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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:

1. **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.
2. **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.
3. **The frequency of resistance present in untreated populations:** if the frequency of resistant genes in a population is relatively high, such as with Group 2 herbicides, resistance will occur quickly. If the frequency is low, such as with Group 9 herbicides, resistance will occur more slowly.
4. **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 grass and broadleaf weed species with herbicide resistance in more than 70 countries worldwide (WeedScience.org).

Herbicide resistance has developed a strong foothold in Australian agriculture since it was first reported in annual ryegrass in 1982. The issue of herbicide resistance has expanded and evolved to include a range of other weed species and become a key management issue for crop production in all states generally with a history of intensive herbicide use.

Current impact on weed management in Australia

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

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 the world's first 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 (previously a letter code and as of July 2021 a number code) in a prominent position. Herbicide mode of action groups are important to consider when making herbicide use decisions, however, resistance management strategies require continual implementation.

MODE OF ACTION

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 3-4 years if no attention is paid to resistance management. Remember that the resistance risk is the same for products having the same mode of action. If you continue to use herbicides with the same mode of action and do not follow a resistance management strategy you are creating future problems for yourself. Mode of action matters.

Mode of action 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 previously by a letter code and as of July 2024 transitioned to a number code on the product label. Australia was the first country to introduce compulsory herbicide mode of action labelling on product labels. Since the introduction of herbicide mode of action labelling in Australia, other countries adopted their own herbicide mode of action classification systems, and this became problematic if cross-referencing herbicide mode of action between Australia and other countries, as many other countries used a different classification system.

The initial herbicide mode of action grouping and labelling system in Australia was revised in 2007. That represented the first major revision of the classification system since its introduction. The original groupings were made based on limited knowledge about modes of action. Groupings were 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 of developing resistance didn't change, however, six additional herbicide mode of action groups were created to more accurately group herbicides.

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

The reason for the changes included:

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

Australia adopted the new globally aligned herbicide mode of action classification system in February 2021. Since July 2021, changes have been made to herbicide labels reflecting the new number-based system rather than letters, with stipulation that all herbicide labels and literature be updated to reflect the new system by 31 December, 2024. There are also some herbicides that change mode of action groups or subgroups based on the latest knowledge about how products work. Five new mode of action groups have been created to cater for new products or to split current modes of action into more defined groups.

HERBICIDES ARE GROUPED BY MODE OF ACTION

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	1	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 18, 19, 23, 24, 30, and 32 have not been developed to date because there are no recorded cases of weeds resistant to members of these groups in Australia.

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

Specific guidelines are also included for the **MODERATE RESISTANCE RISK** herbicides, Groups 3, 4, 5, 6, 9, 10, 12, 13, 14, 15, 22, 27, 31 and 34 herbicides.

INTEGRATED WEED MANAGEMENT STATEGIES

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 mode of action groups within and across years (refer to specific guidelines for each herbicide mode of action group).
- Application of two or more different herbicide modes of action 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 modes of action which are all effective on the target weed.
    - Double-knock" where two herbicides with different modes of action 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 following the instructions to optimise results.
- Always using robust label rates to ensure maximum weed control.
- Rotation of crop and variety.
- Identification and monitoring your surviving weed populations (keep good records of weed populations).
- If a weed control failure is suspected, do not use the same product or product from the same mode of action group.
- Testing to confirm resistance status.
- Incorporation of additional cultural weed control techniques to reduce seed banks e.g., burning, cultivation, varied sowing, competitive crops and varieties, green manuring, grazing and collection or destruction of weed seed at harvest.
- Controlling weed escapes before the weeds set and shed viable seed.
- Ensuring you do not introduce or spread weeds by contaminated seed, grain, livestock, machinery or hay.
- Crop and pasture topping
- Attending training courses e.g., GRDC IWM course, ChemCert, and field days.
- Additional information can be obtained from:
    - CropLife Australia (www.croplife.org.au)
    - Australian Glyphosate Sustainability Working Group (defunct, but archived) https://webarchive.nla.gov.au/awa/20200113011304/http://pandora.nla.gov.au/pan/179386/20200109-1842/glyphosateresistance.org.au/index.html

  - Grains Research & Development Corporation (www.grdc.com.au)
  - WeedSmart (www.weedsmart.org.au)
  - International Information on Herbicide Resistant Weeds (weedscience.org)
  - State Government Departmental publications
- Detailed programs for herbicide resistance management for various herbicide tolerant crops are included (refer CropLife Australia website www.croplife.org.au). Management of herbicide tolerant volunteers, while not covered by Resistance Management Strategies, is addressed in stewardship documents for the relevant production systems.
  - Cotton: Roundup Ready Flex® and XtendFlex® Cotton are available from Bayer.
  - Canola: Roundup Ready® Canola, TruFlex® Canola with Roundup Ready technology, LibertyLink® and Clearfield® Production Systems, imiCrops®, and Optimum GLY® are available from Bayer, BASF, Nufarm, and Corteva Agriscience.
  - Cereals: Clearfield® Production Systems; imiCrops® are available from BASF and Nufarm; CoAXium® Production System; Quizalofop-p-ethyl tolerant cereals are available from Sipcam.
  - Sorghum: INZEN® Production System, Clearfield® Production Systems, and igrowth® are available from BASF/GenTech.
  - Pulses: imi Crops® are available from Nufarm.
- Seek advice from local advisors (agronomists).
- Strategies specific to rice: refer to the Rice crop protection guide.
- 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 weed seed from returning to the seed bank.

Weed control options for IWM

	Herbicidal	Non-herbicidal
Crop phase	Crop topping	Rotate crops/varieties
	Knockdown herbicides e.g. double knock strategy before sowing	Grow a dense and competitive crop
	Selective herbicides before and/or after sowing*	Cultivation • Seed burial • Germination stimulus • Weed tilling
	Utilising moderate resistance risk herbicides	Green/brown manure crops
	Use mixtures and/or sequences of different modes of action	Varied sowing times
		Cut crops for hay/silage
		Burn stubbles/windrows
		Collect and/or destroy weed seeds at harvest
		Grazing
Pasture phase	Spray topping	Good pasture competition
	Winter cleaning	Cut crops for hay/silage
	Selective herbicides*	Cultivation • Seed burial • Germination stimulus • Weed tilling
	Use mixtures and/or sequences of different modes of action	Grazing
Fallow phase	Chemical fallow	Cultivation • Seed burial • Germination stimulus • Weed tilling
	Optical spot spray technology	Grazing
	Use mixtures and/or sequences of different modes of action	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	Limited or no crop rotation
Weed density	Low	Moderate	High
Number 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.

Notes

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

GROUP	0	HERBICIDE

Moderate resistance risk

Globally, herbicide resistance to the Group 0 herbicide mode of action has been confirmed and documented in 8 weed species across 4 countries. This includes resistance to MSMA in Xanthium spp., flamprop resistance in three *Avena* spp., dalapon resistance in Chilean needlegrass and dalapon and flupropinate resistance in giant Paramatta grass as well as flupropinate resistance in serrated tussock and African lovegrass.

Group 0 resistance exists in Australia in 4 species of weeds. These include more than 200 populations of wild oats resistant to flamprop. Many of these flamprop resistant wild oats also show cross resistance to Group 1 herbicides. Dalapon and flupropinate resistance has been observed in giant Paramatta grass as well as flupropinate resistance in serrated tussock and African lovegrass.

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

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 Integrated Weed Management (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 mode of action groups. Always consult the product label prior to use.

Continued on next page.

Chemical family	Active constituent (first registered trade name)
GROUP 0 **Herbicides with unknown and probably diverse sites of action**	
Arylaminopropionic acids	flamprop (Mataven L®)
Chlorocarbonic acids	dalapon (Dalapon®, Onceyear Pathweeder®*, flupropanate (Frenock®)
Phosphorodithioates	bensulide (Prefar®)
Acetamides	napropamide (Altiplano®*, Devrinol®)
Organoarsenicals	DSMA (disodium methylarsonate) (Methar®, Trinoc®*), MSMA (monosodium methylarsonate) (Daconate®)
Fatty acids	Pelargonic acid (Nonanoic acid)

* *This product contains more than one active constituent*

Notes:

1. 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.

GROUP	1	HERBICIDE

High resistance risk

Globally, herbicide resistance to Group 1 herbicides have been confirmed and documented in more than 50 grass weed species across more than 40 countries. Group 1 resistance is extensive and prolific with tens of millions of hectares affected, in fact it is the second most likely herbicide mode of action to develop resistance with only the Group 2 mode of action more likely.

Group 1 resistance commonly exists across wide areas of Australia in the grass weed species including more than 30,000 populations of annual ryegrass, annual veldt 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 golf courses, rice, horticulture, pastures, and bushland reserves situations.

Research has shown that as few as 6 applications to the same population of annual ryegrass can result in the selection of resistant individuals. A population can go from a small area of resistant individuals to a whole paddock failure in one season.

1. FOPs, DIMs and DENs are Group 1 herbicides and carry the same high resistance risk.
2. Where a Group 1 herbicide has been used on a particular paddock for control of any grass weed, avoid using a Group 1 herbicide to control the same grass weed in the following season, irrespective of the performance it gave.
3. Frequent application of Group 1 herbicides to dense weed populations is the worst-case scenario for rapidly selecting for resistance.
4. Where resistance to a member of Group 1 is suspected or known to exist, there is a strong possibility of cross resistance to other Group 1 and 0 herbicides. Therefore, use other control methods and herbicides of other mode of action groups in a future integrated approach.
5. Specific recommendations are available for CoAXium® Production System; Quizalofop-p-ethyl tolerant cereals, which are available from Sipcam: https://www.coaxium.com.au/.

The above recommendations should be incorporated into an Integrated Weed Management (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 mode of action groups. Always consult the product label prior to use.

Continued on next page.

Chemical family	Active constituent (first registered trade name)
GROUP 1 Inhibition of acetyl co-enzyme A carboxylase (/ACC'ase inhibitors)	
Aryloxyphenoxypropionates (FOPs)	clodinafop (Topik®), cyhalofop (Agixa®*, Barnstorm®), diclofop (Cheetah® Gold* Decision®*,), fenoxaprop (Cheetah®, Gold*, Wildcat®), fluazifop (Fusilade® RoundupFNG Weedkiller®), haloxyfop (Verdict®), propaquizafop (Shogun®), quizalofop (Targa®)
Cyclohexanediones (DIMs)	butroxydim (Factor®*), clethodim (Select®, Zero Triple ActionGarden Weedkiller®)), 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.

GROUP	2	HERBICIDE

High resistance risk

Globally, herbicide resistance to the Group 2 herbicide mode of action has been confirmed and documented in more than 170 grass and broadleaf weed species across more than 40 countries. Resistance to Group 2 is extensive and prolific, with tens of millions of hectares affected, in fact it is the most likely herbicide mode of action to develop resistance.

Group 2 resistance exists in Australia in 28 species (10 grasses) including more than 30,000 populations of annual ryegrass, more than 200 populations of barley grass, brome grass, more than 200 populations of wild oats, paradoxa grass and crabgrass and in at least seventeen broadleaf weeds including more than 5,000 populations of wild radish, common sowthistle, black bindweed, charlock, more than 2000 populations of prickly lettuce, more than 1,000 populations of Indian hedge mustard, Mediterranean (wild) turnip and turnip weed. Resistance has developed in broadacre, golf courses, horticulture, rice and pasture situations. In respect to rice, there are Group 2 resistant populations to three broadleaf weeds, namely dirty Dora, arrowhead and starfruit.

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

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

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

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

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

1. Avoid applying more than two# Group 2 herbicide treatments in any four year period on the same paddock. Where more than two treatments are applied introduce alternative control measures to avoid seed set and seed shed in the paddock.

2. A Group 2 herbicide may be used alone on flowering wild radish only if a Group 2 herbicide has not been previously used on that crop.
3. All cases if there are significant escapes following the herbicide application consider using another herbicide with a different mode of action or another control method to stop seed set.
4. Imidazolinone tolerant crops where Intervix® is 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 Integrated Weed Management (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 mode of action groups. Always consult the product label prior to use.

[#] where there are multiple applications of a Group 2 herbicide to the same plants, with none of these applications to new generations of plants (of the same species), this may be viewed as the same as a single application of the Group 2 herbicide with respect to selection for Group 2 resistant plants. This is sometimes the case in turf where Group 2 herbicides are applied for the control of perennial grasses like kikuyu, paspalum or bahia grass, in a program of 2 to 3 applications in close intervals (to the same plants).

Chemical family	Active constituent (first registered trade name)
GROUP 2 Inhibition of acetolactate synthase (ALS inhibitors), acetohydroxyacid synthase (AHAS)	
Imidazolinones (IMIs)	imazamox (Intervix®*, Raptor®), imazapic (Bobcat I-Maxx®*, Flame®, Midas®*, OnDuty®*), imazapyr (Arsenal Xpress®*, Intervix®*, Lightning®*, Midas®* OnDuty®* Roundup PNG Weedkiller®)), imazethapyr (Lightning®*, Spinnaker®)
Pyrimidinylthiobenzoates	bispyribac (Nominee®), pyrithiobac (Staple®)
Sulfonylureas (SUs)	azimsulfuron (Gulliver®), bensulfuron (Londax®), chlorsulfuron (Glean®), ethoxysulfuron (Hero®), flazasulfuron (Katana®), foramsulfuron (Tribute®), halosulfuron (Sempra®), iodosulfuron (Hussar®), mesosulfuron (Atlantis®), metsulfuron (Ally®, Stinger®*, Trounce®*, Ultimate Brushweed®* Herbicide), prosulfuron (Casper®*), rimsulfuron (Titus®), sulfometuron (Oust®, Eucmix Pre Plant®*, Trimac Plus®*), sulfosulfuron (Monza®), triasulfuron (Logran®, Logran® B-Power®*), tribenuron (Express®), trifloxysulfuron (Envoke®, Krismat®*)
Triazolopyrimidines – Type 1	florasulam (Crest®*, Gangster®*, Paradigm®*, Saracen® Vortex®*, X-Pand®*), flumetsulam (Broadstrike®, Thistrol Gold*®), metosulam (Eclipse®)
Triazolopyrimidines – Type 2	pyroxsulam (Crusader® Rexade®*)

* *This product contains more than one active constituent.*

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.

GROUP	3	HERBICIDE

Moderate resistance risk

Globally herbicide resistance to the Group 3 herbicide mode of action has been confirmed and documented in more than 10 grass and broadleaf weed species across more than 8 countries.

Group 3 resistance exists in Australia in 3 weed species including 5,000 populations of annual ryegrass and dense flowered fumitory. Resistance has generally occurred after 10 -15 years of use of Group 3 herbicides.

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

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

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

The above recommendations should be incorporated into an Integrated Weed Management (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 mode of action groups. Always consult the product label prior to use.

Chemical family	Active constituent (first registered trade name)
GROUP 3 Inhibition of microtubule assembly	
Benzamides	propyzamide (Effigy*®, Kerb®)
Dinitroanilines: (DNAs)	oryzalin (Rout®*, Surflan®), pendimethalin (Freehand*®, OH2 Ornamental Herbicide®, 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.

GROUP	4	HERBICIDE

Moderate resistance risk

Globally herbicide resistance to the Group 4 herbicide mode of action has been confirmed and documented in more than 40 grass and broadleaf weed species across more than 20 countries. Resistance to the Group 4 mode of action is common.

Group 4 resistance exists in Australia in 7 weed species including capeweed, winged slender thistle, more than 50 populations of common sow thistle, more than 1,000 populations of wild radish and more than 50 populations of Indian hedge mustard. Resistance has occurred after a long history of use of Group 4 herbicides. The number of populations with Group 4 resistance is increasing.

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

As a general rule in high resistance risk situations:

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

The above recommendations should be incorporated into an Integrated Weed Management (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 mode of action groups. Always consult the product label prior to use.

Chemical family	Active constituent (first registered trade name)
GROUP 4 Disruptors of plant cell growth (Auxin mimics)	
Benzoates	dicamba (Banvel®, Banvel M®*, Barrel®*, Casper®*, Lawnweeder plus®*, Lawn weedkiller*, Mecoban®, Methar Tri-Kombi®*, Nuturf Millennium®*, Sandoban®*)
Phenoxy-carboxylates (Phenoxys)	2,4-D (Actril DS®*, Amicide®, Fallow Boss Tordon®*, Methar Tri-Kombi®*, Pyresta®*, Vortex®*), 2,4-DB (Trifolamine®), dichlorprop (Lantana 600®), MCPA (Agtryne® MA*, Banvel M®*, Barrel®*, Basagran® M60*, Buctril® MA*, Buffalo Pro Weedkiller®*, Condor*®, Flight®*, Lawnweeder plus®*, Lawn Weedkiller*, Midas®*, Paragon®*, Precept®*, Quadrant®*, Silverado®*, Spearhead®*, Thistrol Gold*®, Tigrex®*, Tordon 242®*, Triathlon®*, Zero Triple Action Garden Weedkiller ®), MCPB (Legumine®, Thistrol Gold*®), mecoprop (Mecoban®, Mecopropamine®, Methar Tri Kombi®*, Multiweed®*)
Pyridine carboxylates (Pyridines)	aminocyclopyrachlor (Method®), aminopyralid (Fallow Boss Tordon®*, ForageMax®*, Grazon Extra®*, Grindstone®, Hotshot®*, Stinger®*, Vigilant II®*), clopyralid (Lontrel®, Nuturf Millennium®*, Spearhead®*, Trimac Plus®*, Velmac Plus®*) , florpyrauxifen (Agixa®*, Ubeniq®), halauxifen (ForageMax®*, Paradigm®*, Pixxaro®*, Rexade®*), picloram (Fallow Boss Tordon®*, Grazon Extra®*, Tordon®, Tordon 242®*, Tordon Regrowth Master®*, Trinoc®*, Vigilant II®*)
Quinoline-carboxylates	quinclorac (Drive®)
Pyridyloxy-carboxylates	fluroxypyr (Crest®*, Hotshot®*, Monsoon®*, Pixxaro®*, Roundup FNG Weedkiller®, Roundup PNG Weedkiller®, Starane®), triclopyr (Garlon®, Grazon Extra®*, Tordon Regrowth Master®*, Tough Roundup® Weedkiller*, Ultimate Brushweed®* Herbicide)

* *This product contains more than one active constituent*

Notes:

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

GROUP	5	HERBICIDE

Moderate resistance risk

The herbicides in the new CropLife Group 5 and Group 6 were previously all in Group C in Australia. The Mode of Action was described as "Inhibitors of photosynthesis at photosystem II". Now, to match international grouping, this MOA has been split into two, identified as Group 5 (PSII D1 Serine 264 binders) and Group 6 (PSII D1 Histidine 215 binders). The rationale is that there is still no demonstrated target site cross-resistance between these two groups. (GHRAC MOA Update _2020).

Globally herbicide resistance to the Group 5 herbicide mode of action has been confirmed and documented in more than 80 grass and broadleaf weed species across more than 40 countries. Resistance to the Group 5 mode of action is common; in fact, it is the third most likely herbicide mode of action to develop resistance.

In Australia, Group 5 resistance exists in 9 weed species across more than 100 weed populations including more than 50 populations of annual ryegrass, more than 20 populations of wild radish, liverseed grass, squirrel tail fescue (silver grass), dwarf (stinging) nettles, Indian hedge mustard, brome grass and barnyard grass ("at risk weeds").

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

1. For "at risk weeds", avoid using Group 5 herbicides as the only means of control in the same paddock in consecutive years.
2. Watch and record weed escapes in paddocks with a long history of Group 5 use.
3. Control survivors to prevent seed-set using a herbicide with a different Mode of Action to Group 5 or use another weed management technique, particularly in heavily infested paddocks.
4. 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.
5. **TT Canola** Growing TT Canola in a paddock treated with triazine herbicides in the previous season is a high resistance risk and is not recommended. For ryegrass control, use simazine, atrazine, metribuzin or terbuthylazine plus a pre- emergence herbicide with a different mode of action (e.g. trifluralin) prior to sowing. If necessary, follow-up with a post emergent herbicide with a different mode of action (e.g. clethodim) to control escapes from pre-emergent treatments.

6. **TT-RR Canola** Refer to the specific guidelines for Group 9 herbicides in addition to those given here for triazine herbicides.
7. **TT-LL Canola** Refer to the specific guidelines for Group 10 herbicides in addition to those given here for triazine herbicides.

The above recommendations should be incorporated into an Integrated Weed Management (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 mode of action groups. Always consult the product label prior to use.

Below is a list of Group 5 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.

Chemical family	Active constituent (first registered trade name)
GROUP 5 Inhibitors of photosynthesis at photosystem II (D1 Serine 264 binders)	
Amides	propanil (Stam®)
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®*, 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®), metobromuron (Soleto®), methabenzthiazuron (Tribunil®), siduron (Tupersan®), tebuthiuron (Graslan®)

* *This product contains more than one active constituent*

GROUP	6	HERBICIDE

Moderate resistance risk

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

Globally herbicide resistance to the Group 6 herbicide mode of action is not as common as Group 5, but exists in 5 weed species.

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

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

The above recommendations should be incorporated into an Integrated Weed Management (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 mode of action groups. Always consult the product label prior to use.

Chemical family	Active constituent (first registered trade name)
GROUP 6 Inhibitors of photosynthesis at photosystem II (D1 Histadine 215 binders)	
Benzothiadiazinones	bentazone (Basagran®, Basagran® M60*, Lawnweeder plus®*), pyridate (Tough®)
Nitriles	bromoxynil (Barrel®*, Buctril®, Buctril® MA*, Buffalo Pro Weedkiller®*, Eliminar C®*, Flight®*, Jaguar®*, Monsoon®*, Talinor®*, Quadrant®*, Triathlon®*, Velocity®*), ioxynil (Actril DS*, Totril®)

* *This product contains more than one active constituent*

Notes:

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

GROUP	9	HERBICIDE

Moderate resistance risk

Globally, herbicide resistance to the Group 9 herbicide mode of action has been confirmed and documented in more than 50 weed species across more than 30 countries.

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

Group 9 resistance occurs in Australia in 20 weed species including more than 2,000 populations of annual ryegrass, more than 500 populations of awnless barnyard grass, brome grass, more than 100 populations of common sow thistle, 2000 populations of feathertop Rhodes grass, and more than 100 populations of flax-leaf fleabane.

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

1. Lack of rotation with other herbicide modes of action;
2. A Group 9 herbicide has been used for 12 – 15 years or more; and
3. There has been minimal or no soil disturbance following application.

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

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

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

Given the demonstrated propensity of weeds to develop resistance to multiple herbicide classes, Integrated Weed Management 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 technique1, strategic herbicide rotation, grazing, baling etc.

For further information in canola: http://www.roundupreadycanola.com.au/prod/media/3672/rr-canola-technologies-rmp.pdf.

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

The above recommendations should be incorporated into an Integrated Weed Management (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 mode of action groups. Always consult the product label prior to use.

Chemical family	Active constituent (first registered trade name)
GROUP 9 Inhibition of 5-enolpyruvyl shikimate-3 phosphate synthase (EPSP inhibition)	
Glycines	glyphosate (Arsenal Xpress®*, Bantox*, Broadway®*, Firestorm®*, Illico®*, Resolva®*, Roundup®, Sandoban*®, Tough Roundup® Weedkiller*, Trounce®*, Pathweeder®*)

* *This product contains more than one active constituent*

Notes:

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

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

GROUP	10	HERBICIDE

Moderate resistance risk

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

Resistance to Group 10 herbicides is rare, and currently there are no documented cases of resistant weeds in Australia. Group 10 resistance has been discovered in other countries for 6 weed species – crowsfoot grass, ryegrass), Amaranthus, as well as wintergrass – which demonstrates the potential for weeds to develop resistance to this mode of action.

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:

1. Other herbicides in the farming system, especially glyphosate, have developed resistance;
2. Weed escapes following application of glufosinate-ammonium are allowed to set and shed viable seed; and
3. 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 mode of action, such as Group 22 (e.g. paraquat), Group 34 (e.g. amitrole) or Group 9 (e.g. glyphosate).
2. Where possible use residual herbicides (that are effective on the same weeds as glufosinate-ammonium) either alone or in mixture with glufosinate-ammonium.
3. Where possible use alternative modes of action 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 mode of action, such as Group 22 (e.g. paraquat), Group 34 (e.g. amitrole) or Group 9 (e.g. glyphosate).
2. Where possible use residual herbicides (that are effective on the same weeds as glufosinate-ammonium) either alone or in mixture with glufosinate-ammonium.
3. Where possible use alternative modes of action to selectively control grass and broadleaf weeds.

In Herbicide Tolerant (HT) crops

When using glufosinate-ammonium as a post-emergent application, ideally this should be preceded by an effective pre-emergent herbicide treatment with another mode of action. Also, consider the use of registered tank mixes with herbicides from other modes of action.

For further information in canola: https://crop-solutions.basf.com.au/sites/basf.com.au/files/2021-08/Herbicide_Resistance_Management_Plan.pdf.

The above recommendations should be incorporated into an Integrated Weed Management (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 mode of action groups. Always consult the product label prior to use.

Chemical family	Active constituent (first registered trade name)
GROUP 10 Inhibition of glutamine synthetase	
Phosphinic acids	glufosinate (Basta®, Hellcat®*, 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.

GROUP	12	HERBICIDE

Moderate resistance risk

Globally herbicide resistance to the Group 12 herbicide mode of action has been confirmed and documented in \5 weed species across 3 countries.

Group 12 resistance exists in Australia in 3 weed species including more than 1,000 populations of wild radish and more than 50 populations of Indian hedge mustard. Resistance has generally occurred after a long history of use of Group 12 herbicides. The number of populations with Group 12 resistance is increasing following increased use of these herbicides.

Avoid applying Group 12 herbicides in any two consecutive years unless one application is a mixture with a different mode of action that is active on the same weed, or a follow up spray is conducted (using a different mode of action) 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 mode of action to Group 12 or use another weed management technique.

The above recommendations should be incorporated into an Integrated Weed Management (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 mode of action groups. Always consult the product label prior to use.

Chemical family	Active constituent (first registered trade name)
GROUP 12 Inhibition of carotenoid biosynthesis at the phytoene desaturase step (PDS inhibitors)	
N-Phenyl heterocycles	norflurazon (Solicam®)
Phenyl-ethers	diflufenican (Brodal®, Gangster®*, Infinity Ultra®*, Jaguar®*, Mateno® Complete*, Quadrant®*, Spearhead®*, Tigrex®*, Triathlon®*, 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.

GROUP	13	HERBICIDE

Moderate resistance risk

Globally the number of resistance cases to Group 13 herbicides is extremely low. Resistance to clomazone was first detected in Australia in 1982 in annual ryegrass. It is the only case reported for the Asia Pacific region and occurred at a time when clomazone was still under development. The only other cases of herbicide resistance reported are in barnyard grass in Arkansas in 2008 and in bearded strangletop in California in 2020.

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

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

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

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

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

Chemical family	Active constituent (first registered trade name)
GROUP 13 Inhibitors of deoxy-D-xyulose phosphate synthase (DOXP inhibitors)	
Isoxazolidinones	bixlozone (Overwatch®), clomazone (Altiplano®*, Command®)

* *This product contains more than one active constituent*

Notes:

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

GROUP	14	HERBICIDE

Moderate resistance risk

Group 14 herbicides are inhibitors of the protoporphyrinogen oxidase (PPO) enzyme. There are currently no known populations of weeds resistant to Group 14 in Australia. However, there are 6 weeds with confirmed resistant to Group 14 herbicides in 9 countries, and in particular in populations of Amaranthus spp. in the USA.

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

Tank mixtures and co-formulations

Most current recommendations for Group 14 herbicides are for mixtures with another herbicide, e.g. carfentrazone plus glyphosate, pyraflufen plus MCPA amine. There are also some co-formulations that incorporate at least two 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 modes of action should be employed between seasons.

Stand-alone applications

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

If there are significant escapes following the application of a Group 14 herbicide, consider using another herbicide with a different mode of action 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 Integrated Weed Management (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 mode of action groups. Always consult the product label prior to use.

Chemical family	Active constituent (first registered trade name)
GROUP 14 Inhibitors of protoporphyrinogen oxidase (PPOs)	
Diphenylethers	acifluorfen (Blazer®), fomesafen (Reflex) oxyfluorfen (Goal®, OH2 Ornamental Herbicide®, Rout®, Pathweeder®)
N-phenyl-imides	butafenacil (B-Power®*, Logran® B-Power®*, Resolva®*), saflufenacil (Sharpen®, Voraxor*®), flumioxazin (Valor®, Terrain®) tiafenacil (Terrad'or), trifludimoxazin (Voraxor*®)
N-Phenyl-oxadiazolones	oxadiargyl (Raft®), oxadiazon (Ronstar®)
Phenylpyrazole	pyraflufen (Condor*®, Ecopar®, Sledge® Pyresta®*)
N-Phrnyl-tiazolinones	carfentrazone (Affinity®, Aptitude®*, Broadway®, Buffalo Pro Weedkiller®*, Hellcat®*, 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.

GROUP	15	HERBICIDE

Moderate resistance risk

Globally herbicide resistance to the Group 15 herbicide mode of action has been confirmed and documented in more than 10 weed species across more than 10 countries.

Resistance to Group 15 herbicides in Australia has developed in more than 100 populations of annual ryegrass with resistance to triallate, prosulfocarb and pyroxasulfone as well as 10 populations of winter grass with resistance to ethofumesate. Further development of resistance in the near future is likely given the reliance on Group 15 herbicide chemistry for weed control across large areas of Australia.

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

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

To assist in delaying the onset of resistance, rotate Group 15 herbicides with effective herbicides from other modes of action from one year to the next, mix, or use sequentially on the same weed cohort, with an effective herbicide from a different mode of action.

The above recommendations should be incorporated into an Integrated Weed Management (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 mode of action groups. Always consult the product label prior to use.

Chemical family	Active constituent (first registered trade name)
GROUP 15 Inhibitors of very long chain fatty acid synthesis (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 (Mateno® Complete*, Sakura®)
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®)
Benzofurans	ethofumesate (Tramat®)

* *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.

GROUP	22	HERBICIDE

Moderate resistance risk

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

Group 22 resistance exists in Australia in 10 species including more than 50 populations of annual ryegrass, and in 2 species of barley grass across more than 100 populations, blackberry nightshade, crowsfoot grass, capeweed, fleabane, Pennsylvanian cudweed, squirrel-tailed fescue (silver grass) and small square weed. Most instances have occurred in long-term lucerne stands treated regularly with a Group 22 herbicide but Group 22 resistant barley grass has also occurred in no-till situations.

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

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

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

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

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

Minimum or zero tillage

1. Rotate Group 22 herbicides with other knockdown herbicides with a different mode of action, such as Group 9 (e.g. glyphosate). A full label rate for the weed size targeted should be used for resistance management.
2. Consider utilising the double knock technique where glyphosate is sprayed first followed within 1 - 7 days by a paraquat application. A full label rate for the weed size targeted should be used for the paraquat application for resistance management.

1. Consider occasional mechanical cultivation to aid weed control.

Lucerne

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

Horticulture

1. Rotate Group 22 herbicides with other knockdown herbicides with a different mode of action, such as Group 10 (e.g. glufosinate), Group 34 (e.g. amitrole) or Group 9 (e.g. glyphosate).
2. Where possible, use residual herbicides (that are effective on the same weeds as the Group 22 herbicides) where applicable either alone or in mixture with Group 22 herbicides.
3. Where possible use alternative modes of action to selectively control grass and broadleaf weeds.
4. Consider using the double knock technique where glyphosate is sprayed followed within 1-7 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 Integrated Weed Management (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 mode of action groups. Always consult the product label prior to use.

Chemical family	Active constituent (first registered trade name)
GROUP 22 Inhibitors of photosynthesis at photosystem I via electron diversion (PSI inhibitors)	
Pyridiniums	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.

GROUP	27	HERBICIDE

Moderate resistance risk

Resistance to the Group 27 (HPPD inhibitors) herbicide mode of action 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 mode of action. Continuous usage of Group 27 herbicides in the United States has resulted in resistance in Amaranthus species in a relatively short time.

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

Broadacre cropping

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

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

Fallow

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

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 mode of action. To reduce the likelihood of resistant weeds developing it is recommended that products containing benzofenap (e.g. Taipan®) not be used in consecutive rice crops.

Sugarcane

It is critical to manage weeds effectively to protect sugarcane from yield loss due to competition. Weed management that relies on Group 27 herbicides should incorporate Integrated Weed Management (IWM) principles that include chemical and non-chemical methods of weed control. Chemical methods of weed control should include rotation and/or tank mixing Group 27 herbicides with herbicides from other modes of action 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 Integrated Weed Management (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 mode of action groups. Always consult the product label prior to use.

Chemical family	Active constituent (first registered trade name)
GROUP 27 Inhibition of 4-hydroxyphenyl-pyruvate dioxygenase (HPPD inhibitors)	
Isoxazoles	isoxaflutole (Balance® Palmero TX®*)
Pyrazoles	benzofenap (Taipan ®), pyrasulfotole (Galaxy®, Infinity Ultra®*, Precept®*, Velocity®*), topramezone (Frequency®)
Triketones	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.

GROUP	31	HERBICIDE

Moderate resistance risk

Globally, herbicide resistance to the Group 31 herbicide mode of action has been confirmed in 3 populations of Poa annua in Australia only.

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

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

The above recommendations should be incorporated into an Integrated Weed Management (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 mode of action groups. Always consult the product label prior to use.

Chemical family	Active constituent (first registered trade name)
GROUP 31 Inhibitors of serine threonine protein phosphatase (STPP inhibitors)	
Unknown	endothal (Endothal®)

Notes:

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

GROUP	34	HERBICIDE

Moderate resistance risk

Globally, herbicide resistance to the Group 34 herbicide mode of action has been confirmed and documented in 6 weed species across 4 countries.

Group 34 resistance exists in Australia with 3 populations of annual ryegrass resistant to amitrole. This has only occurred in 3 populations and this type of resistance is rare in Australia.

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

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

The above recommendations should be incorporated into an Integrated Weed Management (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 mode of action groups. Always consult the product label prior to use.

Chemical family	Active constituent (first registered trade name)
GROUP 34 Inhibition of lycopene cyclase	
Triazoles	amitrole (Alliance®*, Amitrole®, RTU Pathweeder®*, Illico®*, Firestorm®*,Onceyear 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.