

Herbicide Resistance Management Strategies

*Developed by the CropLife Australia Herbicide Resistance Management Review Group
and industry researchers*

Valid as at 25 June 2015

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HERBICIDE RESISTANCE

1.1. 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.

1.2. Background to herbicide resistance in Australia

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.

1.3. Current impact on weed management

Today, resistance has been confirmed in 39 grass and broadleaf weed species. More worrying still, resistance has now developed to 11 distinctly different herbicide chemical 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.

1.4. 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. A survey of growers and agronomists (Kondinin, 1998) revealed that 85% of growers are aware of herbicide mode of action groups and consider this important when making buying decisions. This was a good start but resistance management strategies require continual implementation.

MODE OF ACTION

2.1. 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.

2.2. 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 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 products. 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 new herbicide mode of action groups were created to more accurately group herbicides.

HERBICIDES ARE GROUPED BY MODE OF ACTION AND RANKED BY RESISTANCE RISK

Growers and agronomists are now better aided 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 now carry the mode of action group clearly displayed such as: -

GROUP	A	HERBICIDE
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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, G, H, N, 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 in winter cropping systems.

Specific guidelines are also included for the **MODERATE RESISTANCE RISK** herbicides, Group C, Group D, Group F, Group I, Group J, Group L, Group M Group Q and Group Z herbicides.

Specific guidelines for Group H and K herbicides have been developed due to the reliance on this mode of action to manage annual ryegrass, and the possibility of future resistance development.

Detailed programs for herbicide resistance management for weed control in rice are included (refer CropLife Australia website www.croplife.org.au). Details of herbicide resistance management plans in Liberty Link® Cotton, Roundup Ready Flex® Cotton, Roundup Ready Canola® and Clearfield® Production Systems are available from Bayer, Monsanto and BASF respectively.

INTEGRATED WEED MANAGEMENT STRATEGIES

Strategies are designed to prevent and/or reduce the occurrence 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:

- Refer to specific guidelines for each herbicide mode of action group.
- Rotation of herbicide mode of action groups within and across years.
- Keep accurate records of your herbicide applications on a paddock basis.
- Read the herbicide product label and literature carefully and follow the instructions.
- Always use robust label rates to ensure maximum weed control.

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INTEGRATED WEED MANAGEMENT STRATEGIES (cont.)

- Rotation of crop and variety.
- Identify and monitor your surviving weed populations and check for resistant weeds on your farm. Keep good records of weed populations.
- If a failure is suspected do not use the same product or product from the same mode of action group.
- Testing – confirm resistance exists.
- Additional cultural weed control techniques to reduce seed banks, eg. burning, cultivation, delayed 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 or hay.
- Consider crop and pasture topping.
- Attend training courses, eg. 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) and State Government Departmental publications.
- 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.

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INTEGRATED WEED MANAGEMENT STRATEGIES (cont.)

Weed control options for IWM

	<i>Herbicidal</i>	<i>Non-herbicidal</i>
<i>Crop phase</i>	- Crop topping - Knockdown herbicides eg. double knock strategy before sowing - Selective herbicides before and/or after sowing – but ensure escapes don't set seed - Utilising moderate resistance risk herbicides - Use mixtures and/or sequences of different modes of actions	- Rotate crops - Rotate varieties - Grow a dense and competitive crop - Cultivation - Green/brown manure crops - Delay sowing - Cut crops for hay/silage - Burn stubbles/windrows - Collect and/or destroy weed seeds at harvest - Grazing
<i>Pasture phase</i>	- Spray topping - Winter cleaning - Selective herbicides – but ensure escapes don't set seed - Use mixtures and/or sequences of different modes of actions	- Good pasture competition - Hay making or silage - Cultivation - Grazing
<i>Fallow phase</i>	- Chemical fallow - Optical spot spray technology - Use mixtures and/or sequences of different modes of actions - Selective herbicides – but ensure escapes don't set seed - Knockdown herbicides eg. double knock strategy	- Cultivation - Grazing - Burning

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 Departmental Agronomist, or refer to the "Integrated Weed Management Manual" found on the following website <http://www.grdc.com.au/Resources/IWMhub>

You can do something to reduce the impact!

Follow the latest resistance management strategies described in this document.

Note:

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.

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.

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5. SPECIFIC GUIDELINES FOR GROUP A HERBICIDES

GROUP	A	HERBICIDE
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High resistance risk

Group A resistance exists in Australia in the grass weeds including annual ryegrass, annual veld grass, wild oats, phalaris, brome grass, crabgrass, crowsfoot grass and barley grass. Resistance has developed in broadacre and vegetable 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 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 herbicides. Therefore use other control methods and herbicides of other mode of action groups in a future integrated approach.

All the above recommendations should be read in conjunction with the Integrated Weed Management (IWM) strategies

CHEMICAL FAMILY	ACTIVE CONSTITUENT (FIRST REGISTERED TRADE NAME)
GROUP A	Inhibitors of acetyl coA carboxylase (Inhibitors of fat synthesis/ACC'ase inhibitors)
<i>Aryloxyphenoxypropionates:</i> (Fops):	clodinafop (Topik [®]), cyhalofop (Barnstorm [®]), diclofop (Cheetah [®] Gold [*] , Decision ^{®*} , Hoegrass [®]), fenoxaprop (Cheetah [®] Gold [*] , Wildcat [®]), fluazifop (Fusilade [®] , Fusion ^{®*}), haloxyfop (Verdict [®]), propaquizafop (Shogun [®]), quizalofop (Targa [®])
<i>Cyclohexanediones:</i> (Dims):	butoxydim (Falcon [®] , Fusion ^{®*}), clethodim (Select [®]), profoxydim (Aura [®]), sethoxydim (Cheetah [®] Gold [*] , Decision ^{®*}), tepraloxym (Aramo [®]), tralkoxydim (Achieve [®])
<i>Phenylpyrazoles:</i> (Dens):	pinoxaden (Axial [®])

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

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.

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6. SPECIFIC GUIDELINES FOR GROUP B HERBICIDES

GROUP	B	HERBICIDE
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High resistance risk

Group B resistance exists in Australia in annual ryegrass, barley grass, brome grass, wild oats, paradoxa grass and crabgrass and in at least seventeen broadleaf weeds including wild radish, common sowthistle, black bindweed, charlock, Indian hedge mustard, prickly lettuce, Mediterranean (wild) turnip and turnip weed. Resistance has developed in broadacre, rice and pasture situations. In respect to rice three broadleaf weeds, namely dirty dora, arrowhead and starfruit, are known to have Group B resistant populations.

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 a small area 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 in-crop 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 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 modes of action.

When using a group B herbicide for post-emergent broadleaf or grass weed control, this should be preceded by a pre-emergent herbicide treatment with other modes-of-action.

1. 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.
2. 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.
3. In 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 (Clearfield Systems):** Where OnDuty, Midas and Intervix are used refer to the Clearfield Production Systems – best management practice guide (http://www.agro.basf.com.au/images/pdf/clearfield/Clearfield_Stewardship_Best_Management_Practice_2014.pdf). If Sentry is to be used pre-emergent; consult the Crop Care Best Management Guide (<http://www.croplife.com.au/imicrops>)

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GROUP B		Inhibitors of acetolactate synthase (ALS inhibitors)
<i>Imidazolinones:</i> (<i>Imis</i>):		imazamox (Intervix [®] , Raptor [®]), imazapic (Bobcat I-Maxx [®] , Flame [®] , Midas [®] , OnDuty [®]), imazapyr (Arsenal Xpress [®] , Intervix [®] , Lightning [®] , Midas [®] , OnDuty [®]), imazethapyr (Lightning [®] , Spinnaker [®])
<i>Pyrimidinylthiobenzoates:</i>		bispyribac (Nominee [®]), pyrithiobac (Staple [®])
<i>Sulfonylureas:</i> (<i>SUS</i>):		azimsulfuron (Gulliver [®]), bensulfuron (Londax [®]), chlorsulfuron (Glean [®]), ethoxysulfuron (Hero [®]), foramsulfuron (Tribute [®]), halosulfuron (Semptra [®]), iodosulfuron (Hussar [®]), mesosulfuron (Atlantis [®]), metsulfuron (Ally [®] , Harmony [®] M, Stinger [®] *, Trounce [®] *, Ultimate Brushweed [®] * Herbicide), prosulfuron (Casper [®]), rimsulfuron (Titus [®]), sulfometuron (Oust [®]), sulfosulfuron (Monza [®]), thifensulfuron (Harmony [®] M), triasulfuron, (Logran [®] , Logran [®] B-Power [®]), tribenuron (Express [®]), trifloxysulfuron (Envoke [®] , Krismat [®] *)
<i>Triazolopyrimidines:</i> (<i>Sulfonamides</i>):		florasulam (Conclude [®] , Paradigm [®] *, Torpedo [®] , X-Pand [®]), flumetsulam (Broadstrike [®]), metosulam (Eclipse [®]), pyroxsulam (Crusader [®])

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

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7. SPECIFIC GUIDELINES FOR GROUP C HERBICIDES

GROUP	C	HERBICIDE
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Moderate resistance risk

Group C resistance is known to exist in Australia in the weeds annual ryegrass, wild radish, liverseed grass, squirrel tail fescue (silver grass), dwarf (stinging) nettles, Indian hedge mustard 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 Mode of Action 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

- 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 terbutylazine plus a pre-emergence herbicide with a different mode of action (eg trifluralin) prior to sowing. If necessary follow-up with a post emergent herbicide with a different mode of action (eg clethodim) to control escapes from pre-emergent treatments.
- Consult the 'Integrated Weed Management Strategy for TT Canola' for further details (refer to manufacturing companies).

2. TT-RR Canola

- Refer to the specific guidelines for Group M herbicides in addition to those given here for triazine herbicides.

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CHEMICAL FAMILY	ACTIVE CONSTITUENT (FIRST REGISTERED TRADE NAME)
GROUP C	Inhibitors of photosynthesis at photosystem II (PS II inhibitors)
<i>Amides:</i>	propanil (Stam [®])
<i>Benzothiadiazinones:</i>	bentazone (Basagran [®] , Basagran [®] M60*, Multiweed [®] *)
<i>Nitriles:</i>	bromoxynil (Barrel [®] *, Buctril [®] , Buctril [®] MA*, Eliminar C [®] *, Flight [®] *, Jaguar [®] *, Triathlon [®] *, Velocity [®] *), ioxynil (Actril DS*, Totril [®] *)
<i>Phenylcarbamates:</i>	phenmedipham (Betanal [®])
<i>Pyridazinones:</i>	chlorthalozon (Pyramin [®])
<i>Triazines:</i>	ametryn (Amigan [®] *, Gesapax [®] Combi*, Krismat [®] , Primatol Z [®]), atrazine (Gesapax [®] Combi*, Gesaprim [®] , Primextra [®] Gold*), cyanazine (Bladex [®]), prometryn (Bandit [®] *, Cotogard [®] *, Gesagard [®]), propazine (Agaprop [®]), simazine (Gesatop [®]), terbutylazine (terbyne [®]), terbutryn (Agtryne [®] MA*, Amigan [®] *, Igran [®])
<i>Triazinones:</i>	hexazinone (Bobcat I-Maxx [®] *, Velpar [®] K4*, Velpar [®] L), metribuzin (Aptitude [®] *, Sencor [®])
<i>Uracils:</i>	bromacil (Hyvar [®] , Krovar [®] *), terbacil (Sinbar [®])
<i>Ureas:</i>	diuron (Karmex [®] , Krovar [®] *, Velpar [®] K4*), fluometuron (Bandit [®] *, Cotogard [®] *, Cotoran [®]), linuron (Afolon [®]), methabenzthiazuron (Tribunil [®]), siduron (Tupersan [®]), tebuthiuron (Graslan [®])

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

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8. SPECIFIC GUIDELINE FOR GROUP D HERBICIDES

GROUP	D	HERBICIDE
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Moderate resistance risk

Resistance to Group D herbicides is known for an increasing number of populations of annual ryegrass and dense flowered fumitory. Resistance has generally occurred after 10 -15 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 with pre-emergent herbicides from other modes of action. For example Group J or Group K.

All the above recommendations should be read in conjunction with the Integrated Weed Management (IWM) strategies

GROUP D	Inhibitors of microtubule assembly
<i>Benzamides:</i>	propyzamide (Kerb [®])
<i>Benzoic acids:</i>	chlorthal (Dacthal [®] , Prothal [®] *)
<i>Dinitroanilines:</i> (DNAs):	oryzalin (Rout [®] *, Surflan [®]), pendimethalin (Stomp [®]), prodiamine (Barricade [®]), trifluralin (Treflan [®])
<i>Pyridines:</i>	dithiopyr (Dimension [®])

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9. SPECIFIC GUIDELINES FOR GROUP F HERBICIDES

GROUP	F	HERBICIDE
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Moderate resistance risk

Resistance to Group F herbicides is known for a number of populations of wild radish and 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.

Group F includes herbicides that reduce carotenoid biosynthesis through inhibition of phytoene desaturase (PDS).

Avoid applying Group F 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 (eg. Diflufenican) or combinations of active ingredients are applied (eg. 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 F or use another weed management technique.

All the above recommendations should be read in conjunction with the Integrated Weed Management (IWM) strategies

GROUP F	Bleachers: Inhibitors of carotenoid biosynthesis at the phytoene desaturase step (PDS inhibitors)
<i>Pyridazinones:</i>	norflurazon (Solicam [®])
<i>Pyridinecarboxamide:</i>	diflufenican (Brodal [®] , Chipco Spearhead [®] *, Jaguar [®] *, Tigrex [®] *, Triathlon [®] *, Yates Pathweeder [®] *), picolinafen (Eliminar C [®] *, Flight [®] *, Paragon [®] *, Sniper [®])

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10. SPECIFIC GUIDELINES FOR GROUP H HERBICIDES

GROUP	H	HERBICIDE
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Moderate resistance risk

There are currently no known weeds resistant to Group H herbicides in Australia. Resistance to Group H herbicides 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 H herbicides in the United States has resulted in resistance in *Amaranthus* species in a relatively short time.

1. 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.

2. 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.

3. Rice

Where benzofenap has been applied to rice, a follow-up application of 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 (eg. Taipan®) not be used in consecutive rice crops.

Synergistic interactions have been documented for several Group H and Group C herbicide combinations. Where possible, apply a Group H herbicide in combination with a Group C herbicide to maximise efficacy. Always use the label rate of herbicide whether or not a single active ingredient (eg. isoxaflutole) or combinations of active ingredients are applied (eg. isoxaflutole + simazine, pyrasulfotole/bromoxynil).

All the above recommendations should be read in conjunction with the Integrated Weed Management (IWM) strategies

CHEMICAL FAMILY	ACTIVE CONSTITUENT (FIRST REGISTERED TRADE NAME)
GROUP H	Bleachers: Inhibitors of 4-hydroxyphenyl-pyruvate dioxygenase (HPPDs)
<i>Isoxazoles:</i>	isoxaflutole (Balance®)
<i>Pyrazoles:</i>	benzofenap (Taipan®), pyrasulfotole (Precept®*, Velocity®*)

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11. SPECIFIC GUIDELINES FOR GROUP I HERBICIDES

GROUP	I	HERBICIDE
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Moderate resistance risk

Resistance to Group I herbicides is known for a number of populations of common sow thistle, wild radish and 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 modes of action eg. 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 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 I herbicides alone onto the same population of weeds in the same season.
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 I herbicide surviving.

All the above recommendations should be read in conjunction with the Integrated Weed Management (IWM) strategies

GROUP I	Disruptors of plant cell growth (Synthetic Auxins)
<i>Arylpicolinate:</i>	halauxifen (ForageMax [®] , Paradigm [®])
<i>Benzoic acids:</i>	dicamba (Banvel [®] , Banvel M [®] , Barrel [®] , Casper [®] , Mecoban [®] , Methar Tri-Kombi [®])
<i>Phenoxy-carboxylic acids:</i> (Phenoxys):	2,4-D (Atril DS [®] , Amicide [®] , Fallow Boss Tordon [®] , Methar Tri-Kombi [®] , Pyresta [®]), 2,4-DB (Trifolamine [®]), dichlorprop (Lantana 600 [®]), MCPA (Agtryne [®] MA [®] , Banvel M [®] , Barrel [®] , Basagran [®] M60 [®] , Buctril [®] MA [®] , Chipco Spearhead [®] , Conclude [®] , Flight [®] , MCPA, Midas [®] , Multiweed [®] , Paragon [®] , Precept [®] , Tigrex [®] , Tordon 242 [®] , Triathlon [®]), MCPB (Legumine [®]), mecoprop (Mecoban [®] , Mecopropamine [®] , Methar Tri-Kombi [®] , Multiweed [®])
<i>Pyridine carboxylic acids:</i> (Pyridines):	aminopyralid (Fallow Boss Tordon [®] , ForageMax [®] , Grazon Extra [®] , Hotshot [®] , Stinger [®] , Vigilant II [®]), clopyralid (Chipco Spearhead [®] , Lontrel [®] , Torpedo [®]), fluroxypyr (Hotshot [®] , 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)
<i>Quinoline carboxylic acids:</i>	quinclorac (Drive [®])

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12. SPECIFIC GUIDELINES FOR GROUP F HERBICIDES

GROUP	J	HERBICIDE
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Moderate resistance risk

There are isolated cases of weeds resistant to Group J in Australia. There are 2 populations of serrated tussock and 6 populations of Giant Parramatta grass that are confirmed resistant to flupropanate. Resistance to Group J herbicides is possible in other weeds especially annual ryegrass.

To assist in delaying the onset of resistance, where possible rotate Group J herbicides with herbicides from other modes of action. For example, Group K or Group D.

Don't cut herbicide rates. Use Group J herbicides at robust rates eg the maximum label rates to ensure high levels of weed control particularly when targeting annual ryegrass.

All the above recommendations should be read in conjunction with the Integrated Weed Management (IWM) strategies

GROUP J	Inhibitors of fat synthesis (Not ACCase inhibitors)
<i>Benzofurans:</i>	ethofumesate (Tramat [®])
<i>Chlorocarbonic acids:</i>	2,2-DPA (Dalapon [®]), flupropanate (Frenock [®])
<i>Phosphorodithioates:</i>	bensulide (Prefar [®])
<i>Thiocarbamates:</i>	EPTC (Eptam [®]), molinate (Ordram [®]), pebulate (Tillam [®]), prosulfocarb (Boxer [®] Gold*), thiobencarb (Saturn [®]), triallate (Avadex [®]), vernolate (Vernam [®])

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13. SPECIFIC GUIDELINES FOR GROUP

GROUP	K	HERBICIDE
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Moderate resistance risk

Resistance to Group K herbicides is possible in Australia and may develop in broadacre or horticulture situations particularly in annual ryegrass.

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

Don't cut herbicide rates. Use Group K herbicides at robust rates eg 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 modes of action. For example, Group J or Group D.

All the above recommendations should be read in conjunction with the Integrated Weed Management (IWM) strategies

CHEMICAL FAMILY	ACTIVE CONSTITUENT (FIRST REGISTERED TRADE NAME)
GROUP K	Inhibitors of cell division / Inhibitors of very long chain fatty acids (VLCFA inhibitors)
<i>Acetamides:</i>	napropamide (Devrinol [®])
<i>Chloroacetamides:</i>	dimethenamid (Frontier [®] -P, Outlook [®]), metolachlor (Boxer [®] Gold*, Dual [®] Gold, Primextra [®] Gold*), propachlor (Prothal [®] *, Ramrod [®])
<i>Isoxazoline:</i>	Pyroxasulfone (Sakura [®])

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14. SPECIFIC GUIDELINES FOR GROUP L HERBICIDES

GROUP	L	HERBICIDE
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Moderate resistance risk

Group L resistance exists in Australia in annual ryegrass, barley grass (2 species), squirrel-tailed fescue (silver grass), capeweed 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.

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

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

The risk of resistance to Group L herbicides is higher in 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 modes of action. For example, (Group N) eg glufosinate or (Group Q) eg amitrole or (Group M) eg glyphosate.

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

Zero Tillage

1. Rotate Group L herbicides with other knockdown herbicides with a different mode of action
For example (Group M) eg glyphosate
2. Consider utilising the double knock technique¹ 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.
3. Consider occasional mechanical cultivation to aid weed control.

Lucerne

1. If using a Group L herbicide for winter cleaning, where possible include another mode of action eg. Group C.
2. Use alternative modes of action to selectively control grass and broadleaf weeds.
3. Rotate Group L herbicides with other knockdown herbicides with a different mode of action for example (Group M) eg 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 mode of action.
For example (Group N) eg glufosinate or (Group Q) eg amitrole or (Group M) eg 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.

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

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.

All the above recommendations should be read in conjunction with the Integrated Weed Management (IWM) strategies

CHEMICAL FAMILY	ACTIVE CONSTITUENT (FIRST REGISTERED TRADE NAME)
GROUP L	Inhibitors of photosynthesis at photosystem I (PSI inhibitors)
<i>Bipyridyls:</i>	diquat (Reglone [®] , Spray Seed ^{®*}), paraquat (Alliance ^{®*} , Gramoxone [®] , Spray Seed ^{®*})

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15. SPECIFIC GUIDELINES FOR GROUP M HERBICIDES

GROUP	M	HERBICIDE
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Moderate resistance risk

Group M resistance occurs in Australia in annual ryegrass, awnless barnyard grass, brome grass, common sow thistle, flax-leaf fleabane, liverseed grass, sweet summer grass, wild radish and windmill grass.

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

- Lack of rotation of other herbicide modes of action;
- A Group M herbicide has been used for 12 – 15 years or more; and
- 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 <http://www.glyphosateresistance.org.au>

A number of these cases of resistance to glyphosate have occurred in horticultural (vines, tree crops & vegetables) and non-cropping situations (eg. 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 modes of action. For example (Group L) eg paraquat, or (Group N) eg glufosinate or (Group Q) eg 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 technique², strategic herbicide rotation, grazing, baling etc.

For further information on Roundup ready crops visit:

<http://www.monsanto.com/global/au/products/pages/roundup-ready-herbicide.aspx>

All the above recommendations should be read in conjunction with the Integrated Weed Management (IWM) strategies

CHEMICAL FAMILY	ACTIVE CONSTITUENT (FIRST REGISTERED TRADE NAME)
GROUP M	Inhibitors of EPSP synthase
<i>Glycines:</i>	glyphosate (Arsenal Xpress [®] *, Broadway [®] *, Illico [®] *, Resolva [®] *, Roundup [®] *, Tough Roundup [®] Weedkiller*, Trounce [®] *, Yates Pathweeder [®] *)

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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.

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16. SPECIFIC GUIDELINES FOR GROUP Q HERBICIDES

GROUP	Q	HERBICIDE
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Moderate resistance risk

Group Q resistance exists in Australia in 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 Q herbicides with herbicides from other modes of action for example. (Group L) eg paraquat, (Group N) eg glufosinate or (Group M) eg glyphosate.

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

All the above recommendations should be read in conjunction with the Integrated Weed Management (IWM) strategies

CHEMICAL FAMILY	ACTIVE CONSTITUENT (FIRST REGISTERED TRADE NAME)
GROUP Q	Bleachers: Inhibitors of carotenoid biosynthesis unknown target
<i>Isoxazolidinones:</i>	clomazone (Command®)
<i>Triazoles:</i>	amitrole (Alliance®*, Amitrole®, Illico®*)

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17. SPECIFIC GUIDELINES FOR GROUP Z HERBICIDES

GROUP	Z	HERBICIDE
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Moderate resistance risk

Group Z resistance exists in Australia in 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 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.

All the above recommendations should be read in conjunction with the Integrated Weed Management (IWM) strategies

CHEMICAL FAMILY	ACTIVE CONSTITUENT (FIRST REGISTERED TRADE NAME)
GROUP Z	Herbicides with unknown and probably diverse sites of action
<i>Arylamino propionic acids:</i>	flamprop (Mataven L [®])
<i>Dicarboxylic acids:</i>	endothal (Endothal [®])
<i>Organoarsenicals:</i>	DSMA (disodium methylarsonate) (Methar [®] , Trinoc ^{®*}), MSMA (Daconate [®])

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

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.

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 regulator's (APVMA) product data base for contemporary information on products and actives. The data base can be sourced through www.apvma.gov.au. The information given in this strategy is provided in good faith and without any liability for loss or damage suffered as a result of its application and use.

Advice given in this strategy is **valid as at 25 June 2015**. All previous versions of this strategy are now invalid.

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