result of its applicationand use. Advice given in this strategy is valid as at 30 June 2022. All previous versions of this strategy are now invalid.

Introduction

The CropLife Australia Expert Committee on Insecticide Resistance (ECIR) has drafted insect resistance management strategies in conjunction with growers, researchers and agronomists to minimise the development of insect resistance to insecticides. These strategies provide growers with guidelines for insecticide use (and other methods) for sustainable insect control.

Principles of resistance management

Insecticide or acaricide resistance management strategies seek to minimise the selection for resistance to any one type of insecticide or acaricide. This requires an understanding of insecticides as they are grouped according to similarity of Mode of Action (MoA) in controlling insects and mites.

In practice, sequences or rotations of compounds from different MoA groups provide an effective approach to resistance management. These MoA groups are shown in the **Mode of Action Classification for Insecticides** Table.

Effective resistance management strategies use alternations or sequences of different MoAs

The objective of Insecticide Resistance Management is to prevent or delay resistance developing to insecticides, or to help regain susceptibility in insect pest populations in which resistance has already arisen. IRM is important in maintaining the efficacy of valuable insecticides. It is usually easier to prevent resistance occurring than it is to reactively regain susceptibility.

Insecticide applications are often arranged into MoA spray windows or blocks that are defined by the stage of crop development and the biology of the pest(s) of concern. Local expert advice should always be followed with regard to spray windows and timings. Several sprays of a compound may be possible within each spray window but it is generally essential to ensure that successive generations of the pest are not treated with compounds from the same MoA group.

What is resistance?

Resistance to insecticides and acaricides may be defined as 'a heritable change in the sensitivity of a pest population that is reflected in the repeated failure of a product to achieve the expected level of control when used according to the label recommendation for that pest species.'

Resistance arises through the over use or misuse of an insecticide or acaricide against a pest species and results in the selection of resistant forms of the pest and the consequent evolution of populations that are resistant to that insecticide or acaricide.

Resistance mechanisms

There are a number of ways insects can become resistant to insecticidal crop protection products.

Metabolic resistance — Resistant insects may detoxify or destroy the toxin faster than susceptible insects, or quickly rid their bodies of the toxic molecules. Metabolic resistance is the most common mechanism and often presents the greatest challenge. Insects use their internal enzyme systems to break down insecticides. Resistant strains may possess higher levels or more efficient forms of these enzymes. In addition to being more efficient, these enzyme systems also may have a broad spectrum of activity (i.e., they can degrade many different insecticides).

Target-site resistance — The target site where the insecticide acts in the insect may be genetically modified to prevent the insecticide binding or interacting at its site of action thereby reducing or eliminating the pesticidal effect of the insecticide.

Penetration resistance — Resistant insects may absorb the toxin more slowly than susceptible insects. Penetration resistance occurs when the insect's outer cuticle develops barriers which can slow absorption of the chemicals into their bodies. This can protect insects from a wide range of insecticides. Penetration resistance is frequently present along with other forms of resistance, and reduced penetration intensifies the effects of those other mechanisms.

Behavioural resistance — Resistant insects may detect or recognize a danger and avoid the toxin. This mechanism of resistance has been reported for several classes of insecticides, including organochlorines, organophosphates, carbamates and pyrethroids. Insects may simply stop feeding if they come across certain insecticides, or leave the area where spraying occurred (for instance, they may move to the underside of a sprayed leaf, move deeper in the crop canopy or fly away from the target area).

Mode of Action, target-site resistance and cross-resistance

In the majority of cases, not only does resistance render the selecting insecticide ineffective but it often confers cross-resistance to other chemically related compounds. Compounds within a specific chemical group usually share a common target site within the pest, and thus share a common MoA. It is common for resistance to develop that is based on a genetic modification of this target site. When this happens, the compound loses its pesticidal efficacy. Because all compounds within the chemical sub-group share a common MoA, there is a high risk that the resistance will automatically confer cross-resistance to all the compounds in the same sub-group. It is this concept of cross-resistance within chemically related insecticides or acaricides that is the basis of the MoA classification.

Alternation of chemistry

Constant use of insecticides from one chemical grouping (MoA) will increase the risk of rapid build-up of resistance to that chemical group. Alternate use of chemical groups with different MoAs will slow down the process of selection for resistance.

Use of cultural practices

Incorporation of cultural techniques for controlling an insect pest will reduce selection pressure from the insecticides. Any resistance management strategies should incorporate all available methods of control for the insect pest concerned.

Understanding of the insect/ mite lifecycle

A good understanding of the lifecycle of the pest is essential so that control methods can be effectively targeted. An insecticide or acaricide should always be targeted at the pest growth stage that is most susceptible for that insecticide or acaricide.

Application

Label recommendations

Insecticide labels have been carefully developed to ensure the most effective control of the pest. The label should at all times be carefully read and adhered to.

Rates

Full recommended rates of registered insecticides should always be used to ensure the most effective control of the pest.

Coverage

The majority of insecticides require good coverage of the target area to ensure the best possible chance of contact and subsequent control of the pest.

Resistance management strategy design

Crop/pest or regional strategies

The strategies below are provided on a CROP by PEST basis (e.g. Tomato — Heliothis). However, in horticultural and agricultural areas often a range of crops are grown that are attacked by a range of pests.

In many cases, a specific MoA insecticide can be used across this range of crops to control multiple pests that have the ability to move from crop to crop. There is interaction between intensive horticulture and broadacre farming, as with Diamondback Moth (DBM) in Brassica vegetables and resistance strategies that could be compromised by widespread use of insecticides for DBM control in canola.

Also, the pest complex for a specific crop will vary within production regions, especially between Northern and Southern Australia.

For this reason, CROP by PEST strategies can be flawed and further Insecticide Resistance Management (IRM) advice for specific pests should always be sought on a local basis.

An alternative to the CROP by PEST strategy is that of 'Regional strategies' such as those for Cotton, Brassicas and the Southern NSW and Northern Victorian IRM strategy for grain and annual horticultural crops.

These regional or specific crop strategies are available on the CropLife Australia website.

The overall Resistance Management Strategy of avoiding overuse of individual MoAs insecticides should be followed, not just on a specific crop and pest but on a broad perspective of crops and pest complex.

Additional information

Further information on Insecticide Resistance, Management Strategies and Insecticide Mode of Action can be found on the International IRAC (Insecticide Resistance Action Committee) website: **https://www.irac-online.org/**.

Crop: **Bananas**

Insect(s): Banana weevil borer (*Cosmopolites sordidus*) and Rust Thrips (*Chaetanaphothrips signipennis*)

Comments on the strategy:

1. Use only clean planting material.
2. If re-planting into an old banana block, allow at least six months fallow after old banana material has rotted down.
3. Remove weeds and trash around banana stools to allow maximum effectiveness of insecticides and to reduce sheltering sites for weevils. Application of insecticide to trash may lead to reduced control of banana weevil borer.
4. Cut up fallen and harvested pseudostems to reduce weevil breeding sites.
5. Monitor regularly for banana weevil borer activity by trapping (when adult weevils are active) or conduct corm damage ratings.
6. Only use insecticides when populations reach or exceed accepted threshold levels. Refer to local Department of Agriculture guidelines.
7. Only use insecticides at the registered rate of application and apply at times when the particular product will have the maximum impact, i.e. use contact insecticides only when weevil borer adults are active.
8. Use insecticides only in the years indicated in the following diagrams.
9. Consider the impact of the use of other pesticides for other insects or nematodes on banana weevil borers.
10. For rust thrips control, a combination of control methods such as butt/band sprays, stem injection or spray and bunch sprays may be required.

The following two diagrams are alternative RMSs depending on which product(s) are chosen for banana weevil borer and rust thrips control.

Strategy A

Where products **other than** controlled release formulations of imidacloprid are being used to control insects in bananas.

CHEMICAL			Year of use					
Group*	Sub-group	Example	1	2	3	4	5	6
1A or 1B	*Carbamates Organophosphates*	oxamyl[1] or acephate [2] cadusafos[1] chlorpyrifos[3] diazinon[3] prothiofos[1] terbufos[1]	✓	✗	✓	✗	✓	✗
2B	*Phenylpyrazoles (Fiproles)*	fipronil [3]	✓	✗	✓	✗	✓	✗
3A	*Synthetic pyrethroids*	bifenthrin [3]	✗	✓	✗	✓	✗	✓
4A	*Neonicotinoids*	clothianidin,[3] imidacloprid[3]	✗	✓	✗	✓	✗	✓
4A/23	*Tetramic acid*	spirotetramat	✗	✓	✗	✓	✗	✓
5	*Spinosyns*	spinetoram [2]	✗	✓	✗	✓	✗	✓

* Refer: CropLife Australia Expert Committee on Insecticide Resistance Mode of Action Classification for Insecticides.

1 Products registered for banana weevil borer control.

2 Product registered for rust thrips control as bunch sprays only.

3 Products registered for banana weevil borer and rust thrips control.

Guidelines:

1. The RMS may start at any point in the product group rotation and planting may occur in any year of the strategy.
2. The product(s) used in any one year **should not be** followed by product(s) from the same insecticide group in the following year.
3. Only products from the **YES** insecticide groups shown in the diagram above **should be** applied for banana weevil borer control and/or rust thrips control in the same year.
4. If products from **Group 1A** or **1B** (oxamyl, cadusafos or terbufos) are being used for nematode control in a block of bananas, then products from these groups **should not be** used for banana weevil borer control in the following year.
5. Where there is evidence of banana weevil borer or rust thrips resistance to a product or group of products, these should not be used again for banana weevil borer or rust thrips control until there has been use of products from other Insecticide MoA groups for a period of at least two years.

Crop(s): **Bananas**

Insect(s): Banana weevil borer (*Cosmopolites sordidus*) and Rust Thrips (*Chaetanaphothrips signipennis*)

Strategy B

Where products **including** controlled release formulations of imidacloprid are being used to control insects in bananas.

CHEMICAL			Year of use					
Group*	Sub-group	Example	1	2	3	4	5	6
1A or 1B	*Carbamates Organophosphates*	Oxamyl[1] or Acephate[2] cadusafos[1] chlorpyrifos[3] diazinon[3] prothiofos[1] terbufos[1]	✗	✓	✗	✓	✗	✓
2B	*Phenylpyrazole (Fiproles)*	fipronil[3]	✓	✗	✓	✗	✓	✗
3A	*Synthetic pyrethroids*	bifenthrin[3]	✗	✓	✗	✓	✗	✓
4A	*Neonicotinoids*	CR imidacloprid[3]	✓	✓	✓	✗	✗	✗
5	*Spinosyns*	spinetoram[2]	✓	✗	✓	✗	✓	✗

* Refer: CropLife Australia Expert Committee on Insecticide Resistance Mode of Action Classification for Insecticides.

1 Products registered for banana weevil borer control.

2 Product registered for rust thrips control as bunch sprays only.

3 Products registered for banana weevil borer and rust thrips control.

Guidelines:

1. The resistance management strategy may start at year one or year four in the product group rotation.
2. Controlled release imidacloprid provides three years control of banana weevil borer with one application at planting, so after the third year, insecticide products from other Groups are to be used in rotation for at least three years for banana weevil borer and rust thrips control in a given block of bananas.
3. Alternative product groups are provided in these three years for control of rust thrips as soil or stem treatments or bunch sprays.
4. Only products from the **YES** insecticide groups shown in the diagram above **should be** applied for banana weevil borer control and/or rust thrips control in the same year.
5. If products from Group 1A or 1B (oxamyl, cadusafos or terbufos) are being used for nematode control in a block of bananas, then products from these groups **should not be** used for banana weevil borer control in the following year.
6. Where there is evidence of banana weevil borer or rust thrips resistance to a product or group of products, these should not be used again for banana weevil borer control until there has been use of products from other Insecticide MoA groups for a period of at least two years.

Notes regarding the application of insecticides

1. To ensure the most effective control of the pest:
   - **a)** Product labels should at all times be carefully read and adhered to.
   - **b)** Full recommended rates of registered insecticides should always be used.
   - **c)** Ensure good coverage of the target area to maximise contact.

Crop(s): **Brassica, brassica leafy vegetables**

Insect(s): Diamondback moth, Cabbage moth (*Plutella xylostella*)

Guidelines:

1. To help prevent the development of resistance to any one specific active ingredient (see table below), observe the following instructions:
   - **a)** Use in accordance with the current IRMS for your region. For growers in the Lockyer Valley region, please refer to the *Lockyer Valley Diamondback Moth Insecticide Resistance Management Strategy*. For growers in Western Australia, please refer to the Western Australian Department of Primary Industries and Regional Development *two-window strategy*.
   - **b)** Apply a specific active ingredient using a 'window' approach to avoid exposure of consecutive insect pest generations to the same MoA. Multiple successive applications of a specific active ingredient are acceptable if they are used to treat a single pest generation.
   - **c)** Following a 'window' of a specific MoA product, **rotate** to a 'window' of applications of effective insecticides with a different MoA.
   - **d)** The total exposure period of any one MoA 'active window' applied throughout the crop cycle (from seedling to harvest) should not exceed 50 per cent of the crop cycle.
   - **e)** Incorporate IPM techniques into the overall pest management program and
   - **f)** Monitor insect populations for loss of field efficacy.
2. Always read and follow product labels and use the full recommended label rates of application. Some products place a limit on the number of times they can be applied per crop (see table below) and when they can be applied.
3. Monitor crops regularly and only apply insecticide when the pest threshold is reached.
4. When an insecticide with foliar activity on diamondback moth has been used as seed treatment or drench application in nursery production (as determined by label claims), rotate to alternative MoA insecticide for a period covering at least one generation of diamond back moth. This may require a minimum of two applications of alternate MoA insecticides. Ensure spray rig is properly calibrated and achieving good coverage with appropriate sized spray droplets.
5. Time the application to the most susceptible life stage of the target pest.
6. To encourage beneficial insects, use *Bacillus thuringiensis* (Bt) sprays and avoid broad spectrum insecticides where possible, particularly early to mid-crop cycle.
7. Be cautious of using insecticide tank-mixes where both active ingredients control DBM as this strategy is generally not considered best practice for resistance management. Refer to the *IRAC International Insecticide Mixture Statement* for more information on this subject.
8. **DO NOT** re-treat a spray failure with a product from the same chemical group.
9. Practice good crop hygiene to reduce DBM pressure — plant clean seedlings and incorporate crop residue as soon as practical after harvest.

PRODUCT LABEL		
MoA group*	**Active ingredient**	**Number applications permitted per crop per season**
1A	methomyl, thiodicarb	Not specified
2B	fipronil	4 per year within 8-week period
3A	synthetic pyrethroids (various)	Not specified
5	spinetoram	4
6	emamectin benzoate	4 per any one crop
11A	*Bacillus thuringiensis*	Not specified
13	chlorfenapyr	2 but 4 in brussels sprouts
22A	indoxacarb	4
22A + 15	indoxacarb + novaluron	3 (included as application of 22A)
23	spirotetramat	2 but 3 in brassica leafy vegetables
28	chlorantraniliprole, flubendiamide	3 but 1 for mixtures of chlorantraniliprole and thiamethoxam
UN	clitoria ternatea extract	not specified

* Refer: CropLife Australia Expert Committee on Insecticide Resistance Mode of Action Classification for Insecticides.

Notes regarding the application of insecticides

1. To ensure the most effective control of the pest:
   - **a)** Product labels should at all times be carefully read and adhered to.
   - **b)** Full recommended rates of registered insecticides should always be used.
   - **c)** Ensure good coverage of the target area to maximise contact.

Crop(s): **Canola, Forage brassica**

Insect(s): Diamondback moth, Cabbage moth (*Plutella xylostella*)

Guidelines:

1. For information refer to the IPM guidelines: **https://ipmguidelinesforgrains.com.au/ipm-information/resistance-management-strategies/**

Notes regarding the application of insecticides

1. To ensure the most effective control of the pest:
   - **a)** Product labels should at all times be carefully read and adhered to.
   - **b)** Full recommended rates of registered insecticides should always be used.
   - **c)** Ensure good coverage of the target area to maximise contact.

Crop(s): **Cotton**

Insect(s): All pests

Guidelines:

1. For information refer to the current Cotton Pest Management Guide: **www.cottoninfo.com.au/publications/cotton-pest-management-guide**

Notes regarding the application of insecticides

1. To ensure the most effective control of the pest:
   - **a)** Product labels should at all times be carefully read and adhered to.
   - **b)** Full recommended rates of registered insecticides should always be used.
   - **c)** Ensure good coverage of the target area to maximise contact.

Crop(s): **Nursery e.g. vegetable seedlings, trees, ornamentals**

Insect(s): Various

Guidelines:

1. Monitor regularly for insect activity. Where relevant consider the use of light, insect traps or other monitoring tools.
2. Only use insecticides when insect populations reach accepted threshold levels.
3. Always read and follow product labels and use the full recommended label rates of application. Some products place a limit on the number of times they can be applied per crop and when they can be applied.
4. Ensure the spray equipment is properly calibrated and achieving good coverage with appropriately sized spray droplets.
5. In the case of soil applied insecticides, apply only once prior to transplanting. Apply using sufficient water that does not result in any drop point from the soil medium containing the seedling or plant. If watering is required between applications and planting, it should be done sparingly, only as required. **Avoid** water to run-through from the cells, bags etc.
6. When transplanting soil-treated seedlings or plants, ensure that the growing medium is fully transferred to the field with each seedling or plant.
7. **Rotate** between registered insecticides that have different MoAs.
8. Where possible **avoid applying consecutive applications** of insecticides that have the same MoA within and between seasons or exceed the recommended maximum number of applications per crop.
9. **Do not** follow a seed, seedling or soil treatment with a foliar application from the same MoA group.
10. Time the foliar applications to the most susceptible life stage of the target pest.
11. **Do not** re-treat a spray failure with a product from the same MoA group.
12. Avoid using insecticide tank-mixes where both active ingredients control the same insect pests as this strategy is generally not considered best practice for resistance management.
13. Practice good crop hygiene to reduce insect pressure e.g. removing severely infested seedling trays, plants or host weeds.
14. Nurseries supplying treated plants to commercial operations should clearly identify insecticides that have been applied, supply paperwork to the recipient accompanying the plant that indicates the rates and date. For treated seedlings the time of application should also be included, particularly if applied just prior to transplant in the field.

Notes regarding the application of insecticides

1. Refer to the CropLife Australia Expert Committee on Insecticide Resistance (ECIR) Group Mode of Action Classification for Insecticides.
2. There is known cross-resistance between some chemical groups, e.g. **Groups 1A and 1B**.
3. Seek advice from the manufactureres or government advisory services to determine local resistance levels for particular MoA groups.
4. **Do not** exceed the maximum number of applications permitted on the insecticide label.
5. When using insecticides to control other pests, consider the chemical group in relation to contributing to the resistance development of other insect pets.
6. When using insecticides to control insect pests consider the effect on beneficial insects and the potential to flare insect populations.

Crop(s): **Pasture/Winter crops**

Insect(s): Redlegged Earth Mite; RLEM (*Halotydeus destructor*)

Guidelines:

1. **Rotate** insecticide Groups.
2. **Do not** apply consecutive sprays of products from any one insecticide Group.

		Chemcial	
Crop	**MoA group***	**Sub-group**	**Example**
Seed treatment (or in-furrow)	4A 1B 2B	neonicotinoids or organophosphates or phenylpyrazoles	imidacloprid dimethoate fipronil
Bare Earth (pre-emergent)	1B 3A	organophosphates or synthetic pyrethroids	omethoate bifenthrin
Early Season (autumn when limited green growth)	1B 3A 12A	organophosphates or synthetic pyrethroids or mitochondrial ATP synthase inhibitors	chlorpyrifos alpha-cypermethrin diafenthiuron (Canola only)
Spring	1B 3A 12A	organophosphates or synthetic pyrethroids diafenthiuron	omethoate gamma-cyhalothrin diafenthiuron

* Refer: CropLife Australia Expert Committee on Insecticide Resistance Mode of Action Classification for Insecticides.

3. If both autumn and spring applications are needed, alternate chemical groups.
4. Timing of sprays
   - **a)** Monitor RLEM activity carefully and only treat if damage has reached threshold levels. Hatch timing tool can be used to determine season risk.[1]
   - **b)** One well timed spray in autumn or spring will maximise effectiveness of treatment. Optimal timing of spring sprays can be calculated using the TIMERITE tool.[2]
5. Placement of sprays
   - **a)** Apply perimeter sprays where infestations are concentrated on the edge of fields.
   - **b)** Use blanket sprays where appropriate. However, with pyrethriod products, recent research has shown that the risk of pyrethroid resistance can be minimised through the application of foliar pyrethroids in a 50 metre strip with 10 metre spacing.[3]
6. Cultural practices
   - **a)** Heavy grazing or cutting for hay or cultivation will reduce mite numbers.
   - **b)** Control alternative hosts such as Capeweed or Paterson's curse.
   - **c)** Develop damage thresholds.
   - **d)** Rotate crops and pastures that are more tolerant to the pest.
   - **e)** Encourage predator survival by judicious use of insecticides.

For more detail on resistance management for RLEM in grain crops and pastures, refer to: **http://ipmguidelinesforgrains.com.au/ipm-information/resistance-management-strategies/** and **https://grdc.com.au/resources-and-publications/all-publications/publications/2020/redlegged-earth-mite-best-management-practice-guide-southern/RedleggedEarthMite_210X148_10.pdf**

Notes regarding the application of insecticides

1. To ensure the most effective control of the pest:
   - **a)** Product labels should at all times be carefully read and adhered to.
   - **b)** Full recommended rates of registered insecticides should always be used.
   - **c)** Ensure good coverage of the target area to maximise contact.

1 Hatch timing tool developed by Cesar to aid with early season monitoring and predict RLEM risk at crop establishment, **http://cesaraustralia.com/pestfacts/new-redlegged-earth-mite-hatch-timing-tool/**.
2 TIMERITE tool TimeRite (**wool.com**).
3 Strip spraying delays pyrethriod resistance in the redlegged earth mite, Halotydeus destructor: a novel refuge strategy - Maino - 2021 - Pest Management Science - Wiley Online Library.

Crop(s): **Pome fruit**

Insect(s): Two-spotted mite (*Tetranychus urticae*), European red mite (*Panonychus ulmi*)

Guidelines:

1. Make **no more than one application** from each registered miticide group per season. Rotate registered miticides that have different MoA (i.e. **Group 6, Group 10A, Group 10B, Group 12B, Group 12C, Group 13, Group 20B**, **Group 20D**, **Group 21A** and **25A**).
2. For miticides that have the same MoA (e.g. **Group 21A**) do not use consecutive applications within and between seasons.

Group	Chemical sub-group	Example chemical
6	Avermectins, milbemycins	abamectin, milbemectin
10A	Clofentezine, hexythiazox	clofentezine, hexythiazox
10B	Etoxazole	etoxazole
12B	Organotin miticides	fenbutatin oxide
12C	Propargite	propargite
13	Chlorfenapyr	chlorfenapyr
20B	Acequinocyl	acequinocyl
20D	Bifenazate	bifenazate
21A	METI acaricides	fenpyroximate, tebufenpyrad
25A	Cyflumetofen	cyflumetofen

* Refer: CropLife Australia Expert Committee on Insecticide Resistance Mode of Action Classification for Insecticides.

Notes:

1. Miticides should be used as part of an Integrated Mite Control (IMC) program.
2. Mite levels should be monitored and thresholds utilised before deciding to make miticide applications.
3. Where practicable, predatory mites should be incorporated into an IMC program.
4. When using insecticides/miticides to control other pests of pome fruit such as codling moth, lightbrown apple moth and woolly aphid, consider the chemical group and the potential impact it may have on resistance development of mite pests
5. When using insecticides/miticides to control other pests of pome fruit consider the effect on beneficial insects and the potential to flare mite populations
6. For more information refer to the current *NSW Orchard Plant Protection Guide* (**www.dpi.nsw.gov.au/agriculture/horticulture/pests-diseases-hort/information-for-multiple-crops/orchard-plant-protection-guide**).

Notes regarding the application of insecticides:

1. To ensure the most effective control of the pest:
   - **a)** Product labels should at all times be carefully read and adhered to.
   - **b)** Full recommended rates of registered insecticides should always be used.
   - **c)** Ensure good coverage of the target area to maximise contact.

Crop(s): **Potato**

Insect(s): Potato tuber moth / Tomato leafminer (*Phthorimaea operculella*)

1. Monitor pest levels and **do not** spray unless pest thresholds are exceeded.
2. **Rotate** insecticide groups and **do not** use two consecutive applications of products with the same MoA.
3. Integrate both chemical and non-chemical means of control as part of the overall control strategy. Examples are the use of predators/parasites and relevant cultural practices (crop hygiene, rotation of planted areas, and strategic time of planting).

Group	Chemical sub-group	Example chemical
1B	Organophosphates	acephate, azinphos-methyl, methamidophos, diazinon, dichlorvos
1A	Carbamates	carbaryl, methomyl
3A	Pyrethroids	permethrin
5	Spinosyns	spinosad, spinetoram
28	Diamides	chlorantraniliprole, flubendiamide

* Refer: CropLife Australia Expert Committee on Insecticide Resistance Mode of Action Classification for Insecticides.

Notes regarding the application of insecticides:

4. To ensure the most effective control of the pest:
   - **a)** Product labels should at all times be carefully read and adhered to.
   - **b)** Full recommended rates of registered insecticides should always be used.
   - **c)** Ensure good coverage of the target area to maximise contact.

Crop(s): **Sorghum, Maize, Summer & Winter Grain Legumes**

Insect(s): Heliothis/Cotton bollworm/Native budworm (*Helicoverpa spp.*)

Guidelines:

1. To help prevent the development of resistance to any one specific active ingredient (see table below), observe the following instructions:
   - **a)** Use in accordance with the current IRMS for your region.
   - **b)** Apply a specific active ingredient using a 'window' approach to avoid exposure of consecutive insect pest generations to the same MoA. Multiple successive applications of a specific active ingredient are acceptable if they are used to treat a single pest generation.
   - **c)** Following a 'window' of a specific MoA product, rotate to a 'window' of applications of effective insecticides with a different MoA.
   - **d)** The total exposure period of any one mode of action 'active window' applied throughout the crop cycle (from seedling to harvest) should not exceed 50 per cent of the crop cycle.
   - **e)** Incorporate IPM techniques into the overall pest management program and
   - **f)** Monitor insect populations for loss of field efficacy.
2. Always read and follow product labels. Some products place a limit on the number of times they can be applied per crop (see table below) and when they can be applied.
3. Monitor crops regularly and only apply insecticide when the pest threshold is reached.
4. Ensure spray rig is properly calibrated and achieving good coverage with appropriately sized spray droplets.
5. Time the application to the most susceptible life stage of the target pest.
6. To encourage beneficial insects, use *Bacillus thuringiensis* (Bt) or NPV sprays and avoid broad spectrum insecticides where possible, particularly early to mid-crop cycle.
7. Be cautious of using insecticide tank-mixes where both active ingredients control *Helicoverpa* spp. as this strategy is generally not considered best practice for resistance management. Refer to document IRAC *International Insecticide Mixture Statement* for more information on this subject.
8. **Do not** re-treat a spray failure with a product from the same chemical group.
9. Practice effective pupae busting as soon as practicable after harvest

Group*	Active ingredient	No. applications per crop per season^	Crop^
1A	Methomyl (e.g. Lannate® L), thiodicarb (e.g. Larvin®)	Not specified	All cereal grains, oilseed, pulses
3A	synthetic pyrethroids (various, e.g. Bulldock®, Dominex® Duo, Karate® Zeon, Sumi-alpha® Flex, Trojan®)	Not specified	All cereal grains, oilseed, pulses
5	Spinetoram (Success® Neo)	TBC	All pulses
6	emamectin benzoate (e.g. Affirm®)	2	All pulses
11A	*Bacillus thuringiensis* (e.g. Dipel®, Xentari®)	Not specified	All cereal grains, oilseed, pulses
22A	Indoxacarb (e.g. Stew-ard® EC)	1	chickpea, faba bean, mung bean, soybean, azuki bean
28	Chlorantraniliprole (Al-tacor®)	Refer to label	All pulses
Not categorised	Nucleopolyhedrovirus (NPV) — (e.g. Gemstar®, Vivus® Max)	No limit but avoid season long use of low rates	All cereal grains, oilseed, pulses

* Refer: CropLife Australia Expert Committee on Insecticide Resistance Mode of Action Classification for Insecticides

^ Refer: Registered product label.

Notes:

1. For more information refer to the IPM Guidelines *H. armigera* RMS for Australian grains: **https://ipmguidelinesforgrains.com.au/ipm-information/resistance-management-strategies/#heli**

Notes regarding the application of insecticides:

1. To ensure the most effective control of the pest:
   - **a)** Product labels should at all times be carefully read and adhered to.
   - **b)** Full recommended rates of registered insecticides should always be used.
   - **c)** Ensure good coverage of the target area to maximise contact.

Crop(s): **Strawberries/Ornamentals**

Insect(s): Two-spotted mite (*Tetranychus urticae*)

Guidelines:

1. Monitor mite activity and treat infestations before thresholds are reached, i.e. spray earlier rather than later. Seek advice on local threshold levels.
2. **Do not** apply sequential applications of products from any one chemical group.
3. Preferably products with the same MoA should not be used more than twice in a growing season.
4. Incorporate the use of predatory mites for the control of this pest wherever possible.

Notes regarding the application of insecticides:

1. To ensure the most effective control of the pest:
   - **a)** Product labels should at all times be carefully read and adhered to.
   - **b)** Full recommended rates of registered insecticides should always be used.
   - **c)** Ensure good coverage of the target area to maximise contact.

Crop(s): **Sweet Corn**

Insect(s): Corn earworm (*Helicoverpa armigera*) aka Heliothis

Guidelines:

1. The critical stage of infestation is during silking. Even low levels of heliothis infestation are unacceptable at the silking stage. Because sweet corn is less attractive to heliothis before flowering and it is picked soon after silking is completed, there is a relatively short period of protection required.
2. Control of heliothis at the tasselling stage (occurs prior to silking stage) can be important in some regions as the tassel can act as a nursery for heliothis, which can then move onto the young developing cobs. Control of heliothis at this stage is not as difficult as at the silking stage.
3. Use of biological insecticides, Bt and Nuclear Polyhedrosis Virus (NPV), in the early stages of crop development is encouraged.
4. Monitor crops regularly, at least weekly during silking and **do not** spray unless pest thresholds are exceeded.
5. Labels of new products place a limit on the number of applications. If further control is required on one planting, chemicals from different MoA groups within the same window should be used.
6. **Do not** retreat a spray failure with a product from the same chemical group.
7. **Do not** use mixtures of insecticides for controlling heliothis.
8. Cultivation after harvest to destroy pupae will greatly assist in managing heliothis.
9. Seek local advice on pest incidence and on the risk of resistance developing from insecticide programs used to control heliothis in crops other than sweet corn.
10. To help prevent the development of resistance to any one specific active ingredient (see table below), observe the following instructions:
    - **a)** Use in accordance with the current IRMS for your region.
    - **b)** Apply a specific active ingredient using a 'window' approach to avoid exposure of consecutive insect pest generations to the same MoA. Multiple successive applications of a specific active ingredient are acceptable if they are used to treat a single insect generation.
    - **c)** Following a 'window' of a specific MoA product, rotate to a 'window' of applications of effective insecticides with a different MoA.
    - **d)** The total exposure period of any one MoA 'active window' applied throughout the crop cycle (from seedling to harvest) should not exceed 50 per cent of the crop cycle.
    - **e)** Incorporate IPM techniques into the overall pest management program.
    - **f)** Monitor insect populations for loss of field efficacy.

Group*	Active ingredient
1A	Methomyl, thiodicarb
3A	Synthetic pyrethroids (several)
5	Spinetoram
6	Emamectin benzoate
28	Chlorantraniliprole

* Refer: CropLife Australia Expert Committee on Insecticide Resistance Mode of Action Classification for Insecticides.

Notes regarding the application of insecticides:

1. To ensure the most effective control of the pest:
    - **a)** Product labels should at all times be carefully read and adhered to.
    - **b)** Full recommended rates of registered insecticides should always be used.
    - **c)** Ensure good coverage of the target area to maximise contact.

Crop(s): **Sweet Corn**

Insect(s): Corn earworm (*Helicoverpa armigera*) aka Heliothis

Key: L Low pressure M Medium pressure H High pressure

	REGION Nth Qld		SE Qld		Central NSW + Nth Vic		Tas		All regions
January	No crop	L	Spinetoram	H	Spinetoram	H	Chlorantraniliprole	M	Nuclear Polyhedrosis Viruses (NPV's), *Bacillus thuringiensis* (Bt) and Methomyl at the ovicidal rate can be used season long with no resistance management implications
		L		H		H		M	
February		L	Chlorantraniliprole	H		H		M	
		L		H		H	Spinetoram	M	
March	Vegetative phase	M		H	Chlorantraniliprole	H		L	
		H		H		M		L	
April	Emamectin	H	Methomyl,	M		M	No crop	L	
	Benzoate	H	Thiodicard, SPs	M		L		L	
May		H		L	Methomyl,	L		L	
		M	No crop	L	Thiodicard, SPs	L		L	
June	Methomyl,	L		L	No crop	L		L	
	Thiodicard, SPs	L		L		L		L	
July		L		L		L		L	
		L		L		L		L	
August	Chlorantraniliprole	M		L		L		L	
		H	Vegetative phase	L		L		L	
September		H		L		L		L	
		H		M	Vegetative phase	L		L	
October	Spinetoram	H	Emamectin	M		M		L	
		H	Benzoate	H		M		L	
November		H		H	Emamectin	M	Emamectin	L	
		M		H	Benzoate	M	Benzoate	L	
December	No Crop	L	Spinetoram	H		H		L	
		L		H		H		L	

Crop(s): **Tomato**

Insect(s): Heliothis/Tomato budworm (*Helicoverpa* spp.)

Guidelines:

1. Monitor pest levels and **do not** spray unless pest thresholds are reached.
2. **Do not** apply products outside their window of application for that chemical group.
3. Use an integrated pest control approach where both chemical and non-chemical measures are adopted as part of the overall strategy. Examples are the use of predators/parasites and relevant cultural practices (crop hygiene, rotation of planted areas, and strategic time of planting).
4. Seek local advice on pest incidence and the risk of resistance development from insecticide programs used to control heliothis in other crops or to control other pests.
5. When using insecticides/miticides to control other pests on tomato, consider the chemical group in relation to contributing to resistance development of heliothis.
6. Avoid using insecticides from the same chemical group against *Helicoverpa* spp. or other pests, as this will increase the selection pressure.
7. Do not re-spray a crop in the same season where a failure (which is known or unknown) has occurred using the same insecticide or other active ingredients from the same chemical group.

Notes regarding the application of insecticides:

1. To ensure the most effective control of the pest:
   - **a)** Product labels should at all times be carefully read and adhered to.
   - **b)** Full recommended rates of registered insecticides should always be used.
   - **c)** Ensure good coverage of the target area to maximise contact.

Crop(s): **Various**

Insect(s): Fall armyworm (*Spodoptera frugiperda*)

Table 1. List of active constituents approved for use under permits by the APVMA as of May 2020:^

Group*	Chemical subgroup	Active ingredient
1A	Carbamates	Methomyl (e.g. Lannate® L)
3A	Pyrethroids	Gamma-cyhalothrin (Trojan®), alpha-cypermethrin (e.g. Dominex® Duo)
5	Spinosyns	Spinetoram (Success® Neo)
6	Avermectins	Emamectin benzoate (e.g. Affirm®, Proclaim®)
15	Benzoylureas	Diflubenzuron (Dimilin®) (nursery stock only)
22A	Oxadiazines	Indoxacarb (e.g. Steward® EC, Avatar® eVo)
28	Diamides	Chlorantraniliprole (Altacor®, Coragen®), flubendiamide (Belt®).
31	Nucleopolyhedroviruses (NPVs)	*Spodoptera frugiperdu* multiple nucleopolyhedrovirus (SfMNPV) (Fawligen®, Spodovir® plus)

^ Refer to the APVMA's PubCris website (https://portal.apvma.gov.au/permits) to ensure permit is still active.

* CropLife Australia Expert Committee on Insecticide Resistance Mode of Action Classification for Insecticides.

Guidelines:

1. An IPM approach should be adopted in the production system to help manage this pest, with focus on cultural methods and the preservation of beneficial arthropods (insects and spiders).
   - This includes regular crop monitoring (at least two times per week) to determine incidence x crop damage and the impact of beneficial arthropods.
   - Consideration should also be given to the impact of prevailing weather conditions on the rate of pest development in the field.
2. **Avoid** sequential plantings of preferred crops, e.g. corn, sorghum, sugarcane, as this will increase local populations of fall armyworm.
3. Management of crop residues/volunteer plants before planting and after harvest also helps reduce local populations of fall armyworm.
4. Where possible, **avoid** the use of broad spectrum foliar applied insecticides in the production system for both larvae and moth control. If broad-spectrum insecticides are to be used, apply at timings when preservation of beneficial species is less likely to be important – i.e. at end of growing season

5. Consider controlling moths using light or attractant traps and encourage micro-bat habitat (natural or artificial roosting sites) adjacent to production areas.
6. In situations where insecticides are required, consider beneficial arthropods when making spray decisions.
7. When applying insecticides to this pest, key considerations should be given to:
    - Apply insecticides only when needed based on economic thresholds.
    - **Target early instar stages** (hatching larvae) of the pest before they become entrenched in the crop e.g. lower whorl of maize, sweet corn or grain sorghum.
    - Use a **medium spray quality** to ensure sufficient droplets cover the spray target to ensure the larvae ingest a lethal dose of insecticide.
    - Use a well calibrated, functioning boom spray with appropriate water rate for the target crop to ensure optimum spray coverage.
    - Use the recommended insecticide rates as stipulated on the relevant APVMA Emergency Use Permit.
    - Use a recommended adjuvant if stipulated on the relevant APVMA Emergency Use Permit.
    - Inspect the performance of the insecticide three to four days after application. Always document the effectiveness of each insecticide application and never re-spray a failure with an insecticide with the same MoA. Inform your local reseller or agronomist of any spray failures. Internationally, known resistance has occurred to the following MoA groups: Carbamates (Group 1A); Organophosphates (Group 1B); Pyrethroids (Group 3); Bacillus thuringiensis and Cry1F protein (Group 11A).
8. When using selected insecticides in-crop targeting fall armyworm, the following resistance management strategy guidelines should be implemented:
    - If the label allows and it is required for sustained pest management, use two sequential applications of any one MoA insecticide to span a **single generation of fall armyworm** (~20–30 days) and then r**otate to a different MOA insecticide**.
    - Do not treat successive generations with products of the same MoA.
    - The total exposure period of any one MoA insecticide applied throughout the crop cycle (from seedling to harvest) **should not exceed 50 per cent of the crop cycle**.
    - Abide by the individual label recommendation for maximum **number of allowable applications per crop per season**.
    - Abide by individual label recommendation for the minimum reapplication interval and always use the **full recommended label rates**.
    - Where possible, an Area Wide Management strategy should be adopted where the same MoA insecticides are **used by all growers** in the **same time period**.
    - As the industry learns more about how to manage this pest, this Strategy may be updated and regional-specific strategies may be developed. Check the CropLife Resistance Management website (**www.croplife.org.au/resources/programs/resistance-management/**) to ensure you are following the most up to date fall armyworm strategy.
9. Useful fall armyworm reference documents are available at:
    - **https://portal.apvma.gov.au/permits: search for APVMA insecticide permits to use on FAW)**
    - **www.cottoninfo.com.au/insect-and-mite-management**
    - **https://thebeatsheet.com.au/fall-armyworm-should-you-be-concerned/**
    - **https://irac-online.org/pests/spodoptera-frugiperda/**
    - **https://irac-online.org/new-guidelines-on-ipm-irm-for-fall-armyworm-in-s-african-maize/**
    - **https://grdc.com.au/resources-and-publications/resources/fall-armyworm**

Notes regarding the application of insecticides:

1. To ensure the most effective control of the pest:
    - **a)** Product labels should at all times be carefully read and adhered to.
    - **b)** Full recommended rates of registered insecticides should always be used.
    - **c)** Ensure good coverage of the target area to maximise contact.

Crop(s): **Various**

Insect(s): Cotton/Melon Aphid (*Aphis gossypii*) and Green Peach Aphid (*Myzus persicae*)

Guidelines:

1. **Rotate** between registered insecticides that have different MoAs (e.g. **Groups 1, 4, 9, 12A** (cotton crop only), **23, 28** and **29**.
2. **Do not** apply consecutive applications of insecticides that have the same MoA within and between seasons or exceed the recommended maximum number of applications in a crop.
3. **Do not** follow a seed/seedling/soil treatment with a foliar application from the same Group.
4. The MoAs (Groups) and registered insecticides for control of cotton/melon aphid and/or green peach aphid are listed below.

Group*	Chemical sub-group	Example chemical
1A	Carbamates	pirimicarb
1B	Organophosphates	methamidophos
4A	Neonicotinoid	imidacloprid
4C	Sulfoximines	sulfoxaflor
9B	Pymetrozine	pymetrozine
9D	Pyropenes	afidopyropen
12A	Diafenthiuron	diafenthiuron
23	Spirotetramat	spirotetramat
28	Diamide	cyantraniliprole
29	Flonicamid	flonicamid

* Refer: CropLife Australia Expert Committee on Insecticide Resistance Mode of Action Classification for Insecticides

Notes:

1. There is known cross-resistance between **Groups 1A** and **1B**. Rotate between **Group 1** and **Group 4, 9B, 9D, 12A, 23, 28** and **29**.
2. Consecutive applications of a **Group 4A** and **Group 4C** product may be made only if no other effective option is available — either because:
   - no other group is registered in the crop; or
   - the target pest is resistant to the other Groups.
3. Seek advice from the manufacturers and/or government advisory services to determine local resistance levels for particular MoA Groups.
4. **Do not** exceed the maximum number of applications permitted on the insecticide label.
5. When using insecticides/miticides to control other pests, consider the chemical group in relation to contributing to resistance development of Cotton/Melon Aphid and Green Peach Aphid.
6. When using insecticides/aphicides to control other pests consider the effect on beneficial insects and the potential to flare aphid populations.
7. For more information about insecticide resistance in the green peach aphid refer to **http://cesaraustralia.com/latest-news/all/insecticide-resistance-in-the-green-peach-aphid**.
8. For more detail on resistance management of aphids in cotton refer to the current *Cotton Pest Management Guide* or for more detail on resistance management for Green Peach Aphid in grain refer to **https://ipmguidelinesforgrains.com.au/ipm-information/resistance-management-strategies/** or **https://grdc.com.au/resources-and-publications/all-publications/factsheets/2015/07/grdc-fs-greenpeachaphid**

Notes regarding the application of insecticides:

1. To ensure the most effective control of the pest:
   - **a)** Product labels should at all times be carefully read and adhered to.
   - **b)** Full recommended rates of registered insecticides should always be used.
   - **c)** Ensure good coverage of the target area to maximise contact.

Crop(s): **Various**

Insect(s): Silverleaf Whitefly (*Bemisia tabaci*)

Guidelines:

1. Monitor pest numbers and apply control measures before adult populations reach high levels.
2. Select registered insecticide control measures according to the primary growth stage of the pest, the infestation level and the age and type of crop.
3. In cotton, spray decisions should be based on the Silverleaf Whitefly threshold matrix. Refer to the current Cotton Pest Management Guide (**https://cottoninfo.com.au/publications/cotton-pest-management-guide**) for further details
4. Where possible, utilise selective insecticides during the early stages of crop development to minimise the impact on beneficial insects.
5. Rotate between registered insecticides that have different MoAs (e.g. **Groups 1, 3, 4, 7, 12, 23, 28** and **29**).
6. **Do not** apply more than two consecutive applications of insecticides that have the same MoA within and between seasons.
7. The MoAs (groups) and registered insecticides for control of Silverleaf Whitefly are listed below:

Group*	Chemical sub-group	Example chemical
1B	Organophosphate	acephate
3A	Synthetic pyrethroids	bifenthrin
4A	Neonicotinoids	acetamiprid, dinotefuran, imidacloprid, thiamethoxam
4D	Butenolides	flupyradifurone
7C	Pyriproxyfen	pyriproxyfen
12A	Diafenthiuron	diafenthiuron
16	Buprofezin	buprofezin
23	Spirotetramat	spirotetramat
-	Petroleum oil	petroleum oil
28	Diamides	cyantraniliprole
29	Flonicamid	flonicamid

* Refer: CropLife Australia Expert Committee on Insecticide Resistance Mode of Action Classification for Insecticides

8. Seek advice from the manufacturers and/or government advisory services to determine local resistance levels for particular MoA Groups.
9. **Do not** exceed the maximum number of applications permitted on the insecticide label.
10. When using insecticides to control other pests, consider the chemical group in relation to contributing to resistance development of Silverleaf Whitefly.
11. When using insecticides to control other pests consider the effect on beneficial insects and the potential to flare Silverleaf Whitefly populations.

Notes:

1. Not all chemical groups listed have registered products available in all crops affected by Silverleaf Whitefly. Only use products registered for use in crop to be treated.

Cultural practices:

1. In vegetable crops, ensure seedlings are free of pests prior to transplanting. Inspect transplants carefully upon arrival for whitefly eggs, nymphs and adults.
2. Control alternate weed hosts of Silverleaf Whitefly two–three weeks before planting to reduce early population levels.
3. Clean-up crop residues:
   - **a)** Where moderate population levels remain after harvest, apply a registered insecticide or oil treatment effective against adults.
   - **b)** Plough in crops within two–three days of application to kill all remaining nymphs on crop foliage to reduce pest migration into new plantings.

Notes regarding the application of insecticides:

1. To ensure the most effective control of the pest:
   - **a)** Product labels should at all times be carefully read and adhered to.
   - **b)** Full recommended rates of registered insecticides should always be used.
   - **c)** Ensure good coverage of the target area to maximise contact.

Crop(s): **Various**

Insect(s): Western Flower Thrips (*Frankliniella occidentalis*)

Guidelines:

1. For information refer to the NSW Department of Primary Industries website: **http://archive.dpi.nsw.gov.au/content/agriculture/horticulture/pests,-diseases-and-disorders-in-horticultural-crops/wft-resistance**

Notes regarding the application of insecticides:

1. To ensure the most effective control of the pest:
   - **a)** Product labels should at all times be carefully read and adhered to.
   - **b)** Full recommended rates of registered insecticides should always be used.
   - **c)** Ensure good coverage of the target area to maximise contact.

Crop(s): **Wide host range of plant species including onion, potato, brassica, beet, spinach, peas, beans and cut flowers**

Insect(s): Serpentine leafminer (*Liriomyza huidobrensis*)

Guidelines:

1. The Serpentine Leafminer is a highly polyphagous pest of around 50 different plant families including many crops and weeds. Problems with Liriomyza typically result from the destruction of their parasitoids by excessive use of non-selective insecticides. Therefore, an Integrated Pest Management (IPM) approach should be adopted with focus on the preservation of beneficial arthoropods and monitoring of pest populations, including:
   - **a)** Monitoring via regular walk round of crops to determine presence of leafminers, including potential pest reservoir in surrounding crops and weeds.
   - **b)** Focus on areas exposed to prevailing winds and transport route or unloading areas.
2. *Liriomyza* leafminers are vulnerable to a wide range of generalist parasitoid and predator natural enemies, even when introduced into non-endemic regions, thus broad-spectrum products such as Organophosphates, Pyrethroids and Neonicotoids should be avoided where possible, or used at times to minimise impact on natural enemy population, such as the end of a growing season.
3. Larval stages should be targeted by products showing systemicity or good translaminar or locally systemic activity. This includes Cyromazine, Abamectin, Cyantraniliprole, Chlorantraniliprole, Spinetoram, Spirotetramat (use for light infestations — suppression only.
4. Adult flies should be targeted by products with good residual and contact activity, including actives such as Abamectin, Cyantraniliprole, Chlorantraniliprole, Spinetoram.
5. When applying insecticdes to this pest, key considerations should be given to:
   - **a)** Apply insecticides only when needed based on economic damage thresholds (tbd).
   - **b)** Use insecticides appropriate to the insect growth stage, e.g. systemic and translaminar acting products are required for larval stages, and contact and residual activity is key for adults.
   - **c)** Use a medium spray quality to ensure sufficient droplets cover the spray target to ensure the larvae ingest a lethal dose of insecticide.
   - **d)** Use a well calibrated, functioning boom spray with appropriate water rate for the target crop to ensure optimum spray coverage.
   - **e)** Use the recommended insecticide rates as stipulated on the relevant APVMA Emergency Use Permit.
   - **f)** Inspect the performance of the insecticide three–four days after application. Always document the effectiveness of each insecticide application and never re-spray a failure with an insecticide with the same MoA. Inform the permit holder, APVMA and agronomist of any spray failures.
   - **g)** Resistance risk is increased where known incidences have been recorded internationally in *Liriomyza* species. This includes the following MoA groups: Carbamates (Group 1A); Cyclodienes/Organochlorines (Group 2A); Organophosphates (Group 1B); Pyrethroids (Group 3); Spinosyns (Group 5); Abamectin (Group 6); and Cyromazine (Group 17).
   - **h)** When rotating between MoAs, take into account the RMSs for other pest which may be present.
6. When using selected insecticides targeting the Serpentine leafminer, the following RMS guidelines should be implemented:
   - **a)** If the label allows and it is required for sustained pest management, use two sequential applications of any one MoA insecticide to span a **single generation of Serpentine leafminer** (~13–26 days at 20–30°C) and then **rotate to a different MoA insecticide**.
   - **b)** **Do not** treat successive generations with products of the same MoA.
   - **c)** The total exposure period of any one MoA insecticide applied throughout the crop cycle (from seedling to harvest) **should not exceed 50 per cent of the crop cycle**.
   - **d)** Abide by individual label recommendation for **maximum number of allowable applications per crop per season**.
   - **e)** Abide by individual label recommendation for the **minimum reapplication interval** and always use the **full recommended label rates**.
   - **f)** Where possible, an Area Wide Management strategy should be adopted where the same MoA insecticides are used **by all growers** in the **same time period**.
   - **g)** As the industry learns more about how to manage this pest, this strategy may be updated and regional-specific strategies may be developed. Check the CropLife Resistance Management website to ensure you are following the most up-to-date Serpentine leafminer strategy.

List of active constituents approved for use under permits by the Australia Pesticides and Veterinary Medicines Authority (APVMA) as of January 2022.

Group*	Chemical sub-group	Example chemical (as per permit, and named crops)^
1B	Acetylcholinesterase inhibitors	Dimethoate (pulses and ornamental shrubs and trees)
4A	Nicotinic acetylchloline receptor (NaChR) competitive modulators (Neonicotinoids)	Thiamethoxam + Chlorantraniliprole (nursery stock, non-food)
5	Nicotinic acetylcholine receptor (nAChR) allosteric modulators — Site 1 (Spinosyns)	Spinetoram (brassica vegetables [head and leafy], cucurbits, culinary herbs, fruiting vegetables, leafy vegetables, root and tuber vegetables, nursery stock (non-food), fruiting plants (non-bearing), cut flowers, ornamentals, snow peas, sugar snap peas and green beans Spinosad (leafy brassica, cucurbits, culinary herbs, fruiting vegetables, leafy vegetables, root and tuber vegetables, stalk and stem vegetables, ornamentals)
6	Glutamate-gated chloride channel (GluCl) allosteric modulators	Abamectin (cucurbits and other fruiting vegetables [excluding mushroom and corn], leafy vegetables, legume vegetables, root and tuber vegetables, bulb vegetables, head cabbages, celery and rhubarb Chlorantraniliprole + abamectin, Emamectin (nursery stock [non-food]), fruiting plants [non-bearing], cut flowers and ornamentals Emamectin (suppression only in Brassica vegetables)
15	Inhibitors of chitin biosynthesis affecting CHS1 (Benzoylureas)	Diflubenzuron (nursery stock [non-food and non-bearing], cut flowers, ornamentals)
17	Moulting disruptors, Dipteran	Cyromazine (broccoli, fruiting vegetables — cucurbits and others [excluding mushroom and corn], head lettuce, legume vegetables, stalk and stem vegetables, nursery stock [non-food], fruiting plants [non-bearing], cut flowers, ornamentals
22A	Voltage-dependent sodium channel blockers (Oxadiazines)	Indoxacarb (nursery stock [non-food], fruiting plants [non-bearing], cut flowers, ornamentals
23	Inhibitors of COA Carboxylase	Spirotetramat (suppression of snow peas, sugar snap peas, lettuce [head and leafy], parsley, green beans, celery, rhubarb, eggplant, capsicum, chilies, tomatoes.
28	Ryanodine receptors modulators (Diamides)	Chlorantraniliprole (spinach and silverbeet, nursery stock [non-food], fruiting plants [non-bearing], cut flowers, ornamentals Chlorantraniliprole + Thiamethoxam (brassica leafy vegetable and leafy vegetable seedlings) Chlorantraniliprole + Abamectin (nursery stock [non-food], fruiting plants [non-bearing], cut flowers, ornamentals) Cyantraniliprole (bulb vegetables, fruiting vegetables, potatoes, celery, nursery stock [non-food], fruiting plants [non-bearing], cut flowers, ornamentals) Cyclaniliprole (nursery stock [non-food], fruiting plants [non-bearing], cut flowers, ornamentals)
UN	Unknown	Azadirachtin (nursery stock [non-food], fruiting plants [non-bearing], cut flowers, ornamentals)

* Refer: CropLife Australia Expert Committee on Insecticide Resistance Mode of Action Classification for Insecticides

^ Refer to the APVMA's PubCris website (https://portal.apvma.gov.au/permits) to ensure permit is still active.

Notes:

1. Lifecycle prediction tool developed by Cesar: **https://cesaraustralia.shinyapps.io/darabug2/**.
2. Hort innovation guidance document: **https://ausveg.com.au/app/uploads/2020/07/1303CR2_Management-guide_FINAL_150620.pdf**.
3. DPI factsheet: **https://keys.lucidcentral.org/keys/v3/leafminers/key/Polyphagous Agromyzid Leafminers/Media/Html/Liriomyza_huidobrensis.htm**.
4. CABI datasheet, including information on natural enemies: **https://www.cabi.org/isc/datasheet/30956#67C668C3-A81D-40A2-8D80-1A04AF7490B4**.

Mode of Action classification for insecticides

Main MoA Group and primary site of action	Chemical sub-group or exemplifying active constituent	Active constituents[1]		
1* **Acetylcholinesterase inhibitors** Nerve action	**1A** Carbamates*	Bendiocarb	Methiocarb	Propoxur
		Carbaryl	Methomyl	Thiodicarb
		Carbofuran	Oxamyl	
		Carbosulfan	Pirimicarb	
	1B Organophosphates*	Acephate	Dimethoate	Phorate
		Azamethiphos	Ethion	Phosmet
		Azinphos methyl	Fenamiphos	Pirimiphos-methyl
		Cadusafos	Fenitrothion	Profenofos
		Chlorfenvinphos	Fenthion	Prothiofos
		Chlorpyrifos	Maldison (malathion)	Temephos
		Chlorpyrifos-methyl	Methidathion	Terbufos
		Diazinon	Mevinphos	Trichlorfon
		Dichlorvos	Omethoate	
2 **GABA-gated chloride channel blockers** Nerve action	**2A** Cyclodiene organochlorines	No registered actives constituents		
	2B Phenylpyrazoles (Fiproles)	Fipronil		
3 **Sodium channel modulators** Nerve action	**3A** Pyrethroids Pyrethrins	Allethrin	Cyphenothrin	Lambda-cyhalothrin
		Alpha-cypermethrin	Deltamethrin	Permethrin
		Beta-cyfluthrin	Esbiothrin	Prallethrin
		Bifenthrin	Esfenvalerate	Pyrethrins
		Bioallethrin	Fenvalerate	Tau-fluvalinate
		Bioresmethrin	Flumethrin	Tetramethrin
		Cyfluthrin	Gamma-cyhalothrin	Transfluthrin
		Cypermethrin	Imiprothrin	Zeta-cypermethrin
	3B	No registered active constituents in Australia		
4 **Nicotinic acetylcholine receptor (nAChR) competitive modulators** Nerve action	**4A** Neonicotinoids	Acetamiprid	Dinotefuran	Thiacloprid
		Clothianidin	Imidacloprid	Thiamethoxam
	4B Nicotine	No registered active constituents in Australia		
	4C Sulfoximine	Sulfoxaflor		
	4D Butenolides	Flupyradifurone		
5 **Nicotinic Acetylcholine receptor allosteric modulators (nAChR)** Nerve action	Spinosyns	Spinosad	Spinetoram	
6 **Glutamate-gated Chloride (GluCl) channel allosteric modulators** Nerve action	Avermectins Milbemycins	Abamectin	Emamectin benzoate	Milbemectin
7 **Juvenile hormone mimics** Growth regulation	**7A** Juvenile hormone analogues	Methoprene		
	7B Fenoxycarb	Fenoxycarb		
	7C Pyriproxyfen	Pyriproxyfen		

Main MoA Group and primary site of action	Chemical sub-group or exemplifying active constituent	Active constituents[1]
8 **Miscellaneous non-specific (multi-site) inhibitors-**	**8A** Alkyl halides	Methyl bromide
	8B Chloropicrin	Chloropicrin
	8C Fluorides	Sulfuryl fluoride
9 **Chordotonal organ TRPV channel modulators** Nerve Action	**9B** Pyridine azomethine derivatives	Pymetrozine
	9D Pyropenes	Afidopyropen
10 **Mite growth inhibitors** Growth regulation	**10A** Clofentezine Hexythiazox	Clofentezine Hexythiazox
	10B Etoxazole	Etoxazole
11 **Microbial disrupters of insect midgut membranes** (includes transgenic crops expressing *Bacillus thuringiensis* toxins)	**11A** *Bacillus thuringiensis* and the insecticidal proteins they produce.	*Bacillus thuringiensis* subsp. *israelensis* *B. thuringiensis* subsp. *aizawai* *B. thuringiensis* subsp. *kurstaki* *B. thuringiensis* subsp. *tenebrionis* *B. thuringiensis* crop proteins: Cry1Ac Cry2Ab Cry1F Vip3A
	11B *Bacillus sphaericus* and the insecticidal proteins they produce	*Bacillus sphaericus*
12 **Inhibitors of mitochondrial ATP synthase** Energy metabolism	**12A** Diafenthiuron	Diafenthiuron
	12B Organotin miticides	Fenbutatin oxide
	12C Propargite	Propargite
	12D Tetradifon	Tetradifon
13 **Uncoupler of oxidative phosphorylation via disruption of the proton gradient** Energy metabolism	Chlorfenapyr	Chlorfenapyr
14 **Nicotinic acetylcholine receptor channel blockers** Nerve action	Nereistoxin analogues	No registered active constituents in Australia
15 **Inhibitors of chitin biosynthesis, type 0** Growth regulation	Benzoylureas	Bistrifluron, Flufenoxuron, Novaluron Chlorfluazuron, Hexaflumuron, Triflumuron Diflubenzuron, Lufenuron
16 **Inhibitors of chitin biosynthesis, type 1** Growth regulation	Buprofezin	Buprofezin
17 **Moulting disruptor, Dipteran** Growth regulation	Cyromazine	Cyromazine
18 **Ecdysone receptor agonists** Growth regulation	Diacylhydrazines	Methoxyfenozide Tebufenozide
19 **Octopamine receptor agonists** Nerve action	Amitraz	Amitraz

Main MoA Group and primary site of action	Chemical sub-group or exemplifying active constituent	Active constituents[1]		
20 **Mitchondrial complex III electron transport inhibitors** Energy metabolism	**20A** Hydramethylnon	Hydramethylnon		
	20B Acequinocyl	Acequinocyl		
	20C	No registered active constituents in Australia		
	20D Bifenazate	Bifenazate		
21 **Mitchondrial complex I electron transport inhibitors** Energy metabolism	**21A** METI acaricides and insecticides	Fenpyroximate	Pyridaben	Tebufenpyrad
	21B Rotenone	Rotenone (Derris)		
22 **Voltage-dependent sodium channel blockers** Nerve action	**22A** Oxadiazines	Indoxacarb		
	22B Semicarbazones	Metaflumizone		
23 **Inhibitors of acetyl CoA carboxylase** Lipid synthesis, growth regulation	Tetronic Tetramic acid derivatives	Spirotetramat		
24 **Mitochondrial complex IV electron transport inhibitors** Energy metabolism	**24A** Phosphides	Phosphine Magnesium phosphide	Aluminium phosphide	
	24B Cyanides	No registered active constituents in Australia		
25 **Mitochondrial complex II electron transport inhibitors** Energy metabolism	**25A** Beta-ketonitrile derivatives	Cyflumetofen		
	25B Carboxanilides	No registered active constituents in Australia		
28 **Ryanodine receptor modulators** Nerve and muscle action	Diamides	Chlorantraniliprole	Cyantraniliprole	Cyclaniliprole
		Flubendiamide	Tetraniliprole	
29 **Chordotonal organ modulators — undefined target site** Nerve action	Flonicamid	Flonicamid		
30 **GABA-gated chloride channel allosteric modulators** Nerve action	Meta-diamides Isoxazolines	Broflanilide		
31 **Baculoviruses** Host-specific occluded pathogenic viruses (Midgut epithelial columnar cell membrane target site — undefined)	Granuloviruses (GVs)	*Cydia pomonella* granulosis virus strain V22		
	Nucleopolyhedroviruses (NPVs)	Polyhedral occlusion bodies of the NPV of *Helicoverpa zea* or *H. armigera*		
32 **Nicotinic acetylcholine receptor (NACHR) allosteric modulators site 2**	GS-omega/kappa HXTX-Hv1a peptid	No registered active constituents in Australia		
33 **Calcium-activated potassium channel (KCA2) modulators**	Acynonapyr	No registered active constituents in Australia		

Main MoA Group and primary site of action	Chemical sub-group or exemplifying active constituent	Active constituents[1]
34 Mitochondrial Complex III transport inhibitors — QI site	Flometoquin	No registered active constituents in Australia
UN Compounds of unknown or uncertain MoA[1]	Azadirachtin	Azadirachtin
	Beauveria bassiana	*Beauveria bassiana*
	Clitoria ternatea extract	*Clitoria ternatea* extract
	Dicofol	Dicofol
	Lime sulphur	Lime sulphur
	Sulphur	Sulphur
UNM Non-specific mechanical and physical disruptors	Diatomaceous earth	Diatomaceous earth

* All members of the class may not be cross resistant.

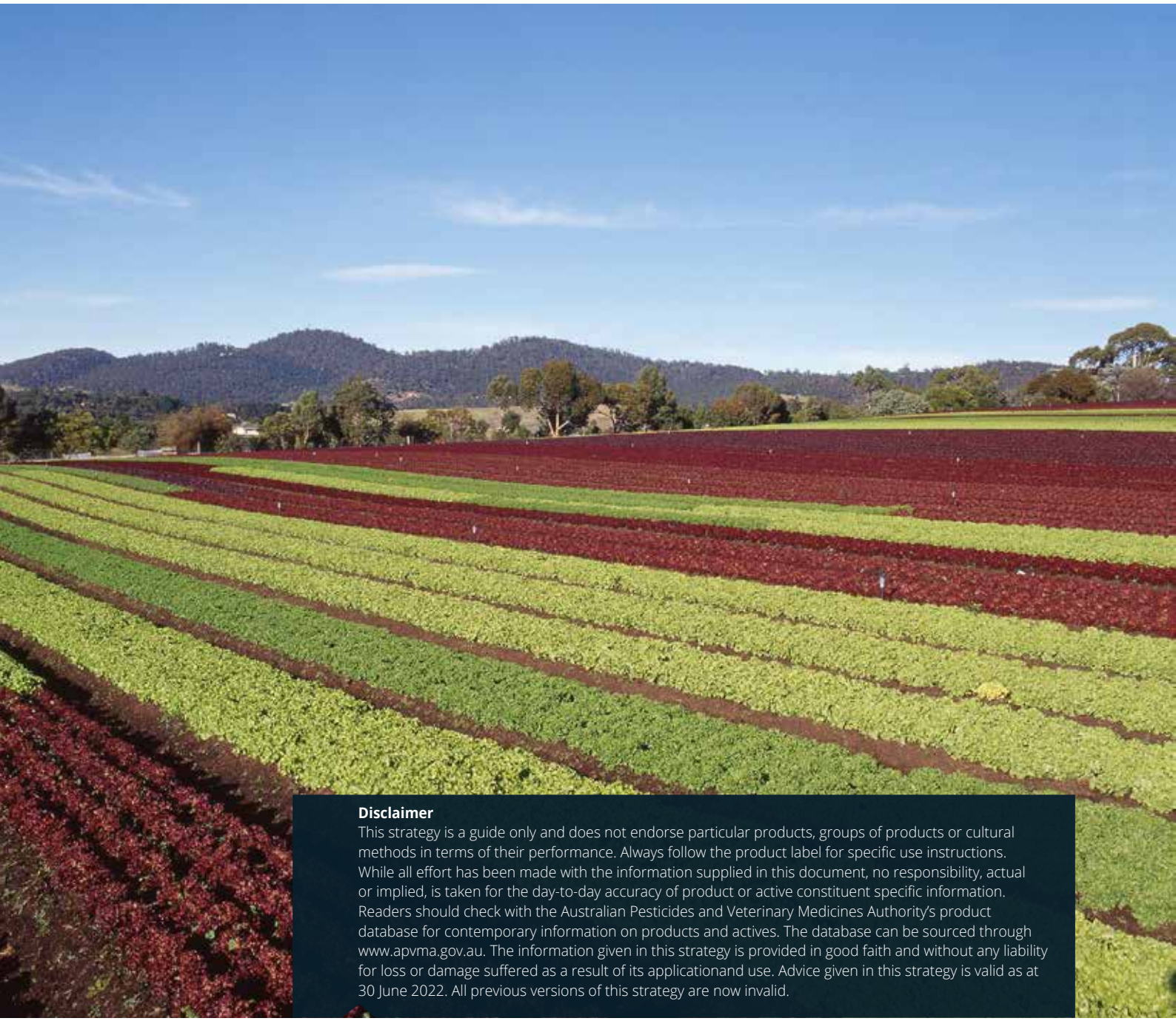
1 A compound with an unknown or controversial MoA or an unknown mode of toxicity will be held in Group UN until evidence becomes available to enable that compound to be assigned to a more appropriate MoA group.

Mode of Action classification for insecticides — active constituent list

Active constituent	Current group
Abamectin	**6**
Acephate	**1B**
Acequinocyl	**20B**
Acetamiprid	**4A**
Afidopyropen	**9D**
Allethrin	**3A**
Alpha-cypermethrin	**3A**
Aluminium phosphide	**24A**
Amitraz	**19**
Azadirachtin	**UN**
Azamethiphos	**1B**
Azinphos methyl	**1B**
Bacillus thuringiensis aizawai	**11**
Bacillus thuringiensis israelensis	**11**
Bacillus thuringiensis kurstaki	**11**
Bacillus sphaericus	**11**
Bacillus thuringiensis tenebrionis	**11**
Beauveria bassiana	**UN**
Bendiocarb	**1A**
Beta-cyfluthrin	**3A**
Bifenazate	**20**
Bifenthrin	**3A**
Bioallethrin	**3A**
Bioresmethrin	**3A**
Bistrifluron	**15**
Broflanilide	**30**
Buprofezin	**16**
Cadusafos	**1B**
Carbaryl	**1A**
Carbofuran	**1A**
Carbosulfan	**1A**
Chlorantraniliprole	**28**
Chlorfenvinphos	**1B**
Chlorfluazuron	**15**
Chlorfenapyr	**13**
Chloropicrin	**8B**
Chlorpyrifos	**1B**
Chlorpyrifos-methyl	**1B**
Clitoria ternatea extract	**UN**
Clofentezine	**10A**
Clothianidin	**4A**
Cyantraniliprole	**28**
Cyclaniliprole	**28**
Cydia pomonella granulosis virus train V22	**31**
Cyflumetofen	**25B**
Cyfluthrin	**3A**
Cypermethrin	**3A**
Cyromazine	**17**
Deltamethrin	**3A**
Diafenthiuron	**12A**
Diazinon	**1B**
Dichlorvos	**1B**
Dicofol	**UN**
Diflubenzuron	**15**
Dimethoate	**1B**
Dinotefuran	**4A**
Emamectin benzoate	**6**
Esbiothrin	**3A**
Ethion	**1B**
Etoxazole	**10B**
Esfenvalerate	**3A**
Fenamiphos	**1B**
Fenbutatin oxide	**12B**
Fenitrothion	**1B**
Fenoxycarb	**7B**
Fenpyroximate	**21A**
Fenthion	**1B**
Fenvalerate	**3A**
Fipronil	**2B**
Flonicamid	**29**
Flubendiamide	**28**
Flufenoxuron	**15**
Flumethrin	**3A**
Gamma-cyhalothrin	**3A**
Hexaflumuron	**15**
Hexythiazox	**10A**
Hydramethylnon	**20A**
Imidacloprid	**4A**
Imiprothrin	**3A**
Indoxacarb	**22A**
Lambda-cyhalothrin	**3A**
Lufenuron	**15**
Magnesium phosphide	**24A**
Maldison (malathion)	**1B**
Metaflumizone	**22B**
Methidathion	**1B**
Methiocarb	**1A**
Methomyl	**1A**
Methoprene	**7A**
Methoxyfenozide	**18**
Methyl bromide	**8A**
Mevinphos	**1B**
Milbemectin	**6**
Oxamyl	**1A**
Omethoate	**1B**
Permethrin	**3A**
Phorate	**1B**
Phosmet	**1B**
Phosphine	**24A**
Polyhedral occlusion bodies of the NPV of *Helicoverpa zea* or *H. armigera*	**31**
Pirimicarb	**1A**
Pirimiphos-methyl	**1B**
Prallethrin	**3A**
Profenofos	**1B**
Propargite	**12C**
Propoxur	**1A**
Prothiofos	**1B**
Pymetrozine	**9B**
Pyrethrins	**3A**
Pyridaben	**21A**
Pyriproxyfen	**7C**
Spinosad	**5**
Spinetoram	**5**
Spirotetramat	**23**
Sulfoxaflor	**4C**
Tau-fluvalinate	**3A**
Tebufenozide	**18**
Tebufenpyrad	**21A**
Temephos	**1B**
Terbufos	**1B**
Tetradifon	**12D**
Tetramethrin	**3A**
Thiacloprid	**4A**
Thiamethoxam	**4A**
Thiodicarb	**1A**
Transfluthrin	**3A**
Trichlorfon	**1B**
Triflumuron	**15**
Zeta-cypermethrin	**3A**

Part 2 Fungicide resistance management strategies

DEVELOPED BY THE CROPLIFE AUSTRALIA EXPERT COMMITTEE ON FUNGICIDE RESISTANCE (ECFR) — VALID AS AT 30 JUNE 2022



Disclaimer

This strategy is a guide only and does not endorse particular products, groups of products or cultural methods in terms of their performance. Always follow the product label for specific use instructions. While all effort has been made with the information supplied in this document, no responsibility, actual or implied, is taken for the day-to-day accuracy of product or active constituent specific information. Readers should check with the Australian Pesticides and Veterinary Medicines Authority's product database for contemporary information on products and actives. The database can be sourced through www.apvma.gov.au. The information given in this strategy is provided in good faith and without any liability for loss or damage suffered as a result of its applicationand use. Advice given in this strategy is valid as at 30 June 2022. All previous versions of this strategy are now invalid.

Introduction

The CropLife Australia Expert Committee on Fungicide Resistance (ECFR) has drafted disease resistance management strategies in conjunction with growers, researchers and agronomists to minimise the development of resistance to fungicides. These strategies provide growers with guidelines for fungicide use (and other methods) for sustainable disease control.

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 mainly through the incorrect use of fungicides, which selects for the resistant individuals. 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.

What can be done to prevent or delay resistance?

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. In Australia, 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.

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 lifecycle 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 sublethal rates. Particular attention should be given to label recommendations, rates and coverage. Adherence to suggested disease threshold levels is also good resistance management practice.

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.

Working with industry bodies such as the CropLife Australia Expert Committee on Fungicide Resistance 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.

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.

Certain environments are conducive to continuous infection and consistently high disease pressure. Examples of such environments are nurseries, tunnels, greenhouses and other structures of protected cultivation. Because protected cultivation usually requires multiple applications of fungicides at short intervals to control high disease incidence, there is a much higher risk of development of resistance to fungicides. Users of fungicides under these conditions should be particularly mindful of the enhanced resistance risk. 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.

Resistance risk

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 and BM) 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 and BM fungicides is not limited, as these fungicides carry an inherently low risk of fungicide resistance developing.

Activity group labelling in Australia

In order to help fungicide users to manage fungicide resistance, all fungicide products sold in Australia are classified according to the chemical activity group of their active constituent. The activity group must be indicated by a letter code on the product label. Australia was the first country to introduce compulsory activity group labelling on products. Since the introduction of activity group labelling in Australia, other countries have adopted activity group classification systems, however caution should be shown if cross-referencing activity groups between Australia and other countries, as there are some differences in classification.

Changes to activity groups

In 2008, CropLife Australia completely revised Australia's fungicide activity grouping system to bring it into line with the international Fungicide Resistance Action Committee (FRAC) activity group classification system. This was the first major revision of the Australian classification system since its introduction several years ago. Activity group codes have now been changed from letters to numbers (or letter/number combinations). For a complete list of all fungicide active constituents registered in Australia and their old and new activity groups, see the *Fungicide Activity Group Table* on the CropLife Australia website at **www.croplife.org.au**.

Table 1. Plant pathogens accepted as showing a medium risk of development of resistance to fungicides.

FRAC Pathogen	Crop	Disease
Bremia lactucae	Lettuce	Downy mildew
*Gibberella fujikuroi**	Rice	Bakanae
Leptosphaera nodorum (Stagonospora nodorum)	Wheat	Leaf spot
Monilinia spp.	Stone and pome fruit	Monilinia rots
Mycosphaerella graminicola (Septoria tritici)	Wheat	Septoria
Mycosphaerella musicola	Banana	Yellow Sigatoka (Leaf spot)
Peronospora spp.	Various	Downy mildew
Podosphaera leucotricha	Apple	Powdery mildew
Puccinia spp.	Wheat/barley	Rusts
Pyrenophora teres	Barley	Net Blotch
Pyrenophora tritici-repentis	Wheat	Tan spot (yellow spot)
Tapesia spp.	Wheat/barley	Eyespot
Erysiphe necator *	Grapevine	Powdery mildew

* The EPPO Guideline lists these pathogens as high risk and baselines are normally requested.

Table 2. Plant pathogens accepted as showing a high risk of development of resistance to fungicides (adapted from EPPO, 2002).

FRAC Pathogen	Crop	Disease
Botrytis cinerea	Various, especially grapevine	Grey mould
Erysiphe graminis	Wheat/barley	Powdery mildew
Mycosphaerella fijiensis	Banana	Black sigatoka
Phytophthora infestans	Potato	Late blight
Plasmopara viticola	Grapevine	Downy mildew
Pseudoperonospora cubensis and related	Cucurbits	Downy mildew
Pyricularia oryzae	Rice	Rice blast
Sphaerotheca fuliginea and related	Cucurbits	Powdery mildew
Venturia spp.	Apple, pear	Scab

Table 3. Plant pathogens for which resistance has been confirmed or suspected in Australian field conditions. Users are advised to at all times adhere to appropriate resistance management strategies.

FRAC pathogen	Crop	Resistance confirmed against	FRAC group	Disease
Botrytis cinerea	Strawberries	Iprodione	2	Grey mould
		Strobilurins	11	
		Pyrimethanil	9	
		Fenhexamid	17	
Blumeria graminis f.s.p. *hordei*	Barley	Triazoles	3	Powdery mildew
Podosphaera xanthii	Cucurbits	Buprimate	8	Powdery mildew
		Strobilurins	11	
		Triadimenol	3	
Erysiphe necator	Grapes	Strobilurins	11	Powdery mildew
Venturia inaequalis	Apples	Triazoles	3	Black spot
Plasmopara viticola	Grapes	Phenylamides	4	Downy mildew
		Strobilurins	11	
Mycosphaerella musicola	Bananas	Strobilurins	11	Yellow sigatoka

Pathogens with high resistance risk

In some cases, fungicides from additional fungicide activity groups may be available under permit for use in the above crop/pest situations. Details of such permits can be obtained from the Australian regulator's website (**www.apvma.gov.au**). In the absence of a resistance management strategy for activity groups of products available under permit, or in the absence of restrictions contained within the permit, it is strongly advised that those products (excluding **Group M** and **BM** fungicides) be used in alternation with registered products from other fungicide activity groups, which should be used in accordance with the following resistance management strategies.

Pathogens with medium or unlisted resistance risk

In some cases, fungicides from additional fungicide activity groups may be available under permit for use in the above crop/pest situation. Details of such permits can be obtained from the Australian regulator's website: (**www.apvma.gov.au**). In the absence of a resistance management strategy for activity groups of products available under permit, it is advised that spray programs incorporating those products (excluding Group M fungicides) also incorporate registered products from other fungicide activity groups. Programs should be used in accordance with the following resistance management strategies.

Crop(s): **Almonds**

Disease(s): Blossom blight and brown rot

RMS for:

- **Group 2** Dicarboximides
- **Group 3** Demethylation inhibitors (DMI)
- **Group 7** Succinate dehydrogenase inhibitors (SDHI)
- **Group 11** Quinone outside inhibitor (QoI)
- **Group 11+3** QoI + DMI
- **Group 11+7** QoI + SDHI

		Recommended max. no. of sprays containing Group:			
		2	**3**	**7** (incl. 7+11)	**11** (incl. 11+3 & 7+11)
Total no. of blossom blight/ brown rot targeting sprays	**1**	1	1	1	1
	2	2	2	1	1
	3	2	2	1	2
	4	2	2	1	2
	5	2	2	1	2
	6	3	3	2	2
	7	3	3	2	2
	8	3	3	2	2
	9+	3	3	3	3

1. **Do not** apply consecutive sprays of products containing **Group 7 or 11**. Consecutive sprays include mixtures containing **Group 7 or 11**.
2. **Do not** apply more than three **Group 2** sprays in one season. Apply no more than two consecutive sprays before changing to another group.
3. Consecutive application includes from the end of one season to the start of the following season.
4. The spray program should be considered and the strategy applied on a whole-orchard basis.
5. No specific resistance management strategy has been developed for low-risk fungicides, including those in **Group M** and **BM**. These products should be included in a management strategy as rotation and mixing partners as per label recommendations.

Crop(s): **Almonds**

Disease(s): Rust

RMS for:

- **Group 3** Demethylation inhibitors (DMI)
- **Group 7** Succinate dehydrogenase inhibitors (SDHI)
- **Group 11** Quinone outside inhibitor (QoI)
- **Group 11+3** QoI + DMI
- **Group 11+7** QoI + SDHI

		Recommended max. no. of sprays containing Group:		
		3	**7** (incl. 7+11)	**11** (incl. 11+3 & 7+11)
Total no. of rust targeting sprays	**1**	1	1	1
	2	2	1	1
	3	2	1	2
	4	2	1	2
	5	2	1	2
	6	3	2	2
	7	3	2	2
	8	3	2	2
	9+	3	3	3

1. **Do not** apply consecutive sprays of products containing **Group 7+11**. If applying **Group 7** or **Group 11** fungicides in mixtures, e.g. **Group 11+7**, consecutive application is allowed. **Do not** apply more than two consecutive sprays before changing to another group.
2. If two consecutive sprays of **Group 3** or **Group 11+3** fungicides are used, then use the same number of sprays of an alternative group(s) before using another **Group 3**, including sprays in the following seasons.
3. Rotate with products from **Groups M2**, **M3** and **M5**.
4. The spray program should be considered and the strategy applied on a whole-orchard basis.

Crop(s): **Apples, Pears**

Disease(s): Apple and Pear scab

RMS for:

- **Group 3** Demethylation inhibitors (DMI)
- **Group 7** Succinate Dehydrogenase inhibitors (SDHI)
- **Group 7+11** SDHI + Quinone outside inhibitor (QoI)
- **Group 9** Anilinopyrimidines (AP)
- **Group 11** QoI
- **Group U12** Guanidines

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.
2. 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.
3. **Do not** apply more than four sprays per season of **Group 9** fungicides (solo products).
4. **Do not** apply more than four sprays per season of products containing a combination of a **Group 9** and a **Group 3** fungicide and no more than two consecutive applications.
5. Where spray programs include solo **Group 9** products and combination products, the maximum cumulative number of applications is four per season and no more than two consecutive applications.
6. In locations where resistance has been reported use a **Group 9** only in mixture with a registered, alternative MoA for which resistance is not known.
7. Always apply SDHI fungicides as per the label recommendations and only use as preventative treatment.
8. **Do not** apply more than three sprays pers season of **Group 7** or **Group 11** fungicides. If two consecutive applications of **Group 7** or **Group 11** fungicides are used, then they must be followed by at least the same number of applications of fungicide(s) from a different MoA group(s) before a **Group 7** or **Group 11** fungicide is used again, either in the current or following season.
9. When mixtures are used for SDHI fungicide resistance management, applied as tank mix or as a co-formulated mixture, the mixture partner should provide satisfactory disease control when used alone on the target disease and must have a different MoA.
10. Pomefruit spray guidelines for SDHI fungicides:

Max recommended:	**Total no. of spray applications per crop**												
	1	**2**	3	4	5	6	7	8	9	10	11	12	>12
Alone SDHI fungicide sprays	1	1	1	1	2	2	2	2	2	3	3	3	3
SDHI fungicide sprays in mixture of coforumulated	1	1	2	2	2	3	3	3	3	3	3	4	4

11. To prevent or delay the onset of resistance to **Group U12**, **do not** apply more than three consecutive sprays of **Group U12**, and no more than a total of six **Group U12** sprays per seasons.
12. If more sprays are required, tank mix **Group U12** with a protectant product at the registered rate.

Crop(s): **Avocado and Mango**

Disease(s): Anthracnose (*Colletotrichum spp.*)

RMS for:

- **Group 3** Demethylation inhibitors (DMI)
- **Group 7+11** Succinate Dehydrogenase inhibitors (SDHI) + Quinone outside Inhibitor (QoI)
- **Group 11** QoI

1. If applying **Group 11** (including **7+11**) fungicides, **do not** apply more than two consecutive sprays before changing to another group. **Do not** apply more than three **Group 11** sprays per season within the field. If consecutive sprays are used, then use the same number of sprays of an alternative group before using another **Group 11**.
2. **Do not*** apply more than four **Group 3** sprays in a season. Apply no more than two consecutive sprays of a **Group 3** fungicide alone.
3. No specific resistance management strategy has been developed for low-risk fungicides, including those in **Group M** and **BM**. These products should be included in a management strategy as per label recommendations.

* Appropriate in mangoes only.

Crop(s): **Banana**

Disease(s): Yellow sigatoka

RMS for:

- **Group 3** Demethylation inhibitors (DMI)
- **Group 7** Succinate dehydrogenase inhibitors (SDHI)
- **Group 7+3** SDHI + DMI
- **Group 9** Anilinopyrimidine (AP)
- **Group 11** Quinone outside inhibitors (QoI)

Far North Queensland

1. De-leafing must be conducted in accordance with industry guidelines.
2. Apply a regular schedule of protectant sprays.
3. When disease potential is high, apply a maximum of two consecutive **Group 3** sprays before changing to a fungicide of a different activity group.
4. **Do not** apply more than six **Group 3** sprays in any 12-month period. **Do not** apply any **Group 3** sprays in the months of June, July, August and September.
5. **Do not** apply more than two **Group 11** sprays in any 12-month period. **Do not** apply **Group 11** sprays in the months of May, June, July, August and September.
6. **Do not** apply more than four **Group 7** sprays in any 12-month period. **Do not** apply **Group 7** sprays in the months of June, July, August and September.
7. **Group 7** or **11** fungicides should be applied in mixture with another fungicide from a different activity Group registered for the control of Yellow Sigatoka at the full registered rate.
8. **Do not** apply consecutive sprays of **Group 7** or **11** fungicides.
9. Apply a minimum of two sprays from a different activity group between sprays of a **Group 7** or **11** fungicide.
10. **Do not** apply more than six **Group 9** sprays in any 12-month period.
11. **Do not** apply more than two consecutive sprays of a **Group 9** fungicide before changing to a fungicide of a different activity group. When using consecutive applications of **Group 9** fungicides, follow with at least as many different activity group fungicides before resuming with a **Group 9** fungicide.

Chemical group	Max. no. of applications per year	Max. no. of consecutive sprays	Restricted (no-spray) periods
3	6 (& no more than 2 of 3 sprays)	2	June to September inclusive
7	4 (& no more than 1 of 3 sprays)	Not allowed	June to September inclusive
9	6 (& no more than 2 of 4 sprays)	2	No restriction
11	2 (& no more than 1 of 3 sprays)	Not allowed	May to September inclusive

Everywhere except Far North Queensland

1. When using **Group 3** fungicides, apply a maximum of two consecutive **Group 3** sprays before changing to a fungicide of a different activity group.
2. **Do not** apply more than six **Group 3** sprays in any 12-month period.
3. **Do not** apply more than four **Group 7** or **11** sprays in any 12-month period.
4. **Do not** apply consecutive sprays of **Group 7** or **11** fungicides.
5. Apply a minimum of two sprays from a different activity group between sprays of a **Group 7** or **11** fungicide.
6. **Do not** apply more than six **Group 9** sprays in any 12-month period.
7. **Do not** apply more than two consecutive sprays of **Group 9** fungicides before changing to a fungicide of a different activity group. When using consecutive applications of **Group 9** fungicides, follow with at least as many different activity group fungicides before resuming with a **Group 9** fungicide.

Chemical group	Max. no. of applications per year	Max. no. of consecutive sprays	Restricted (no-spray) periods
3	6 (& no more than 2 of 3 sprays)	2	6 (& no more than 2 of 3 sprays)
7	4 (& no more than 1 of 3 sprays)	Not allowed	4 (& no more than 1 of 3 sprays)
9	6 (& no more than 2 of 4 sprays)	2	6 (& no more than 2 of 4 sprays)
11	4 (& no more than 1 of 3 sprays)	Not allowed	4 (& no more than 1 of 3 sprays)

Crop(s): **Barley**

Disease(s): Powdery mildew

RMS for:

- **Group 3** Demethylation inhibitors (DMI)
- **Group 5** Morpholines
- **Group 7** Succinate dehydrogenase inhibitors (SDHI)
- **Group 7+3** SDHI + DMI
- **Group 11+3** Quinone outside inhibitor (QoI) + DMI
- **Group 11+4** QoI + phenylamides (PA)
- **Group 13** Aza-napthalenes
- **Group 11+7+3** QoI + SDHI + DMI

1. Fungicides should be used preventatively or at first sign of disease. If disease is established within the canopy, fungicides may not produce optimal results and there is high chance of selection for fungicide resistance. In high risk disease environments, integrated management approaches should be used to reduce fungicide resistance risk including the removal of stubble, control of green bridge volunteers and the use of resistant varieties. Monitor if conditions favour disease development and reapply an appropriate fungicide from 21 to 28 days after first application. Use the higher label rate ranges where conditions favour disease development.
2. **Do not** apply more than two applications per growing season of **Group 3**, **5**, **7** (**7+3**, **11+7+3**), **11** (**11+3**, **11+7+3** or **11+4**) or **13** containing products. This includes in-furrow or seed treatments that have activity on powdery mildew. Combinations of in-furrow and seed treatment are counted as one application.
3. Use **Group 13** products in mixture with an effective partner or alternate with fungicides of a different activity group. Always apply in mixture with a curative fungicide where disease is established. Where applied alone, only use as a protectant (preventative) treatment.
4. **Do not** apply consecutive applications of **Group 11** containing products. This includes in-furrow i.e. if a **Group 11+4** fungicide has been used in-furrow at planting, the first foliar fungicide spray must not contain a **Group 11** fungicide.
5. If a **Group 7** seed treatment has been used with foliar activity (as determined by label claims), the first foliar fungicide applied must not contain a **Group 7** fungicide.
6. **Group 7** foliar fungicides must always be in a co-formulation or in mixture with a registered mixing partner with a different MoA, with no known resistance.
7. Minimise use of **Group 3** fungicides which are known to have compromised efficacy due to resistance.

Crop(s): **Barley**

Disease(s): Scald and net blotch

RMS for:

- **Group 3** Demethylation inhibitors (DMI)
- **Group 7** Succinate dehydrogenase inhibitors (SDHI)
- **Group 7+3** SDHI + DMI
- **Group 11+3** Quinone outside inhibitors (QoI) + DMI
- **Group 11+4** QoI + phenylamides (PA)
- **Group 11+7+3** QoI +SDHI + DMI

1. Fungicides should be used as protectant treatments — where no more than 5 per cent leaf area infection evident anywhere in the canopy. In high risk disease environments, integrated management approaches should be used to reduce fungicide resistance risk, which may include:
   - **a)** removal of stubble
   - **b)** crop rotation (**avoid** barley on barley)
   - **c)** control of green bridge volunteers
   - **d)** use of tolerant and resistant varieties.
2. **Do not** apply more than one application of a **Group 7** seed treatment with foliar activity in any two consecutive growing seasons.
3. **Do not** apply more than two applications per growing season of **Group 11** or **7** containing products. This includes foliar sprays as well as in-furrow or seed treatments that have activity on foliar diseases. Combinations of in-furrow and seed treatment are counted as one application.
4. **Do not** apply consecutive applications of **Group 11** containing products. This includes in-furrow i.e. if a **Group 11+4** or **11+3+7** fungicide has been used in-furrow at planting, the first foliar fungicide spray must not contain a **Group 11** fungicide.
5. If a **Group 7** seed treatment has been used with foliar activity (as determined by label claims), the first foliar fungicide applied should not contain a **Group 7** fungicide.
6. If a **Group 7** fungicide is being applied as a foliar spray, it must be in a co-formulation or in mixture with a registered mixing partner with a different MoA, with no known resistance.
7. **Do not** apply more than three applications containing **Group 3** fungicides per growing season. This total of three applications includes DMIs applied as **Group 11+3** or **Group 11+7+3** co-formulations and in-furrow or seed treatments that have activity on foliar diseases. Combinations of in-furrow and seed treatments are counted as one application.
8. Minimise use of **Group 3** fungicides which are known to have compromised resistance status.

Net Blotch on Yorke Peninsula, South Australia

1. Minimise use of **Group 7** fungicides with foliar activity where resistance has been confirmed.
2. Minimise the use of **Group 7** fungicides (seed treatments and foliar sprays) to high risk crop varieties.
3. **Group 7** fungicides **should not** comprise more than 50 per cent of the total number of fungicide applications targeting this disease, which includes seed treatments with foliar activity and foliar sprays per season.

Crop(s): **Broccoli/Cauliflower**

Disease(s): White blister

RMS for:

- **Group 4** Phenylamides (PA)
- **Group 11** Quinone outside inhibitors (QoI)
- **Group 21** Quinone inside inhibitors (QiI)
- **Group 28+43** Carbamates + benzamides

1. Apply fungicides from **Group 4**, **11**, **21** or **28+43** in a preventative strategy when conditions favour disease development. Applications made within the nursery count towards the total number of applications allowed per crop.
2. Always apply **Group 4** in mixtures for foliar applications. Apply no more than two consecutive sprays of products containing **Group 4** actives.
3. Apply no more than two consecutive sprays of fungicides containing **Group 11** or **21**. Consecutive sprays should only be adopted if these groups are applied in mixture with an alternative MoA fungicide. **Group 11** or **21** fungicides should be applied in strict alternation with other fungicide groups if being applied without mix partners.
4. **Do not** apply more than two applications of **Group 4** and **Group 11** fungicides per crop.
5. **Do not** apply more than three applications of a **Group 21** or **28+43** fungicide per crop.

Crop(s): **Broccoli/Cauliflower**

Disease(s): Downy mildew

RMS for:

- **Group 4** Phenylamides (PA)
- **Group 11** Quinone outside inhibitors (QoI)
- **Group 21** Quinone inside inhibitors (QiI)
- **Group 49** Oxysterol binding protein inhibitors (OSBP)

1. Applications made within the nursery count towards the total number of applications allowed per crop. It is recommended that disease control is started early and maintain a regular program using a fungicide from groups other than **Group 4**, **11**, **21** or **49**.
2. When conditions favour disease development, **do not** wait for disease to appear, but apply two consecutive sprays of a **Group 4**, **11**, **21** or **49** product at the interval recommended on the label. Then resume the program of sprays using products from a different group to the **Group 4**, **11**, **21** or **49** products just applied.
3. **Do not** apply more than three sprays of a **Group 4**, **11**, **21** or **49** product or 33 per cent of the total number of fungicide sprays per season, whichever is more restrictive.
4. Apply **Group 4** and **49** fungicides preventatively and only in mixtures with effective protectant fungicides from a different group.
5. **Do not** use a **Group 49** product if it will be the last fungicide applied to the crop.
6. Continue alternation of fungicides between successive crops. **Do not** make more than six total applications of a **Group 49** product per year on the same area targeting the same disease.

Crop(s): **Canola**

Disease(s): Blackleg and Sclerotinia

RMS for:

- **Group 2** Dicarboxamides
- **Group 3** Demethylation inhibitors (DMI)
- **Group 7** Succinate dehydrogenase inhibitors (SDHI)
- **Group 7+3** SDHI + DMI
- **Group 7+12** SDHI + phenylpyrroles (PP)
- **Group 11+3** Quinone outside Inhibitors (QoI) + DMI

1. Fungicides should be used primarily as a preventative or at first sign of disease. If disease is established within the canopy, fungicides may not produce optimal results and there is very strong potential to select for fungicide resistance. Sclerotinia targeted applications should be applied during flowering of the crop, prior to an infection period. Application of fungicides for Sclerotinia may put selection pressure on the blackleg population.
2. In high risk disease environments, integrated management approaches should be used to reduce fungicide resistance risk. This includes growing canola at least 500 metres from previous season's canola stubble, the use of resistant varieties, using alternative fungicide MoAs and stubble management such as knocking down and/or strategic burning.
3. The risk of developing resistance to fungicides can be reduced by incorporating different MoAs into blackleg management programs as either mixtures, co-formulations or rotations.
4. If a **Group 7** seed treatment has been used with foliar activity on blackleg (as determined by label claims), the seedling fungicide application at four to six leaf stage targeting blackleg should not contain a **Group 7** fungicide.
5. **Do not** apply more than two applications containing **Group 7** fungicides per growing season. Combinations of in furrow and seed treatment are counted as one application.
6. **Do not** apply more than two consecutive applications of a **Group 3** fungicide.
7. **Do not** apply more than one application container a **Group 11** fungicide.
8. Minimise use of fungicides which are known to have compromised resistance status.
9. If seasonal conditions require a second fungicide application at 50 per cent flowering after a 20 per cent flowering timing, the second application should be from a different group.

Application stage (disease being controlled)		**Rotation options for different fungicide active groups**											
Seed dressing & in-furrow (Blackleg)		None	None	None	None	None	None	3	3	3	3	3	3
Seedling foliar (Blackleg)		None	3	7	7+3	7+12	11+3	None	3	7	7+3	7+12	11+3
20 per cent flower (Sclerotinia). Choose only one option from this section	**1**	None	None	None	None	None	None	None	None	None	None	None	None
	2	2	2	2	2	2	2	2	2	2	2	2	2
	3	3	3	3	3	3	3	-	3	-	3	3	-
	4	7+3	7+3	7+3	7+3	7+3	-	-	7+3	-	7+3	7+3	-
	5	7+12	7+12	7+12	7+12	-	7+12	7+12	7+12	7+12	-	-	7+12
	6	11+3	11+3	11+3	11+3	11+3	-	-	11+3	-	11+3	11+3	-

Application stage (disease being controlled)		**Rotation options for different fungicide active groups**					
Seed dressing & in-furrow (Blackleg)		7	7	7	7+3	7+3	7+3
Seedling foliar (Blackleg)		None	3	11+3	None	3	11+3
20 per cent flower (Sclerotinia) Choose only one option from this section	**1**	None	None	None	None	None	None
	2	2	2	2	2	2	2
	3	3	3	3	3	-	-
	4	7+3	7+3	7+3	7+3	-	-
	5	7+12	7+12	7+12	7+12	7+12	7+12
	6	11+3	11+3	-	11+3	-	-

If a second application at 50 per cent flowering required:

	Application at 20 per cent flowering				
	2	**3**	**7 + 3**	**7+12**	**11 + 3**
Rotation options for 50 per cent flowering second application	-	2	2	2	2
	3	-	-	3	-
	7+3	-	-	-	-
	11+3	-	-	11+3	-

Crop(s): **Cucurbits**

Disease(s): Downy mildew

RMS for:

- **Group 4** Phenylamides (PA)
- **Group 11** Quinone outside inhibitors (QoI)
- **Group 28+43** Carbamates + benzamides
- **Group 40** Carboxylic acid amide (CAA)
- **Group 45+40** Quinone outside inhibitors, stigmatellin binding type (QoSI) + CAA
- **Group 49** Oxysterol binding protein inhibitors (OSBPI)
- **Group 49+11** OSBPI + QoI

1. Applications made within the nursery count towards the total number of applications allowed per crop. It is recommended that disease control is started early and maintain a regular program using a fungicide from groups other than **Groups 4**, **11**, **28+43**, **40**, **45+40**, **49** or **49+11**.
2. When conditions favour disease development, **do not** wait for disease to appear, but apply two consecutive sprays of a **Group 4**, **11**, **28+43**, **45+40**, **49** or **49+11** fungicide, at the interval recommended on the label, or a single spray of a **Group 11** fungicide. Then resume the program of sprays using products from a different group to the **Group 4**, **11**, **28+43**, **45+40**, **49** or **49+11** fungicide just applied.
3. **Do not** apply more than four sprays of a **Group 4** or **Group 40** product per season.
4. **Do not** apply more than three sprays of a **Group 49** containing product. **Group 49** containing sprays should not consist of more than one in every three sprays of the total number of fungicide sprays per crop. **Group 49+11** sprays count as both a **Group 49** and a **Group 11** spray.
5. **Do not** apply more than two sprays of **Group 28+43**, **45+40** or **11** containing fungicides (including **49+11**) per crop.
6. Apply **Group 4**, **11**, **45+40** and **49** (including **49+11**) fungicides preventatively.
7. Apply **Group 4** and **49** fungicides only in mixtures or co-formulations with a registered fungicide from a different MoA group with no known resistance.
8. Continue alternation of fungicides between successive crops. **Do not** make more than six total applications of a **Group 49** product per year on the same area targeting the same disease.

Crop(s): **Cucurbits**

Disease(s): Powdery mildew

RMS for:

- **Group 3** Demethylation inhibitors (DMI)
- **Group 7** Succinate dehydrogenase inhibitors (SDHI)
- **Group 7+3** SDHI + DMI
- **Group 8** Hydroxy-(2-amino-)pyrimidines
- **Group 11** Quinone outside inhibitors (QoI)
- **Group 11+7** QoI + SDHI
- **Group 13** Aza-napthalenes
- **Group U6** Phenyl-acetamide
- **Group 50** Actin disruptors (aryl-phenyl-ketones)

1. Start disease control early. **Do not** wait for powdery mildew to appear before spraying but start as soon as possible after crop emergence.
2. Use protectant sprays in early crop growth. Apply protectant sprays up to the fruit set stage of the crop if the disease normally occurs during this period. If this schedule is interrupted (e.g. by rain) use a tank mix of protectant plus systemic before recommencing the protectant program.
3. After fruit set, use systemic fungicides in one or more of the following ways:
   - **a)** Tank mix systemic fungicides with a protectant fungicide **and** use fungicides from at least two different MoA groups per crop.
   - **b)** Alternate systemic fungicides with a protectant fungicide **and** use fungicides from at least two different MoA groups per crop.
   - **c)** Alternate systemic fungicides from at least three different activity groups per crop.
4. Apply **Group 7 and 11** fungicides preventatively.
5. Use a maximum of one **Group 11** containing spray out of every three fungicide applications.
6. **Do not** use consecutive applications of **Group 11** or **Group U6** fungicides.
7. **Do not** apply more than two **Group 11** (including **11+7**) or **Group U6** products per crop.
8. **Do not** apply more than three **Group 7** or **Group 13** products per crop and no more than two consecutive applications per year.
9. SDHI guideline — use SDHI fungicides as per label instructions and as protectants only.

Max recommended:	**Total no. of spray applications per crop**												
	1	**2**	3	4	5	6	7	8	9	10	11	12	>12
Alone SDHI fungicide sprays (apply in strict alternation)	1	1	1	1	2	2	2	3	3	3	3	4	*
SDHI fungicide sprays in mixture (apply a max. of 2 consecutive applications)	1	1	1	2	2	3	3	3	3	3	4	4	*

* When more than 12 fungicide applications are made, observe the following guidelines:

1. When using an SDHI fungicide alone, the number of applications should be no more than one-third (one in every three sprays) of the total number of fungicide applications per season.
2. If used along, apply SDHI fungicides in strict alternation with fungicides from a different cross-resistance group.
3. For programs in which tank mixes or pre-mixes of SDHI fungicides are utilised, the number of SDHI-containing applications should be no more than half (50 per cent) of the total number of fungicide applications per season.
4. If used in mixture, apply SDHI fungicides in a maximum of two consecutive applications.
5. In programs where SDHIs are made with both alone and in mixtures, the number of SDHI-containing applications should be no more than half (50 per cent) of the total number of fungicides applied per season.

Crop(s): **Grape**

Disease(s): Grey mould (*Botrytis* bunch rot)

RMS for:

- **Group 2** Dicarmoximides
- **Group 7** Succinate dehydrogenase inhibitors (SDHI)
- **Group 7+3** SDHI + Demethylation inhibitors (DMI)
- **Group 7+12** SDHI +Phenylpyrroles (PP)
- **Group 9** Anilinopyrimidines (AP)
- **Group 9+12** AP + PP
- **Group 11** Quinone outside inhibitors (QoI)
- **Group 11+3** QoI + DMI
- **Group 17** Keto reductase inhibitors (KRI)

1. Always use an integrated disease management approach to grey mould management in vines. Manipulate the bunch zone microclimate to reduce humidity and enable rapid drying of wet bunches. Always aim to reduce spore load, flower and fruit infection and limit regrowth of latent infections and disease spread by timely fungicide application in an IDM approach. Use registered fungicides at label rates from as many different MoA groups as possible when needed.
2. Apply all these fungicides as protectants before the first sign of disease.
3. Consecutive applications include from the end of one season to the start of the next.
4. Varying the number of fungicides applied targeting *Botrytis* changes the relative resistance risk to any one fungicide group. When three or fewer sprays are applied, it is recommended that three different groups of fungicides are used (see table below). When four sprays are applied, try to use three or four different groups of fungicide.

		Recommended max. no. of sprays containing Group:					
		2	**7** (incl. 7+3, 7+12)	**9** (incl. 9+12)	**11** (incl. 11+3)	**12** (incl. 7+12, 9+12)	**17**
Total no. of *Botrytis* targeting sprays	**1**	1	1	1	1	1	1
	2	1	1	1	1	2	1
	3	1	1	1	1	2	1
	4	2	1	2	2	2	2
	5+	2	2	2	2	2	2

5. If a **Group 11** or **7** fungicide is used solo, it should only be used in strict alternation with fungicides from a different MoA group.
6. **Do not** apply more than two consecutive sprays from the same fungicide group, for any **Group 2**, **7**, **9** (including combinations with **Group 12**) **11+3** or **17** fungicide, including from the end of one season to the start of the following season.
7. If two consecutive applications of **Group 11+3** 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** (including combinations with **Group 3**) fungicide is used again, either in the current or following season.
8. If resistance to a fungicide group has been detected within a region, only use that fungicide group in mixtures or in strict alternation with fungicides from a different cross resistance group. A fungicide group that has been applied as the final application of the season should not be the first fungicide in the following season.
9. No specific resistance management strategy has been developed for low-risk fungicides, including those in Group M and BM. These products should be included in a management strategy as per label recommendations.

Crop(s): **Grape**

Disease(s): Downy mildew

RMS for:

- **Group 4** Phenylamides (PA)
- **Group 11** Quinone outside inhibitors (QoI)
- **Group 21** Quinone inside inhibitors (QiI)
- **Group 40** Carboxylic acid amides (CAA)
- **Group 45** Quinone outside inhibitors, stigmatellin binding type fungicides (QoSI)
- **Group 45+50** QoSI + CAA
- **Group 49** Oxysterol binding protein homologue inhibitors (OSBPI)

1. Apply all these fungicides preventatively. **Group 4** fungicides should be applied before the first sign of oilspots or as soon as possible after an infection period.
2. **Group 49** fungicides should be applied prior to infection and only in mixtures with effective fungicides applied at an effective rate from a different cross resistance group. The mixing partner should give effective control of downy mildew at the rate and interval selected. Only apply **Group 49** for a maximum of one in every three sprays of the total number of downy mildew sprays, and no more than two applications per season.
3. Mixtures are defined as co-formulations or tank mixes with label rate of alternative MoA.
4. Apply a maximum of two consecutive applications of any one group.
5. Start preventative disease control sprays using **non-Group 4** protectant fungicides, typically when shoots are 10–20cm long. Continue spraying at intervals of 7–21 days depending on disease pressure, label directions and rate of vine growth.
6. Limit the use of **Group 4** fungicides to periods when conditions favour disease development. Always apply **Group 4** fungicides in mixtures.
7. **Do not** apply **Group 11** consecutively when applying alone.
8. Apply a maximum of two sprays per season per **Group 11** (including mixtures) **Group 45+50** and **Group 49**.
9. Do not apply a spray containing **Group 40** as the last spray of the season.
10. Only apply a spray containing **Group 40** a maximum of 50 per cent of the total number of downy mildew sprays.

	Group					
	4	11	21+M1	40, 45+40 40+M3	45+40	49
Max. no. of consecutive applications	2	None	2	2	2	2
Max. no. of solo applications	None	2	3	2 (50%)	None	None
Max. no. of spray per season	4-mix	2	3	4-mix (50%)*	2	2-mix
Areas of higher agronomic risk	Mix	Mix	N/a	Mix	N/a	mix

* Refer to point 10.

Crop(s): **Grape**

Disease(s): Powdery mildew

RMS for:

- **Group 3** Demethylation inhibitors (DMI)
- **Group 5** Amines (morpholines)
- **Group 7** Succinate dehydrogenase inhibitors (SDHI)
- **Group 7 + 3** SDHI + DMI
- **Group 7 + 12** SDHI + phenylpyrroles (PP)
- **Group 11** Quinone outside inhibitors (QoI)
- **Group 11 + 3** QoI and DMI
- **Group 13** Aza-napthalenes
- **Group U6** Phenyl-acetamide
- **Group 50** Actin disruptors (aryl-phenyl-ketones)

1. Apply all these fungicides preventatively.
2. Consecutive applications include from the end of one season to the start of the next. Medium to high risk fungicides (**Group 7** and **11**) if used consecutively should be applied in a mixture or co-formulation with a registered, alternative MoA for which resistance is not known — where these fungicides have been routinely used for many seasons, field research indicates there is an increased risk of powdery mildew resistance. To ensure effective powdery mildew control in these circumstances, either use alternative MoAs or apply in mixutures.
3. Do not apply more than two consecutive sprays of **Group 3**, **5**, **13**, **50** and **U6**.

	Recommended max. no. of sprays containing Group:						
	3	**5**	**7** (incl. 7 + 3, 7 + 12)	**11** (incl. 11 + 3)	**13**	**50**	**U6**
Total no. of powdery mildew targeting sprays **1**	1	1	1	1	1	1	1
2	1	1	1	1	2	1	1
3	2	2	1	2	2	1	1
4	2	2	1	2	2	2	2
5	2	2	1	2	2	2	2
6	3	3	2	2	3	3	2
7	3	3	2	2	3	3	2
8	3	3	2	2	3	3	2
9+	3	3	3	2	3	3	2

Crop(s): **Lettuce**

Disease(s): Botrytis & Sclerotinia

RMS for:

- **Group 2** Dicarboximides
- **Group 7** Succinate dehydrogenase inhibitors (SDHI)
- **Group 7+11** SDHI + Quinone outside inhibitors (QoI)
- **Group 7+12** SDHI + Phenylpyrroles (PP)
- **Group 9** Anilinopyrimidines (AP)
- **Group 11** QoI
- **Group 9 + 12** AP + PP

1. Maintain a cover with protectant fungicide sprays at seven to ten day intervals from planting.
2. **Do not** apply **Group 2** fungicides more than four times per season, irrespective of the target disease.
3. **Do not** apply more than two fungicides containing **Group 9** per crop (including **Group 9+12**).
4. **Do not** apply more than three **Group 7** or **Group 11** containing fungicides per crop and no more than two consecutive sprays per crop. If a **Group 7** or **11** fungicide has been used solo it should be in strict alternation with other MoAs. If used in a mixture, no more than two consecutive sprays per crop. This includes the treatment at the end of one crop and the start of the next as consecutive.
5. **Group 7** containing sprays should not make up more than one in every three of the spray program.
6. **Do not** apply more than two consecutive applications of a **Group 12** containing fungicide.
7. No specific resistance management strategy has been developed for low-risk fungicides, including those in **Group M** and **BM**. These products should be included in a management strategy as per label recommendations.

	Recommended max. no. of sprays containing Group:				
	2	**7** (incl. 7 + 11)	**9** (incl. 9 + 12)	**11** (incl. 11 + 7)	**12** (incl. 12 + 7)
Total no. of botrytis & sclerotinia targeting sprays **1**	1	1	1	1	1
2	1	1	1	1	2
3	1	1	1	1	2
4	2	1	2	2	2
5	2	1	2	2	2
6	2	2	2	2	2

Crop(s): **Lettuce**

Disease(s): Downy mildew

RMS for:

- **Group 4** Phenylamides (PA)
- **Group 28+43** Carbamates + benzamides
- **Group 40** Carboxylic acid amides (CAA)
- **Group 45 + 40** Quinone outside inhibitors, stigmatellin binding type (QoSI) + CAA
- **Group 49** Oxysterol binding protein inhibitors (OSBPI)
- **Group 49+11** OSBPI + Quinone outside inhibitors (QoI)

1. Applications made within the nursery count towards the total number of applications allowed per crop. It is recommended that disease control is started early and maintain a regular program using a fungicide from groups other than **Group 4**, **40**, **45+40**, **49** (or **49+11**) or **28+43**.
2. When conditions favour disease development, **do not** wait for disease to appear, but apply two consecutive sprays of a **Group 4**, **40**, **49**, **49+11** or **28+43** product at the interval recommended on the label. Then resume the program of sprays using an alternative fungicide group to what was just applied.
3. **Do not** apply more than four sprays of a **Group 4** or **40** product per season.
4. **Do not** apply more than four sprays of a **Group 45+40** product per crop.
5. Apply **Group 45+40** fungicides preventatively.
6. **Group 49** including **Group 49+11** fungicides should only consist of a maximum of one in every three of the total fungicide sprays per season targeting downy mildew. **Do not** apply more than three sprays of a **Group 49** containing product including **Group 49+11** sprays. **Group 49+11** sprays count as both a **Group 49** and a **Group 11** spray.
7. **Do not** apply more than three sprays of a **Group 28+43** product per crop.
8. Apply **Group 4** and **49** (or **49+11**) fungicides preventatively and only in mixtures or co-formulations with a registered fungicide from a different MoA group, with no known resistance.
9. Continue alternation of fungicide MoAs between successive crops. **Do not** make more than six total applications of a **Group 49** product per year on the same area targeting the same disease.

Crop(s): **Macadamia**

Disease(s): Husk spot

RMS for:

- **Group 1** Methyl benzimidazole carbamates (MBC)
- **Group 3** Demethylation inhibitors (DMI)
- **Group 7** Succinate dehydrogenase inhibitors (SDHI)
- **Group 11** Quinone outside inhibitors (QoI)
- **Group 7+11** SDHI + QoI

		Recommended max. no. of sprays containing Group:				
		1	**3**	**7**	**7+11**	**11** (incl. 7+11)
Total no. of husk spot targeting sprays	**1**	1	1	1	1	1
	2	2	2	1	1	1
	3	2	2	1	1	1
	4	2	2	1	2	2
	5	2	2	1	2	2
	6	3	3	2	3	3
	6+	3	3	2	3	3

Guidelines

1. Do not apply consecutive sprays of products containing **Group 7** or **11**. Consecutive sprays icnlude mixtures containing **Group 7** or **11**.
2. If applying **Group 1** or **3** fungicides, **do not** apply more than two consecutive sprays (including from one season to the next) of fungicides from the same group before changing to another group. This applies for fungicides sprayed alone or in tank mix with another MoA.
3. When mixtures are used for **Group 7** resistance management, applied as tank mix or as a co-formulated mixture, the mixture partner should provide satisfactory disease control when used alone on the target disease and must have a different MoA.
4. When using **Group 7** fungicide alone, the number of applications should be no more than one in every three sprays of the total number of fungicide applications per season.
5. If used alone, apply **Group 7** fungicides in strict alternation with fungicides from a different cross-resistance group.

Crop(s): **Onion**

Disease(s): Downy mildew

RMS for:

- **Group 4** Phenylamides (PA)
- **Group 28+43** Carbamate + benzamides
- **Group 40** Carboxylic acid amides (CAA)
- **Group 45 + 40** Quinone outside inhibitors, stigmatellin binding type (QoSI) + CAA
- **Group 49** Oxysterol binding protein inhibitors (OSBPI)
- **Group 49+11** OSBPI + Quinone outside inhibitors (QoI)

1. Start disease control early and maintain a regular program using a fungicide from groups other than **Group 4**, **40**, **45+40** or **49** (or **49+11**).
2. When conditions favour disease development, **do not** wait for disease to appear, but apply two consecutive sprays of a **Group 4**, **28+43**, **40**, **49** (or **49+11**) product at the interval recommended on the label. Then resume the program of sprays using products from a different MoA group to the **Group 4**, **28+43**, **40**, **49** or **49+11** products just applied.
3. **Do not** apply more than four sprays of a **Group 4** or **40** product per season.
4. **Do not** apply more than three sprays of a **Group 28+43** or **49** (or **49+11**) product per crop. **Group 49** (or **49+11**) containing sprays should not consist of more than one in every three of the total number of fungicide sprays per crop.
5. **Do not** apply more than two sprays of a **Group 45+40** product per season.
6. Apply **Group 4**, **40**, **45+40** and **49** (including **49+11**) fungicides preventatively.
7. Apply **Group 4** and **49** (or **49+11**) fungicides only in mixtures with a registered fungicide from a different MoA group, with no known resistance.
8. Continue alternation of fungicides between successive crops. **Do not** make more than six total applications of a **Group 49** (or **49+11**) product per year on the same area targeting the same disease.
6. For programs in which tank mixes or pre-mixes of **Group 7** fungicides are used, the number of SDHI-containing applications should be no more than half (50 per cent) of the total number of fungicide applications per season.
7. If used in mixtures, apply **Group 7** fungicides in a maximum of two consecutive applications.
8. In programs where **Group 7** fungicides are made with both solo products and mixtures, the number of SDHI-containing applications should be no more than half (50 per cent) of the total number of fungicides applied per season.
9. The spray program should be considered and the strategy applied on a whole-orchard basis.

Crop(s): **Ornamentals**

Disease(s): Grey mould (*Botrytis*)

RMS for:

- **Group 2** Dicarboximide
- **Group 9** Anilinopyrimidine (AP)
- **Group 9+12** AP + phenylpyrroles (PP)
- **Group 11** Quinone outside inhibitors (QoI)
- **Group 11+3** QoI + Demethylation inhibitors (DMI)
- **Group 17** Hydroxyanilide

1. If three or fewer Botrytis fungicide sprays are applied per season, use only one spray containing a **Group 9** fungicide (including **9+12**). If four to six sprays are applied per season, use a maximum of two sprays containing **Group 9** fungicides. If seven or more sprays are applied per season use a maximum of three sprays containing **Group 9** fungicides.
2. **Do not** apply more than two consecutive sprays of a **Group 2**, **9**, **11**, **12** or **17** fungicides.
3. No specific resistance management strategy has been developed for low-risk fungicides, including those in **Group M** and **BM**. These products should be included in a management strategy as per label recommendations.

Crop(s): **Poppies**

Disease(s): Downy mildew

RMS for:

- **Group 4** Phenylamides (PA)
- **Group 11** Quinone outside inhibitors (QoI)
- **Group 28+43** Carbamates + benzamides
- **Group 40** Carboxylic acid amides (CAA)
- **Group 45 + 40** Quinone outside inhibitors, stigmatellin binding type (QoSI) + CAA
- **Group 49** Oxysterol binding protein inhibitors (OSBPI)
- **Group 49+11** OSBPI + QoI

1. Start disease control early and maintain a regular protectant program. Fungicide applications need to start before the six-leaf stage for early season control to be effective.
2. When conditions favour disease development (high humidity, still weather, overcast skies), prior to visible disease symptoms (white downy growth on the underside of lower leaves followed by brown angular lesions) apply a single spray of a **Group 49** fungicide, or up to two consecutive sprays of a **Group 4**, **11**, **40** or **28+43** product (including mixtures containing **Group 4**, **11** or **40**), at the interval recommended on the label. Then resume the program of sprays using products from a different group to the **Group 4**, **11**, **40**, **49** or **28+43** products just applied.
3. **Do not** apply more than two sprays per season of a product containing a **Group 4**, **11**, **40** (including **45+40**) or **49+11** fungicide. **Group 49** containing sprays should not exceed one in every three sprays of the of the total number of fungicide sprays per season.
4. **Do not** apply more than three sprays of a **Group 28+43** product per crop.
5. Apply **Group 11**, **Group 45+40** and **Group 49+11** fungicides preventatively.
6. Apply **Group 4** and **49** fungicides preventatively and only in mixtures with an effective protectant fungicide from a different MoA group.
7. **Do not** use a **Group 49** (or **49+11**) product if it will be the last fungicide applied to the crop.

Crop(s): **Potato**

Disease(s): Target spot (early blight)

RMS for:

- **Group 2** Dicarboximides
- **Group 3** Demethylation inhibitors (DMI)
- **Group 7** Succinate dehydrogenase inhibitors (SDHI)
- **Group 7+3** SDHI + DMI
- **Group 7+12** SDHI + phenylpyrroles (PP)
- **Group 9** Anilinopyrimidine
- **Group 11** Quinone outside inhibitors (QoI)
- **Group 11+3** QoI + DMI

	Recommended max. no. of sprays containing Group:					
		2	**3**	**7** (incl. 7 + 3, 7 + 12)	**9**	**11** (incl. 11 + 3)
Total no. of early blight targeting sprays	**1**	1	1	1	1	1
	2	2	2	1	1	1
	3	2	2	1	1	2
	4	3	3	2	2	2
	5	4	4	2	2	3
	6	4	4	2	2	3
	7	5	5	2	3	3
	8	6	6	2	3	3
	9	6	6	3	3	3
	10	6	6	3	3	3

Guidelines

1. Limit the use of **Group 2**, **3**, **7**, **9** or **11** fungicides to periods when conditions favour disease development. Apply these fungicides preventatively before disease symptoms are visible.
2. **Do not** apply more than six **Group 2** or **3** sprays in one season. Apply no more than two consecutive sprays of a **Group 2** or **3** fungicides.
3. If used solo, apply **Group 7** fungicides in strict alternation with fungicides from a different cross resistance group. If fungicides containing **Group 7** are used in mixture, apply a maximum of two consecutive applications.
4. Apply no more than two consecutive sprays containing a **Group 9** fungicide.
5. Do not apply more than two consecutive **Group 11** sprays per crop. If consecutive applications of **Group 11** containing 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** containing fungicide is used again, either in the current or following season. When using a **Group 11** fungicide in-furrow at planting, use a fungicide from a different group as the first foliar spray.
6. No specific RMS has been developed for low-risk fungicides, including those in **Group M** and **BM**. These products should be included in a management strategy as per label recommendations.

Crop(s): **Pulse crops**

Disease(s): Grey mould (*Botrytis*) and ascochyta

RMS for:

- **Group 1** Methyl benzimidazole carbamates
- **Group 2** Dicarboximides
- **Group 3+11** Demethylation inhibitors (DMI) + Quinone outside inhibitors (QoI)
- **Group 7*** Succinate dehydrogenase inhibitors (SDHI)
- **Group 7+3** SDHI + DMI
- **Group 7 + 12** SDHI + phenylpyrroles (PP)

1. **Do not** apply more than two **Group 1**, **2**, **3+11**, **7+3** or **7+12** sprays in one season (including seed treatment).
2. **Do not** apply more than two consecutive **Group 1**, **2** or **7** sprays, including from season to season and seed treatments. The final foliar spray of the previous season should be considered when planning which fungicide group to use in seed treatments and the first foliar application. **Group 7** containing sprays should not make up more than one in every three of the total of the spray program.
3. If a **Group 7** containing fungicide is used as a seed treatment, the first foliar fungicide used must not contain a **Group 7** fungicide.
4. No specific resistance management strategy has been developed for low-risk fungicides, including those in **Group M** and **BM**. These products should be included in a management strategy as per label recommendations.

* Currently only available under temporary permit. Always check that permits are valid prior to use.

Crop(s): **Stone fruit**

Disease(s): Blossom blight (*Monilinia laxa*) and brown rot (*M. fructicola*)

RMS for:

- **Group 2** Dicarboximides
- **Group 3** Demethylation inhibitors (DMI)
- **Group 7** Succinate dehydrogenase inhibitors (SDHI)
- **Group 7+11** SDHI + Quinone outside inhibitors (QoI)
- **Group 9** Anilinopyrimidines (AP)
- **Group 11** Quinone outside inhibitors (QoI)

1. If applying **Group 2**, **3**, **7**, **11** or **7+11** fungicides, **do not** apply more than two consecutive sprays of fungicides from the same group before changing to another group, this includes the last application made in-field from one season to the next.
2. Do not apply more than three sprays of a **Group 7**, **9**, **11** or **7+11** fungicide per season. Alone, tank mixed or co-formulated all count to total. If **Group 7** applied alone, apply **Group 7** in strict alternation with fungicides from a different cross-resistance group.
3. When mixtures are used for **Group 7** resistance management, applied as tank mix or as a co-formulation mixture, the mixture partner should provide satisfactory disease control when used alone on the target disease and must have a different MoA.
4. Always apply **Group 7** fungicides as per label instructions and use preventatively.
5. If consecutive sprays of fungicides from the same chemical group are applied, they must be followed by at least the same number of sprays from an alternative chemical group, before returning to the original group.

	Group					
	2	3	7	9	11	7+11
Max. no. of consecutive sprays when applied alone	2	2	2	2	2	2
Max. no. of consecutive sprays when applied in mix with a different MoA	2	2	2	2	2	2
Max. no. of sprays per season	3	3	3	3	3	3

6. A post-harvest treatment should also be counted as an application.
7. The last blossom blight spray and the first pre-harvest brown rot spray should be regarded as consecutive applications.
8. The spray program should be considered and the resistance management strategy applied on a whole-orchard basis.
9. No specific resistance management strategy has been developed for low-risk fungicides, including those in **Group M** and **BM**. These products should be included in a management strategy as per label recommendations.

Crop(s): **Strawberry**

Disease(s): Powdery mildew

RMS for:

- **Group 3** Demethylation inhibitors (DMI)
- **Group 7** Succinate dehydrogenase inhibitors (SDHI)
- **Group 7+12** SDHI + phenylpyrroles
- **Group 11** Quinone outside inhibitors (QoI)
- **Group U6** Phenyl-acetamide

1. Apply a program of protectant fungicides from early crop establishment and maintain a regular spray program throughout the crop growing cycle. If weather conditions favour powdery mildew development, use a **Group 3** or **11** fungicide.
2. **Do not** use the same fungicide group as the last application on runner production and the first application to in-field fruit production.
3. **Do not** use **Group 3** fungicides as eradicants (once symptoms are visible).
4. **Do not** apply more than four **Group 3** sprays per season.
5. **Do not** apply more than two consecutive sprays of **Group 3** fungicides, including from one season to the next.
6. If applying **Group 7** fungicides (including **7+12**), **do not** apply more than two consecutive sprays before changing to another group.
7. **Do not** apply more than three **Group 7** sprays per season. If consecutive sprays are used, then use the same number of sprays of an alternative group before using another **Group 7**, including sprays in consecutive seasons.
8. Apply **Group 11** or **U6** fungicides preventively.
9. **Do not** apply consecutive sprays of **Group 11** or **U6** fungicides, including from one season to the next.
10. If three or fewer powdery mildew fungicide sprays are applied per crop, use only one spray containing a **Group 11** fungicide. If four to six sprays are applied per crop, use no more than two sprays containing a **Group 11** fungicide. If seven or more sprays are applied per crop use a maximum of three sprays containing a **Group 11** fungicide. **Do not** apply more than three **Group 11** sprays per season.
11. **Do not** apply more than two **Group U6** sprays per crop.
12. No specific resistance management strategy has been developed for low-risk fungicides, including those in **Group M** and **BM**. These products should be included in a management strategy as per label recommendations.

Crop(s): **Strawberry runner production**

Disease(s): Powdery mildew

RMS for:

- **Group 3** Demethylation inhibitors (DMI)
- **Group 7** Succinate dehydrogenase inhibitors (SDHI)
- **Group 7+12** SDHI + phenylpyrroles (PP)
- **Group 8*** Hydroxy-(2-amino-) pyrimidines
- **Group 11** Quinone outside inhibitor (QoI)
- **Group 13*** Aza-naphthalenes
- **Group U6** Phenyl-acetamide

1. This strategy is for the additional range of compounds available to strawberry runner producers under permit.
2. Apply a program of protectant fungicides from early crop establishment and maintain a regular spray program throughout the crop growing cycle. If weather conditions favour powdery mildew development, use a **Group 3** or **11** fungicide.
3. **Do not** use **Group 3** fungicides as eradicants (once symptoms are visible).
4. **Do not** apply more than four **Group 3** sprays per season.
5. **Do not** apply more than two consecutive sprays of **Group 3** fungicides, including from one season to the next.
6. If applying **Group 7** fungicides (including **7+12**), **do not** apply more than two consecutive sprays before changing to another group.
7. **Do not** apply more than three **Group 7** sprays per season. If consecutive sprays are used, then use the same number of sprays of an alternative group before using another **Group 7**, including sprays in consecutive seasons.
8. Apply **Group 11** and **U6** fungicides preventively.
9. **Do not** apply consecutive sprays of **Group 11** and **U6** fungicides, including from one season to the next.
10. If three or fewer powdery mildew fungicide sprays are applied per crop, use only one spray containing a **Group 11** fungicide. If four to six sprays are applied per crop, use no more than two sprays containing a **Group 11** fungicide. If seven or more sprays are applied per crop use a maximum of three sprays containing a **Group 11** fungicide. Do not apply more than three **Group 11** sprays per season.
11. Fungicides from **Group 8** and **13** are available for use on strawberry runner crops under individual permits from the APVMA.
12. Apply a maximum of two (2) **Group U6** sprays per season.
13. Apply a maximum of four (4) **Group 8** or **13** sprays per season. **Do not** apply more than two consecutive sprays before changing to another group.
14. No specific resistance management strategy has been developed for low-risk fungicides, including those in **Group M** and **BM**. These products should be included in a management strategy as per label recommendations.

* Currently only available under temporary permit. Always check that permits are valid prior to use

Crop(s): **Turf**

Disease(s): Various

RMS for:

- **Group 1** Benzimidazoles
- **Group 2** Dicarboxamides
- **Group 3** Demethylation inhibitors (DMI)
- **Group 4** Phenylamides (PA)
- **Group 7 (N3)** Succinate Dehydrogenase inhibitors (SDHI)
- **Group 7 + 11** SDHI + Quinone outside inhibitors (QoI)
- **Group 11** QoI
- **Group 11 + 2** QoI + dicarboxamides
- **Group 11 + 3** QoI + DMI
- **Group 12** Phenylpyrroles (PP)
- **Group 14** Aromatic hydrocarbons (chlorophenyls and nitroanilines)
- **Group 21** Quinone inside inhibitors (QiI)
- **Group 28** Carbamates
- **Group 33** Phosphonates

1. Fungicide groups that are classified as medium to high risk for fungicide resistance development; **Groups 1**, **2**, **4**, **7 (N3)**, **11** and **21** should be rotated as a key feature to reduce the development of resistance.
2. **Do not** apply consecutive sprays of fungicides from the same activity group, unless mixed with a registered fungicide from a different MoA group with no known resistance.
3. **Group N3** nematicides are also classified as **Group 7** fungicides and consecutive application should be avoided, even if targeting different pests/pathogens.
4. If consecutive sprays are applied of fungicides from a high risk fungicide group (i.e. **Group 1**, **2**, **4**, **7**, **11** or **21**) they must be followed by at least the same number of applications of fungicide(s) from a different group(s) before the same high risk fungicide is used again.

Crop(s): **Wheat**

Disease(s): Septoria blotch

RMS for:

- **Group 3** Demethylation inhibitors (DMI)
- **Group 7** Succinate dehydrogenase inhibitors (SDHI)
- **Group 3 + 7** DMI + SDHI
- **Group 11+3** Quinone outside inhibitors (QoI) + DMI

1. Fungicides should be used as protectant treatments — prior to symptoms of disease when conditions are conducive to disease development.
2. In high-risk disease environments, integrated management approaches should be used to reduce fungicide resistance risk, which may include:
   - **a)** removal or burning of stubble
   - **b)** crop rotation (**avoid** wheat on wheat)
   - **c)** control of green bridge volunteers
   - **d)** use of tolerant and resistant varieties.
3. **Do not** apply more than one application of a **Group 7** seed treatment with foliar activity in any two consecutive growing seasons.
4. **Do not** apply more than two applications per growing season of **Group 11** or **7** containing products. Foliar sprays and in-furrow or seed treatments that have activity on foliar diseases, count toward total. Combinations of in-furrow and seed treatment are counted as one application.
5. If a **Group 7** seed treatment has been used with foliar activity (as determined by label claims), the first foliar fungicide applied must not contain a **Group 7** fungicide.
6. If a **Group 7** or **11** fungicide is being applied as a foliar spray, it must be in a co-formulation or in mixture with a registered mixing partner with a different MoA, with no known resistance. The mixture partner should also provide satisfactory disease control when used alone on the target disease.
7. **Do not** apply more than three applications containing **Group 3** fungicides per growing season. This total of three applications includes DMIs applied as **Group 11+3** co-formulations and in-furrow or seed treatments that have activity on foliar diseases. Combinations of in-furrow and seed treatments are counted as one application.
8. Minimise use of **Group 3** fungicides which are known to have compromised resistance status.
9. Reduced rates, including multiple applications, must not be used. Always use labelled rates.

Crop(s): **Wheat**

Disease(s): Yellow spot, powdery mildew

RMS for:

- **Group 3** Demethylation inhibitors (DMI)
- **Group 7** Succinate dehydrogenase inhibitors (SDHI)
- **Group 7+3** SDHI + DMI
- **Group 11+3** Quinone outside inhibitors (QoI) + DMI
- **Group 11+4** QoI + phenylamides (PA)
- **Group 11+7+3** QoI + SDHI + DMI.

1. Fungicides should be used as protectant treatments prior to symptoms of disease when conditions are conducive to disease development.
2. In high-risk disease environments, integrated management approaches should be used to reduce fungicide resistance risk, which may include:
   - **a)** removel or burning of stubble
   - **b)** crop rotation (**avoid** wheat on wheat)
   - **c)** control of green bridge volunteers
   - **d)** use of tolerant and resistant varieties.
3. **Do not** apply more than two applications per growing season of **Group 11** or **7** containing products. This includes in-furrow or seed treatments that have activity on foliar diseases. Combinations of in-furrow and seed treatment are counted as one application.
4. **Do not** apply consecutive applications of **Group 11** containing products. This includes in-furrow i.e. if a **Group 11+4** fungicide has been used in-furrow at planting, the first foliar fungicide spray must not contain a **Group 11** fungicide.
5. If a **Group 7** seed treatment has been used with foliar activity (as determined by label claims), the first foliar fungicide applied should not contain a **Group 7** fungicide.
6. **Do not** apply more than one application of a **Group 7** seed treatment with foliar activity in any two consecutive growing seasons.
7. If a **Group 7** or **11** fungicide is being applied as a foliar spray, it must be in a co-formulation or in mixture with a registered mixing partner with a different MoA, with no known resistance. The mixture partner should also provide satisfactory disease control when used alone on the target.
8. **Do not** apply more than three applications containing **Group 3** fungicides per growing season. This total of three applications includes DMIs applied as **Group 11+3** or **Group 11+7+3** co-formulations and in-furrow or seed treatments that have activity on foliar diseases. Combinations of in furrow and seed treatment are counted as one application.
9. Minimise use of **Group 3** fungicides which are known to have compromised resistance status.
10. Reduced rates, including multiple applications, must not be used. Always use labelled rates.

Fungicide activity group table

FRAC code	Fungicide MoA group	Chemical family	Active constituent	**Trade name** (product name)
1	MBC — fungicides (methyl benzimidazole carbamates)	benzimidazoles	carbendazim	various
			thiabendazole	Various e.g. Tecto®
		thiophanates	thiophanate-methyl	various e.g. Banrot®
2	Dicarboximide	dicarboximides	iprodione	various e.g. Rovral®
			procymidone	various e.g. Sumisclex®
3	DMI fungicides (demethylation inhibitors) (SBI: Class 1)	imidazoles	imazalil	various e.g. Fungaflor
			prochloraz	various e.g. Octave®
		piperazine	triforine	various e.g. Saprol®
		triazoles	bitertanol	various e.g. Baycor®
			cyproconazole	various e.g. Alto®
			difenoconazole	various e.g. Score®
			epoxiconazole	various e.g. Opus®
			fluquinconazole	various e.g. Jockey®
			flusilazole	various e.g. Nustar®
			flutriafol	various e.g. Armour®
			hexaconazole	various
			ipconazole	Rancona®
			mefentrifluconazole	Belanty®
			myclobutanil	various e.g. Systhane®
			penconazole	various e.g. Topas®
			propiconazole	various e.g. Tilt®
			tebuconazole	various e.g. Folicur®, Raxil®
			tetraconazole	Domark®
			triadimefon	various e.g. Bayleton®
			triadimenol	various e.g. Bayfidan®, Baytan®
			triticonazole	various e.g. Premis®
		triazolinthiones	prothioconazole	various e.g. Prosaro®
4	PA — fungicides (phenylamides)	acylalanines	benalaxyl (+ mancozeb)	Galben®M
			furalaxyl	various e.g. Fongarid®
			metalaxyl	various e.g. Apron®, Ridomil®
			metalaxyl-M (=mefenoxam)	various e.g. Ridomil® Gold, Apron XL®
		oxazolidinone	oxadixyl (+propineb)	Rebound®
5	Amines (morpholines) (SBI: Class II)	spiroketalamine	spiroxamine	various e.g. Prosper®

FRAC code	Fungicide MoA group	Chemical family	Active constituent	**Trade name** (product name)
7	SDHI (succinate dehydrogenase inhibitors)	n-methoxy-(phenyl- ethyl)-pyrazole-carbox amide	pydiflumetofen	Miravis®, Saltro®
		oxathiin carboxamides	carboxin	various e.g. Vitavax®,
			oxycarboxin	Plantvax®
		phenyl benzamides	flutolanil	Monstar®, Moncut®
		Phenyl-oxo-ethyl thiophene amide	isofetamid	Kenja®
		pyridine carboxamides	boscalid	various e.g. Filan®
		pyrazole -4-carboxamide	bixafen	Aviator® Xpro®
			benzovindiflupyr	Elatus®
			fluxapyroxad	Merivon®, Sercadis®, Systiva®
			isopyrazam	Seguris®
			penflufen	EverGol® Prime
			penthiopyrad	Fontelis®
			sedaxane	Vibrance®
		pyridinyl-ethyl- benzamides	fluopyram	Ilevo®, Luna®
8	Hydroxy-(2-amino-) pyrimidine	hydroxy-(2-amino-) pyrimidine	bupirimate	Nimrod®
9	AP fungicides (anilinopyrimidines)	anilinopyrimidine	cyprodinil	various e.g. Chorus®
			pyrimethanil	various e.g. Scala®
11	QoI fungicides (quinone outside Inhibitors)	methoxy acrylate	azoxystrobin	various e.g. Amistar®, Dynasty®
		oximino acetates	kresoxim-methyl	various e.g. Stroby®
			trifloxystrobin	various e.g. Flint®
		methoxy carbamate	pyraclostrobin	various e.g. Cabrio®
		methoxy-acetamide	mandestrobin	Intuity®
12	PP-fungicides (Phenylpyrroles)	phenylpyrroles	fludioxonil	various e.g. Maxim®
13	Aza-naphthalenes	aryloxyquinolines	quinoxyfen	Legend®
		quinazolinone	proquinazid	Talendo®
14	AH fungicides (aromatic hydrocarbons) (chlorophenyls, nitroanilines)	aromatic hydrocarbons	quintozene (PCNP)	various e.g. Terraclor®
			tolclofos-methyl	various e.g Rizolex®
	Heteroaromatics	1,2,4-thiadiazole	etridiazole	various e.g. Terrazole®
17	KRI fungicides (keto reductase inhibitors) (SBI: Class III)	hydroxyanilide	fenhexamid	various e.g. Teldor®
		amino-pyrazolinone	fenpyrazamine	Prolectus®
19	Polyoxins	Peptidyl pyrimidine nucleoside	Polyoxin D	Intervene ®
20	Phenylureas	phenylureas	pencycuron	Monceren®
21	QiI fungicides (quinone inside inhibitors)	cyano-imidazole	cyazofamid	RanMan®
		sulfamoyl-triazole	amisulbrom	Amicus blue®
28	Carbamates	carbamate	iodocarb	various
			propamocarb	various e.g. Previcur®
29	Uncouplers of oxidative phosphorylation	2,6-dinitro-anilines	fluazinam	various e.g. Shirlan®
40	CAA fungicides (carboxylic acid amides)	cinnamic acid amides	dimethomorph	various e.g. Acrobat®
		malic acid amides	mandipropamid	Revus®
43	Benzamides	pyridinylmethyl- benzamides	fluopicolide	Infinito®
45	QoSI fungicides (quinone outside inhibitor, stigmatellin binding type)	triazolo-pyrimidylamine	ametoctradin	Zampro®
46	Plant extract	terpene hydrocarbons, terpene alcohols and terpene phenols	Extract from *Melaleuca alternifolia* (tea tree) plant oils (mixtures): eugenol, geraniol, thymol	Timorex® Gold: Novellus Fungicide®

FRAC code	Fungicide MoA group	Chemical family	Active constituent	Trade name (product name)
49	OSBPI oxysterol binding protein homologue inhibition	piperidinyl-thiazole- isoxazolines	oxathiapiprolin	Orondis®, Zorvec® Enicade®
50	Actin disruption (aryl-phenyl-ketones)	benzophenone	metrafenone	Vivando®
		benzoylpyridine	pyriofenone	Kusabi®
M	Multi-site activity	inorganic	chlorine dioxide	Vibrex®
			hydrogen peroxide + peroxyacetic acid	various e.g. Peratec®
			iodine	various
			mercury	Shirtan®
			sodium metabisulphite	Osku-vid®
		hydroxyquinoline	8-hydroxyquinoline	Staehler Grafting Wax
M1	Multi-site activity inorganic (electrophiles)	inorganic	copper cuprous oxide	various
			copper hydroxide	various e.g. Kocide®
			copper oxychloride	various e.g. Oxydul®
			copper ammonium acetate	various e.g. Liquicop®
			tribasic copper sulphate	various e.g. Tri-base Blue®
			copper octanoate	Tricop®
M2	Multi-site activity inorganic (electrophiles)	inorganic	sulphur	various e.g. Thiovit®, Kumulus®
			potassium bicarbonate	various e.g. Ecocarb®
			calcium polysulfide	Miller Lime Sulfur Solution Fungicide Insecticide®
M3	Multi-site activity dithiocarbamate and relatives (electrophiles)	dithiocarbamate and relatives	mancozeb	various e.g. Dithane® Rainshield® Neo Tec® Fungicide®
			metiram	Polyram®
			thiram	various e.g. Thiram®
			propineb	various e.g. Antracol®
			zineb	Zineb®
			ziram	various e.g. Ziram®
M4	Multi-site activity phthalimides (electrophiles)	phthalimide	captan	various e.g. Captan®
M5	Multi-site activity chloronitriles (phthalonitriles) (unspecified mechanism)	chloronitriles (phthalonitriles)	chlorothalonil	various e.g. Bravo®
M6	Multi-site activity sulfamides (electrophiles)	sulfamide	tolylfluanid	Euparen Multi®
M7	Multi-site activity bis-guanidine (membrane disruptors, detergents)	bis-guanidine	guazatine	various e.g. Panoctine®
M9	Multi-site activity quinones (anthraquinones) (electrophiles)	quinone (anthraquinone)	dithianon	various e.g. Delan®
BM01	Multi-site activity plant extract	polypeptide (lectin)	extract from the cotyledons of lupine plantlets ('BLAD')	ProBlad Plus fungicide®

FRAC code	Fungicide MoA group	Chemical family	Active constituent	Trade name (product name)
BM02	Multi-site activity microbial (living microbes or extract, metabolites)	*streptomyces* sp.	*Streptomyces lydicus* strain WYEC108	Actinovate®
		Bacillus spp.	*B.acillus amyloliquefaciens** strain QST 713 *synonyms for *Bacillus amyloliquefaciens* are *Bacillus subtilis* and *B. subtilis var. amyloliquefaciens* (previous taxonomic classification)	Serenade®
			*B.acillus amyloliquefaciens** strain MBI600	Serifel®
		Trichoderma spp.	*Trichoderma harzianum* strain AG1, AG2, AG3, AG5, AG8, AG11 & AG15	VineVax®
			Trichoderma harzianum rifae isolate T-39	Trichodex® Bio-Fungicide
P01	Benzothiadiazole	Benzothiadiazole	Acibenzolar-S-methyl	Bion®
P03	Host plant defence inducer via systemic acquired resistance		isotianil	Routine® 200SC
P07 (33)	Phosphonates	ethyl phosphonate	fosetyl-Al	various e.g. Aliette®
U1	Unknown	potassium salts of fatty acids	potassium salts of fatty acids	EcoProtector®
U6	Unknown phenyl-acetamide	phenyl-acetamide	cyflufenamid	Flute®
U12	Cell membrane disruption (proposed) guanidines	guanidines	dodine	Syllit®

Notes

1. The table does not include active constituents that have not yet been assigned an activity group by CropLife Australia.
2. Products with the same active constituent but different use patterns are also included in the table for example, seed treatments and foliar.
3. New active constituents and products can only be included in the activity group table once they are formally registered by the APVMA for commercial use.
4. Some products are mixtures of fungicides from different activity groups. These appear only once in the table.
5. If multiple trade names exist, the trade name entry is listed as various and the first registered trade name included.
6. ® Registered trademark

Part 3 Herbicide resistance management strategies

DEVELOPED BY THE CROPLIFE AUSTRALIA EXPERT COMMITTEE ON HERBICIDE RESISTANCE (ECHR) — VALID AS AT 30 JUNE 2022

Disclaimer

This strategy is a guide only and does not endorse particular products, groups of products or cultural methods in terms of their performance. Always follow the product label for specific use instructions. While all effort has been made with the information supplied in this document, no responsibility, actual or implied, is taken for the day-to-day accuracy of product or active constituent specific information. Readers should check with the Australian Pesticides and Veterinary Medicines Authority's product database for contemporary information on products and actives. The database can be sourced through www.apvma.gov.au. The information given in this strategy is provided in good faith and without any liability for loss or damage suffered as a result of its applicationand use. Advice given in this strategy is valid as at 30 June 2022. All previous versions of this strategy are now invalid.

Herbicide resistance

Herbicides have proven to be the most efficient and cost-effective methods of weed control in farming systems. Their use has enabled farmers to practice large scale conservation agriculture which has delivered substantial productivity gains.

Whilst the use of herbicides has been rewarding to farmers, the selection of resistant weed populations to the products that would otherwise control them is a challenge for the longer-term sustainability of modern agriculture.

In spite of this, no herbicides have been lost to agriculture as a result of herbicide resistance; they are today, and will remain, an integral part of food production through their effective use in combination with other weed control practices (HRAC 2018).

Evolution of herbicide resistance

Herbicide resistance evolves following the intensive use of herbicides for weed control. In any weed population there are likely to be a small number of individuals that are naturally resistant to herbicides due to genetic diversity, even before the herbicides are used. When a herbicide is used, these individuals survive and set seed whereas the majority of susceptible plants are killed. Continued use of a herbicide or herbicide group will eventually result in a significant fraction of the weed population with resistance.

There are four main factors that influence the evolution of resistance. These are:

- **The intensity of selection pressure:** this refers to how many weeds are killed by the herbicide. It is good practice to use robust labelled rates of herbicides to control weeds, as this will lead to the highest and most consistent levels of weed control. Failure to control weeds adequately will lead to increases in weed populations and put pressure on all herbicides used.
- **The frequency of use of a herbicide or MoA group:** for most weeds and herbicides, the number of years of herbicide use is a good measure of selection intensity. The more often a herbicide is applied the higher the selection pressure and the higher the risk of herbicide resistance developing.
- **The frequency of resistance present in untreated populations:** if the frequency of resistant genes in a population is relatively high, such as with Group 2 herbicides, resistance will occur quickly. If the frequency is low, such as with Group 9 herbicides, resistance will occur more slowly.
- **The biology and density of the weed:** weed species that produce large numbers of seed and have a short seed bank life in the soil will evolve resistance faster than weed species with long seed bank lives. Weed species with greater genetic diversity are more likely to evolve resistance. Resistance is also more likely to be detected in larger weed populations.

Definitions of resistance

- **Weed Resistance:** resistance is the naturally occurring inheritable ability of some weed biotypes within a given weed population to survive a herbicide treatment that would, under normal use conditions, effectively control that weed population. Selection of resistant biotypes may result in control failures (HRAC 2018).
- **Cross Resistance:** cross resistance exists when a weed population is resistant to two or more herbicide MoAs. The presence of such a mechanism can complicate the selection of alternate herbicides as tools to control a resistance situation. It is for this reason that integrated weed management strategies must be adopted.
- **Resistance Mechanisms:** the resistance mechanism refers to the method by which a resistant plant overcomes the effect of a herbicide. Broadly there are two main mechanisms of resistance including target site mechanisms and non-target site mechanisms. Target site mechanisms involve a change to the protein that binds the herbicide resulting in a lack of inhibition of the biochemical pathway. Non-target site resistance mechanisms allow plants to survive application of the herbicide by not allowing sufficient herbicide to reach the target site (Preston 2014).
- **Herbicide MoA:** refers to the biochemical mechanism by which a herbicide causes growth to cease in target weeds. Herbicides can be classified into groups according to their mode of activity within the plant (HRAC 2018).

Background to herbicide resistance globally and in Australia

Globally, the first case of herbicide resistance in weeds was identified in 1964. Currently, there are more than 250 grass and broadleaf weed species with herbicide resistance in more than 70 countries worldwide (Heap 2018).

Herbicide resistance has developed a strong foothold in Australian agriculture since it was first reported in annual ryegrass in 1982. It has spread and diversified to become a key constraint to crop production in all states generally with a history of intensive herbicide use.

Mode of Action

Current impact on weed management in Australia

Today, resistance has been confirmed in a range of grass and broadleaf weed species (refer to the **List of Herbicide Resistant Weeds document**). More worrying still, resistance has now developed to 14 distinctly different herbicide MoA groups. This significantly reduces herbicide options for the grower. Cases of multiple resistance have also been commonly reported where, for example, annual ryegrass proves resistant to multiple MoAs.

Action by industry and researchers

CropLife Australia, with support from the CRC for Australian Weed Management and the Grains Research and Development Corporation (GRDC), introduced a classification system for herbicides enabling farmers and advisers to understand the MoA grouping. It is mandatory for all herbicide product labels in Australia to carry the designated MoA group (previously a letter code and as of July 2021 a number code) in a prominent position. Herbicide MoA groups are important to consider when making herbicide use decisions, however, resistance management strategies require continual implementation.

Mode of Action matters!

The main reason resistance has developed is because of the repeated and often uninterrupted use of herbicides with the same MoA. Selection of resistant strains can occur in as little as three to four years if no attention is paid to resistance management. Remember that the resistance risk is the same for products having the same MoA. If you continue to use herbicides with the same MoA and do not follow a resistance management strategy you are creating future problems for yourself. Mode of action matters.

MoA labelling in Australia

In order to facilitate management of herbicide resistant weeds, all herbicides sold in Australia are grouped by MoA. The MoA is indicated previously by a letter code and as of July 2021 transitioning to a number code on the product label. Australia was the first country to introduce compulsory herbicide MoA labelling on product labels. Since the introduction of herbicide MoA labelling in Australia, other countries have adopted their own herbicide MoA classification systems, and this became problematic if cross-referencing herbicide MoA between Australia and other countries, as many other countries used a different classification system.

The initial herbicide MoA grouping and labelling system in Australia was revised in 2007. That represented the first major revision of the classification system since its introduction. The original groupings were made based on limited knowledge about MoAs. Groupings were changed to improve the accuracy and completeness of the MoAs to ultimately enable more informed decisions be made about herbicide rotation and resistance management. The general intent of groups based on their risk did not change, however, six additional herbicide MoA groups were created to more accurately group herbicides.

In 2020 the global Herbicide Resistance Action Committee (HRAC global) recommended that all countries adopt one globally aligned herbicide MoA classification system.

The reason for the changes included:

- Farming is increasingly global and it's important to have herbicide MoA alignment globally.
- A letter-based system has minimal scope for new MoA expansion; numerals are infinite.
- Fungicide and insecticide MoA classification systems are already utilising numbers.
- A revision was needed to more accurately reflect MoA groupings based on the current knowledge.

Australia adopted the new globally aligned herbicide MoA classification system in February 2021. As of July 2021, changes will be made to herbicide labels reflecting the new number-based system rather than letters. There are also some herbicides that change MoA groups or subgroups based on the latest knowledge about how products work. Five new MoAs groups have been created to cater for new products or to split current MoAs into more defined groups. A three year transition period in Australia will occur where labels and literature will be updated to the new system.

Herbicides are grouped by MoA and ranked by resistance risk

Herbicide users and advisors are well equipped to understand the huge array of herbicide products in the marketplace in terms of MoA grouping and resistance risk by reference to the MoA chart. All herbicide labels carry the MoA group clearly displayed such as:

GROUP	**1**	**HERBICIDE**

Know your herbicide groups to make use of this!

Not all MoA groups carry the same risk for resistance development, therefore specific guidelines for Groups 6, 18, 19, 23, 24, 29, 30, 31 and 32 have not been developed to date because there are no recorded cases of weeds resistant to members of these groups in Australia.

Products represented in Group 1 and Group 2 are **HIGH RESISTANCE RISK** herbicides and specific guidelines are written for use of these products.

Specific guidelines are also included for the **MODERATE RESISTANCE RISK** herbicides, Groups 3, 4, 5, 9, 10, 12, 13, 14, 15, 22, 27 and 34 herbicides.

Integrated Weed Management strategies

Strategies are designed to minimise the development of resistance by adopting Integrated Weed Management (IWM) strategies. Do not rely on a single strategy to keep resistance at bay but integrate them into the crop production program. Some of the key strategies are:

- Rotation of herbicide MoA groups within and across years (refer to specific guidelines for each herbicide MoA group).
- Apply two or more different herbicide MoAs on a particular weed. For example:
  - Tank mix two or more compatible herbicides with different MoAs which are all effective on the target weed and recommended on the product labels. Apply each herbicide at full label rates.
  - Use herbicides which already contain two or more actives with different MoA which are all effective on the target weed.
  - 'Double-knock' where two herbicides with different MoAs are applied to the target weed in sequential applications.
- Keeping accurate records of your herbicide applications on a paddock basis.
- Reading the herbicide product label and literature carefully and follow the instructions.
- Always using robust label rates to ensure maximum weed control.
- Rotation of crop and variety.
- Identification and monitoring your surviving weed populations (keep good records of weed populations).
- If a weed control failure is suspected do not use the same product or product from the same MoA group.
- Testing — confirm resistance status.
- Additional cultural weed control techniques to reduce seed banks, e.g. burning, cultivation, varied sowing, competitive crops and varieties, green manuring, grazing and collection and/or destruction of weed seed at harvest.
- Control weed escapes before the weeds set and shed viable seed.
- Do not introduce or spread weeds by contaminated seed, grain, livestock, machinery or hay.
- Crop and pasture topping.
- Attend training courses, e.g. GRDC IWM course, ChemCert and field days.
- Additional information can be obtained from:
  - CropLife Australia (**www.croplife.org.au**)
  - Australian Glyphosate Sustainability Working Group (defunct, but archived) **https://webarchive.nla.gov.au/awa/20200113011304/http://pandora.nla.gov.au/pan/179386/20200109-1842/glyphosateresistance.org.au/index.html**
  - Grains Research & Development Corporation (**www.grdc.com.au**)
  - WeedSmart (**www.weedsmart.org.au**)
  - International Information on Herbicide Resistant Weeds (**weedscience.org**)
  - State Government Departmental publications.
- Detailed programs for herbicide resistance management for weed control in canola, cotton and rice are included (refer CropLife Australia website **www.croplife.org.au**).
  - Cotton: Roundup Ready Flex® Cotton is available from Bayer.
  - Canola: Roundup Ready Canola®, TruFlex® Canola with Roundup Ready technology and Clearfield® Production Systems are available from BASF, Bayer and Nufarm.
  - Sorghum: INZEN® Production System is available from BASF/GenTech.
- Seek advice from local advisers (agronomists).
- Consider using alternative methods of weed control to reduce weed numbers before applying herbicides. If applying herbicides to high density weed populations and/or to crops that are poor competitors with limited weed control options, always follow-up with tactics that prevent seed from returning to the seed bank.

Weed control options for IWM

Phase	Herbicidal	Non-herbicidal
Crop	Crop topping	Rotate crops/varieties
	Knockdown herbicides e.g. double knock strategy before sowing	Grow a dense and competitive crop
	Selective herbicides before and/or after sowing*	Cultivation: • Seed burial • Germination stimulus • Weed tilling
	Utilising moderate resistance risk herbicides	Green/brown manure crops
	Use mixtures and/or sequences of different MoAs	Varied sowing times
		Cut crops for hay/silage
		Burn stubbles/windrows
		Collect and/or destroy weed seeds at harvest
		Grazing
Pasture	Spray topping	Good pasture competition
	Winter cleaning	Cut crops for hay/silage
	Selective herbicides*	Cultivation: • Seed burial • Germination stimulus • Weed tilling
	Use mixtures and/or sequences of different MoAs	Grazing
Fallow	Chemical fallow	Cultivation: • Seed burial • Germination stimulus • Weed tilling
	Optical spot spray technology	Grazing
	Use mixtures and/or sequences of different MoAs	Burning
	Selective herbicides*	
	Knockdown herbicides e.g. double knock strategy	

* Ensure escapes do not set seed

Risk of herbicide resistance development

Management option	Low	Medium	High
Herbicide mix or rotation in cropping system	> 2 MoAs	2 MoAs	1 MoA
Weed control in cropping system	Herbicide and many non-herbicidal methods	Herbicide and some non-herbicidal methods	Herbicide only
Use of same MoA per season	Once	Twice	Many times
Cropping system crop rotation	Diverse range of crops grown in rotation	Some crop rotation	Limited or no crop rotation
Weed density	Low	Moderate	High
No. of applications per field	0–5	5–10	10+
Weeds which set seed and enter seedbank	None / minimal	Some	Most

Adapted from HRAC resistance risk table 2018

Diversity is the key to managing resistance. Incorporate as many diverse weed control and cropping system practices as possible to minimise the risk of herbicide resistance development.

Keep yourself informed and be pro-active in the fight-back against resistance.

For further information on resistance management strategies, consult your reseller agronomist, farm consultant or government agronomist, or refer to the GRDC ***Integrated Weed Management Manual***.

You CAN do something to reduce the impact!

Follow the latest resistance management strategies described in this document.

Note

1. In the specific guidelines for each MoA group in the following pages, the boxes contain the chemical families, followed by a list of active constituents, with the trade name of the first registered product or successor in parentheses.
2. For a complete list of registered products containing each active constituent, refer to the website of the Australian Pesticides and Veterinary Medicines Authority (APVMA) at **www.apvma.gov.au** for the PUBCRIS database.

Specific guidelines:
Group o herbicides

Resistance risk: Moderate

Globally, herbicide resistance to the Group 0 herbicide MoA has been confirmed and documented in eight weed species across four countries. This includes resistance to MSMA in Zanthium spp., flamprop resistance in three Avena spp., dalapon resistance in Chilean needlegrass and dalapon and flupropinate resistance in Paramatta grass as well as flupropinate resistance in serrated tussock and African lovegrass.

Group 0 resistance exists in Australia in four species of weeds. These include more than 200 populations of wild oats resistant to flamprop. Many of these flamprop resistant wild oats also show cross resistance to Group 1 herbicides. Dalapon and flupropinate resistance has been observed in giant Paramatta grass as well as flupropinate resistance in serrated tussock and African lovegrass.

To assist in delaying the onset of resistance, rotate with herbicides from other MoAs.

Consider using alternative methods of weed control to reduce weed numbers before applying herbicides. These may include summer crop rotations, delayed sowing to control wild oats with a knockdown herbicide, higher seeding rates, brown manuring to stop seed set, etc.

The above recommendations should be incorporated into an IWM program. In all cases try to ensure surviving weeds from any treatment do not set and shed viable seed. Keep to integrated strategies mentioned in this brochure including cultural weed control techniques to reduce the weed seedbank. Make sure you mix and rotate herbicides from different MoA groups. Always consult the product label prior to use.

GROUP o
Herbicides with unknown and probably diverse sites of action

Chemical family	**Active constituent** (first registered trade name)
Arylaminopropionic acids	flamprop (Mataven L®)
Chlorocarbonic acids	dalapon (Dalapon®, Yates Onceyear Pathweeder®*, flupropanate (Frenock®)
Phosphorodithioates	bensulide (Prefar®)
Acetamides	napropamide (Altiplano®*, Devrinol®)
Organoarsenicals	DSMA (disodium methylarsonate) (Methar®, Trinoc®*), MSMA (monosodium methylarsonate) (Daconate®)
Fatty acids	Pelargonic acid (Nonanoic acid)

* This product contains more than one active constituent.
Notes: List of chemical families, approved active constituents and, in parenthesis, the trade name of the first registered product or successor. Refer to the APVMA website (**www.apvma.gov.au**) to obtain a complete list of registered products from the PUBCRIS database.

Specific guidelines:
Group 1 herbicides

Resistance risk: High

Globally, herbicide resistance to Group 1 herbicides has been confirmed and documented in more than 40 grass weed species across more than 40 countries. Group 1 resistance is extensive and prolific with tens of millions of hectares affected, in fact it is the second most likely herbicide MoA to develop resistance with only the Group 2 MoA more likely.

Group 1 resistance commonly exists across wide areas of Australia in the grass weed species including more than 20,000 populations of annual ryegrass, annual veld grass, more than 5,000 populations of wild oats, phalaris, more than 200 populations of brome grass, crabgrass, crowsfoot grass and more than 200 populations of barley grass. Resistance has developed in broadacre and vegetable situations.

Research has shown that as few as six applications to the same population of annual ryegrass can result in the selection of resistant individuals. A population can go from a small area of resistant individuals to a whole paddock failure in one season.

1. FOPs, DIMs and DENs are Group 1 herbicides and carry the same high resistance risk.
2. Where a Group 1 herbicide has been used on a particular paddock for control of any grass weed, avoid using a Group 1 herbicide to control the same grass weed in the following season, irrespective of the performance it gave.
3. Frequent application of Group 1 herbicides to dense weed populations is the worst-case scenario for rapidly selecting for resistance.
4. Where resistance to a member of Group 1 is suspected or known to exist, there is a strong possibility of cross resistance to other Group 1 and 0 herbicides. Therefore, use other control methods and herbicides of other MoA groups in a future integrated approach.

The above recommendations should be incorporated into an IWM program. In all cases try to ensure surviving weeds from any treatment do not set and shed viable seed. Keep to integrated strategies mentioned in this brochure including cultural weed control techniques to reduce the weed seedbank. Make sure you mix and rotate herbicides from different MoA groups. Always consult the product label prior to use.

GROUP 1
Inhibition of acetyl co-enzyme A carboxylase (/ACC'ase inhibitors)

Chemical family	**Active constituent** (first registered trade name)
Aryloxyphenoxy-propionates (FOPs)	clodinafop (Topik®), cyhalofop (Agixa®*, Barnstorm®), diclofop (Cheetah® Gold* Decision®*, Hoegrass®), fenoxaprop (Cheetah®, Gold*, Wildcat®), fluazifop (Fusilade®), haloxyfop (Verdict®), propaquizafop (Shogun®), quizalofop (Targa®)
Cyclohexanediones (DIMs)	butroxydim (Factor®*), clethodim (Select®), profoxydim (Aura®), sethoxydim (Cheetah® Gold*, Decision®*), tralkoxydim (Achieve®)
Phenylpyrazoles (DENs)	pinoxaden (Axial®)

* This product contains more than one active constituent.
Notes: List of chemical families, approved active constituents and, in parenthesis, the trade name of the first registered product or successor. Refer to the APVMA website (**www.apvma.gov.au**) to obtain a complete list of registered products from the PUBCRIS database.

Specific guidelines:
Group 2 herbicides

Resistance risk: High

Globally, herbicide resistance to the Group 2 herbicide MoA has been confirmed and documented in more than 150 grass and broadleaf weed species across more than 40 countries. Resistance to Group 2 is extensive and prolific, with tens of millions of hectares affected, in fact it is the most likely herbicide MoA to develop resistance.

Group 2 resistance exists in Australia in 26 species (nine grasses) including more than 20,000 populations of annual ryegrass, more than 200 populations of barley grass, brome grass, more than 200 populations of wild oats, paradoxa grass and crabgrass and in at least seventeen broadleaf weeds including more than 5,000 populations of wild radish, common sowthistle, black bindweed, charlock, more than 2,000 populations of prickly lettuce, more than 1,000 populations of Indian hedge mustard, Mediterranean (wild) turnip and turnip weed. Resistance has developed in broadacre, rice and pasture situations. In respect to rice, there are Group 2 resistant populations to three broadleaf weeds, namely dirty Dora, arrowhead and starfruit.

Research has shown that as few as four applications to the same population of annual ryegrass can result in the selection of resistant individuals and as few as six applications for wild radish. A population can go from an apparently small number of resistant individuals to a whole paddock failure in one season.

A significant challenge facing growers managing Group 2 resistance is the control of brome grass and barley grass in winter cereal crops. Group 2 herbicides are presently the only post-emergent herbicides that provide effective control of these grass weeds and this poses a severe risk of Group 2 resistance for growers with cereal dominant rotations.

If a pre-emergent application is made with a Group 2 herbicide for broadleaf or grass weed control, monitor results and, if required, apply a follow up spray, preferably with a non-Group 2 herbicide, for control of escapes and to avoid weed seed set. If a follow up Group 2 (post-emergent herbicide) is applied, ensure that complete weed seed set control is achieved.

Whether using Group 2 herbicides as a pre-emergent or post-emergent application, consider the use of registered tank mixes with herbicides from other MoAs.

When using a Group 2 herbicide for post-emergent broadleaf or grass weed control, ideally this should be preceded by an effective pre-emergent herbicide treatment with other MoA.

1. Avoid applying more than two* Group 2 herbicide treatments in any four year period on the same paddock. Where more than two treatments are applied introduce alternative control measures to avoid seed set and seed shed in the paddock.
2. A Group 2 herbicide may be used alone on flowering wild radish only if a Group 2 herbicide has not been previously used on that crop.
3. In all cases if there are significant escapes following the herbicide application consider using another herbicide with a different MoA or another control method to stop seed set.
4. Imidazolinone tolerant crops where OnDuty®, Midas® and Intervix® are used refer to the ***Clearfield® Production Systems — best management practice guide***. If Sentry® or Intercept® is to be used consult the ***Nufarm Best Management Practices Guide***.

The above recommendations should be incorporated into an IWM program. In all cases, try to ensure surviving weeds from any treatment do not set and shed viable seed. Keep to integrated strategies mentioned in this brochure including cultural weed control techniques to reduce the weed seedbank. Make sure you mix and rotate herbicides from different MoA groups. Always consult the product label prior to use.

* Where there are multiple applications of a Group 2 herbicide to the same plants, with none of these applications to new generations of plants (of the same species), this may be viewed as the same as a single application of the Group 2 herbicide with respect to selection for Group 2 resistant plants. This is sometimes the case in turf where Group 2 herbicides are applied for the control of perennial grasses like kikuyu, paspalum or bahia grass, in a program of two to three applications in close intervals (to the same plants).

GROUP 2
Inhibition of acetolactate synthase (ALS inhibitors), acetohydroxyacid synthase (AHAS)

Chemical family	Active constituent (first registered trade name)
Imidazolinones (IMIs)	imazamox (Intervix®*, Raptor®), imazapic (Bobcat I-Maxx®*, Flame®, Midas®*, OnDuty®*), imazapyr (Arsenal Xpress®*, Intervix®*, Lightning®*, Midas®* OnDuty®*), imazethapyr (Lightning®*, Spinnaker®)
Pyrimidinylthiobenzoates	bispyribac (Nominee®), pyrithiobac (Staple®)
Sulfonylureas (SUs)	azimsulfuron (Gulliver®), bensulfuron (Londax®), chlorsulfuron (Glean®), ethoxysulfuron (Hero®), foramsulfuron (Tribute®), halosulfuron (Sempra®), iodosulfuron (Hussar®), mesosulfuron (At-lantis®), metsulfuron (Ally®, Harmony®* M, Stinger®*, Trounce®*, Ultimate Brushweed®* Herbicide), prosulfuron (Casper®*), rimsulfuron (Titus®), sulfometuron (Oust®, Eucmix Pre Plant®*, Trimac Plus®*), sulfosulfuron (Monza®), thifensulfuron (Harmony®* M), triasulfuron (Logran®, Logran® B-Power®*), tribenuron (Express®), trifloxysulfuron (En-voke®, Krismat®*)
Triazolopyrimidines (Type 1)	florasulam (Crest®*, Gangster®*, Paradigm®*, Saracen® Vortex®*, X-Pand®*), flumetsulam (Broadstrike®, Thistrol Gold*®), metosu-lam (Eclipse®),
Triazolopyrimidines (Type 2)	pyroxsulam (Crusader® Rexade®*)

* This product contains more than one active constituent.
Notes: List of chemical families, approved active constituents and, in parenthesis, the trade name of the first registered product or successor. Refer to the APVMA website (**www.apvma.gov.au**) to obtain a complete list of registered products from the PUBCRIS database.

Specific guidelines: **Group 3 herbicides**

Resistance risk: Moderate

Globally herbicide resistance to the Group 3 herbicide MoA has been confirmed and documented in more than ten grass and broadleaf weed species across more than five countries.

Group 3 resistance exists in Australia in three weed species including 5,000 populations of annual ryegrass and dense flowered fumitory. Resistance has generally occurred after ten to fifteen years of use of Group 3 herbicides.

Where possible, avoid the use of Group 3 herbicides on dense ryegrass populations. Consider using alternative methods of weed control to reduce weed numbers before applying herbicides.

To assist in delaying the onset of Group 3 resistance, rotate and/or tank mix with herbicides from other MoAs.

Use Group 3 herbicides at robust rates e.g. the maximum label rates to ensure high levels of weed control particularly when targeting annual ryegrass.

The above recommendations should be incorporated into an IWM program. In all cases try to ensure surviving weeds from any treatment do not set and shed viable seed. Keep to integrated strategies mentioned in this brochure including cultural weed control techniques to reduce the weed seedbank. Make sure you mix and rotate herbicides from different MoA groups. Always consult the product label prior to use.

GROUP 3
Inhibition of microtubule assembly

Chemical family	Active constituent (first registered trade name)
Benzamides	propyzamide (Effigy*®, Kerb®)
Benzoic acids	chlorthal (Dacthal®, Prothal®*)
Dinitroanilines: (DNAs)	oryzalin (Rout®*, Surflan®), pendimethalin (Freehand*®, Stomp®), prodiamine (Barricade®), trifluralin (Bolta Duo*, Jetti Duo®*, Tre-flan®)
Pyridines	dithiopyr (Dimension®)

* This product contains more than one active constituent.
Notes: List of chemical families, approved active constituents and, in parenthesis, the trade name of the first registered product or successor. Refer to the APVMA website (**www.apvma.gov.au**) to obtain a complete list of registered products from the PUBCRIS database.

Specific guidelines:
Group 4 herbicides

Resistance risk: Moderate

Globally herbicide resistance to the Group 4 herbicide MoA has been confirmed and documented in more than 30 grass and broadleaf weed species across more than 20 countries. Resistance to the Group 4 MoA is common.

Group 4 resistance exists in Australia in four weed species including capeweed, more than 50 populations of common sow thistle, more than 1,000 populations of wild radish and more than 50 populations of Indian hedge mustard. Resistance has occurred after a long history of use of Group 4 herbicides. The number of populations with Group 4 resistance is increasing.

Of particular concern is the resistance in wild radish, which is the most important broadleaf weed in broadacre agriculture. Some populations may also have resistance to other MoAs e.g. Group 12 herbicides which can be important for control of wild radish in lupins where other selective non-Group 4 options are limited. Because of the long soil life of wild radish seed, measures to reduce seed return to the soil would be useful for this weed. Wild radish seed that is confined to the top 5 cm soil has a shorter life than seed buried deeper.

As a general rule in high resistance risk situations:

1. Avoid applying two applications of Group 4 herbicides alone onto the same population of weeds in the same season. To assist in delaying the onset of Group 4 resistance, rotate and/or tank mix with herbicides from other MoAs.
2. Where possible combine more than one MoA in a single application. Each product should be applied at rates sufficient for control of the target weed alone to reduce the likelihood of weeds resistant to the Group 4 herbicide surviving.

The above recommendations should be incorporated into an IWM program. In all cases try to ensure surviving weeds from any treatment do not set and shed viable seed. Keep to integrated strategies mentioned in this brochure including cultural weed control techniques to reduce the weed seedbank. Make sure you mix and rotate herbicides from different MoA groups. Always consult the product label prior to use.

GROUP 4
Disruptors of plant cell growth (Auxim mimics)

Chemical family	**Active constituent** (first registered trade name)
Benzoates	dicamba (Banvel®, Banvel M®*, Barrel®*, Casper®*, Lawnweeder plus®*, Lawn weedkiller*, Mecoban®, Methar TriKombi®*, Nuturf Millennium®*, Sandoban®*)
Phenoxy-carboxylates	chlorthal (Dacthal®, Prothal®*)
(Phenoxys)	2,4-D (Actril DS®*, Amicide®, Fallow Boss Tordon®*, Methar Tri-Kombi®*, Pyresta®*, Vortex®*), 2,4-DB (Trifolamine®), dichlorprop (Lan-tana 600®), MCPA (Agtryne® MA*, Banvel M®*, Barrel®*, Basagran® M60*, Buctril® MA*, Buffalo Pro Weedkiller®*, Condor*®, Flight®*, Lawnweeder plus®*, Lawn Weedkiller*, Midas®*, Paragon®*, Precept®*, Quadrant®*, Silverado®*, Spearhead®*, Thistrol Gold*®, Ti-grex®*, Tordon 242®*, Triathlon®*), MCPB (Legumine®, Thistrol Gold*®), mecoprop (Mecoban®, Mecopropamine®, Methar Tri Kombi®*, Multiweed®*)
Pyridine carboxylates	dithiopyr (Dimension®)
(Pyridines)	aminopyralid (Fallow Boss Tordon®*, ForageMax®*, Grazon Extra®*, Hot-shot®*, Stinger®*, Vigilant II®*), clopyralid (Lontrel®, Nuturf Millennium®*, Spearhead®*, Trimac Plus®*, Velmac Plus®*) , florpyrauxifen (Agixa®*, Ubeniq®), halauxifen (ForageMax®*, Paradigm®*, Pixxaro®*, Rexade®*), picloram (Fallow Boss Tordon®*, Grazon Extra®*, Tordon®, Tordon 242®*, Tordon Regrowth Master®*, Trinoc®*, Vigilant II®*),
Quinoline-carboxylates	quinclorac (Drive®)
Pyridyloxy-carboxylates	fluroxypyr (Crest®*, Hotshot®*, Pixxaro®*, Starane®), triclopyr (Garlon®, Grazon Extra®*, Tordon Regrowth Master®*, Tough Roundup® Weedkiller*, Ultimate Brushweed®* Herbicide)

* This product contains more than one active constituent.
Notes: List of chemical families, approved active constituents and, in parenthesis, the trade name of the first registered product or successor. Refer to the APVMA website (**www.apvma.gov.au**) to obtain a complete list of registered products from the PUBCRIS database.

Specific guidelines: **Group 5 herbicides**

Resistance risk: Moderate

The herbicides in the new CropLife Group 5 and Group 6 were previously all in Group C in Australia. The MoA was described as 'Inhibitors of photosynthesis at photosystem II'. Now, to match international grouping, this MoA has been split into two, identified as Group 5 (PSII D1 Serine 264 binders) and Group 6 (PSII D1 Histidine 215 binders). The rationale is that there is still no demonstrated target site cross-resistance between these two groups. (GHRAC MoA update, 2020).

Globally herbicide resistance to the Group 5 herbicide MoA has been confirmed and documented in more than 70 grass and broadleaf weed species across more than 40 countries. Resistance to the Group 5 MoA is common; in fact, it is the third most likely herbicide MoA to develop resistance.

In Australia, Group 5 resistance exists in nine weed species across more than 100 weed populations including more than 50 populations of annual ryegrass, more than 20 populations of wild radish, liverseed grass, squirrel tail fescue (silver grass), dwarf (stinging) nettles, Indian hedge mustard, brome grass and barnyard grass ('at risk weeds').

In all situations the resistance status of 'at risk weeds' should be determined prior to sowing. Resistance has developed in broadacre, horticultural and non-crop situations. CropLife Australia gives specific guidelines for the use of Group 5 herbicides in all situations and particularly in triazine tolerant (TT) canola, and canola with both glyphosate tolerance and triazine tolerance (TT-RR canola) following increasing reports of resistance development:

- For 'at risk weeds' avoid using Group 5 herbicides as the only means of control in the same paddock in consecutive years.
- Watch and record weed escapes in paddocks with a long history of Group 5 use.
- Control survivors to prevent seed-set using a herbicide with a different MoA to Group 5 or use another weed management technique, particularly in heavily infested paddocks.
- Avoid dry sowing in heavily weed infested paddocks. Wait for a germination of weeds after the opening rains in weedy paddocks and use a pre-plant knockdown or cultivation to maximise weed control at this stage.
- **TT Canola** — Growing TT Canola in a paddock treated with triazine herbicides in the previous season is a high resistance risk and is not recommended. For ryegrass control, use simazine, atrazine, metribuzin or terbuthylazine plus a pre-emergence herbicide with a different MoA (e.g. trifluralin) prior to sowing. If necessary, follow-up with a post-emergent herbicide with a different MoA (e.g. clethodim) to control escapes from pre-emergent treatments.
- **TT-RR Canola** — Refer to the specific guidelines for Group 9 herbicides in addition to those given here for triazine herbicides.

The above recommendations should be incorporated into an IWM program. In all cases try to ensure surviving weeds from any treatment do not set and shed viable seed. Keep to integrated strategies mentioned in this brochure including cultural weed control techniques to reduce the weed seedbank. Make sure you mix and rotate herbicides from different MoA groups. Always consult the product label prior to use.

GROUP 5
Inhibitors of photosynthesis at photosystem II (D1 Serine 264 binders)

Chemical family	**Active constituent** (first registered trade name)
Amides	propanil (Stam®)
Phenylcarba-mates	phenmedipham (Betanal®)
Pyridazinones	chloridazon (Pyramin®)
Triazines	ametryn (Amigan®*, Gesapax® Combi*, Krismat®, Primatol Z®), atrazine (Gesapax® Combi*, Gesaprim®, Primextra® Gold*), cyanazine (Bladex®), prometryn (Bandit®*, Cotogard®*, Gesagard®), propazine (Agaprop®), simazine (Brunnings RTU Path Weeder®*, Gesatop®, Bantox®*, Yates Onceyear Path Weeder®*), terbuthylazine (Effigy*®, Firestorm®*, Palmero TX®*, Terbyne®), terbutryn (Agtryne® MA*, Amigan®*, Igran®)
Triazinones	amicarbazone (Amitron®*) hexazinone (Bobcat I-Maxx®*, Velmac Plus®*, Velpar® K4*, Velpar® L), metribuzin (Aptitude®*, Sencor®)
Uracils	bromacil (Hyvar®, Krovar®*), terbacil (Eucmix Pre Plant®*, Sinbar®, Trimac Plus®*)
Ureas	diuron (Karmex®, Krovar®*, Velpar® K4*), fluometuron (Bandit®*, Cotogard®*, Cotoran®), linuron (Afalon®), methabenzthiazuron (Tribunil®), siduron (Tuper-san®), tebuthiuron (Graslan®)

* This product contains more than one active constituent.
Notes: List of chemical families, approved active constituents and, in parenthesis, the trade name of the first registered product or successor. Refer to the APVMA website (**www.apvma.gov.au**) to obtain a complete list of registered products from the PUBCRIS database.

Specific guidelines:
Group 6 herbicides

Resistance risk: Moderate

The herbicides in the new CropLife Group 5 and Group 6 were previously all in Group C in Australia. The MoA was described as 'Inhibitors of photosynthesis at photosystem II'. Now, to match international grouping, this MoA has been split into two, identified as Group 5 (PSII D1 Serine 264 binders) and Group 6 (PSII D1 Histidine 215 binders). The rationale is that there is still no demonstrated target site cross-resistance between these two groups. (GHRAC MoA update, 2020).

Globally herbicide resistance to the Group 6 herbicide MoA is not as common as Group 5.

In all situations the resistance status of 'at risk weeds' should be determined prior to sowing. For 'at risk weeds', avoid using Group 6 herbicides as the only means of control in the same paddock in consecutive years.

- Watch and record weed escapes in paddocks with a long history of Group 6 use.
- Control survivors to prevent seed-set using a herbicide with a different MoA to Group 6 or use another weed management technique, particularly in heavily infested paddocks.
- Avoid dry sowing in heavily weed infested paddocks. Wait for a germination of weeds after the opening rains in weedy paddocks and use a pre-plant knockdown or cultivation to maximise weed control at this stage.

The above recommendations should be incorporated into an IWM program. In all cases try to ensure surviving weeds from any treatment do not set and shed viable seed. Keep to integrated strategies mentioned in this brochure including cultural weed control techniques to reduce the weed seedbank. Make sure you mix and rotate herbicides from different MoA groups. Always consult the product label prior to use.

GROUP 6
Inhibitors of photosynthesis at photosystem II (D1 Histadine 215 binders)

Chemical family	**Active constituent** (first registered trade name)
Benzothiadiazinones	bentazone (Basagran®, Basagran® M60*, Lawnweeder plus®*), pyridate (Tough®)
Nitriles	bromoxynil (Barrel®*, Buctril®, Buctril® MA*, Buffalo Pro Weedkiller®*, Eliminar C®*, Flight®*, Jaguar®*, Talinor®*, Quadrant®*, Triathlon®*, Velocity®*), ioxynil (Actril DS*, Totril®,)

* This product contains more than one active constituent.
Notes: List of chemical families, approved active constituents and, in parenthesis, the trade name of the first registered product or successor. Refer to the APVMA website (**www.apvma.gov.au**) to obtain a complete list of registered products from the PUBCRIS database.

Specific guidelines: **Group 9 herbicides**

Resistance risk: Moderate

Globally, herbicide resistance to the Group 9 herbicide MoA has been confirmed and documented in more than 30 weed species across more than 25 countries.

Resistance to Group 9 herbicides is significant given it is the most important and most widely used herbicide.

Group 9 resistance occurs in Australia in 20 weed species including more than 1,000 populations of annual ryegrass, more than 200 populations of awnless barnyard grass, brome grass, more than 50 populations of common sow thistle, ten populations of feathertop Rhodes grass, one population each of capeweed and Patterson's curse, more than 100 populations of flax-leaf fleabane, liverseed grass, sweet summer grass, wild radish, wild oats and windmill grass.

The following factors are common to all cases of Group 9 resistance:

- Lack of rotation of other herbicide MoA.
- A Group 9 herbicide has been used for 12–15 years or more.
- There has been minimal or no soil disturbance following application.

Given the very important role of glyphosate in Australian farming systems, the Australian agricultural industry has developed strategies for sustainable use of glyphosate. For more information refer to the Australian Glyphosate Sustainability Working Group website **https://webarchive.nla.gov.au/awa/20200113011304/http://pandora.nla.gov.au/pan/179386/20200109-1842/glyphosateresistance.org.au/index.html**

A number of these cases of resistance to glyphosate have occurred in horticultural (vines, tree crops and vegetables) and non-cropping situations (e.g. airstrips, railways, firebreaks, fencelines, roadsides, driveways, irrigation ditches, around sheds), with the balance occurring in no-till broadacre cropping systems.

To assist in delaying the onset of resistance, consider alternating Group 9 herbicides with herbicides from other MoA, such as Group 22 (e.g. paraquat), Group 10 (e.g. glufosinate) or Group 34 (e.g. amitrole).

Given the demonstrated propensity of weeds to develop resistance to multiple herbicide classes, IWM principles should be incorporated wherever possible to minimise the risk of selecting for glyphosate resistance. Strategies may include the use of cultivation, the double knock technique[1] , strategic herbicide rotation, grazing, baling etc.

- For further information in canola: **www.roundupreadycanola.com.au/prod/media/3672/rr-canola-technologies-rmp.pdf**
- For further information in cotton: **www.cottoninfo.com.au/publications/herbicide-resistance-management-strategy and http://www.bollgard3.com.au/prod/media/1708/m0074-weed-resistant-management-plan_v15.pdf**

The above recommendations should be incorporated into an IWM program. In all cases try to ensure surviving weeds from any treatment do not set and shed viable seed. Keep to integrated strategies mentioned in this brochure including cultural weed control techniques to reduce the weed seedbank. Make sure you mix and rotate herbicides from different MoA groups. Always consult the product label prior to use.

GROUP 9
Inhibition of 5-enolpyruvyl shikimate-3 phosphate synthase (EPSP inhibition)

Chemical family	**Active constituent** (first registered trade name)
Glycines	glyphosate (Arsenal Xpress®*, Bantox*, Broadway®*, Firestorm®*, Illico®*, Resolva®*, Roundup®, Sandoban*®, Tough Roundup® Weedkiller*, Trounce®*, Yates Pathweeder®*)

* This product contains more than one active constituent.
Notes: List of chemical families, approved active constituents and, in parenthesis, the trade name of the first registered product or successor. Refer to the APVMA website (**www.apvma.gov.au**) to obtain a complete list of registered products from the PUBCRIS database.

1 The double knock technique is defined as using a full cut cultivation OR the full label rate of a paraquat-based product (Group 22) following the glyphosate (Group 9) knockdown application.

Specific guidelines:
Group 10 herbicides

Resistance risk: Moderate

Glufosinate-ammonium (Basta®, Liberty®) is the only Group 10 herbicide registered in Australia.

Resistance to Group 10 herbicides is rare, and currently there are no documented cases of resistant weeds in Australia. Group 10 resistance has been discovered in other countries for two weed species — crowsfoot grass (Eleusine indica) and Italian ryegrass (Lolium perenne ssp. multiflorum) — which demonstrates the potential for weeds to develop resistance to this MoA.

The risk of resistance to glufosinate-ammonium will be highest in situations where there is a reliance on this herbicide alone for weed control. This includes situations where:

- Other herbicides in the farming system, especially glyphosate, have developed resistance.
- Weed escapes following application of glufosinate-ammonium are allowed to set and shed viable seed.
- There is a lack of non-herbicide weed control methods used.

Weed control from glufosinate-ammonium is affected by climatic conditions (refer to the product label).

Horticulture

1. Rotate glufosinate-ammonium with other knockdown herbicides with a different MoA, such as Group 22 (e.g. paraquat), Group 34 (e.g. amitrole) or Group 9 (e.g. glyphosate).
2. Where possible use residual herbicides (that are effective on the same weeds as glufosinate-ammonium) either alone or in mixture with glufosinate-ammonium.
3. Where possible use alternative MoAs to selectively control grass and broadleaf weeds.

Fallow

In high summer rainfall areas, weed control in fallow is heavily reliant on herbicides. Multiple sprays are often required to maintain a clean fallow between winter crops.

1. Rotate glufosinate-ammonium with other knockdown herbicides with a different MoA, such as Group 22 (e.g. paraquat), Group 34 (e.g. amitrole) or Group 9 (e.g. glyphosate).
2. Where possible use residual herbicides (that are effective on the same weeds as glufosinate-ammonium) either alone or in mixture with glufosinate-ammonium.
3. Where possible use alternative MoAs to selectively control grass and broadleaf weeds.

The above recommendations should be incorporated into an IWM program. In all cases try to ensure surviving weeds from any treatment do not set and shed viable seed. Keep to integrated strategies mentioned in this brochure including cultural weed control techniques to reduce the weed seedbank. Make sure you mix and rotate herbicides from different MoA groups. Always consult the product label prior to use.

GROUP 10
Inhibition of glutamine synthetase

Chemical family	**Active constituent** (first registered trade name)
Phosphinic acids	glufosinate (Basta®, Liberty®)

* This product contains more than one active constituent.
Notes: List of chemical families, approved active constituents and, in parenthesis, the trade name of the first registered product or successor. Refer to the APVMA website (**www.apvma.gov.au**) to obtain a complete list of registered products from the PUBCRIS database.

Specific guidelines:
Group 12 herbicides

Resistance risk: Moderate

Globally herbicide resistance to the Group 12 herbicide MoA has been confirmed and documented in four weed species across three countries.

Group 12 resistance exists in Australia in two weed species including more than 1,000 populations of wild radish and more than 50 populations of Indian hedge mustard. Resistance has generally occurred after a long history of use of Group 12 herbicides. The number of populations with Group 12 resistance is increasing following increased use of these herbicides.

Avoid applying Group 12 herbicides in any two consecutive years unless one application is a mixture with a different MoA that is active on the same weed, or a follow up spray is conducted (using a different MoA) to control escapes. Always use the label rate of herbicide whether or not a single active ingredient (e.g. diflufenican) or combinations of active ingredients are applied (e.g. diflufenican/MCPA, picolinafen/MCPA), apply to weeds at the labelled growth stage and ensure that no weeds set and shed viable seed. Control survivors to prevent seed set with a herbicide with a different MoA to Group 12 or use another weed management technique.

The above recommendations should be incorporated into an IWM program. In all cases try to ensure surviving weeds from any treatment do not set and shed viable seed. Keep to integrated strategies mentioned in this brochure including cultural weed control techniques to reduce the weed seedbank. Make sure you mix and rotate herbicides from different MoA groups. Always consult the product label prior to use.

GROUP 12
Inhibition of carotenoid biosynthesis at the phytoene desaturase step (PDS inhibitors)

Chemical family	**Active constituent** (first registered trade name)
N-Phenyl heterocycles	norflurazon (Solicam®)
Phenyl-ethers	diflufenican (Brodal®, Gangster®*, Jaguar®*, Quadrant®*, Spearhead®*, Tigrex®*, Triathlon®*, Yates Pathweeder®*), picolinafen (Eliminar C®*, Flight®*, Paragon®*, Quadrant®*, Sniper®)

* This product contains more than one active constituent.
Notes: List of chemical families, approved active constituents and, in parenthesis, the trade name of the first registered product or successor. Refer to the APVMA website (**www.apvma.gov.au**) to obtain a complete list of registered products from the PUBCRIS database.

Specific guidelines: **Group 13 herbicides**

Resistance risk: Moderate

Globally the number of resistance cases to Group 13 herbicides is extremely low. Resistance to clomazone was first detected in Australia in 1982 in annual ryegrass (*Lolium rigidum*). It is the only case reported for the Asia–Pacific region and occurred at a time when clomazone was still under development. The only other cases of herbicide resistance reported are in barnyard grass in Arkansas in 2008 and in bearded strangletop bearded sprangletop (*Leptochloa fusca*) in California in 2022.

The increased use of Group 13 herbicides in broadacre cropping in Australia will increase the risk of resistant weed populations developing. The risk for Group 13 herbicide resistance is highest where they are used alone, e.g. bixlozone as pre-emergent herbicide in cereals, therefore to assist in minimising the risk of development of resistance, additional strategies can be adopted:

- Where possible, follow the pre-emergent application of a Group 13 herbicide using another herbicide with a different MoA.
- Implement agronomic strategies aiming to maximise the crop competitiveness e.g. planting date, competitive crop and/or varieties.
- Avoid using Group 13 herbicides in the same paddock in successive seasons (back-to-back).

It is recommended to apply Group 13 herbicides in mixtures with another effective herbicide belonging to a different mode of action group, e.g. bixlozone plus an active ingredient from a Group 15 (e.g. tri-allate) or Group 5 (e.g. atrazine) or clomazone plus Group 3 (e.g. pendimethalin). Mixtures should be applied at full label rates to provide robust weed control.

Where possible, avoid the use of Group 13 herbicides on dense barnyard grass, annual ryegrass or wild radish populations.

The above recommendations should be incorporated into an IWM program. In all cases try to ensure surviving weeds from any treatment (chemical or cultural) do not set and shed viable seed to reduce the weed seedbank. Always consult the product label prior to use.

GROUP 13
Inhibitors of deoxy-D-xyulose phosphate synthase (DOXP inhibitors)

Chemical family	**Active constituent** (first registered trade name)
Isoxazolidinones	bixlozone (Overwatch®), clomazone (Altiplano®*, Command®)

* This product contains more than one active constituent.
Notes: List of chemical families, approved active constituents and, in parenthesis, the trade name of the first registered product or successor. Refer to the APVMA website (**www.apvma.gov.au**) to obtain a complete list of registered products from the PUBCRIS database.

Specific guidelines: **Group 14 herbicides**

Resistance risk: Moderate

Group 14 herbicides are inhibitors of the protoporphyrinogen oxidase (PPO) enzyme. There are currently no known populations of weeds resistant to Group 14 in Australia. However, there are six weeds with confirmed resistant to Group 14 herbicides elsewhere in the world and in particular in populations of Amaranthus spp. in the USA.

The increased use of Group 14 herbicides as stand-alone herbicides in Australia is likely to increase the risk of resistant populations developing. The use of Group 14 herbicides in co-formulations or as tank mixtures in-crop or on fallows has a lower risk of resistant populations developing.

Tank- mixtures and co-formulations

Most current recommendations for Group 14 herbicides are for mixtures with another herbicide, e.g. carfentrazone plus glyphosate, pyraflufen plus MCPA amine. There are also some co-formulations that incorporate at least two MoAs e.g. Aptitude® (carfentrazone + metribuzin) and Pyresta® (pyraflufen + 2,4-D).

- Mixtures should be applied at full label rates to provide robust weed control.
- Rotation of all herbicide MoAs should be employed between seasons.

Stand-alone applications

The risk for Group 14 herbicide resistance is highest where they are used alone, e.g. flumioxazin in cotton or oxyfluorfen as a residual herbicide.

- If there are significant escapes following the application of a Group 14 herbicide, consider using another herbicide with a different MoA or a non-herbicide control method to stop seed set. If not possible, be sure to include a different MoA in the next herbicide application.

The above recommendations should be incorporated into an IWM program. In all cases try to ensure surviving weeds from any treatment do not set and shed viable seed. Keep to integrated strategies mentioned in this brochure including cultural weed control techniques to reduce the weed seedbank. Make sure you mix and rotate herbicides from different MoA groups. Always consult the product label prior to use.

GROUP 14
Inhibitors of protoporphyrinogen oxidase (PPOs)

Chemical family	Active constituent (first registered trade name)
Diphenylethers	acifluorfen (Blazer®), fomesafen (Reflex) oxyfluorfen (Goal®, Rout®, Yates Pathweeder®)
N-phenyl-imides	butafenacil (B-Power®*, Logran® B-Power®*, Resolva®*), saflufenacil (Sharpen®, Voraxor*®), flumioxazin (Valor®, Terrain®) tiafenacil (Terrad'or), trifludimoxazin (Voraxor*®)
N-Phenyl-oxadiazolones	oxadiargyl (Raft®), oxadiazon (Ronstar®)
Phenylpyrazole	pyraflufen (Condor*®, Ecopar®, Sledge® Pyresta®*)
N-Phrenyl-triazolinones	carfentrazone (Affinity®, Aptitude®*, Broadway®, Buffalo Pro Weedkiller®*, Silverado®*)

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Specific guidelines: **Group 15 herbicides**

Resistance risk: Moderate

Globally herbicide resistance to the Group 15 herbicide MoA has been confirmed and documented in ten weed species across five countries.

Resistance to Group 15 herbicides in Australia has developed in more than 100 populations of annual ryegrass with resistance to triallate, prosulfocarb and pyroxasulfone as well as ten populations of winter grass with resistance to ethofumesate. Further development of resistance in the near future is likely given the reliance on Group 15 herbicide chemistry for weed control across large areas of Australia.

Where possible, avoid the use of Group 15 herbicides on dense annual ryegrass populations. Consider using alternative methods of weed control to reduce weed numbers before applying herbicides.

Use Group 15 herbicides at robust rates e.g. the maximum label rates to ensure high levels of weed control particularly when targeting annual ryegrass.

To assist in delaying the onset of resistance, rotate Group 15 herbicides with herbicides from other MoAs.

The above recommendations should be incorporated into an IWM program. In all cases try to ensure surviving weeds from any treatment do not set and shed viable seed. Keep to integrated strategies mentioned in this brochure including cultural weed control techniques to reduce the weed seedbank. Make sure you mix and rotate herbicides from different MoA groups. Always consult the product label prior to use.

GROUP 15
Inhibitors of very long chain fatty acid synthesis (VLCFA inhibitors)

Chemical family	Active constituent (first registered trade name)
Acetamides	napropamide (Altiplano®*, Devrinol®)
Chloroacetamides	dimethenamid (Freehand*, Frontier®-P, Outlook ®), metazachlor (Butisan®), metolachlor (Boxer® Gold*, Dual® Gold, Primextra® Gold*), propachlor (Prothal®*, Ramrod®)
Isoxazoline	pyroxasulfone (Sakura®)
Thiocarbamates	EPTC (Eptam®), molinate (Ordram®), pebulate (Tillam®), prosul-focarb (Arcade®, Bolta Duo*, Boxer® Gold*, Diablo Duo®*), thio-bencarb (Saturn®), triallate (Avadex®, Diablo Duo®*, Jetti Duo®*), vernolate (Vernam®)
Benzofurans	ethofumesate (Tramat®)

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Specific guidelines:
Group 22 herbicides

Resistance risk: Moderate

Globally herbicide resistance to the Group 22 herbicide MoA has been confirmed and documented in more than 30 weed species across 16 countries

Group 22 resistance exists in Australia in ten species including annual ryegrass, and in two species of barley grass across more than 100 populations, blackberry nightshade, crowsfoot grass, capeweed, fleabane, Pennsylvanian cudweed, squirrel-tailed fescue (silver grass) and small square weed. Most instances have occurred in long-term lucerne stands treated regularly with a Group 22 herbicide but Group 22 resistant barley grass has also occurred in no-till situations.

The following factors are common to most cases of Group 22 resistance:

- A Group 22 herbicide is the major or only herbicide used.
- A Group 22 herbicide has been used for 12–15 years or more.
- There has been minimal or no soil disturbance following application.

The risk of resistance to Group 22 herbicides is higher in minimum/zero tillage broadacre cropping. Other high resistance risk situations include: irrigated clover pivots, orchards, vineyards or pure lucerne stands where frequent applications of a Group 22 herbicide are made each season, cultivation is not used and there is reliance on a Group 22 herbicide alone for weed control.

To assist in delaying the onset of resistance, consider alternating Group 22 herbicides with herbicides from other MoAs. For example, Group 10 (e.g. glufosinate) or Group 34 (e.g. amitrole) or Group 9 (e.g. glyphosate).

Below are strategies that address these high resistance risk situations to reduce the risk of Group 22 resistance developing.

Minimum/Zero Tillage

1. Rotate Group 22 herbicides with other knockdown herbicides with a different MoA, such as Group 9 (e.g. glyphosate). A full label rate for the weed size targeted should be used for resistance management.
2. Consider utilising the double knock technique where glyphosate is sprayed first followed within one to seven days by a paraquat application. A full label rate for the weed size targeted should be used for the paraquat application for resistance management.
3. Consider occasional mechanical cultivation to aid weed control.

Lucerne

1. If using a Group 22 herbicide for winter cleaning, where possible include another MoA e.g. Group 5.
2. Use alternative MoAs to selectively control grass and broadleaf weeds.
3. Rotate Group 22 herbicides with other knockdown herbicides with a different MoA (such as Group 9 e.g. glyphosate) prior to sowing lucerne and prior to sowing future crops in that paddock.

Horticulture

1. Rotate Group 22 herbicides with other knockdown herbicides with a different MoA, such as Group 10 (e.g. glufosinate), Group 34 (e.g. amitrole) or Group 9 (e.g. glyphosate).
2. Where possible, use residual herbicides (that are effective on the same weeds as the Group 22 herbicides) where applicable either alone or in mixture with Group 22 herbicides.
3. Where possible use alternative MoA to selectively control grass and broadleaf weeds.
4. Consider using the double knock technique where glyphosate is sprayed followed within one to seven days by a paraquat application. A full label rate for the weed size targeted should be used for the paraquat application for resistance management.

The above recommendations should be incorporated into an IWM program. In all cases try to ensure surviving weeds from any treatment do not set and shed viable seed. Keep to integrated strategies mentioned in this brochure including cultural weed control techniques to reduce the weed seedbank. Make sure you mix and rotate herbicides from different MoA groups. Always consult the product label prior to use.

GROUP 22
Inhibitors of photosynthesis at photosystem I via electron diversion (PSI inhibitors)

Chemical family	**Active constituent** (first registered trade name)
Pyridiniums	diquat (Reglone®, Spray Seed®*), paraquat (Alliance®*, Gramoxone®, Spray Seed®*)

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Specific guidelines:
Group 27 herbicide

Resistance risk: Moderate

Resistance to the Group 27 (HPPD inhibitors) herbicide MoA is known for a number of populations of Amaranthus species in the United States (US), which demonstrates the potential for weeds to develop resistance to this MoA. Continuous usage of Group 27 herbicides in the US has resulted in resistance in Amaranthus species in a relatively short time.

There is one known population of wild radish resistant to Group 27 herbicides in Australia, however, continued resistance development to this MoA is inevitable given its continued usage.

Broadacre cropping

Of particular concern in Australia is the potential for development of Group 27 resistance in wild radish. In some areas, because of a lack of alternate herbicide options, growers are heavily reliant on Group 27 herbicides for control of wild radish populations. It is essential to integrate additional cultural weed control techniques to reduce the seed bank and minimise seed set, thereby decreasing the selection pressure on Group 27 herbicides. Where Group 27 (HPPD inhibitors) herbicides are used post-emergent it's important to target small weeds with robust rates. Always mix Group 27 herbicides with an effective alternate mode of action herbicide, such as Group 6 products like bromoxynil, which are synergistic, Group 4 products, such as MCPA, or other alternate MoA herbicides.

Where Group 27 (HPPD inhibitors) herbicides are used pre-emergent in cereals, it is important to use an alternative MoA as a follow-up spray to control any subsequent survivors. If two Group 27 herbicides are used in one season, a herbicide from an alternate MoA should be used after the first or second applications of Group 27 to control any weed survivors.

Fallow

In high summer rainfall areas, weed control in fallow is heavily reliant on herbicides. Multiple sprays are often required to maintain a clean fallow between winter crops. IWM principles should be incorporated wherever possible, including cultivation — the double knock technique, grazing and combining more than one MoA in a single application.

To assist in delaying the onset of Group 27 resistance, rotate and/or tank mix with herbicides from other MoAs.

Rice

Where benzofenap has been applied to rice, a follow-up application of MCPA or bentazone and MCPA is recommended where appropriate to provide a secondary MoA. To reduce the likelihood of resistant weeds developing it is recommended that products containing benzofenap (e.g. Taipan®) not be used in consecutive rice crops.

Sugarcane

It is critical to manage weeds effectively to protect sugarcane from yield loss due to competition. Weed management that relies on Group 27 herbicides should incorporate IWM principles that include chemical and non-chemical methods of weed control. Chemical methods of weed control should include rotation and/or tank mixing Group 27 herbicides with herbicides from other MoAs and may also include the use of non-selective knockdown herbicides and techniques such as 'double knock' and spot spraying. Non-chemical methods of weed control include the use of fallow crops, controlling weed seed set, regular slashing area around the crop, good machinery hygiene, mechanical control in plant cane and a trash blankets in ratoon crops.

The above recommendations should be incorporated into an IWM program. In all cases try to ensure surviving weeds from any treatment do not set and shed viable seed. Keep to integrated strategies mentioned in this brochure including cultural weed control techniques to reduce the weed seedbank. Make sure you mix and rotate herbicides from different MoA groups. Always consult the product label prior to use.

GROUP 27
Inhibition of 4-hydroxyphenyl-pyruvate dioxygenase (HPPD inhibitors)

Chemical family	**Active constituent** (first registered trade name)
Isoxazoles	isoxaflutole (Balance® Palmero TX®*)
Pyrazoles	benzofenap (Taipan ®), pyrasulfotole (Precept®*, Velocity®*), topramezone (Frequency®)
Triketones	bicyclopyrone (Talinor®*), mesotrione (Callisto®)

* This product contains more than one active constituent.
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Specific guidelines: **Group 31 herbicides**

Resistance risk: Moderate

Globally, herbicide resistance to the Group 31 herbicide MoA has been confirmed in three populations of *Poa annua* in Australia only.

To assist in delaying the onset of resistance, rotate with herbicides from other MoAs.

Consider using alternative methods of weed control to reduce weed numbers before applying herbicides.

The above recommendations should be incorporated into an IWM program. In all cases try to ensure surviving weeds from any treatment do not set and shed viable seed. Keep to integrated strategies mentioned in this brochure including cultural weed control techniques to reduce the weed seedbank. Make sure you mix and rotate herbicides from different MoA groups. Always consult the product label prior to use.

GROUP 31
Inhibitors of serine threonine protein phosphatase (STPP inhibitors)

Chemical family	**Active constituent** (first registered trade name)
Unknown	endothal (Endothal®)

Notes: List of chemical families, approved active constituents and, in parenthesis, the trade name of the first registered product or successor. Refer to the APVMA website (**www.apvma.gov.au**) to obtain a complete list of registered products from the PUBCRIS database.

Specific guidelines: **Group 34 herbicides**

Resistance risk: Moderate

Globally, herbicide resistance to the Group 34 herbicide MoA has been confirmed and documented in six weed species across four countries.

Group 34 resistance exists in Australia with three populations of annual ryegrass resistant to amitrole. This has only occurred in three populations and this type of resistance is rare in Australia.

To assist in delaying the onset of resistance, consider alternating Group 34 herbicides with herbicides from other MoAs, such as Group 22 (e.g. paraquat), Group 10 (e.g. glufosinate) or Group 9 (e.g. glyphosate).

Consider using alternative methods of weed control to reduce weed numbers before applying herbicides.

The above recommendations should be incorporated into an IWM program. In all cases try to ensure surviving weeds from any treatment do not set and shed viable seed. Keep to integrated strategies mentioned in this brochure including cultural weed control techniques to reduce the weed seedbank. Make sure you mix and rotate herbicides from different MoA groups. Always consult the product label prior to use.

GROUP 34
Bleachers: Inhibitors of lycopene cyclase

Chemical family	**Active constituent** (first registered trade name)
Triazoles	amitrole (Alliance®*, Amitrole®, Brunnings RTU Pathweeder®*, Illico®*, Firestorm®*, Yates Onceyear Pathweeder®*)

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Herbicide Mode of Action groups

High resistance risk

Chemical family	**Active constituent** (first registered trade name)
GROUP 1 **Inhibition of acetyl co-enzyme A carboxylase (ACC'ase inhibitors)**	
Aryloxyphenoxy-propionates (FOPs)	clodinafop (Topik®), cyhalofop (Agixa®*, Barnstorm®), diclofop (Cheetah® Gold* Decision®*, Hoegrass®), fenoxaprop (Cheetah®, Gold*, Wildcat®), fluazifop (Fusilade®), haloxyfop (Verdict®), propaquizafop (Shogun®), quizalofop (Targa®)
Cyclohexanediones (DIMs)	butroxydim (Factor®*), clethodim (Select®), profoxydim (Aura®), sethoxydim (Cheetah® Gold*, Decision®*), tralkoxydim (Achieve®)
Phenylpyrazoles (DENs)	pinoxaden (Axial®)
GROUP 2 **Inhibition of acetolactate synthase (ALS inhibitors), acetohydroxyacid synthase (AHAS)**	
Imidazolinones (IMIs)	imazamox (Intervix®*, Raptor®), imazapic (Bobcat I-Maxx®*, Flame®, Midas®*, OnDuty®*), imazapyr (Arsenal Xpress®*, Intervix®*, Lightning®*, Midas®* OnDuty®*), imazethapyr (Lightning®*, Spinnaker®)
Pyrimidinyl–thio-benzoates	bispyribac (Nominee®), pyrithiobac (Staple®)
Sulfonylureas (SUs)	azimsulfuron (Gulliver®), bensulfuron (Londax®), chlorsulfuron (Glean®), ethoxysulfuron (Hero®), foramsulfuron (Tribute®), halosul-furon (Sempra®), iodosulfuron (Hussar®), mesosulfuron (Atlantis®), metsulfuron (Ally®, Harmony®* M, Stinger®*, Trounce®*, Ultimate Brushweed®* Herbicide), prosulfuron (Casper®*), rimsulfuron (Titus®), sulfometuron (Oust®, Eucmix Pre Plant®*, Trimac Plus®*), sulfosulfuron (Monza®), thifensulfuron (Harmony®* M), triasulfuron (Logran®, Logran® B-Power®*), tribenuron (Express®), trifloxysulfuron (Envoke®, Krismat®*)
Triazolopyrimidines-Type 1	florasulam (Crest®*, Gangster®*, Paradigm®*, Saracen®, Vortex®*, X Pand®*), flumetsulam (Broadstrike®, Thistrol® Gold*), metosulam (Eclipse®)
Triazolopyrimidines-Type 2	pyroxsulam (Crusader® Rexade®*)

* This product contains more than one active constituent

Moderate resistance risk

Chemical family	**Active constituent** (first registered trade name)
GROUP 0 **Herbicides with unknown MoA**	
Arylaminopropionic acids	flamprop (Mataven® L)
Acetamides	napropamide (Altiplano®*, Devrinol®)
Organoarsenicals	DSMA (disodium methylarsonate) (Methar®, Trinoc®*), MSMA (monosodium methylarsonate) (Daconate®)
Fatty acids	Pelargonic acid (Nonanoic acid) (Slasher®)
Chlorocarbonic acids	dalapon (Dalapon®, Yates Onceyear Pathweeder®*, flupropanate (Frenock®)
Phosphorodithioates	bensulide (Prefar®)
GROUP 3 **Inhibition of microtubule assembly**	
Benzamides	propyzamide (Effigy®*, Kerb®)
Benzoic acids	chlorthal (Dacthal®, Prothal®*)
Dinitroanilines: (DNAs)	oryzalin (Rout®*, Surflan®), pendimethalin (Freehand*®, Stomp®), prodiamine (Barricade®), trifluralin (Bolta Duo®*, Jetti Duo®*, Treflan®)
Pyridines	dithiopyr (Dimension®)

Moderate resistance risk

Chemical family	**Active constituent** (first registered trade name)
GROUP 4 **Disruptors of plant cell growth (Auxin mimics)**	
Benzoates	dicamba (Banvel®, Banvel M®*, Barrel®*, Casper®*, Lawnweeder plus®*, Lawn weedkiller*, Mecoban®, Methar Tri-Kombi®*, Nuturf Millennium®*, Sandoban®*)
Phenoxy-carboxylates (Phenoxys)	2,4-D (Actril DS®*, Amicide®, Fallow Boss Tordon®*, Methar Tri-Kombi®*, Pyresta®*, Vortex®*), 2,4-DB (Trifolamine®), dichlorprop (Lantana 600®), MCPA (Agtryne® MA*, Banvel M®*, Barrel®*, Basagran® M60*, Buctril® MA*, Buffalo Pro Weedkiller®*, Condor*®, Flight®*, Lawnweeder plus®*, Lawn Weedkiller*, Midas®*, Paragon®*, Precept®*, Quadrant®*, Silverado®*, Spearhead®*, Thistrol Gold*®, Tigrex®*, Tordon 242®*, Triathlon®*), MCPB (Legumine®, Thistrol Gold*®), mecoprop (Mecoban®, Mecopropamine®, Methar Tri Kombi®*, Multiweed®*)
Pyridine carboxylates (Pyridines)	Aminocyclopyrachlor (Method®), aminopyralid (Fallow Boss Tordon®*, ForageMax®*, Grazon Extra®*, Hotshot®*, Stinger®*, Vigilant II®*), clopyralid (Lontrel®, Nuturf Millennium®*, Spearhead®*, Trimac Plus®*, Velmac Plus®*) , florpyrauxifen (Agixa®*, Ubeniq®), halauxifen (ForageMax®*, Paradigm®*, Pixxaro®*, Rexade®*), picloram (Fallow Boss Tordon®*, Grazon Extra®*, Tordon®, Tordon 242®*, Tordon Regrowth Master®*, Trinoc®*, Vigilant II®*)
Quinoline-carboxylates	quinclorac (Drive®)
Pyridyloxy-carboxylates	fluroxypyr (Crest®*, Hotshot®*, Pixxaro®*, Starane®), triclopyr (Garlon®, Grazon Extra®*, Tordon Regrowth Master®*, Tough Roundup® Weedkiller*, Ultimate Brushweed®* Herbicide)
GROUP 5 **Inhibition of photosynthesis at photosystem II — D1 Serine 264 binders (and other non-histidine binders) (PS II Serine 264 inhibitors)**	
Amides	propanil (Stam®)
Phenylcarbamates	phenmedipham (Betanal®)
Pyridazinones	chloridazon (Pyramin®)
Triazines	ametryn (Amigan®*, Gesapax® Combi*, Krismat®, Primatol Z®), at-razine (Gesapax® Combi*, Gesaprim®, Primextra® Gold*), cyanazine (Bladex®), prometryn (Bandit®*, Cotogard®*, Gesagard®), propazine (Agaprop®), simazine (Brunnings RTU Path Weeder®*, Gesatop®, Bantox®*, Yates Once A Year Path Weeder®*), terbuthylazine (Effigy*®, Firestorm®*, Palmero TX®*, Terbyne®), terbutryn (Agtryne® MA*, Amigan®*, Igran®)
Triazinones	amicarbazone (Amitron®*) hexazinone (Bobcat I-Maxx®*, Velmac Plus®*, Velpar® K4*, Velpar® L), metribuzin (Aptitude®*, Sencor®)
Uracils	bromacil (Hyvar®, Krovar®*), terbacil (Eucmix Pre Plant®*, Sinbar®, Trimac Plus®*)
Ureas	diuron (Karmex®, Krovar®*, Velpar® K4*), fluometuron (Bandit®*, Cotogard®*, Cotoran®), linuron (Afalon®), methabenzthiazuron (Tribunil®), siduron (Tupersan®), tebuthiuron (Graslan®)
GROUP 6 **Inhibition of photosynthesis at photosystem II - D1 Histadine 215 binders (PS II Histadine 215 inhibitors)**	
Benzothiadiazinones	bentazone (Basagran®, Basagran® M60*, Lawnweeder Plus®*)
Nitriles	bromoxynil (Barrel®*, Buctril®, Buctril® MA*, Buffalo Pro Weedkiller®*, Eliminar C®*, Flight®*, Jaguar®*, Quadrant®*, Talinor®*, Triathlon®*, Velocity®*), ioxynil (Actril® DS*, Totril®)
GROUP 9 **Inhibition of 5-enolpyruvyl shikimate-3 phosphate synthase (EPSP inhibition)**	
Glycines	glyphosate (Arsenal Xpress®*, Bantox*, Broadway®*, Firestorm®*, Illico®*, Resolva®*, Roundup®, Sandoban*®, Tough Roundup® Weedkiller*, Trounce®*, Yates Pathweeder®*)
GROUP 10 **Inhibition of glutamine synthetase**	
Phosphinic acids	glufosinate (Basta®, Liberty®)
GROUP 12 **Inhibition of carotenoid biosynthesis at the phytoene desaturase step (PDS inhibitors)**	
N-Phenyl heterocycles	norflurazon (Solicam®)
Phenyl-ethers	diflufenican (Brodal®, Gangster®*, Jaguar®*, Mateno® Complete*, Quadrant®*, Spearhead®*, Tigrex®*, Triathlon®*, Yates Pathweeder®*), picolinafen (Eliminar C®*, Flight®*, Paragon®*, Quadrant®*, Sniper®)

Moderate resistance risk

Chemical family	**Active constituent** (first registered trade name)
GROUP 13 **Inhibition of deoxy-D-xyulose phosphate synthase (DOXP inhibitors)**	
Isoxazolidinones	bixlozone (Overwatch®), clomazone (Altiplano®*, Command®)
GROUP 14 **Inhibition of protoporphyrinogen oxidase (PPO inhibitors)**	
Diphenyl ethers	acifluorfen (Blazer®), fomesafen (Reflex®), oxyfluorfen (Goal®, Rout®, Yates Pathweeder®)
N-Phenyl-oxadiazolones	oxadiargyl (Raft®), oxadiazon (Ronstar®)
Phenylpyrazoles	pyraflufen (Condor*®, Ecopar®, Pyresta®*)
N-Phenyl-imides	butafenacil (B-Power®*, Logran® B-Power®*, Resolva®*), flumioxazin (Valor®, Terrain®), saflufenacil (Sharpen®, Voraxor*®), tiafenacil (Terrad'Or®), trifludimoxazin (Voraxor*®)
N-Phenyl-triazolinones	carfentrazone (Affinity®, Aptitude®*, Broadway®, Buffalo Pro Weedkiller®*, Silverado®*)
GROUP 15 **Inhibition of very long chain fatty acid synthesis (VLCFA inhibitors)**	
α-Chloroacetamides	dimethenamid (Freehand*, Frontier®-P, Outlook ®), metazachlor (Butisan®), metolachlor (Boxer® Gold*, Dual® Gold, Primextra® Gold*), propachlor (Prothal®*, Ramrod®)
Benzofurans	ethofumesate (Tramat®)
Isoxazolines	pyroxasulfone (Mateno® Complete*, Sakura®)
Thiocarbamates	EPTC (Eptam®), molinate (Ordram®), pebulate (Tillam®), prosulfocarb (Arcade®, Bolta Duo®*, Boxer® Gold*, Diablo Duo®*), thiobencarb (Saturn®), tri-allate (Avadex®, Diablo Duo®*, Jetti Duo®*), vernolate (Vernam®)
GROUP 18 **Inhibition of dihydropteroate synthase (DHP inhibitors)**	
Carbamates	asulam (Asulox®)
GROUP 19 **Inhibition of auxin transport (ATIs)**	
Aryl-carboxylates	naptalam (Alanap-L®)
GROUP 22 **Inhibition of photosynthesis at photosystem I via electron diversion (PSI electron diversion)**	
Pyridiniums	diquat (Reglone®, Spray Seed®*), paraquat (Alliance®*, Gramox-one®, Spray Seed®*)
GROUP 23 **Inhibition of microtubule organisation**	
Carbamates	carbetamide (Carbetamex®, [Ultro®]), chlorpropham (Chlorpropham®)
GROUP 27 **Inhibition of 4-hydroxyphenyl-pyruvate dioxygenase (HPPD inhibitors)**	
Isoxazoles	isoxaflutole (Balance® Palmero TX®*)
Pyrazoles	benzofenap (Taipan®), pyrasulfotole (Precept®*, Velocity®*) topramezone (Frequency®)
Triketones	bicyclopyrone (Talinor®*), mesotrione (Callisto®)
GROUP 29 **Inhibition of cellulose biosynthesis**	
Alkylazines	indaziflam (Specticle®)
Benzamides	isoxaben (Gallery®, X-Pand®*)
Nitriles	dichlobenil (Casoron®)
GROUP 30 **Inhibition of fatty acid thioesterase**	
Benzyl ether	cinmethylin (Luximax®), methiozolin (PoaCure Turf®)

Moderate resistance risk

Chemical family	**Active constituent** (first registered trade name)
GROUP 31 **Inhibition of serine-threonine protein phosphatase (STPP inhibitors)**	
Unknown	endothal (Endothal®)
GROUP 32 **Inhibition of solanesyl diphosphate synthase**	
Diphenyl ether	aclonifen (Mateno® Complete*)
GROUP 34 **Inhibition of lycopene cyclase**	
Triazoles	amitrole (Alliance®*, Amitrole®, Brunnings RTU Pathweeder®*, Illico®*, Firestorm®*, Yates Onceyear Pathweeder®*)

* This product contains more than one active constituent.
Notes: List of approved active constituents in each 'Group' and, for ease of identification, at the discretion of the Expert Committee on Herbicide Resistance the trade name of the first registered product or successor. Refer to the APVMA website (**www.apvma.gov.au**) to obtain a complete list of registered products from the PUBCRIS database.

List of herbicide resistant weeds in Australia

Grass weeds	Groups	Sites
African lovegrass (*Eragrostis curvula*)	0 (was J)	8
Annual ryegrass (*Lolium Rigidum*)	1 (was A)	>20,000
	2 (was B)	>20,000
	3 (was D)	>5,000
	5 (was C)	>50
	9 (was M)	>1,000
	13 (was Q)	3
	15 (was J,K)	>100
	22 (was L)	40
	34 (was Q)	3
Annual veld grass (*Ehrharta longiflora*)	1 (was A)	6
Awnless barnyard grass (*Echinochloa colona*)	9 (was M)	>200
Barnyard grass (*Echinochloa crus-galli*)	1 (was A)	1
	5 (was C)	1
Barley grass (*Hordeum spp.*)	1 (was A)	>200
	2 (was B)	>200
	9 (was M)	5
	22 (was L)	>100
Brome grass (*Bromus spp.*)	1 (was A)	>200
	2 (was B)	>1,000
	5 (was C)	1
	9 (was M)	5
Crabgrass (large) (*Digitaria sanguinalis*)	1 (was A)	2
	2 (was B)	1
Crowsfoot grass (*Eleusine indica*)	1 (was A)	1
	22 (was L)	5
Feathertop Rhodes grass (*Chloris virgata*)	9 (was M)	>1000
Giant Parramatta grass (*Sporobolus fertilis*)	0 (was J)	6
Johnson grass (Sorghum halepense)	9 (was M)	1
Lesser Canary grass (*Phalaris minor*)	1 (was A)	20
	2 (was B)	10
Liverseed grass (*Urochloa panicoides*)	5 (was C)	7
	9 (was M)	4
Paradoxa grass (*Phalaris paradoxa*)	1 (was A)	7
	2 (was B)	4
Serrated tussock (*Nassella trichotoma*)	0 (was J)	32
Silver grass (*Vulpia bromoides*)	5 (was C)	3
	22 (was L)	1
Sweet summer grass (*Brachiaria eruciformis*)	9 (was M)	1
Wild oat (*Avena* spp.)	1 (was A)	>5,000
	2 (was B)	>200
	9 (was M)	2
	0 (was Z)	>200
Windmill grass (*Chloris truncata*)	9 (was M)	13
Winter grass (*Poa annua*)	1 (was A)	3
	2 (was B)	20
	3 (was D)	>100
	5 (was C)	10
	9 (as M)	10
	15 (was J)	10
	31 (was Z)	3

Broadleaf weeds	Groups	Sites
African turnip weed (*Sisymbrium thellungii*)	2 (was B)	2
Arrowhead (*Sagittaria montevidensis*)	2 (was B)	20
Bedstraw / Cleavers (*Galium aparine*)	2 (was B)	3
Black bindweed (*Fallopia convolvulus*)	2 (was B)	2
Blackberry nightshade (*Solanum nigrum*)	22 (was L)	2
Calomba daisy (*Oncosiphon suffruticosum*)	2 (was B)	2
Capeweed (*Arctotheca calendula*)	4 (was I)	1
	9 (was M)	1
	12 (was F)	1
	22 (was L)	1
Charlock (*Sinapis arvensis*)	2 (was B)	2
Common sowthistle (*Sonchus oleraceus*)	2 (was B)	>10,000
	4 (was I)	>50
	9 (was M)	>50
Dense-flowered fumitory (*Fumaria densiflora*)	3 (was D)	2
Dirty Dora (*Cyperus difformis*)	2 (was B)	>50
Fleabane (*Conyza bonariensis*)	2 (was B)	>100
	9 (was M)	>1,000
	22 (was L)	1
Iceplant (*Mesembryanthemum crystallinum*)	2 (B)	2
Indian hedge mustard (*Sisymbrium orientale*)	2 (was B)	>1,000
	4 (was I)	>50
	5 (was C)	16
	12 (was F)	>50
Lincoln weed (*Diplotaxis tenuifolia*)	2 (was B)	20
Paterson's curse (*Echium plantagineum*)	2 (was B)	2
	9 (was M)	1
Pennsylvania cudweed (*Gamochaeta pensylvanica*)	22 (was L)	2
Prickly lettuce (*Lactuca serriola*)	2 (was B)	>2,000
	9 (was M)	1
Small square weed (*Mitracarpus hirtus*)	22 (was L)	1
Starfruit (*Damasonium minus*)	2 (was B)	5
Stinging nettle / Dwarf nettle (*Urtica urens*)	5 (was C)	1
Tall Fleabane (*Conyza sumatrensis*)	9 (was M)	10
Tridax daisy (*Tridax procumbens*)	9 (was M)	1
Turnip weed (*Rapistrum rugosum*)	2 (was B)	5
Wild radish (Raphanus raphanistrum)	2 (was B)	>5,000
	4 (was I)	>1,000
	5 (was C)	>20
	9 (was M)	3
	12 (was F)	>1,000
	29 (was O)	2
Wild turnip / Mediterranean turnip (Brassica tournefortii)	2 (was B)	>100
Willow leaf lettuce (Lactuca saligna)	9 (was M)	2

CropLife acknowledges the assistance of Dr Chris Preston (University of Adelaide) in compiling this list. If you suspect a case of herbicide resistance that is not on this list please notify Dr Preston at christopher.preston@adelaide.edu.au so that he can maintain a register of herbicide resistance in Australia. These observations are independent of registered label claims for these herbicide MoA groups.

Weed species with high risk of developing herbicide resistance

Some weed species have been identified as having a high risk of herbicide resistance development. The weeds listed below fall into this category and more information on their management can be found in the links provided.

Annual ryegrass (*Lolium rigidum*)

Annual ryegrass (*Lolium rigidum*) is the most important and costly weed to Australian winter crops with an estimated yield loss of $34.1 million to the Southern region. Ryegrass remains the major weed in terms of the cost of herbicide resistance with the cost being greater than the sum of all other forms of resistance (Rick Llewellyn, GRDC project code CSA 00043).

Herbicide resistance has been confirmed in annual ryegrass in Australia in approximately 50,000 populations across nine MoAs; Groups 1, 2, 3, 5, 9, 13, 15, 22, 34 (**croplife.org.au**). Resistance to Groups 1 and 2 are particularly widespread with more than an estimated 40,000 populations of ryegrass affected.

Herbicide resistance has developed in annual ryegrass due to its biology, including the high level of seed production, combined with high frequency of herbicide use.

Management should include a mix of herbicide and cultural strategies along with resistance testing to manage populations pro-actively.

Refer to GRDC's *Integrated Weed Management Manual* for further information: **https://grdc.com.au/resources-and-publications/all-publications/publications/2014/07/iwmm**

Refer to CropLife Australia's Herbicide Resistant Weeds list for further information: **www.croplife.org.au/wp-content/uploads/2019/06/Herbicide-Resistant-Weeds.pdf**

Wild Oats (*Avena* spp.)

Wild oats (*Avena spp*.) is the most important winter cropping weed in northern New South Wales and southern Queensland. It is second in importance to annual ryegrass in most of the southern region and a significant weed in much of Western Australia.

Group 1 herbicide resistance has been present in Australian populations of wild oats since the mid-1980s and is now common in the majority of winter crop growing regions with more than 5,000 populations of Wild oats affected. Resistance has also been confirmed to Group 2 and Group 0 with more than 200 populations of wild oats affected

The incidence of Group 1 'dim' (e.g. Achieve®) resistance in wild oats continues to increase.

Group 0 (flamprop methyl) resistance is also now common in the northern NSW and southern Queensland growing regions. Much of the resistance to flamprop methyl is also cross-resistant with Group 1 herbicides with one in three 'fop' resistant wild oat populations being observed to also have Group 0 resistance. Group 2 resistance in wild oats has also been increasing over the past decade to levels where it is also common in the northern winter crop growing regions.

Reducing the seed bank is essential for effective management of wild oats. Effective management must take place over many years due to the persistence of viable wild oat seeds in the soil. It is also important to conduct a resistance test for all key herbicides when an herbicide strategy employed is no longer completely effective. A resistance test is useful to develop or modify an herbicide strategy to prevent the build-up of resistant populations.

Refer to GRDC's *Integrated Weed Management Manual* for further information: **https://grdc.com.au/resources-and-publications/all-publications/publications/2014/07/iwmm**

Refer to CropLife Australia's Herbicide Resistant Weeds list for further information: **www.croplife.org.au/wp-content/uploads/2019/06/Herbicide-Resistant-Weeds.pdf**

Brome grass (*Bromus spp*.)

Brome grass occurs in both high and low rainfall areas across Australia and is a highly competitive weed in pasture and cropping systems. The two most common species are Bromus diandrus and Bromus rigidus and they are an increasing problem in cereal crops.

Herbicide resistance is known to occur in three MoAs (Groups 1, 2, and 9) across more than 1,000 populations in Australia. Resistance to these MoAs is not surprising considering the strong adoption of grass selective herbicides (Group 1) in the 1980s and 1990s; followed by a move to sulfonylureas and imidazolinones (Group 2) in the 2000s to present day.

Brome grass has a later germination pattern compared with other grass weeds, such as annual ryegrass or barley grass. Plants germinating in winter or early spring mean it's difficult to gain effective control with pre-sow knockdown herbicides or pre-emergent herbicides.

Further information can be found on the GRDC website: **https://grdc.com.au/resources-and-publications/all-publications/factsheets/2011/05/brome-grass**

Refer to GRDC's *Integrated Weed Management Manual* for further information: **https://grdc.com.au/resources-and-publications/all-publications/publications/2014/07/iwmm**

Refer to CropLife Australia's Herbicide Resistant Weeds list for further information: **www.croplife.org.au/wp-content/uploads/2019/06/Herbicide-Resistant-Weeds.pdf**

Barley grass (*Hordeum* spp.)

Barley grass is the widely used name for *Hordeum glaucum* and *Hordeum leporinum*. Barley grasses are annual species dominant in the winter rainfall (southern) areas of the cropping belt of Australia.

There are over 200 populations of barley grass resistant to Group 2 herbicides and over 200 populations resistant to Group 1 herbicides (mostly 'fop' but also some populations resistant to 'dim' herbicides plus some cross-resistance to 'dim' herbicides). There are also more than 100 populations resistant to Group 22 herbicides (paraquat and diquat) and at least four populations resistant to Group 9 (glyphosate)

Barley grasses are commonly a problem in low rainfall cropping environments where cereals are grown in long succession and dry sowing is routinely practiced. In these environments, barley grasses are becoming more problematic as an increasing number of populations have evolved to have longer seed dormancy. This enables barley grasses to escape knockdown herbicides pre-sowing and then germinate in-crop, where there are limited herbicide options.

In cropping systems, low-disturbance disc equipment favours barley grasses compared with knife point and conventional sowing systems. This is the opposite situation to wild oats and annual ryegrass, which are less viable if left on the soil surface.

There is no evidence indicating that barley grasses produce a persistent seed-bank. Over 99 per cent of seeds germinate in the first year after seed-set. Where activities such as pasture spray-topping are correctly timed, field observations indicate that control will be very high (as evidenced by reduced autumn germinations).

Refer to GRDC's *Integrated Weed Management Manual* for further information: **https://grdc.com.au/resources-and-publications/all-publications/publications/2014/07/iwmm**

Refer to CropLife Australia's Herbicide Resistant Weeds list for further information: **www.croplife.org.au/wp-content/uploads/2019/06/Herbicide-Resistant-Weeds.pdf**

Barnyard grass (*Echinochloa* spp.)

Of the top five weeds considered to be most troublesome to world agriculture, two belong to the genus *Echinochloa*;[2] *Echinochloa colona* (awnless barnyard grass) and E*chinochloa crus-gralli* (barnyard grass). Barnyard grasses have increased in prevalence in Australia over the last 20 years with the greater adoption of minimum tillage systems. These grass species are problematic because they are prolific seeders, are not consistently controlled with commonly used herbicides, and can be highly competitive.

At least 200 populations of awnless barnyard grass have confirmed resistance to glyphosate. Tactics against this weed need to change from glyphosate alone.

At least one population of barnyard grass is also confirmed resistant to Group 1 herbicides, and at least one more resistant to Group 5 herbicides. Further information on barnyard grass can be accessed at the following sites:

- **https://grdc.com.au/resources-and-publications/all-publications/publications/2014/07/iwmm**
- **www.daf.qld.gov.au/__data/assets/pdf_file/0008/55277/Managing-barnyard-and-liverseed-grasses.pdf**
- Refer to CropLife Australia's Herbicide Resistant Weeds list for further information: **www.croplife.org.au/wp-content/uploads/2019/06/Herbicide-Resistant-Weeds.pdf**

2 Storrie AM (ed) 2014, *Integrated weed management in Australian cropping systems,* Grains Research and Development Corporation.

Fleabane (*Conyza* spp.)

Fleabane is a woody weed that presents a major problem to broadacre and horticulture growers, particularly in fallow situations and where there is limited cultivation. The most common species of fleabane in Australia is flaxleaf fleabane (*Conyza bonariensis*), a widespread problem in southern Queensland and northern New South Wales, but also prevalent in southern and western states in summer. Tall fleabane (*Conyza sumatrensis*) is also now emerging in Western Australia.

Fleabane is notoriously difficult to control with herbicides due to a natural tolerance to glyphosate. Incidences of resistance to Groups 2, 5 and 22 have been recorded globally. Currently in Australia, resistance has been confirmed in approximately 200 populations to Groups 2, 9 and 22 herbicides. Because of this, fleabane can be managed effectively with residual herbicides applied both in fallow and in-crop.

It is recommended to use an integrated weed management approach when targeting fleabane, incorporating non-chemical means such as crop competition.

Further information can be accessed on the following sites:

- **www.agric.wa.gov.au/grains-research-development/fleabane**
- **https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2015/07/farming-systems-strategies-to-manage-fleabane-and-feathertop-rhodes-grass**
- **www.daf.qld.gov.au/data/assets/pdf_file/0005/65903/Flaxleaf-fleabane.pdf**
- Refer to CropLife Australia's Herbicide Resistant Weeds list for further information: **www.croplife.org.au/wp-content/uploads/2019/06/Herbicide-Resistant-Weeds.pdf**

Common sowthistle (*Sonchus oleraceus*)

Common sowthistle, or milk thistle (*Sonchus oleraceus*), is a weed of broadacre and horticulture regions across Australia.

It is an important weed for the following reasons:

- Populations are increasing.
- It has become less seasonal in occurrence, with germination associated with sufficient soil moisture across a range of soil temperatures.
- It is a prolific seed producer.
- There is widespread resistance (greater than 10,000 populations) to a range of (once very effective) Group 2 herbicides, with recently identified isolated populations resistant to Group 4 (>50 populations) and Group 9 (>50 populations) herbicides.

Sowthistle seed is dispersed by wind, but typically most seed falls within a few metres of the parent plant. Seed typically germinates from near the soil surface. If seed is not buried it generally does not persist for more than one season.

Preventing seed set is an important tactic of an integrated weed management strategy. It is suggested that growers monitor the performance of herbicides applied in fallow, especially glyphosate-based applications.

While herbicides from Group 4 remain generally very effective, the identification of (as yet very isolated) populations that are resistant are of concern due to the reliance on this MoA group.

References:

Widderick M & Walker S 2009, *Management of common sowthistle* fact sheet, Leslie Research Centre, Toowoomba.

Further information can be accessed on the following sites:

- **https://grdc.com.au/resources-and-publications/all-publications/publications/2014/07/iwmm**
- WeedSmart: **https://weedsmart.org.au/?s=sowthistle**
- Australian Glyphosate Sustainability Working Group: **www.glyphosateresistance.org.au/group_I_resistance.html**
- CropLife Australia's Herbicide Resistant Weeds list for further information: **www.croplife.org.au/wp-content/uploads/2019/06/Herbicide-Resistant-Weeds.pdf**

Wild radish (*Raphanus raphanistrum*)

Wild radish (*Raphanus raphanistrum*) is one of the most widespread and competitive weeds of grain cropping and horticulture in Australia. It is the most costly broadleaf weed nationally in terms of yield loss in winter broadacre crops.

Wild radish has developed resistance to 5 herbicide MoAs including Groups 2, 4, 5, 9, 12, and 29. Whilst resistance to some herbicides has been slow to develop e.g. Group 5 (20 populations) Group 29 (two populations), or has been discovered only recently e.g. Group 9 (three populations), resistance to Group 2 (more than 5,000 populations), Group 12 (more than 1,000 populations) and Group 4 (more than 1,000 populations) is now widespread. Increasingly, wild radish populations are developing resistance to multiple MoAs.

Reducing the seed bank is essential for effective management of wild radish. Effective management must take place over many years due to the persistence of viable wild radish seeds in the soil. It is also important to conduct a resistance test for all key herbicides when an herbicide strategy employed is no longer completely effective. A resistance test is useful to develop or modify an herbicide strategy to prevent the build-up of resistant populations.

References

Llewellyn RS, Ronning D, Ouzman J, Walker S, Mayfield A & Clarke M 2016, *Impact of Weeds on Australian Grain Production: the cost of weeds to Australian grain growers and the adoption of weed management and tillage practices Report for GRDC*, CSIRO, Australia.

Refer to GRDC's *Integrated Weed Management Manual* for further information: **https://grdc.com.au/resources-and-publications/all-publications/publications/2014/07/iwmm**

Refer to CropLife Australia's Herbicide Resistant Weeds list for further information: **www.croplife.org.au/wp-content/uploads/2019/06/Herbicide-Resistant-Weeds.pdf**

Prickly lettuce (*Lactuca serriola*)

Prickly lettuce (*Lactuca serriola*) is a weed of cereal and pulse crops, orchards, vines and non-crop areas.

It is self-compatible and self-pollinated with little evidence of interspecific hybridisation. Seed production of this species is high but varies according to growing conditions. The seeds are light, windborne via a pappus, germinate readily, have no primary dormancy and have a short-lived seed bank.

Sulfonylurea-resistant prickly lettuce was first reported from a continuous no-till winter wheat crop in 1987. As of June 2018, there are reported to be more than 2,000 populations resistant to Group 2 herbicides. There is one reported case of Group 9 (glyphosate) resistance.

References

Baker J, Yi Qing Lu and Preston C, 'Spread of resistance to acetolactate synthase inhibiting herbicides in a wind borne, self-pollinated weed, *Lactuca serriola* L. (prickly lettuce)', *Australian Weeds Conference 2015*, pp. 519–21.

Further information can be accessed on the following sites:

- Queensland Government: **https://keyserver.lucidcentral.org/weeds/data/media/Html/lactuca_serriola.htm**
- Agriculture Victoria: **http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/sip_salt_prickly_lettuce**
- CropLife Australia's Herbicide Resistant Weeds list for further information: **www.croplife.org.au/wp-content/uploads/2019/06/Herbicide-Resistant-Weeds.pdf**

Indian hedge mustard (*Sisymbrium orientale*)

IIndian hedge mustard (*Sisymbrium orientale*) is a widespread, introduced weed of many regions of Australia.

There are significant populations resistant to Group 2 (more than 1,000 populations), Group 4 (50 populations) and some resistant to both groups. There are also small populations (less than 50) resistant to Group 5 and Group 12 herbicides. The first cases of Group 2 resistance were confirmed in the early 1990s in New South Wales, South Australia and southern Queensland. These collections were growing in continuously cropped wheat paddocks where chlorsulfuron had been applied for between six to ten years. Random weed surveys across western South Australia, on the Eyre Peninsula in 2009, and western Victoria in 2010 revealed that 52 per cent and 35 per cent, respectively, of Indian hedge mustard populations were resistant to chlorsulfuron. Also, 57 per cent and 38 per cent of the samples from South Australia and western Victoria, respectively, were also resistant to metosulam.

The first case of 2,4 D resistance in Indian hedge mustard was identified in 2007 in South Australia. Subsequent directed surveys in this region identified 12 Indian hedge mustard populations occurring on seven farms with resistance to both 2,4-D and Group 2 herbicides. Resistance to Group 2 and 4 herbicides is of particular concern as it limits weed control options.

Because its seeds have a relatively short innate dormancy and germinate more readily in seasons with good rainfall, Indian hedge mustard germinates during autumn to winter. In these seasons effective control can be achieved by pre-sowing knockdown herbicides. However, in seasons when opening rains are late, there can be a serious infestation of Indian hedge mustard in sown crops as it continues to emerge after post-emergent herbicides have been applied.

Refer to GRDC's *Integrated Weed Management Manual* for further information: **https://grdc.com.au/resources-and-publications/all-publications/publications/2014/07/iwmm**

Refer to CropLife Australia's Herbicide Resistant Weeds list for further information: **www.croplife.org.au/wp-content/uploads/2019/06/Herbicide-Resistant-Weeds.pdf**

Mediterranean / Wild turnip (*Brassica tournefortii*)

Wild turnip (*Brassica tournefortii*) is a weed common in southern and central Queensland, many parts of New South Wales, Victoria, Tasmania and South Australia, and in southern and central Western Australia. This weed can germinate at any time of the year, though most germination occurs either in autumn or spring.

Like other brassica weeds, there are numerous (greater than 100) populations of wild turnip that have evolved resistance to Group 2 herbicides. Resistance to Group 2 herbicides was first confirmed in South Australia and Western Australia in 1996. Herbicide usage records show that resistance has developed after three to ten years of selection with chlorsulfuron.

Refer to GRDC's *Integrated Weed Management Manual* for further information: **https://grdc.com.au/resources-and-publications/all-publications/publications/2014/07/iwmm**

Refer to CropLife Australia's Herbicide Resistant Weeds list for further information: **www.croplife.org.au/wp-content/uploads/2019/06/Herbicide-Resistant-Weeds.pdf**

CropLife Australia

croplife.org.au/resistance-management