CropLife Australia

Resistance Management Strategies

INSECTICIDES | FUNGICIDES | HERBICIDES

2020–2021

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Search the strategies online by keyword, crop, pest or type of product at:
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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

Pests, weeds and diseases continue to be major threats to the productivity, profitability and sustainability of Australia's farming sector. To ensure the longevity and viability of agricultural chemical products, appropriate strategies to minimise resistance must be adopted.

CropLife Australia's resistance management strategies for fungicides, herbicides and insecticides assist farmers, agronomists and environmental land managers to ensure important crop protection products remain an effective tool.

The strategies are developed as part of CropLife and our members' commitment to make the most up-to-date resistance management advice freely available. They are reviewed and updated on an annual basis 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 and innovative agricultural chemical products each year, allowing farmers to access economically viable and environmentally sustainable crop protection solutions. This investment includes a commitment to the responsible and ethical management of industry products throughout their lifecycle.

These resistance management strategies are part of 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.

Importantly, the resistance management strategies do not replace product labels, they simply supplement them. Crop protection products must be handled and applied as specified on the registered product label or approved permit.

Having an integrated pest management system and an effective resistance management strategy for chemical crop protection products is crucial to the long-term viability and profitability of Australian farming.

I strongly encourage all farmers, spray applicators, agronomists and environmental land managers to utilise these strategies for important and current advice on managing resistance so crop protection products maintain their effectiveness and the life of these crucial farming tools is extended.

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
IMC	Integrated mite control
IPM	Integrated Pest Management
IRAC	Insecticide Resistance Action Committee
IRMRG	Insecticide Resistance Management Review Group
IRM	Insecticide resistance managemenet
IWM	Integrated weed management
MoA	Mode of Acion
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 INSECTICIDE RESISTANCE MANAGEMENT REVIEW GROUP AND INDUSTRY RESEARCHERS — VALID AT 10 JUNE 2020

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 taken 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 it application and use. Advice given in this strategy is valid as at 10 June 2020. All previous versions of this strategy are now invalid.

Introduction

The CropLife Australia Insecticide Resistance Management Review Group (IRMRG) 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 modes of action

The objective of Insecticide Resistance Management (IRM) 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 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 (RMS) of avoiding overuse of individual MoA 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 IRM strategies and insecticide MoA can be found on the International IRAC (Insecticide Resistance Action Committee) website: **www.irac-online.org/**.

Crop: **Bananas**

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

Comments on the strategy:

1. If replanting into an old banana block, allow at least six months fallow after old banana material has rotted down.
2. 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.
3. Cut up fallen and harvested pseudostems to reduce weevil breeding sites.
4. Monitor regularly for banana weevil borer activity by trapping (when adult weevils are active) or conduct corm damage ratings.
5. Only use insecticides when populations reach or exceed accepted threshold levels. Refer to local Department of Agriculture guidelines.
6. 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.
7. Use insecticides only in the years indicated in the following diagrams.
8. Consider the impact of the use of other pesticides for other insects or nematodes on banana weevil borers.
9. 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 Resistance Management Strategies 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]	✗	✓	✗	✓	✗	✓
5	*Spinosyns*	spinetoram [2]	✗	✓	✗	✓	✗	✓

* Refer: CropLife Australia Insecticide Resistance Management Review Group 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 Insecticide Resistance Management Review Group 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**

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:
   - **b)** 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*.
   - **c)** Apply a specific active ingredient using a 'window' approach to avoid exposure of consecutive insect pest generations to the same mode of action. Multiple successive applications of a specific active ingredient are acceptable if they are used to treat a single pest generation.
   - **d)** Following a 'window' of a specific mode of action product, **rotate** to a 'window' of applications of effective insecticides with a different mode of action.
   - **e)** 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.
   - **f)** Incorporate IPM techniques into the overall pest management program and
   - **g)** 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 mode of action insecticide for a period covering at least one generation of diamond back moth. This may require a minimum of two applications of alternate mode of action 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
23	spirotetramat	2 but 3 in brassica leafy vegetables
28	chlorantraniliprole, flubendiamide	3 but 1 for mixtures of chlorantraniliprole and thiamethoxam

* Refer: CropLife Australia Insecticide Resistance Management Review Group 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): **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.

Crop	MoA group*	Chemical sub-group	Example chemical
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	organophosphates or synthetic pyrethroids	chlorpyrifos alpha-cypermethrin
Spring	1B 3A	organophosphates or synthetic pyrethroids	omethoate gamma-cyhalothrin

* Refer: CropLife Australia Insecticide Resistance Management Review Group Mode of Action Classification for Insecticides.

3. If both autumn and spring applications are needed, alternate between synthetic pyrethroids and organophosphates.
4. Timing of sprays
   - **a)** Monitor Redlegged Earth Mite (RLEM) activity carefully and only treat if damage has reached threshold levels.
   - **b)** One well timed spray in Autumn or Spring will maximise effectiveness of treatment.
3. Placement of sprays
   - **a)** Apply perimeter sprays where infestations are concentrated on the edge of fields.
   - **b)** Use blanket sprays where appropriate.
3. Cultural practices
   - **a)** Heavy grazing or cutting for hay or cultivation will reduce mite numbers.
   - **b)** Develop damage thresholds.
   - **c)** Rotate crops and pastures that are more tolerant to the pest.
   - **d)** Encourage predator survival by judicious use of insecticides.
   - **e)** Control alternative hosts such as Capeweed and Paterson's curse. For more detail on resistance management for RLEM in grain crops and pastures, refer to: **http://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): **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 mode of action (i.e. **Group 6, Group 10A**, **Group 10B**, **Group 12B**, **Group 12C**, **Group 13**, **Group 20D** and **Group 21A**).
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
20D	Bifenazate	bifenazate
21A	METI acaricides	fenpyroximate, tebufenpyrad

* Refer: CropLife Australia Insecticide Resistance Management Review Group 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**.

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 Insecticide Resistance Management Review Group Mode of Action Classification for Insecticides

Notes regarding the application of insecticides:

4. To ensure the most effective control of the pest:
   - **e)** Product labels should at all times be carefully read and adhered to.
   - **f)** Full recommended rates of registered insecticides should always be used.
   - **g)** 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 mode of action. 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. 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^	Example chemical
1A	methomyl, thiodicarb	not specified	All cereal grains, oilseed, pulses
3A	synthetic pyrethroids (various)	not specified	All cereal grains, oilseed, pulses
5	spinetoram	TBC	All cereal grains, oilseed, pulses
6	emamectin benzoate	2	All pulses
11A	*Bacillus thuringiensis*	not specified	All pulses
22A	indoxacarb	1	chickpea, faba bean, mung bean, soybean, azuki bean
28	chlorantraniliprole	Refer to label	All pulses
NC	Nucleopolyhedrovirus (NPV)	no limit but avoid season long use of low rates	All cereal grains, oilseed, pulses

NC Not categorised.

* Refer: CropLife Australia Insecticide Resistance Management Review Group 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 mode of action 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 mode of action. 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 Insecticide Resistance Management Review Group Mode of Action Classification for Insecticides

Notes regarding the application of insecticides:

1. To ensure the most effective control of the pest:
    - **b)** Product labels should at all times be carefully read and adhered to.
    - **c)** Full recommended rates of registered insecticides should always be used.
    - **d)** 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): 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 MoA 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 Insecticide Resistance Management Review Group 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
   - 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): 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
3A	pyrethroids	Gamma-cyhalothrin, alpha-cypermethrin
5	spinosyns	Spinetoram
6	Avermectins	Emamectin benzoate
22A	oxadiazines	indoxacarb
28	Diamides	chlorantraniliprole, flubendiamide

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

^ Refer to CropLife Australia Insecticide Resistance Management Review Group 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 broadspectrum 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 mode of action. 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 rotate 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 to ensure you are following the most up-to-date fall armyworm strategy.

2. 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): 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*** 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 modes of action (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 MoA 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
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 Insecticide Resistance Management Review Group 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 to 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 to 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.

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		
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		
8 **Miscellaneous non-specific (multi-site) inhibitors-**	**8A** Alkyl halides	Methyl bromide		
	8B Chloropicrin	Chloropicrin		
	8C Fluorides	Sulfuryl fluoride		

Main MoA Group and primary site of action	Chemical sub-group or exemplifying active constituent	Active constituents[1]		
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 Chlorfluazuron Diflubenzuron	Flufenoxuron Hexaflumuron Lufenuron	Novaluron Triflumuron
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		
20 **Mitchondrial complex III electron transport inhibitors** Energy metabolism	**20A** Hydramethylnon	Hydramethylnon		
	20B	No registered active constituents in Australia		
	20C	No registered active constituents in Australia		
	20D Bifenazate	Bifenazate		

Main MoA Group and primary site of action	Chemical sub-group or exemplifying active constituent	Active constituents[1]		
21 **Mitchondrial complex I electron transport inhibitors**	**21A** METI acaricides and insecticides	Fenpyroximate	Pyridaben	Tebufenpyrad
Energy metabolism	**21B** Rotenone	Rotenone (Derris)		
22 **Voltage-dependent sodium channel blockers**	**22A** Oxadiazines	Indoxacarb		
Nerve action	**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**	**24A** Phosphides	Phosphine Magnesium phosphide	Aluminium phosphide	
Energy metabolism	**24B** Cyanides	No registered active constituents in Australia		
25 **Mitochondrial complex II electron transport inhibitors**	**25A** Beta-ketonitrile derivatives	No registered active constituents in Australia		
Energy metabolism	**25B** Carboxanilides	No registered active constituents in Australia		
28 **Ryanodine receptor modulators**	Diamides	Chlorantraniliprole	Cyantraniliprole	Cyclaniliprole
Nerve and muscle action		Flubendiamide		
29 **Chordotonal organ modulators — undefined target site**				
Nerve action	Flonicamid	Flonicamid		
30 **GABA-gated chloride channel allosteric modulators**	Meta-diamides Isoxazolines	Broflanilide		
Nerve action				
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*		
UN Compounds of unknown or uncertain mode of action[1]	Azadirachtin	Azadirachtin		
	Beauveria bassiana	*Beauveria bassiana*		
	Clitoria ternatea extract	*Clitoria ternatea* extract		
	Dicofol	Dicofol		
	Lime sulphur	Lime sulphur		
	Sulphur	Sulphur		

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

1 A compound with an unknown or controversial mode of action 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 mode of action group.

Mode of Action classification for insecticides — active constituent list

Active constituent	Current group
Abamectin	**6**
Acephate	**1B**
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**

Active constituent	Current group
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**

Active constituent	Current group
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 FUNGICIDE RESISTANCE MANAGEMENT REVIEW GROUP AND INDUSTRY RESEARCHERS — VALID AS AT 10 JUNE 2020

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 taken 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 it application and use. Advice given in this strategy is valid as at 10 June 2020. All previous versions of this strategy are now invalid.

Introduction

The CropLife Australia Fungicide Resistance Management Review Group (FRMRG) 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 through the incorrect use of fungicides by selection of the resistant forms of fungi. Continued use of a fungicide or fungicide chemical group can result in a significant build-up of resistant individuals in the fungal population — to the point where that particular product, or other products from the same chemical group, is no longer effective. In some cases, removal of the selection pressure can result in the fungal population regaining its sensitivity to the fungicide group, but this is not always the case. The risk of fungicide resistance developing varies between different chemical groups and different fungal pathogens, such that specific strategies are recommended for those situations considered to carry the highest risk.

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 Fungicide Resistance Management Review Group 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 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, glasshouses and other structures of protected cultivation. Because protected cultivation usually requires multiple applications of fungicides at short intervals to control high disease incidence, these are often the origin of resistance to fungicides. Users of fungicides should be particularly mindful of the resistance risk under these conditions. Do not use a fungicide product to which resistance has been confirmed and stop using a product if resistance is suspected. When the fungicide in question no longer gives adequate control, stop using it temporarily and consult the supplier on its current resistance status.

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) be limited to a maximum of one-third of the total number of fungicide applications. The use of consecutive applications of fungicides from the same activity group should also be limited by alternating between products from different activity groups. The use of Group M fungicides is not limited, as these fungicides carry an inherently low risk of fungicide resistance developing.

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

FRAC Pathogen	Crop	Disease
Botryotinia fuckeliana (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 4. Plant pathogens for which resistance has been confirmed 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 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 (DMIs)
- **Group 7** Succinate dehydrogenase inhibitors (SDHIs)
- **Group 11** Quinone outside inhibitor (QoI)
- **Group 11+3** QoI + DMI
- **Group 11+7** QoI + SDHI

1. **Do not** apply consecutive sprays of products containing **Group 7**. Consecutive sprays include mixtures containing **Group 7**.
2. Do not apply consecutive sprays of products containing **Group 11**. Consecutive sprays include mixtures containing **Group 11**.
3. **Do not** apply more than three **Group 3**, **7** or **11** sprays per season (including mixtures of **Group 11+3** and **Group 11+7**).
4. **Do not** apply more than three **Group 2** sprays in one season. Apply no more than two consecutive sprays before changing to another group.
5. Consecutive application includes from the end of one season to the start of the following season.
6. The spray program should be considered and the strategy applied on a whole-orchard basis.
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 rotation and mixing partners as per label recommendations.

Crop(s): **Almonds**

Disease(s): Rust

RMS for:

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

1. **Do not** apply consecutive sprays of solo products containing **Group 7**. Consecutive sprays include mixtures containing **Group 7**.
2. Do not apply consecutive sprays of solo products containing **Group 11**. Consecutive sprays include mixtures containing **Group 11**.
3. **Do not** apply more than three **Group 3**, **7** or **11** sprays per season (including mixtures of **Group 11+3** and **Group 11+7**).
4. 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.
5. If applying **Group 7** or **Group 11** fungicides in mixtures e.g. **Group 11+7**. **Do not** apply more than two consecutive sprays before changing to another group.
6. Rotate with products from **Groups M2**, **M3** and **M5**.
7. 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 (DMIs)
- **Group 7** Succinate Dehydrogenase Inhibitors (SDHIs)
- **Group 9** Anilinopyrimidine
- **Group 11** Quinone outside Inhibitor (QoI)
- **Group U12** Cell membrane disruption fungicides

1. To prevent or delay the onset of resistance to **Group 3** fungicides, **do not** apply more than four (4) **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. **Do not** apply more than three sprays per 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 group(s) before a **Group 7** or **Group 11** fungicide is used again, either in the current or following season.
6. 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.
7. 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.
8. 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 season.
9. If more sprays are required, tank mix **Group U12** with a protectant product at the registered rate.

Crop(s): **Banana**

Disease(s): Yellow sigatoka

RMS for:

- **Group 3** Demethylation inhibitors (DMIs)
- **Group 7** Succinate dehydrogenase inhibitors (SDHIs)
- **Group 7+3** SDHI + DMI
- **Group 9** Anilinopyrimidine
- **Group 11** Quinone outside Inhibitor (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 (2) **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 (4) **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 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 (DMIs)
- **Group 5** Morpholines
- **Group 7** Succinate dehydrogenase inhibitors (SDHIs)
- **Group 7+3** SDHI + DMI
- **Group 11+3** Quinone outside Inhibitor (QoI) + DMI
- **Group 11+4** QoI + Phenylamide
- **Group 13** Aza-napthalene
- **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 (DMIs)
- **Group 7** Succinate dehydrogenase inhibitors (SDHIs)
- **Group 7+3** SDHI + DMI
- **Group 11+3** Quinone outside Inhibitor (QoI) + DMIs
- **Group 11+4** QoI + Phenylamide
- **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:
   - removal of stubble
   - crop rotation (**avoid** barley on barley)
   - control of green bridge volunteers
   - 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 infurrow 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** Phenylamide
- **Group 11** Quinone outside Inhibitors (QoI)
- **Group 21** Quinone inside Inhibitors
- **Group 28+43** Carbamate + Benzamide

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 mode of action 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** Phenylamide
- **Group 11** Quinone outside inhibitor (QoI)
- **Group 21** Quinone inside Inhibitor
- **Group 49** Oxysterol binding protein inhibitor (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 (DMIs)
- **Group 7** Succinate dehydrogenase inhibitor (SDHI)
- **Group 7+3** SDHI + DMI
- **Group 11+3** Quinone outside Inhibitor + 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 seasons canola stubble, the use of resistant varieties, using alternative fungicide modes of action 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. Minimise use of fungicides which are known to have compromised resistance status.
8. 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	3	3	3	3	7	7	7+3	7+3
Seedling foliar (Blackleg)		None	3	7	7+3	None	3	7	7+3	None	3	None	3
20–50 per cent flowering (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	7+3	
	5	11+3	11+3	11+3	11+3	11+3		11+3		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**	**11 + 3**
Rotation options for 50 per cent flowering second application	3	2	2	2
	7+3			
	11+3			

Crop(s): **Cucurbits**

Disease(s): Downy Mildew

RMS for:

- **Group 4** Phenylamide
- **Group 11** Quinone outside Inhibitor (QoI)
- **Group 28+43** Carbamate + Benzamide
- **Group 40** Carboxylic acid amide
- **Group 49** Oxysterol binding protein inhibitor (OSBP)
- **Group 49+11** OSBP + 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**, **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**, **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**, **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 33 per cent 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** or **11** containing fungicides (including **49+11**) per crop.
6. Apply **Group 4**, **11** 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 inhibitor (DMI)
- **Group 7** Succinate dehydrogenase inhibitors (SDHIs)
- **Group 8** Hydroxy-(2-amino-)pyrimidine
- **Group 11** Quinone outside Inhibitor (QoI)
- **Group 11+7** QoI + SDHI
- **Group 13** aza-napthalenes
- **Group U6** Phenyl-acetamide
- **Group 50** Actin inhibitors

1. Start disease control early. **Do not** wait for powdery mildew to appear before spraying but start as soon as practicable 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:
   - Tank mix systemic fungicides with a protectant fungicide **and** use fungicides from at least two different systemic activity groups per crop.
   - Alternate systemic fungicides with a protectant fungicide **and** use fungicides from at least two different systemic activity groups per crop.
   - Alternate systemic fungicides from at least three different activity groups per crop.
   - Apply **Group 11** fungicides preventatively.
   - Use a maximum of one **Group 11** containing spray out of every three fungicide applications.
   - **Do not** use consecutive applications of **Group 11** or **Group U6** fungicides.
   - **Do not** apply more than two **Group 11** (including **11+7**) or **Group U6** products per crop.
   - **Do not** apply more than three **Group 7** or **Group 13** products per crop and no more than two consecutive applications per year.

Crop(s): **Fruit (post-harvest treatment)**

Disease(s): Post-harvest diseases

RMS for:

- **Group 2** Dicarboximide + other 'systemic' fungicides
- **Group 3** Demethylation inhibitors (DMIs)
- **Group 3+12** DMI + Phenylpyrroles
- **Group 9** Anilinopyrimidine
- **Group 11+12** Quinone outside Inhibitors (QoI) + Phenylpyrroles
- **Group 12** Phenylpyrroles

1. For the last pre-harvest spray, use a fungicide with a different activity group to the fungicide planned for use as a post-harvest treatment.
2. Where alternatives are available, rotate to use as many different activity groups as possible.
3. **Do not** dispose of unused dip solutions as a spray to crops or orchards.
4. **Do not** dispose of unused dip solutions within or near the crop or orchard area.

Crop(s): **Grape**

Disease(s): Downy Mildew

RMS for:

- **Group 4** Phenylamide
- **Group 11** Quinone outside Inhibitor (QoI)
- **Group 21** Quinone inside Inhibitor
- **Group 40** Carboxylic acid amide
- **Group 45** QoI, stigmatellin binding type fungicides

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. Mixtures — co-formulations or tank mixes with label rate of alternative MoA.
3. Apply a maximum of two consecutive applications of any one group.
4. 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.
5. Limit the use of **Group 4** fungicides to periods when conditions favour disease development. Always apply **Group 4** fungicides in mixtures.

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

* Refer to point 6.

6. **Group 40:**
   - do not apply as the last spray of the season
   - apply a maximum of 50 per cent of the total number of downy sprays.
7. **Group 11:**
   - if applied alone, do not make consecutive applications
   - apply a maximum of two sprays per season, including mixtures.

Crop(s): **Grape**

Disease(s): Grey Mould (*Botrytis* Bunch Rot)

RMS for:

- **Group 2** Dicarmoximide
- **Group 7** Succinate dehydrogenase inhibitors (SDHIs)
- **Group 9** Anilinopyrimidine
- **Group 9+12** Anilinopyrimidine + Phenylpyrroles
- **Group 12** Phenylpyrroles
- **Group 11** Quinone outside Inhibitor (QoI)
- **Group 11+3** QoI + Demethylation inhibitors (DMI)
- **Group 17** Hydroxyanilide

1. Apply all these fungicides as protectants before the first sign of disease.
2. Consecutive applications include from the end of one season to the start of the next.
3. 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**	**9** (incl. 9+12)	**11** (incl. 11+3)	**17**
Total no. of *Botrytis* targeting sprays	**1**	1	1	1	1	1
	2	1	1	1	1	1
	3	1	1	1	1	1
	4	2	2	2	2	2
	5+	2	2	2	2	2

4. 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.
5. **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.
6. 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.
7. If resistance to a fungicide group has been detected, 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.
8. 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): Powdery Mildew

RMS for:

- **Group 3** Demethylation inhibitors (DMIs)
- **Group 5** Amines (morpholines)
- **Group 7** Succinate dehydrogenase inhibitors (SDHIs)
- **Group 11** Quinone outside inhibitors (QoI)
- **Group 11 + 3** QoI and DMI (refer to **Group 11** in table)
- **Group 13** Aza-napthalenes
- **Group U6** Phenyl-acetamide
- **Group 50** Actin disruptors (aryl-phenyl-ketone)

1. Apply all these fungicides preventatively.
2. Consecutive applications include from the end of one season to the start of the next.
3. Mixtures — co-formulations or tank mixes with label rate of alternative MoA.

	Group						
	3	5	7	11	13	U6	50
Max. no. consecutive sprays when only fungicide applied	2	2	None	None	2	2	2
Max. no. consecutive sprays when applied as tank-mix or co-formulant	2	2	2	2	2	2	2
Max. no. sprays per season	2	2	3	2	3	2	4

4. 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 mixtures.
5. **Group 11**:
   - if applied alone, as the only fungicide, do not make consecutive applications, apply a maximum of two sprays per season
   - if applied with another fungicide, can be used consecutively except where they have been used routinely for many seasons, apply a maximum of two sprays per season.

Crop(s): **Lettuce**

Pest(s): Botrytis & Sclerotinia

RMS for:

- **Group 2** Dicarboximide
- **Group 7** Succinate dehydrogenase inhibitors (SDHIs)
- **Group 9** anilinopyrimidine
- **Group 11** Quinone outside inhibitor (QoI)
- **Group 9 + 12** anilinopyrimidine + phenylpyrroles

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** 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 MoA. 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.

Crop(s): **Lettuce**

Disease(s): Downy Mildew

RMS for:

- **Group 4** Phenylamide
- **Group 28+43** Carbamate + Benzamide
- **Group 40** Carboxylic acid amide
- **Group 49** Oxysterol binding protein inhibitor (OSBP)
- **Group 49+11** OSBP + Quinone outside Inhibitor (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**, **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. **Group 49** including **Group 49+11** fungicides should only consist of a maximum of 33 per cent 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.
5. **Do not** apply more than three sprays of a **Group 28+43** product per crop.
6. 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.
7. Continue alternation of fungicide modes of action 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
- **Group 3** Demethylation inhibitor (DMI)
- **Group 7** Succinate dehydrogenase inhibitors (SDHIs)
- **Group 11** Quinone outside Inhibitors (QoI)
- **Group 7+11** SDHI + QoI

1. If applying **Group 1**, **3**, **7** or **11** 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.

	Group				
	1	3	7	11	7+11
Max. no. of consecutive sprays when applied alone	None	None	None	None	1
Max. no. of consecutive sprays when applied in mix with a different MoA	2	2	2	2	2
Max. no. of sprays per season	2	2	2	2	2

2. The limit of two sprays per season for **Group 7** and **11** applies to co-formulated products.
3. The spray program should be considered and the strategy applied on a whole-orchard basis.

Crop(s): **Onion**

Disease(s): Downy Mildew

RMS for:

- **Group 4** Phenylamide
- **Group 28+43** Carbamate plus Benzamide
- **Group 40** Carboxylic acid amide
- **Group 49** Oxysterol binding protein inhibitor (OSBP)
- **Group 49+11** OSBP + Quinone outside Inhibitor (QoI)

1. Start disease control early and maintain a regular program using a fungicide from groups other than **Group 4**, **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 33 per cent of the total number of fungicide sprays per crop.
5. Apply **Group 4**, **40** and **49** (including **49+11**) fungicides preventatively. Apply solo products of **Group 4** and **49** fungicides only in mixtures with a registered fungicide from a different MoA group, with no known resistance.
6. Apply **Group 4** and **49** (or **49+11**) fungicides preventatively and only in mixtures with a registered fungicide from a different MoA group, with no known resistance.
7. 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.

Crop(s): **Ornamentals**

Disease(s): Grey Mould

RMS for:

- **Group 2** Dicarboximide
- **Group 9** Anilinopyrimidine

1. If three or fewer *Botrytis* fungicide sprays are applied per crop, use only one spray containing a **Group 9** fungicide. If four to six sprays are applied per crop, use a maximum of two sprays containing **Group 9** fungicides. If seven or more sprays are applied per crop use a maximum of three sprays containing **Group 9** fungicides.
2. Avoid applying more than two successive sprays of a **Group 9** fungicide, including from the end of one season to the next.
3. **Do not** apply more than two consecutive sprays of a **Group 2** fungicide.

Crop(s): **Passionfruit**

Disease(s): Alternata Spot (*Alternaria* spp.)

RMS for:

- **Group 2** Dicarboximide
- **Group 11** Quinone outside Inhibitors (QoI)

1. Maintain a protective cover with a protectant fungicide such as mancozeb.
2. Limit the use of **Group 2** to strategic periods, i.e. before, during and after extended wet periods.
3. Always tank mix the **Group 2** fungicide with a protectant such as mancozeb.
4. **Do not** apply more than four **Group 2** sprays in a season.
5. The total number of **Group 11** sprays should be no more than one-third of the total number of fungicide sprays per season.
6. **Do not** apply more than two consecutive applications of a **Group 11** spray.
7. If two consecutive applications of a **Group 11** spray are applied, they must be followed by at least the same number of sprays from an alternative chemical group.

Crop(s): Peanut

Disease(s): Leaf Spots, Rust, Net Blotch

RMS for:

- **Group 3** Demethylation inhibitor (DMI)
- **Group 11** Quinone outside Inhibitor (QoI)
- **Group 3+11** DMI + QoI

1. **Do not** apply more than three consecutive **Group 3** sprays alone, before changing to a fungicide of a different activity group.
2. Apply a maximum of five **Group 3** sprays per season.
3. **Do not** apply **Group 11** products as more than 50 per cent of the total number of sprays in any one season, up to a maximum of three sprays of **Group 11**.
4. **Do not** apply more than two consecutive applications of a **Group 11** spray.
5. If two consecutive applications of a **Group 11** spray are applied, they must be followed by at least the same number of sprays from an alternative chemical group.

Crop(s): **Poppies**

Disease(s): Downy Mildew

RMS for:

- **Group 4** Phenylamide
- **Group 11** Quinone outside Inhibitor (QoI)
- **Group 28+43** Carbamate plus Benzamide
- **Group 40** Carboxylic acid amide
- **Group 49** Oxysterol binding protein inhibitor (OSBP)
- **Group 49+11** OSBP + 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** or **49+11** fungicide. **Group 49** containing sprays should not exceed 33 per cent 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** 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): Late Blight (Irish Blight)

RMS for:

- **Group 4** Phenylamide
- **Group 11** Quinone outside Inhibitor (QoI)
- **Group 21** Cyazofamid
- **Group 28+43** Carbamate plus Benzamide
- **Group 40** Carboxylic acid amide

1. Start disease control early and maintain a regular program using a fungicide from groups other than **Group 4**, **11** or **40**.
2. When conditions favour disease development, **do not** wait for disease to appear, but apply two consecutive sprays of a **Group 4**, **11**, **40** or **28+43** fungicide at the interval recommended on the label. Then resume the program of sprays using products from a different group to the **Group 4**, **11**, **40** or **28+43** fungicides just applied.
3. **Do not** apply more than four sprays of a **Group 4** or **40** fungicides per season.
4. **Do not** apply more than two sprays of a **Group 28+43** product per crop.
5. Apply **Group 11** fungicides preventively. The total number of **Group 11** fungicide applications per season should not exceed one-third of the total number of fungicide applications per crop. No more than two consecutive **Group 11** sprays should be applied. If consecutive applications of **Group 11** fungicides are used, then they must be followed by at least the same number of applications of fungicide(s) from a different group(s) before a **Group 11** fungicide is used again, either in the current or following season.

Crop(s): **Potato**

Disease(s): Target Spot (Early Blight)

RMS for:

- **Group 2** Dicarboximide
- **Group 3** Demethylation inhibitors (DMIs)
- **Group 7** Succinate dehydrogenase inhibitors (SDHIs)
- **Group 9** Anilinopyrimidine
- **Group 11** Quinone outside Inhibitor (QoI)
- **Group 11+3** QoI + DMI treat as **Group 11**

1. Limit the use of **Group 2**, **3**, **9** or **11** fungicides to periods when conditions favour disease development.
2. **Do not** apply more than six **Group 2** sprays in one season. Apply no more than two consecutive sprays of a **Group 2** fungicide.
3. **Do not** apply more than six **Group 3** sprays in a season. Apply no more than two consecutive sprays of a **Group 3** fungicide alone.
4. If three or fewer fungicide sprays for target spot are applied per crop, use only one spray containing a **Group 7** fungicide. If four to six sprays are applied per crop, use a maximum of two sprays containing **Group 7** fungicides. If seven or more sprays are applied per crop use a maximum of three sprays containing **Group 7** fungicides. 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.
5. If three or fewer fungicide sprays for target spot are applied per crop, use only one spray containing a **Group 9** fungicide. If four to six sprays are applied per crop, use a maximum of two sprays containing **Group 9** fungicides. If seven or more sprays are applied per crop use a maximum of three sprays containing **Group 9** fungicides.
6. Apply no more than two consecutive sprays containing a **Group 9** fungicide.
7. Apply **Group 11** containing fungicides preventively. **Do not** apply more than three foliar applications of a **Group 11** containing fungicide per crop, no 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.
8. When using a **Group 11** fungicide in-furrow at planting, use a fungicide from a different group as the first foliar spray.

Crop(s): **Pulse Crops**

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

RMS for:

- **Group 1** Methyl Benzimidazole Carbamates
- **Group 2** Dicarboximide
- **Group 3+11** Demethylation inhibitor (DMI) + Quinone outside Inhibitor (QoI)
- **Group 7*** Succinate dehydrogenase inhibitors (SDHIs)
- **Group 7+3** SDHI + DMI
- **Group M3** dithiocarbamate
- **Group M4*** phthalimide

1. **Do not** apply more than two **Group 1**, **2**, **3+11**, **7+3**, **M3** or **M4** sprays in one season (including seed treatment).
2. **Do not** apply more than two consecutive **Group 1** or **M3** 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.
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.

* 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** Dicarboximide
- **Group 3** Demethylation inhibitors (DMIs)
- **Group 7** Succinate dehydrogenase inhibitors (SDHIs)
- **Group 9** Anilinopyrimidine
- **Group 11** Quinone outside Inhibitor (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.
3. 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

4. A post-harvest treatment should also be counted as an application.
5. The last blossom blight spray and the first pre-harvest brown rot spray should be regarded as consecutive applications.
6. The spray program should be considered and the resistance management strategy applied on a whole-orchard basis.
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.

Crop(s): **Strawberry**

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

RMS for:

- **Group 2** Dicarboximide
- **Group 7** Succinate dehydrogenase inhibitors (SDHIs)
- **Group 9** Anilinopyrimidine
- **Group 9+12** Anilinopyrimidine + Phenylpyrroles
- **Group 17** Hydroxyanilide

1. Apply a program of protectant fungicides during flowering. If conditions favour disease development during this period, use a **Group 2**, **9**, **12** or **17** fungicide.
2. **Do not** apply more than two successive sprays of **Group 2**, **9**, **12** or **17** fungicides.
3. If applying **Group 7** fungicides, **do no**t apply more than two consecutive sprays before changing to another group. **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.
4. If three or fewer *Botrytis* fungicide sprays are applied per crop, use only one spray containing a **Group 9** fungicide. If four to six sprays are applied per crop use a maximum of two sprays containing **Group 9** fungicides. If seven or more sprays are applied per crop use a maximum of three sprays containing **Group 9** fungicides.
5. If three or fewer *Botrytis* fungicide sprays are applied per crop, use only one spray containing a **Group 12** fungicide. If four to six sprays are applied per crop use a maximum of two sprays containing **Group 12** fungicides. If seven or more sprays are applied per crop use a maximum of three sprays containing **Group 12** fungicides.

Crop(s): **Strawberry**

Disease(s): Powdery Mildew

RMS for:

- **Group 3** Demethylation inhibitors (DMIs)
- **Group 7** Succinate dehydrogenase inhibitors (SDHIs)
- **Group 11** Quinone outside Inhibitor (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** apply more than four **Group 3** sprays per season.
3. **Do not** apply more than two consecutive sprays of **Group 3** fungicides, including from one season to the next.
4. If applying **Group 7** fungicides, **do not** apply more than two consecutive sprays before changing to another group.
5. **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.
6. Apply **Group 11** fungicides preventively.
7. **Do not** apply consecutive sprays of **Group 11** fungicides, including from one season to the next.
8. 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.
9. **Do not** use **Group 3** fungicides curatively.

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

Disease(s): Powdery mildew

RMS for:

- **Group U6*** thiazolidine
- **Group 8*** hydroxy-(2-amino-) pyrimidines
- **Group 13*** azanaphthalenes

1. Strawberry runner growers should also refer to the resistance management strategy for strawberry — powdery mildew, as it applies equally to strawberry runner growers. This strategy is for the additional range of compounds available to strawberry runner producers under permit.
2. Fungicides from **Group U6**, **8** and **13** are available for use on strawberry runner crops under individual permits from the APVMA.
3. Each permit states '**Do not** apply to fruit producing strawberry plants'.
4. Apply a maximum of two **Group U6** sprays per season.
5. Apply a maximum of four **Group 8** or **13** sprays per season.
6. Refer to individual permits for information relating to spray interval etc.

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

Crop(s): **Tomato**

Disease(s): Grey Mould

RMS for:

- **Group 2** Dicarboximide
- **Group 7** Succinate dehydrogenase inhibitors (SDHIs)

1. Tank mix **Group** 2 fungicides with a protectant such as chlorothalonil. Avoid applying two **Group 2** fungicides in succession, unless tank mixed with a protectant.
2. **Do not** apply more than four **Group 2** sprays in a season.
3. If applying **Group 7** fungicides, **do not** apply more than two consecutive sprays before changing to another group. **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.

Crop(s): **Tomato**

Disease(s): Powdery Mildew

RMS for:

- **Group 3** Demethylation inhibitor (DMI)
- **Group 11+3** Quinone outside Inhibitor (QoI) + DMI
- **Group 7** Succinate dehydrogenase inhibitors (SDHIs)
- **Group 13** aza-napthalenes

1. Apply fungicides before disease becomes established.
2. **Do not** apply more than four sprays of a **Group 3** containing fungicide per crop.
3. If applying a **Group 7**, **11** (or **11+3**) or **13** containing fungicides, do not apply more than two consecutive sprays before changing to another group. Do not apply more than three applications containing a **Group 7**, **11** (or **11+3**) or **13** fungicide per season. If consecutive sprays are used, then use the same number of sprays of an alternative group before using another **Group 7**, **11** (or **11+3**) or **13**, which includes sprays from consecutive seasons.

Crop(s): **Tomato**

Disease(s): Target Spot (Early Blight)

RMS for:

- **Group 2** Dicarboximide
- **Group 3** Demethylation inhibitors (DMIs)
- **Group 7** Succinate dehydrogenase inhibitors (SDHIs)
- **Group 9** Anilinopyrimidine
- **Group 11** Quinone outside Inhibitor (QoI)
- **Group 11+3** QoI + DMI

1. Limit the use of **Group 2**, **3**, **9** or **11** fungicides to periods when conditions favour disease development.
2. **Do not** apply more than four **Group 2** sprays in one season. Apply no more than two consecutive sprays of a **Group 2** fungicide.
3. **Do not** apply more than six **Group 3** sprays in a season. Apply no more than two consecutive sprays of a **Group 3** fungicide alone.
4. If applying **Group 7** fungicides, **do not** apply more than two consecutive sprays before changing to another group. **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.
5. If three or fewer fungicide sprays for target spot are applied per crop, use only one spray containing a **Group 9** fungicide. If four to six sprays are applied per crop, use a maximum of two sprays containing **Group 9** fungicides. If seven or more sprays are applied per crop, use a maximum of three sprays containing **Group 9** fungicides.
6. Apply no more than two consecutive sprays containing a **Group 9** fungicide.
7. Apply **Group 11** fungicides preventively. **Do not** apply more than six sprays, or one-third of the total sprays (whichever is lower) from **Group 11** fungicides. **Do not** apply more than two consecutive sprays of **Group 11** fungicides. If consecutive applications of **Group 11** fungicides are used, then they must be followed by at least the same number of applications of fungicide(s) from a different group(s) before a **Group 11** fungicide is used again, either in the current or following season.

Crop(s): **Turf**

Disease(s): Various

RMS for:

- **Group 1** Benzimidazole
- **Group 2** Dicarboxamide
- **Group 3** Demethylation Inhibitor (DMI)
- **Group 4** Phenylamides
- **Group 7** Succinate dehydrogenase inhibitors (SDHI)
- **Group 7+11** SDHI + Quinone outside Inhibitor (QoI)
- **Group 11** QoI
- **Group 11+2** QoI + dicarboxamide
- **Group 11+3** QoI + DMI
- **Group 12** Phenylpyrroles
- **Group 14** Chlorophenyls + Nitroanilines
- **Group 21** Quinone inside Inhibitors
- **Group 28** Carbamate
- **Group 33** Phosphonate

1. Fungicide groups that are classified as medium to high risk for fungicide resistance development; **Groups 1**, **2**, **4**, 7, **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. If consecutive sprays are done 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 (DMIs)
- **Group 7** Succinate dehydrogenase inhibitor (SDHIs)
- **Group 3 + 7** DMI + SDHI
- **Group 11+3** Quinone outside Inhibitor (QoI) + DMI

1. Fungicides should be used as protectant treatments — where there is 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:
   - removal or burning of stubble
   - crop rotation (**avoid** wheat on wheat)
   - control of green bridge volunteers
   - 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. 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.
5. 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.
6. **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 infurrow and seed treatments are counted as one application.
7. Minimise use of **Group 3** fungicides which are known to have compromised resistance status.

Crop(s): **Wheat**

Disease(s): Yellow Spot, Powdery Mildew

RMS for:

- **Group 3** Demethylation Inhibitors (DMI)
- **Group 7** Succinate dehydrogenase Inhibitor (SDHI)
- **Group 7+3** SDHI + DMI
- **Group 11+3** Quinone outside Inhibitor (QoI) + DMI
- **Group 11+4** QoI + Phenylamide
- **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 including the removal of stubble, control of green bridge volunteers and the use of tolerant and resistant varieties.
2. **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.
3. **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.
4. 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.
5. **Do not** apply more than one application of a **Group 7** seed treatment with foliar activity in any two consecutive growing seasons.
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 treatment are counted as one application.
8. Minimise use of **Group 3** fungicides which are known to have compromised resistance status.

Fungicide activity group table

FRAC code	Fungicide MoA group	Chemical family	Active constituent	**Trade name** (product name)
1	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®
			fenbuconazole	Indar®
			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	Phenylamide	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®
		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® Privilege, Luna® Sensation
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®
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	Unspecified	2,6-dinitro-anilines	fluazinam	various e.g. Shirlan®
P07 (33)	Phosphonates	ethyl phosphonate	fosetyl-Al	various e.g. Aliette®
			phosphorous acid and salts	various e.g. Foli-R-Fos®
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	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®

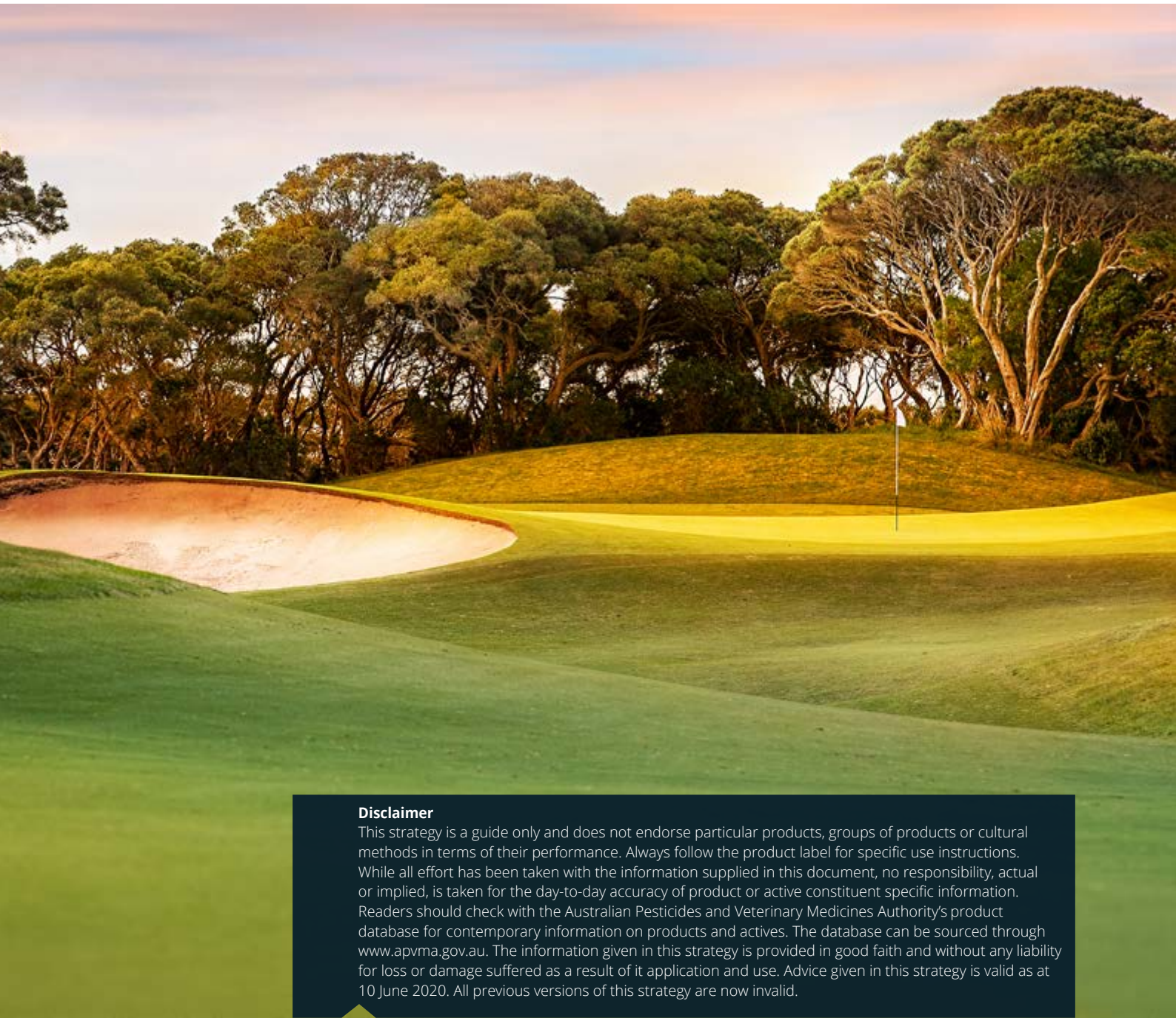
FRAC code	Fungicide MoA group	Chemical family	Active constituent	Trade name (product name)
BM02	Multi-site activity microbial (living microbes or extract, metabolites)	*streptomyces* sp.	*Streptomyces lydicus* strain WYEC108	Actinovate®
		Bacillus spp.	*B.acillus amyloliquefaciens** strain QST 713 *synonyms 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®
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 HERBICIDE RESISTANCE MANAGEMENT REVIEW GROUP AND INDUSTRY RESEARCHERS — VALID AS AT 10 JUNE 2020



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 taken 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 it application and use. Advice given in this strategy is valid as at 10 June 2020. 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 mode of action 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 B herbicides, resistance will occur quickly. If the frequency is low, such as with Group M 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 modes of action. 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 Mode of Action:** 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 resistant grass and broadleaf weed species 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 eleven 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 two or more chemical groups.

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 mode of action grouping. It is mandatory for all herbicide product labels in Australia to carry the designated mode of action group letter in a prominent position. Herbicide mode of action groups are important to consider when making buying 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 mode of action. 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 mode of action. The mode of action is indicated by a letter code on the product label. The mode of action labelling is based on the resistance risk of each group of herbicides. Australia was the first country to introduce compulsory mode of action labelling on product labels. The letters and codes used in Australia are unique because they were the first, they are compulsory and they reflect the relative risk of resistance evolving in each group. Since the introduction of mode of action labelling in Australia, other countries have adopted mode of action classification systems, however caution should be shown if cross-referencing mode of action between Australia and other countries, as many other countries use a different classification system.

The herbicide mode of action grouping and labelling system in Australia was revised in 2007. This is the first major revision of the classification system since its introduction. The original groupings were made several years ago based on limited knowledge about modes of action. Groupings have now been changed to improve the accuracy and completeness of the modes of action to ultimately enable more informed decisions to be made about herbicide rotation and resistance management. The general intent of groups based on their risk has not changed. However, six additional herbicide mode of action groups were created to more accurately group herbicides.

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 mode of action grouping and resistance risk by reference to the mode of action chart. All herbicide labels carry the mode of action group clearly displayed such as:

GROUP	A	HERBICIDE

Know your herbicide groups to make use of this!

Not all mode of action groups carry the same risk for resistance development, therefore specific guidelines for Groups E, O, P and R 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 A and Group B 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 C, D, F, G, H I, J, K, L, M, N, Q and Z 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 mode of action group).
- Apply two or more different herbicide MoAs on a particular weed. For example:
  - Tank mix two or more compatible herbicides with different modes of action 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 MoAs 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.
- Rotatation 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 mode of action 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 (**www.glyphosateresistance.org.au**)
- 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
	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
	Use mixtures and/or sequences of different MoAs	Grazing
Fallow	Chemical fallow	Cultivation
	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 modes of action	2 modes of action	1 mode of action
Weed control in cropping system	Herbicide and many non-herbicidal methods	Herbicide and some non-herbicidal methods	Herbicide only
Use of same mode of action per season	Once	Twice	Many times
Cropping system crop rotation	Diverse range of crops grown in rotation	Some crop rotation	Limted 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 APVMA at **www.apvma.gov.au** for the PUBCRIS database.

Specific guidelines:
Group A herbicides

Resistance risk: High

Globally, herbicide resistance to Group A herbicides has been confirmed and documented in more than 40 grass weed species across more than 40 countries. Group A 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 B MoA more likely.

Group A 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 A herbicides and carry the same high resistance risk.
2. Where a Group A herbicide has been used on a particular paddock for control of any grass weed, avoid using a Group A herbicide to control the same grass weed in the following season, irrespective of the performance it gave.
3. Frequent application of Group A herbicides to dense weed populations is the worst-case scenario for rapidly selecting for resistance.
4. Where resistance to a member of Group A is suspected or known to exist, there is a strong possibility of cross resistance to other Group A and Z 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 A
Inhibitors of acetyl co-enzyme A carboxylase (Inhibitors of fat synthesis/ACC'ase inhibitors)

Chemical family	**Active constituent** (first registered trade name)
Aryloxyphenoxypropionates (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 B herbicides

Resistance risk: High

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

Group B 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 17 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 B 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 B resistance is the control of brome grass and barley grass in winter cereal crops. Group B herbicides are presently the only post-emergent herbicides that provide effective control of these grass weeds and this poses a severe risk of Group B resistance for growers with cereal dominant rotations.

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

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

10. Avoid applying more than two* Group B 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.

11. A Group B herbicide may be used alone on flowering wild radish only if a Group B herbicide has not been previously used on that crop.

12. 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.

13. 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 B 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 B herbicide with respect to selection for Group B resistant plants. This is sometimes the case in turf where Group B 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 B
Inhibitors 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 (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 (Sulfonamides)	florasulam (Crest®*, Gangster®*, Paradigm®*, Vortex®*, X-Pand®*), flumetsulam (Broadstrike®, Thistrol Gold*®), metosulam (Eclipse®), 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 C herbicides

Resistance risk: Moderate

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

In Australia, Group C 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 C 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 C 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 C use.
- Control survivors to prevent seed-set using a herbicide with a different MoA to Group C or use another weed management technique.
- 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.

1. **TT Canola**
   - **a)** Growing TT Canola in a paddock treated with triazine herbicides in the previous season is a high resistance risk and is not recommended.
   - **b)** 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.
2. **TT-RR Canola**
   - **a)** Refer to the specific guidelines for Group M 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 C
Inhibitors of photosynthesis at photosystem II (PS II inhibitors)

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

Resistance risk: Moderate

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

Group D 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 D herbicides.

Where possible, avoid the use of Group D 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 D resistance, rotate and/or tank mix with herbicides from other MoA.

Use Group D 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 D
Inhibitors 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®*, Treflan®)
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 F herbicides**

Resistance risk: Moderate

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

Group F 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 F herbicides. The number of populations with Group F resistance is increasing following increased use of these herbicides.

Avoid applying Group F 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 labeled 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 F 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 F
Bleachers: Inhibitors of carotenoid biosynthesis at the phytoene desaturase step (PDS inhibitors)

Chemical family	**Active constituent** (first registered trade name)
Pyridazinones	norflurazon (Solicam®)
Pyridinecarboxamide	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 G herbicides

Resistance risk: Moderate

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

The increased use of Group G herbicides as stand-alone herbicides in Australia is likely to increase the risk of resistant populations developing. The use of Group G 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 G 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 modes of action 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 MoA should be employed between seasons.

Stand-alone applications

The risk for Group G 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 G 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 mode of action 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 G
Inhibitors of protoporphyrinogen oxidase (PPOs)

Chemical family	**Active constituent** (first registered trade name)
Diphenylethers	acifluorfen (Blazer®), oxyfluorfen (Goal®, Rout®, Yates Pathweeder®)
N-phenylphthalimides	flumioxazin (Valor®, Terrain®)
Oxadiazoles	oxadiargyl (Raft®), oxadiazon (Ronstar®)
Phenylpyrazole	pyraflufen (Condor*®, Ecopar®, Pyresta®*)
Pyrimidindiones	butafenacil (B-Power®*, Logran® B-Power®*, Resolva®*), saflufenacil (Sharpen®, Tirexor*®), trifludimoxazin (Tirexor*®)
Triazolinones	carfentrazone (Affinity®, Aptitude®*, Broadway®, Buffalo Pro Weedkiller®*, Silverado®*)

* 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 H herbicides**

Resistance risk: Moderate

Resistance to the Group H (HPPD) herbicide MoA is known for a number of populations of Amaranthus species in the United States, which demonstrates the potential for weeds to develop resistance to this MoA. Continuous usage of Group H 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 H 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 H resistance in wild radish. In some areas, because of a lack of alternate herbicide options, growers are heavily reliant on Group H 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 H herbicides. Where Group H (HPPD) herbicides are used post emergent it's important to target small weeds with robust rates. Always mix Group H herbicides with an effective alternate MoA herbicide, such as Group C products like bromoxynil, which are synergistic, Group I products, such as MCPA, or other alternate MoA herbicides.

Where Group H (HPPD) herbicides are used pre-emergent in cereals, it's important to use an alternative MoA as a follow-up spray to control any subsequent survivors. If two Group H herbicides are used in one season, a herbicide from an alternate mode of action should be used after the first or second applications of Group H 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 H resistance, rotate and/or tank mix with herbicides from other MoA.

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 H 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 H 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 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 H
Bleachers: Inhibitors of 4-hydroxyphenyl-pyruvate dioxygenase (HPPDs)

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

* 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 I herbicides

Resistance risk: **Moderate**

Globally herbicide resistance to the Group I 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 I MoA is common.

Group I 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 I herbicides. The number of populations with Group I resistance is increasing.

Of particular concern is that apart from the resistance being 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 F herbicides which can be important for control of wild radish in lupins where other selective non-Group I 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 5cm 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 I herbicides alone onto the same population of weeds in the same season. To assist in delaying the onset of Group I resistance, rotate and/or tank mix with herbicides from other MoA.
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 I 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 I
Disruptors of plant cell growth (Synthetic Auxins)

Chemical family	**Active constituent** (first registered trade name)
Arylpicolinate	florpyrauxifen (Agixa®*, Ubeniq®), halauxifen (ForageMax®*, Paradigm®*, Pixxaro®*, Rexade®*)
Benzoic acids	dicamba (Banvel®, Banvel M®*, Barrel®*, Casper®*, Lawnweeder plus®*, Lawn weedkiller*, Mecoban®, Methar Tri-Kombi®*, Nuturf Millennium®*, Sandoban®*)
Phenoxycarboxylic acids (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*®), MCPP (Mecoban®, Mecopropamine®, Methar TriKombi®*, Multiweed®*)
Pyridine carboxylic acids (Pyridines)	aminopyralid (Fallow Boss Tordon®*, ForageMax®*, Grazon Extra®*, Hotshot®*, Stinger®*, Vigilant II®*), clopyralid (Lontrel®, Nuturf Millennium®*, Spearhead®*, Trimac Plus®*, Velmac Plus®*) , fluroxypyr (Crest®*, Hotshot®*, Pixxaro®*, Starane®), picloram (Fallow Boss Tordon®*, Grazon Extra®*, Tordon®, Tordon 242®*, Tordon Regrowth Master®*, Trinoc®*, Vigilant II®*), triclopyr (Garlon®, Grazon Extra®*, Tordon Regrowth Master®*, Tough Roundup® Weedkiller*, Ultimate Brushweed®* Herbicide)
Quinoline carboxylic acids	quinclorac (Drive®)

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

Resistance risk: Moderate

Globally herbicide resistance to the Group J herbicide MoA has been confirmed and documented in more than ten weed species across more than six countries.

Group J resistance exists in Australia in four weed species including two populations of serrated tussock, six populations of giant Parramatta grass, ten populations of winter grass and more than 50 populations of annual ryegrass that are confirmed resistant to Group J herbicides.

To assist in delaying the onset of resistance, where possible rotate or tank mix Group J herbicides with herbicides from other MoAs.

Use Group J 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 J
Inhibitors of lipid synthesis (Not ACCase inhibitors)

Chemical family	**Active constituent** (first registered trade name)
Benzofurans	ethofumesate (Tramat®)
Chlorocarbonic acids	2,2–DPA (Dalapon®, Yates Onceyear Pathweeder®*, flupropanate (Frenock®)
Phosphorodithioates	bensulide (Prefar®)
Thiocarbamates	EPTC (Eptam®), molinate (Ordram®), pebulate (Tillam®), prosulfocarb (Arcade®, Bolta Duo*, Boxer® Gold*, Diablo Duo®*), thiobencarb (Saturn®), triallate (Avadex®, Diablo Duo®*, Jetti Duo®*), vernolate (Vernam®)

* 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 K herbicides**

Resistance risk: Moderate

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

Resistance to Group K herbicides in Australia has developed in more than 20 populations of annual ryegrass. Further development of resistance in the near future is likely given the reliance on Group K herbicide chemistry for weed control across large areas of Australia.

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

Use Group K 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 K 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 K
Inhibitors of cell division / Inhibitors of very long chain fatty acids (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®)

* **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 L herbicides**

Resistance risk: Moderate

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

Group L resistance exists in Australia in annual ryegrass, and in two species of barley grass across more than 100 populations, blackberry nightshade, crowsfoot grass, capeweed, 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 L herbicide but Group L resistant barley grass has also occurred in no-till situations.

Common factors in most cases of Group L resistance include:

- a Group L herbicide is the major or only herbicide used
- a Group L 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 L 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 L herbicide are made each season, cultivation is not used and there is reliance on a Group L herbicide alone for weed control.

To assist in delaying the onset of resistance, consider alternating Group L herbicides with herbicides from other MoAs. For example, Group N (e.g. glufosinate) or Group Q (e.g. amitrole) or Group M (e.g. glyphosate).

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

Minimum/Zero Tillage

1. Rotate Group L herbicides with other knockdown herbicides with a different MoA, such as Group M (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[1] 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.

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

Lucerne

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

Horticulture

1. Rotate Group L herbicides with other knockdown herbicides with a different MoA, such as Group N (e.g. glufosinate), Group Q (e.g. amitrole) or Group M (e.g. glyphosate).
2. Where possible, use residual herbicides (that are effective on the same weeds as the Group L herbicides) where applicable either alone or in mixture with Group L 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 L
Inhibitors of photosynthesis at photosystem I via electron diversion (PSI inhibitors)

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

* 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 M herbicides**

Resistance risk: Moderate

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

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

Group M resistance occurs in Australia in 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, more than 100 populations of flax-leaf fleabane, liverseed grass, sweet summer grass, wild radish, wild oats and windmill grass.

Common factors in all cases of Group M resistance include:

- lack of rotation of other herbicide MoAs
- use of a Group M herbicide for 12–15 years or more
- 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 **www.glyphosateresistance.org.au**.

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 M herbicides with herbicides from other MoAs, such as Group L (e.g. paraquat), Group N (e.g. **glufosinate**) or **Group Q** (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[2], 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 about cotton:
www.cottoninfo.com.au/publications/herbicide-resistance-management-strategy and
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 M
Inhibitors of 5-enolpyruvyl shikimate-3 phosphate (EPSP) synthase

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.

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

Specific guidelines:
Group N herbicide

Resistance risk: Moderate

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

Resistance to Group N herbicides is rare, and currently there are no documented cases of resistant weeds in Australia. Group N 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 L (e.g. paraquat), Group Q (e.g. amitrole) or Group M (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 L (e.g.paraquat), Group Q (e.g. amitrole) or Group M (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 N
Inhibitors 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 Q herbicides**

Resistance risk: Moderate

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

Group Q 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 Q herbicides with herbicides from other MoAs, such as Group L (e.g. paraquat), Group N (e.g. **glufosinate**) or **Group M** (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 Q
Bleachers: Inhibitors of carotenoid biosynthesis unknown target

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

Specific guidelines: **Group Z herbicides**

Resistance risk: Moderate

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

Group Z resistance exists in Australia in more than 200 populations of wild oats resistant to flamprop. Many of these flamprop resistant wild oats also show cross resistance to Group A herbicides. There is also endothal resistance confirmed in annual poa (winter grass).

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 Z
Herbicides with unknown and probably diverse sites of action

Chemical family	**Active constituent** (first registered trade name)
Arylaminopropionic acids	flamprop (Mataven L®)
Dicarboxylic acids	endothal (Endothal®)
Organoarsenicals	DSMA (disodium methylarsonate) (Methar®, Trinoc®*), MSMA (monosodium methylarsonate) (Daconate®)
Fatty acids	Pelargonic acid (Nonanoic acid)

* This product contains more than one active constituent.
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Herbicide Mode of Action groups

High resistance risk

Chemical family	**Active constituent** (first registered trade name)
GROUP A **Inhibitors of acetyl co-enzyme A carboxylase (Inhibitors of fat synthesis/ACC'ase inhibitors)**	
Aryloxyphenoxypropionates (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 B **Inhibitors 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®)
Pyrimidinylthiobenzoates	bispyribac (Nominee®), pyrithiobac (Staple®)
Sulfonylureas (SUs)	azimsulfuron (Gulliver®), bensulfuron (Londax®), chlorsulfuron (Glean®), ethoxysulfuron (Hero®), foramsulfuron (Tribute®), halosulfuron (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 (Sulfonamides)	florasulam (Crest®*, Gangster®*, Paradigm®*, Vortex®*, X-Pand®*), flumetsulam (Broadstrike®, Thistrol Gold*®), metosulam (Eclipse®), pyroxsulam (Crusader® Rexade®*)

* This product contains more than one active constituent

Moderate resistance risk

Chemical family	**Active constituent** (first registered trade name)
GROUP C **Inhibitors of photosynthesis at photosystem II (PS II inhibitors)**	
Amides	propanil (Stam®)
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®,)
Phenylcarbamates	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 (Tupersan®), tebuthiuron (Graslan®)

Moderate resistance risk

Chemical family	**Active constituent** (first registered trade name)
GROUP D **Inhibitors 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®)
GROUP E **Inhibitors of mitosis / microtubule polymerisation**	
Carbamates	carbetamide (Carbetamex®), chlorpropham (Chlorpropham®)
GROUP F **Bleachers: Inhibitors of carotenoid biosynthesis at the phytoene desaturase step (PDS inhibitors)**	
Pyridazinones	norflurazon (Solicam®)
Pyridinecarboxamide	diflufenican (Brodal®, Gangster®*, Jaguar®*, Quadrant®*, Spearhead®*, Tigrex®*, Triathlon®*, Yates Pathweeder®*), picolinafen (Eliminar C®*, Flight®*, Paragon®*, Quadrant®*, Sniper®)
GROUP G **Inhibitors of protoporphyrinogen oxidase (PPOs)**	
Diphenylethers	acifluorfen (Blazer®), oxyfluorfen (Goal®, Rout®, Yates Pathweeder®)
N-phenylphthalimides	flumioxazin (Valor®, Terrain®)
Oxadiazoles	oxadiargyl (Raft®), oxadiazon (Ronstar®)
Phenylpyrazole	pyraflufen (Condor*®, Ecopar®, Pyresta®*)
Pyrimidindiones	butafenacil (B-Power®*, Logran® B-Power®*, Resolva®*), saflufenacil (Sharpen®, Tirexor*®), trifludimoxazin (Tirexor*®)
Triazolinones	carfentrazone (Affinity®, Aptitude®*, Broadway®, Buffalo Pro Weedkiller®*, Silverado®*)
GROUP H **Bleachers: Inhibitors of 4-hydroxyphenyl-pyruvate dioxygenase (HPPDs)**	
Isoxazoles	isoxaflutole (Balance® Palmero TX®*)
Pyrazoles	benzofenap (Taipan ®), pyrasulfotole (Precept®*, Velocity®*) topramezone (Frequency®)
Triketone	bicyclopyrone (Talinor®*), mesotrione (Callisto®)
GROUP I **Disruptors of plant cell growth (Synthetic Auxins)**	
Arylpicolinate	florpyrauxifen (Agixa®*, Ubeniq®), halauxifen (ForageMax®*, Paradigm®*, Pixxaro®*, Rexade®*)
Benzoic acids	dicamba (Banvel®, Banvel M®*, Barrel®*, Casper®*, Lawnweeder plus®*, Lawn weedkiller*, Mecoban®, Methar Tri-Kombi®*, Nuturf Millennium®*, Sandoban®*)
Phenoxycarboxylic acids (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*®), MCPP (Mecoban®, Mecopropamine®, Methar TriKombi®*, Multiweed®*)
Pyridine carboxylic acids (Pyridines)	aminopyralid (Fallow Boss Tordon®*, ForageMax®*, Grazon Extra®*, Hotshot®*, Stinger®*, Vigilant II®*), clopyralid (Lontrel®, Nuturf Millennium®*, Spearhead®*, Trimac Plus®*, Velmac Plus®*) , fluroxypyr (Crest®*, Hotshot®*, Pixxaro®*, Starane®), picloram (Fallow Boss Tordon®*, Grazon Extra®*, Tordon®, Tordon 242®*, Tordon Regrowth Master®*, Trinoc®*, Vigilant II®*), triclopyr (Garlon®, Grazon Extra®*, Tordon Regrowth Master®*, Tough Roundup® Weedkiller*, Ultimate Brushweed®* Herbicide)
Quinoline carboxylic acids	quinclorac (Drive®)
GROUP J **Inhibitors of lipid synthesis (Not ACCase inhibitors)**	
Benzofurans	ethofumesate (Tramat®)
Chlorocarbonic acids	2,2–DPA (Dalapon®, Yates Onceyear Pathweeder®*, flupropanate (Frenock®)
Phosphorodithioates	bensulide (Prefar®)
Thiocarbamates	EPTC (Eptam®), molinate (Ordram®), pebulate (Tillam®), prosulfocarb (Arcade®, Bolta Duo*, Boxer® Gold*, Diablo Duo®*), thiobencarb (Saturn®), triallate (Avadex®, Diablo Duo®*, Jetti Duo®*), vernolate (Vernam®)

Moderate resistance risk

Chemical family	**Active constituent** (first registered trade name)
GROUP K **Inhibitors of cell division / Inhibitors of very long chain fatty acids (VLCFA inhibitors)**	
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®)
GROUP L **Inhibitors of photosynthesis at photosystem I via electron diversion (PSI inhibitors)**	
Bipyridyls	diquat (Reglone®, Spray Seed®*), paraquat (Alliance®*, Gramoxone®, Spray Seed®*)
GROUP M **Inhibitors of 5-enolpyruvyl shikimate-3 phosphate (EPSP) synthase**	
Glycines	glyphosate (Arsenal Xpress®*, Bantox*, Broadway®*, Firestorm®*, Illico®*, Resolva®*, Roundup®, Sandoban*®, Tough Roundup® Weedkiller*, Trounce®*, Yates Pathweeder®*)
GROUP N **Inhibitors of glutamine synthetase**	
Phosphinic acids	glufosinate (Basta®, Liberty®)
GROUP O **Inhibitors of cell wall (cellulose) synthesis**	
Alkylazine	indaziflam (Specticle®)
Benzamides	isoxaben (Gallery®, X-Pand®*)
Nitriles	dichlobenil (Casoron®)
GROUP P **Inhibitors of auxin transport**	
Phthalamates	naptalam (Alanap-L®)
GROUP Q **Bleachers: Inhibitors of carotenoid biosynthesis unknown target**	
Isoxazolidinones	bixlozone (Overwatch®), clomazone (Altiplano®*, Command®)
Triazoles	amitrole (Alliance®*, Amitrole®, Brunnings RTU Pathweeder®*, Illico®*, Firestorm®*, Yates Onceyear Pathweeder®*)
GROUP R **Inhibitors of dihydropteroate synthase (DHP inhibitors)**	
Carbamates	asulam (Asulox®)
GROUP T **Inhibition of fatty acid thioesterase**	
Benzyl ether	cinmethylin (Luximax®)
GROUP Z **Herbicides with unknown and probably diverse sites of action**	
Arylaminopropionic acids	flamprop (Mataven L®)
Dicarboxylic acids	endothal (Endothal®)
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 approved active constituents in each 'Group' and, for ease of identification, at the discretion of the Herbicide Resistance Management Review Group 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
Annual ryegrass (*Lolium Rigidum*)	A	>20,000
	B	>20,000
	C	>50
	D	>5,000
	J	>50
	K	20
	L	20
	M	>1,000
	Q	3
Annual veld grass (*Ehrharta longiflora*)	A	6
Awnless barnyard grass (*Echinochloa colona*)	M	>200
Barnyard grass (*Echinochloa crus-galli*)	C	1
Barley grass (*Hordeum spp.*)	A	>200
	B	>200
	L	>100
	M	2
Brome grass (*Bromus spp.*)	A	>200
	B	>1,000
	C	1
	M	5
Crabgrass (*Digitaria sanguinalis*)	A	2
	B	1
Crowsfoot grass (*Eleusine indica*)	A	1
	L	5
Feathertop Rhodes grass (*Chloris virgata*)	M	10
Giant Parramatta grass (*Sporobolus fertilis*)	J	6
Johnson grass (Sorghum halepense)	M	1
Lesser Canary grass (*Phalaris minor*)	A	20
	B	10
Liverseed grass (*Urochloa panicoides*)	C	7
	M	4
Paradoxa grass (*Phalaris paradoxa*)	A	7
	B	4
Serrated tussock (*Nassella trichotoma*)	J	2
Silver grass / Squirrel-tailed fescue (*Vulpia bromoides*)	C	3
	L	1
Sweet summer grass (*Brachiaria eruciformis*)	M	1
Wild oat (*Avena* spp.)	A	>5,000
	B	>200
	M	2
	Z	>200
Windmill grass (*Chloris truncata*)	M	13
Winter grass / Annual poa (*Poa annua*)	A	3
	B	20
	C	10
	D	>100
	J	10
	M	10
	Z	3

Broadleaf weeds	Groups	Sites
African turnip weed (*Sisymbrium thellungii*)	B	2
Arrowhead (*Sagittaria montevidensis*)	B	20
Bedstraw / Cleavers (*Galium aparine*)	B	3
Black bindweed (*Fallopia convolvulus*)	B	2
Blackberry nightshade (*Solanum nigrum*)	L	2
Calomba daisy (*Oncosiphon suffruticosum*)	B	2
Capeweed (*Arctotheca calendula*)	I	1
	L	1
Charlock (*Sinapis arvensis*)	B	2
Common sowthistle (*Sonchus oleraceus*)	B	>10,000
	I	>50
	M	>50
Dense-flowered fumitory (*Fumaria densiflora*)	D	2
Dirty Dora (*Cyperus difformis*)	B	>50
Flax-leaf fleabane (*Conyza bonariensis*)	B	>100
	L	1
	M	>100
Iceplant (*Mesembryanthemum crystallinum*)	B	2
Indian hedge mustard (*Sisymbrium orientale*)	B	>1,000
	C	16
	F	>50
	I	>50
Lincoln weed / Sand rocket (*Diplotaxis tenuifolia*)	B	20
Paterson's curse (*Echium plantagineum*)	B	2
Pennsylvania cudweed (*Gamochaeta pensylvanica*)	L	2
Prickly lettuce (*Lactuca serriola*)	B	>2,000
	M	1
Small square weed (*Mitracarpus hirtus*)	L	1
Starfruit (*Damasonium minus*)	B	5
Stinging nettle / Dwarf nettle (*Urtica urens*)	C	1
Tall Fleabane (*Conyza sumatrensis*)	M	10
Tridax daisy (*Tridax procumbens*)	M	1
Turnip weed (*Rapistrum rugosum*)	B	3
Wild radish (Raphanus raphanistrum)	B	>5,000
	C	>20
	F	>1,000
	I	>1,000
	M	3
Wild turnip / Mediterranean turnip (Brassica tournefortii)	B	>100
Willow leaf lettuce (Lactuca saligna)	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 MoA; Groups A, B, C, D, J, K, L, M, Q (**croplife.org.au**). Resistance to Groups A and B 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 A 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 B and Group Z with more than 200 populations of wild oats affected

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

Group Z (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 A herbicides with one in three 'fop' resistant wild oat populations being observed to also have Group Z resistance. Group B 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 A, B, and M) across more than 1,000 populations in Australia. Resistance to these MoAs is not surprising considering the strong adoption of grass selective herbicides (Group A) in the 1980s and 1990s; followed by a move to sulfonylureas and imidazolinones (Group B) 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 B herbicides and more than 200 populations resistant to Group A 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 L herbicides (paraquat and diquat) and at least one population resistant to Group M (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*;[3] *Echinochloa colona* (awnless barnyard grass) and Echinochloa 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 C 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**

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 NSW, 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 B, C and L have been recorded globally. Currently in Australia, resistance has been confirmed in approximately 200 populations to Groups B, L and M 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.

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

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**
- **https://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 B herbicides, with recently identified isolated populations resistant to Group I (five populations) and Group M (one population) 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 IWM strategy. It is suggested that growers monitor the performance of herbicides applied in fallow, especially glyphosate-based applications.

While herbicides from Group I 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**
- 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 1.

Wild radish has developed resistance to five herbicide modes of action including Groups B, C, F, I and M. Whilst resistance to some herbicides has been slow to develop, e.g. Group C (less than 20 populations), or has been discovered only recently, e.g. Group M (three populations), resistance to Group B (more than 5,000 populations), Group F (more than 1,000 populations) and Group I (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 over 2,000 populations resistant to Group B herbicides. There is one reported case of Group M (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*)

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

There are significant populations resistant to Group B (more than 1,000 populations), Group I (50 populations) and some resistant to both groups. There are also small populations (less than 50) resistant to Group C and Group F herbicides. The first cases of Group B resistance were confirmed in the early 1990s in NSW, 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 B herbicides. Resistance to Group B and I 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 NSW, 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 B herbicides. Resistance to Group B herbicides was first confirmed in South Australia and West 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**

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