GRDC Grains Research & Development Corporation

CropLife AUSTRALIA

NOVEMBER 2008

HERBICIDE RESISTANCE
MODE OF ACTION GROUPS

MANAGING HERBICIDE RESISTANCE

What is herbicide resistance?

Herbicide resistance is caused by the intensive use of herbicides for weed control. A small number of weeds can be naturally resistant to herbicides, even before the herbicides are used.

When a herbicide is used, these individual weeds can 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 number of the weed population developing resistance.

Main causes of resistance are:

- The intensity of selection pressure and frequency of use. This refers to how many weeds are killed by the herbicide. For most weeds and herbicides, the number of years of herbicide use is a good measure of selection intensity.
- The frequency of use of a herbicide or mode of action group.
- The frequency of resistance present in untreated populations.
  If the frequency of resistance 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 develop resistance faster than weed species with long seed bank lives. Weed species with greater genetic diversity are more likely to develop resistance. Resistance is also more likely to be detected in larger weed populations.

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.

Current situation in Australia

Today, resistance has been confirmed in 34 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.

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 code 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 is a good start but resistance management strategies require continual implementation.

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 table. 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, K, 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-RISK herbicides and specific guidelines are written for use of these products in winter cropping systems.

Specific guidelines for the MODERATE 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 (barley grass, silver grass, square weed and capeweed), Group M (annual ryegrass, barnyard grass and liverseed grass), Group Q (annual ryegrass) and Group Z (wild oats) have been added.

Detailed programs for herbicide resistance management for weed control in rice have also been 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 BASF 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.

Some important points to remember

- Assess the efficacy of a product/s after application.
- If a failure is suspected do not use the same product or product from the same mode of action group.
- Testing – confirm resistance exists.
- Seek advice from local advisers (agronomists).
- Rotating herbicides to another effective mode of action group the following year will prolong herbicide effectiveness.
- Control weed escape before the weeds set viable seed.

You can do something to reduce the impact!

Use the mode of action group for the herbicide from the following table to determine the resistance management strategy detailed on the CropLife Australia website www.croplifeaustralia.org.au under Resistance Management.

MODE OF ACTION

Mode of action matters!

The mode of action table and the herbicide resistance management strategies with their specific guidelines can be found on the CropLife Australia website www.croplifeaustralia.org.au. 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 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. Titles describing some of the existing herbicide groups were also changed to more accurately describe those groups. The old groups E, F and K have the most changes. Most of the other groups remain unchanged. See details of the changes below.

Changes to mode of action groupings for some herbicides (see table overleaf)

CropLife Australia recently revised the Australian herbicide mode of action groupings and added six new groups (Groups H, O, P, Q, R and Z). The old groups E, F and K have the most changes (see table overleaf). Most groups and herbicide products have not been changed, but the following active constituents and products have changed group and the new group should be used when referring to the resistance management strategies. Herbicide product registrants have three years (from February 2008) to update labels to reflect the new mode of action groups, but in the interim, some product labels may display the old mode of action group. Where there is a temporary difference in mode of action group on labels, the new mode of action group in the first table overleaf should be used when choosing the appropriate resistance management strategy.

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Changes to mode of action groupings for some herbicides

ACTIVE CONSTITUENT	FIRST REGISTERED PRODUCT NAME	CHEMICAL FAMILY	OLD MOA GROUP AND STRATEGY	NEW MOA GROUP AND STRATEGY
amitrole	Amitrole®, Illico®	Triazoles	GROUP F	GROUP Q
asulam	Asulox®	Carbamates	GROUP K	GROUP R
bensulide	Prefar®	Phosphorodithioates	GROUP E	GROUP J
benzofenap	Taipan®, Viper®	Pyrazoles	GROUP F	GROUP H
clomazone	Command®, Viper®	Isoxazolidinones	GROUP F	GROUP Q
dichlobenil	Casoron®	Nitriles	GROUP K	GROUP O
dithiopyr	Dimension®	Pyridines	GROUP E	GROUP D
DSMA	DSMA®, Methar®	Organoarsenicals	GROUP K	GROUP Z
MSMA	Daconate®	Organoarsenicals	GROUP K	GROUP Z
endothal	Endothal®	Dicarboxylic acids	GROUP K	GROUP Z
EPTC	Eptam®	Thiocarbamates	GROUP E	GROUP J
ethofumesate	Tramat®	Benzofurans	GROUP K	GROUP J
flamprop	Mataven®	Arylaminopropionic acids	GROUP K	GROUP Z
isoxaben	Gallery®	Benzamides	GROUP K	GROUP O
isoxaflutole	Balance®	Isoxazoles	GROUP F	GROUP H
molinate	Ordram®	Thiocarbamates	GROUP E	GROUP J
naptalam	Alanap-L®	Phthalamates	GROUP K	GROUP P
pebulate	Tillam®	Thiocarbamates	GROUP E	GROUP J
phenmedipham	Betanal®	Phenylcarbamates	GROUP K	GROUP C
propyzamide	Kerb®	Benzamides	GROUP K	GROUP D
thiazopyr	Visor®	Pyridines	GROUP E	GROUP D
thiobencarb	Saturn®	Thiocarbamates	GROUP E	GROUP J
triallate	Avadex®	Thiocarbamates	GROUP E	GROUP J
vernolate	Vernam®	Thiocarbamates	GROUP E	GROUP J

The trade name of the first registered product or successor containing each active constituent is listed under 'First Registered Product Name'. Refer to the website of the Australian Pesticides and Veterinary Medicines Authority (APVMA) (www.apvma.gov.au) to obtain a complete list of registered products in the PUBCRIS database.

HERBICIDE RESISTANCE MODE OF ACTION GROUPS

The following table (as at 10 September 2008), lists approved active constituents in each mode of action group, and for ease of identification, the trade name of only the first registered product or successor. Go to the PUBCRIS database on the APVMA website www.apvma.gov.au to obtain a complete list of registered products. The table does not include active constituents that have not yet been officially assigned a mode of action group by CropLife Australia.

High Risk

CHEMICAL FAMILY	ACTIVE CONSTITUENT (FIRST REGISTERED PRODUCT 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 (Correct®), 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®)
GROUP B	**Inhibitors of acetolactate synthase (ALS inhibitors)**
Sulfonylureas (SUs):	azimsulfuron (Gulliver®), bensulfuron (Londax®), chlorsulfuron (Glean®), halosulfuron (Sempra®), iodosulfuron (Hussar®), mesosulfuron (Atlantis®), metsulfuron (Ally®, Harmony®* M, Trounce®*), 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 (Torpedo®*, X-Pand®*), metosulam (Eclipse®), pyroxsulam (Crusader®)
Pyrimidinylthiobenzoates:	pyrithiobac-Na (Staple®)

*This product contains more than one active constituent

Moderate Risk

CHEMICAL FAMILY	ACTIVE CONSTITUENT (FIRST REGISTERED PRODUCT 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®), 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®*), ioxynil (Totril®, Actril® DS*)
Benzothiadiazinones:	bentazone (Basagran®, Basagran® M60*)
GROUP D	**Inhibitors of microtubule assembly**
Dinitroanilines (DNAs):	oryzalin (Surflan®, Yield®*), pendimethalin (Stomp®), trifluralin (Treflan®, Yield®*)
Benzoic acids:	chlorthal (Dacthal®, Prothal®*)
Benzamides:	propyzamide (Kerb®)
Pyridines:	dithiopyr (Dimension®), thiazopyr (Visor®)
GROUP E	**Inhibitors of mitosis / microtubule organisation**
Carbamates:	carbetamide (Carbetamex®), chlorpropham (Chlorpropham®)
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®)
Pyridazinones:	norflurazon (Solicam®)
GROUP G	**Inhibitors of protoporphyrinogen oxidase (PPOs)**
Diphenylethers:	acifluorfen (Blazer®), oxyfluorfen (Goal®)
N-phenylphthalimides:	flumioxazin (Pledge®)
Oxadiazoles:	oxadiargyl® (Raft), oxadiazon (Ronstar®)
Triazolinones:	carfentrazone (Affinity®)
Pyrimidindiones:	butafenacil (Logran® B-Power®*)
Phenylpyrazole:	pyraflufen (Ecopar®)
GROUP H	**Bleachers: Inhibitors of 4-hydroxyphenyl-pyruvate dioxygenase (HPPDs)**
Pyrazoles:	benzofenap (Taipan®, Viper®), pyrasulfotole (Precept®*)
Isoxazoles:	isoxaflutole (Balance®)
GROUP I	**Disruptors of plant cell growth**
Phenoxycarboxylic acids (Phenoxys):	2,4-D (Amicide®, Actril DS®*), 2,4-DB (Trifolamine®), dichlorprop (Lantana 600®), MCPA (MCPA, Buctril® MA*, Banvel M®*, Midas®*, Paragon®*, Tigrex®*, Barrel®*, Tordon 242®*, Basagran® M60*, Chipco Spearhead®*, Agtryne® MA*, Precept®*), 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®*)
Quinoline carboxylic acids:	quinclorac (Drive®)

*This product contains more than one active constituent.

GROUP J	Inhibitors of fat synthesis (Not ACC'ase 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®)
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®*)
GROUP L	**Inhibitors of photosynthesis at photosystem I (PSI inhibitors)**
Bipyridyls:	diquat (Reglone®, Spray Seed®*), paraquat (Gramoxone®, Spray Seed®*, Alliance®*)
GROUP M	**Inhibitors of EPSP synthase**
Glycines:	glyphosate (Roundup®, Trounce®*, Illico®*, Arsenal Xpress®*)
GROUP N	**Inhibitors of glutamine synthetase**
Phosphinic acids:	glufosinate (Basta®, Liberty®)
GROUP O	**Inhibitors of cell wall (cellulose) synthesis**
Nitriles:	dichlobenil (Casoron®)
Benzamides:	isoxaben (Gallery®, X-Pand®*)
GROUP P	**Inhibitors of auxin transport**
Phthalamates:	naptalam (Alanap-L®)
GROUP Q	**Bleachers: Inhibitors of carotenoid biosynthesis unknown target**
Triazoles:	amitrole (Amitrole®, Illico®*, Alliance®*)
Isoxazolidinones:	clomazone (Command®, Viper®*)
GROUP R	**Inhibitors of dihydropteroate synthase (DHP inhibitors)**
Carbamates:	asulam (Asulox®)
GROUP Z	**Herbicides with unknown and probably diverse sites of action**
Arylaminopropionic acids:	flamprop (Mataven L®)
Dicarboxylic acids:	endothal (Endothal®)
Organoarsenicals:	DSMA [disodium methylarsonate] (Methar®), MSMA (Daconate®)

*This product contains more than one active constituent.

Produced by the GRDC in collaboration with CropLife Australia.

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