Herbicide Resistance Management Strategies

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

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1. 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 38 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.

2. 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.

3. 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	G	HERBICIDE

Know your herbicide groups to make use of this!

Not all mode of action groups carry the same risk for resistance development, therefore specific guidelines for Groups E, 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 (mostly targeted at annual ryegrass and wild oats) and Group B (broadleaf and grass weeds) are HIGH RESISTANCE RISK herbicides and specific guidelines are written for use of these products in winter cropping systems.

Specific guidelines also follow for the MODERATE RESISTANCE RISK herbicides, Group C (annual ryegrass, wild radish and silver grass), Group D (annual ryegrass and fumitory), Group F (wild radish), Group I (wild radish and Indian hedge mustard), Group J (serrated tussock and giant Parramatta grass), Group L (annual ryegrass, barley grass, silver grass, square weed and capeweed), Group M (annual ryegrass, barnyard grass, fleabane, liverseed grass and windmill grass) Group Q (annual ryegrass) and Group Z (wild oats and winter grass).

Specific guidelines for Group K 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.croplifeaustralia.org.au). Details of herbicide resistance management plans in Liberty Link® Cotton, Roundup Ready® Cotton, Roundup Ready Flex® Cotton, Roundup Ready Canola® and Clearfield® Production Systems are available from Bayer, Monsanto and Nufarm respectively.

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 the integrated strategies mentioned in this brochure including rotation of mode of action groups. Make sure you rotate between products from different mode of action groups.

4. 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
- 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 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.croplifeaustralia.org.au), **Australian Glyphosate Sustainability Working Group (www.glyphosateresistance.org.au), Grains Research & Development Corporation** (www.grdc.com.au) and State Government Departmental publications.
- Seek advice from local advisers (agronomists).

4. INTEGRATED WEED MANAGEMENT STRATEGIES (cont.)

Weed control options for IWM

	Herbicidal	***Non-herbicidal***
Crop phase	- Crop topping in pulse/legume crops - 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	- 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 weed seeds at harvest
Pasture phase	- Spray topping - Winter cleaning - Selective herbicides – but ensure escapes don't set seed	- Good pasture competition - Hay making or silage - Cultivated fallow - Grazing

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 www.glyphosateresistance.org.au

You can do something to reduce the impact!

Follow the latest resistance management strategies described here.

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.

5. SPECIFIC GUIDELINES FOR GROUP A HERBICIDES

GROUP	A	HERBICIDE

High resistance risk

Group A resistance exists in Australia in the grass weeds including annual ryegrass, wild oats, phalaris, brome grass, crab grass, goosegrass 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.

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 the integrated strategies mentioned in this brochure including rotation of mode of action groups. Make sure you rotate between products from different mode of action groups.

CHEMICAL FAMILY	ACTIVE CONSTITUENT (FIRST REGISTERED TRADE NAME)
GROUP A	**Inhibitors of acetyl coA carboxylase (Inhibitors of fat synthesis/ACC'ase inhibitors)**
Aryloxyphenoxypropionates: (Fops):	clodinafop (Topik®), cyhalofop (Barnstorm®), diclofop (Cheetah® Gold*, Decision®*, Hoegrass®, Tristar® Advance*), fenoxaprop (Cheetah® Gold*,Tristar® Advance*, Wildcat®), fluazifop (Fusilade®, Fusion®*), haloxyfop (Motsa®*, Verdict®), propaquizafop (Shogun®), quizalofop (Targa®)
Cyclohexanediones: *(Dims):*	butroxydim (Falcon®, Fusion®*), clethodim (Motsa®*, Select®), profoxydim (Aura®), sethoxydim (Cheetah® Gold*, Decision®*, Sertin®), tepraloxydim (Aramo®), tralkoxydim (Achieve®)
Phenylpyrazoles: *(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.

6. SPECIFIC GUIDELINES FOR GROUP B HERBICIDES

GROUP	B	HERBICIDE

High resistance risk

Group B resistance exists in Australia in the grass weeds, annual ryegrass, barley grass, brome grass, wild oats and crab grass and in at least 16 broadleaf weeds including: wild radish, common sowthistle, climbing buckwheat, turnip weed, wild mustard, Indian hedge mustard, prickly lettuce, wild turnip and African turnip weed. Resistance has developed in broadacre, rice and pasture situations. In respect to rice, three broadleaf weeds have been discovered, namely: dirty dora, arrowhead and starfruit.

Research has shown that as few as 4 applications to the same population of annual ryegrass can result in the selection of resistant individuals and as few as 6 applications for wild radish. A population can go from a small area of resistant individuals to a whole paddock failure in one season.

1. Avoid applying more than two Group B herbicides in any four year period on the same paddock.

2. **Broadleaf weed control:**
   If a pre-emergent application is made with a Group B herbicide for broadleaf weed control, monitor results and, if required, apply a follow up spray with a non-Group B herbicide for control of escapes and to reduce seed set.

   If a post-emergent application is made with a Group B herbicide for broadleaf weed control, this should preferably be as an APVMA approved tank-mix with another mode of action that controls or has significant activity against the target weed. If no APVMA approved tank-mix is available then monitor results and if required, apply a follow up spray with a non-Group B herbicide for control of escapes and to reduce seed set.

   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. **Grass weed control:**
   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. **Clearfield Systems**:
   Where OnDuty®, Midas® and Intervix® are used refer to the Clearfield® Production System - Best Management Practice guide.

The above recommendations should be incorporated into an Integrated Weed Management (IWM) program. In all cases try and ensure surviving weeds from any treatment do not set and shed viable seed. Keep to the integrated strategies mentioned in this brochure including rotation of mode of action groups. Make sure you rotate between products from different mode of action groups.

CHEMICAL FAMILY	ACTIVE CONSTITUENT (FIRST REGISTERED TRADE NAME)
GROUP B	**Inhibitors of acetolactate synthase (ALS inhibitors)**
Sulfonylureas: *(SUs):*	azimsulfuron (Gulliver®), bensulfuron (Londax®), chlorsulfuron (Glean®), ethoxysulfuron (Hero®), formasulfuron (Tribute®) halosulfuron (Sempra®), iodosulfuron (Hussar®), mesosulfuron (Atlantis®) metsulfuron (Ally®, Harmony®* M, Trounce®*, Ultimate Brushweed®* Herbicide), rimsulfuron (Titus®), sulfometuron (Oust®), sulfosulfuron (Monza®), thifensulfuron (Harmony®* M), triasulfuron, (Logran®, Logran® B-Power®*), tribenuron (Express®), trifloxysulfuron (Envoke®, Krismat®*)
Imidazolinones: *(Imis):*	imazamox (Raptor®, Intervix®*), imazapic (Flame®, Midas®*, OnDuty®*), imazapyr (Arsenal Xpress®*, Midas®*, OnDuty®*, Intervix®*, Lightning®*), imazethapyr (Spinnaker®, Lightning®*)
Triazolopyrimidines: *(Sulfonamides)*:	flumetsulam (Broadstrike®), florasulam (Conclude®*,Torpedo®*, X-Pand®*), metosulam (Eclipse®), pyroxsulam (Crusader®)
Pyrimidinylthiobenzoates:	Bispyribac (Nominee®) pyrithiobac (Staple®)

***** ***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.

7. SPECIFIC GUIDELINES FOR GROUP C HERBICIDES

GROUP	C	HERBICIDE

Moderate resistance risk

Group C resistance is known to exist in Australia in the weeds annual ryegrass, wild radish, liverseed grass, silver grass, stinging nettles and barnyard grass. Resistance has developed in broadacre, horticultural and non-crop situations.

CropLife Australia gives specific guidelines for the use of Group C herbicides in triazine tolerant canola and in winter legume crops, following increasing reports of resistance development: -

1. Avoid using Group C herbicides in the same paddock in consecutive years. Growing TT Canola in a paddock treated with triazine herbicides in the previous season is a high resistance risk and is not recommended.

2. **For use of triazines in triazine tolerant canola (TT): -**
   - Avoid dry sowing in heavily weed infested paddocks. Wait for a second weed germination after the opening rains in weedy paddock situations. Use a pre-plant knockdown or cultivation to maximise weed control at this stage.

   - Adapt the weed control program to the anticipated weed spectrum and pressure –

     a) Broadleaf weeds and annual ryegrass
     Use simazine or atrazine or metribuzin plus trifluralin pre-emergence. A follow up with a Group A herbicide (if ryegrass is susceptible) or atrazine may be necessary

     b) Broadleaf weeds only
     Use atrazine post-emergence

   - Watch and record for weed escapes, especially in paddocks with a long history of Group C use.

   Consult the **'Integrated Weed Management Strategy for TT Canola'** for further details**. (refer to manufacturing companies)**

3. **The resistance status of the "at-risk" weeds should be determined prior to sowing.**
   Always use the label rate of herbicide whether or not a single active ingredient (eg. Bromoxynil) or combinations of active ingredients are applied (eg. Bromoxynil/MCPA, pyrasulfatole/bromoxynil), 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 C or use another weed management technique.

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

**** 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.

8. SPECIFIC GUIDELINES FOR GROUP D HERBICIDES

GROUP	D	HERBICIDE

Moderate resistance risk

Resistance to Group D herbicides is known for an increasing number of populations of annual ryegrass and 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.

Rotate with herbicides from other modes of action. For annual ryegrass consider rotating trifluralin with products such as Boxer Gold®.

The above recommendations should be incorporated into an Integrated Weed Management (IWM) program. In all cases try and ensure surviving weeds from any treatment do not set and shed viable seed. Keep to the integrated strategies mentioned in this brochure including rotation of mode of action groups. Where possible, rotate between products from different mode of action groups.

CHEMICAL FAMILY	ACTIVE CONSTITUENT (FIRST REGISTERED TRADE NAME)
GROUP D	**Inhibitors of microtubule assembly**
Dinitroanilines: (DNAs):	oryzalin (Surflan®, Rout®*), pendimethalin (Stomp®), prodiamine (Barricade®), trifluralin (Treflan®)
Benzoic acids:	chlorthal (Dacthal®, Prothal®*)
Benzamides:	propyzamide (Kerb®)
Pyridines:	dithiopyr (Dimension®), thiazopyr (Visor®)

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

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9. SPECIFIC GUIDELINES FOR GROUP F HERBICIDES

GROUP	F	HERBICIDE

Moderate resistance risk

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

If applicable, apply a follow up spray with a non-Group F herbicide for control of escapes and to reduce seed set. In all cases, aim to ensure surviving weeds from any treatment do not set and shed viable seed.

The above recommendations should be incorporated into an Integrated Weed Management (IWM) program. In all cases try and ensure surviving weeds from any treatment do not set and shed viable seed. Keep to the integrated strategies mentioned in this brochure including rotation of mode of action groups. Where possible, rotate between products from different mode of action groups.

CHEMICAL FAMILY	ACTIVE CONSTITUENT (FIRST REGISTERED TRADE NAME)
GROUP F	**Bleachers: Inhibitors of carotenoid biosynthesis at the phytoene desaturase step (PDS inhibitors)**
Nicotinanilides:	diflufenican (Brodal®, Jaguar®*, Tigrex®*, Chipco Spearhead®*)
Picolinamides:	picolinafen (Paragon®*, Sniper®, Flight®*)
Pyridazinones:	norflurazon (Solicam®)

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10. SPECIFIC GUIDELINES FOR GROUP I HERBICIDES

GROUP	I	HERBICIDE

Moderate resistance risk

Resistance to Group I herbicides is known for a number of populations of 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 are cross resistant 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.

The above recommendations should be incorporated into an Integrated Weed Management (IWM) program. In all cases try and ensure surviving weeds from any treatment do not set and shed viable seed. Keep to the integrated strategies mentioned in this brochure including rotation of mode of action groups. Make sure you rotate between products from different mode of action groups.

CHEMICAL FAMILY	ACTIVE CONSTITUENT (FIRST REGISTERED TRADE NAME)
GROUP I	**Disruptors of plant cell growth (Synthetic Auxins)**
Phenoxycarboxylic acids: *(Phenoxys):*	2,4-D (Amicide®, Actril DS®*, **Pyresta®***), 2,4-DB (Trifolamine®), dichlorprop (Lantana 600®), MCPA (MCPA, Buctril® MA*, Banvel M®*, Conclude®*, Midas®*, Paragon®*, Tigrex®*, Barrel®*, Tordon 242®*, Basagran® M60*, Chipco Spearhead®*, Agtryne® MA*, Precept®*, Flight®*), MCPB (Legumine®), mecoprop (Mecopropamine®, Mecoban® , Methar Tri-Kombi®*)
Benzoic acids:	dicamba (Banvel®, Banvel M®*, Barrel®*, Mecoban® Methar Tri-Kombi®*)
Pyridine carboxylic acids: *(Pyridines):*	aminopyralid (Hotshot®*, Grazon Extra®*), clopyralid (Lontrel®, Torpedo®*, Chipco Spearhead®*), fluroxypyr (Starane®, Hotshot®*), picloram (Tordon®, Tordon 242®*, Grazon®*, Grazon Extra®*), triclopyr (Garlon®, Grazon®*, Grazon Extra®*, Ultimate Brushweed®* Herbicide)
Quinoline carboxylic acids:	quinclorac (Drive®)

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11. SPECIFIC GUIDELINES FOR GROUP J HERBICIDES

GROUP	J	HERBICIDE

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.

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

The above recommendations should be incorporated into an Integrated Weed Management (IWM) program. In all cases try and ensure surviving weeds from any treatment do not set and shed viable seed. Keep to the integrated strategies mentioned in this brochure including rotation of mode of action groups. Where possible, rotate between products from different mode of action groups.

CHEMICAL FAMILY	ACTIVE CONSTITUENT (FIRST REGISTERED TRADE NAME)
GROUP J	**Inhibitors of fat synthesis (Not ACCase inhibitors)**
Chlorocarbonic acids:	2,2–DPA (Dalapon®), flupropanate (Frenock®)
Thiocarbamates:	EPTC (Eptam®), molinate (Ordram®), pebulate (Tillam®), prosulfocarb (Boxer® Gold*), thiobencarb (Saturn®), triallate (Avadex®), vernolate (Vernam®)
Phosphorodithioates:	bensulide (Prefar®)
Benzofurans:	ethofumesate (Tramat®)

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12. SPECIFIC GUIDELINES FOR GROUP K HERBICIDES

GROUP	K	HERBICIDE

Moderate resistance risk

Resistance to Group K herbicides is possible in Australia and may develop in broadacre situations.

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.

Rotate with herbicides from other modes of action.

The above recommendations should be incorporated into an Integrated Weed Management (IWM) program. In all cases try and ensure surviving weeds from any treatment do not set and shed viable seed. Keep to the integrated strategies mentioned in this brochure including rotation of mode of action groups. Where possible, rotate between products from different mode of action groups.

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

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13. SPECIFIC GUIDELINES FOR GROUP L HERBICIDES

GROUP	L	HERBICIDE

Moderate resistance risk

Group L resistance exists in Australia in annual ryegrass, barley grass (2 species), silver grass, capeweed and 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.

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.
2. Consider utilising the double knock technique[1] 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. diuron (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 prior to sowing lucerne and prior to sowing future crops in that paddock.

[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***

Horticulture

1. Rotate Group L herbicides with other knockdown herbicides with a different mode of action.
2. Where possible use residual herbicides (that are effective on the same weeds as the Group L herbicides) where applicable either alone or in mixture with Group L herbicides.
3. Where possible use alternative 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 and ensure surviving weeds from any treatment do not set and shed viable seed. Always try to apply herbicides to the smallest weed density. Keep to the integrated strategies mentioned in this brochure including rotation of mode of action groups. Make sure you rotate between products from different mode of action groups.

CHEMICAL FAMILY	**ACTIVE CONSTITUENT (FIRST REGISTERED TRADE NAME)**
GROUP L	**Inhibitors of photosynthesis at photosystem I (PSI inhibitors)**
Bipyridyls:	diquat (Reglone®, Spray Seed®*), paraquat (Gramoxone®, Spray Seed®*, Alliance®*)

***** ***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.

14. SPECIFIC GUIDELINES FOR GROUP M HERBICIDES

GROUP	M	HERBICIDE

Moderate resistance risk

Group M resistance occurs in Australia in annual ryegrass, awnless barnyard grass, fleabane, liverseed grass and windmill grass.

Herbicide resistance to glyphosate was first discovered in annual ryegrass in Australia in 1996. Since that time, a number of new cases of glyphosate resistance in annual ryegrass, awnless barnyard grass, fleabane, liverseed grass and windmill grass have been confirmed.

The following factors are common to all cases of Group M resistance:
- A Group M herbicide is the major or only herbicide used;
- 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

All cases of glyphosate resistant weeds confirmed to date share three common factors:
- Intensive (year to year) use of glyphosate;
- Lack of rotation of other herbicide modes of action; and
- Little or no tillage/cultivation following the application of glyphosate.

A number of these cases of ryegrass resistance to glyphosate have occurred in horticultural and non-cropping situations (eg. firebreaks, fencelines, driveways, irrigation ditches), with the balance occurring in no-till broadacre cropping systems.

Given the demonstrated propensity of annual ryegrass to develop resistance to multiple herbicide classes, Integrated Weed Management principles should be incorporated wherever possible to minimise the risk of selecting for glyphosate resistant ryegrass. Strategies may include the use of cultivation, the double knock technique[2], strategic herbicide rotation, grazing, baling etc.

The above recommendations should be incorporated into an Integrated Weed Management (IWM) program. In all cases try and ensure surviving weeds from any treatment do not set and shed viable seed. Always try to apply herbicides to the smallest weed density. Keep to the integrated strategies mentioned in this brochure including rotation of mode of action groups. Make sure you rotate between products from different mode of action groups.

CHEMICAL FAMILY	ACTIVE CONSTITUENT (FIRST REGISTERED TRADE NAME)
GROUP M	**Inhibitors of EPSP synthase**
Glycines:	glyphosate (Roundup®, Trounce®*, Illico®*, Arsenal Xpress®*, Broadway®*)

* ***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.

[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.***

15. SPECIFIC GUIDELINES FOR GROUP Q HERBICIDES

GROUP	Q	HERBICIDE

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 with herbicides from other modes of action eg. paraquat, glufosinate or 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 and ensure surviving weeds from any treatment do not set and shed viable seed. Keep to the integrated strategies mentioned in this brochure including rotation of mode of action groups. Where possible, rotate between products from different mode of action groups.

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

***** ***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.

16. SPECIFIC GUIDELINES FOR GROUP Z HERBICIDES

GROUP	Z	HERBICIDE

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 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.

The above recommendations should be incorporated into an Integrated Weed Management (IWM) program. In all cases try and ensure surviving weeds from any treatment do not set and shed viable seed. Keep to the integrated strategies mentioned in this brochure including rotation of mode of action groups. Where possible, rotate between products from different mode of action groups.

CHEMICAL FAMILY	ACTIVE CONSTITUENT (FIRST REGISTERED TRADE NAME)
GROUP Z	**Herbicides with unknown and probably diverse sites of action**
Arylaminopropionic acids:	flamprop (Mataven L®)
Dicarboxylic acids:	endothal (Endothal®)
Organoarsenicals:	DSMA (Methar®), 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.