Regulatory Directive DIR99-06

Voluntary Pesticide Resistance-Management Labelling Based on Target Site/Mode of Action

The Pest Management Regulatory Agency (PMRA) has introduced a voluntary pesticide resistance-management labelling initiative based on target site/mode of action for agricultural uses of herbicides, fungicides/bactericides and insecticides/acaricides. This document provides schemes of classification of pesticides according to their sites/modes of action (Appendices I–III), a standard format for showing group identification symbols on the end-use product labels, and guidelines for labelling resistance-management strategies in the use directions. It covers both new products governed by the registration process and old (existing) products governed by the re-evaluation process.

This document replaces Regulatory Proposal Pro96-03, *Pesticide Resistance Management Labelling*, published for public comments in December 1996. Comments received were taken into consideration in the final version of the guidelines.

Canada, the United States (U.S.) and Mexico, working cooperatively under the auspices of the North American Free Trade Agreement (NAFTA), are developing and publishing these guidelines for voluntary pesticide resistance-management labelling to a uniform standard for implementation in North America. This activity forms part of the work done by the Risk Reduction Subcommittee of the NAFTA Technical Working Group (TWG) on Pesticides. A uniform approach across North America will help reduce the development of pesticide resistance and support joint registration decisions by providing consistency in the resistance-management labelling being considered for approval in any or all of the NAFTA countries.

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1.0 Scope

This Directive applies to resistance-management labelling for herbicide, fungicide/ bactericide and insecticide/acaricide products that are intended for general agricultural use. This document covers both new products governed by the registration process and old (existing) products governed by the re-evaluation process.

2.0 Implementation

The implementation of this program is to be on a voluntary basis by the pesticide industry. Close cooperation of all registrants is required to achieve this important task. Registrants are encouraged to add the resistance-management grouping symbols and statements to both new and existing product labels. Revisions to labels for existing products can be made at the next printing of the labels. All new and existing products are encouraged to have the resistance-management grouping symbols and statements on the label by January 1, 2004. Information on amending labels can be obtained from the PMRA Information Service at 1-800-267-6315 (toll-free within Canada) or (613) 736-3799. In view of the importance of resistance management to a sustainable pest-management system, the PMRA will closely monitor the progress of the industry's implementation of resistance-management labelling.

3.0 Introduction

The PMRA, the U.S. Environmental Protection Agency (EPA) and the Cicoplafest of Mexico are committed to encouraging the development of sustainable pest-management systems. Under the auspices of NAFTA, Canada, the U.S. and Mexico have joined together to develop and publish guidelines for voluntary pesticide resistance-management labelling for implementation in North America. The development of these guidelines is part of the activities of the Risk Reduction Subcommittee of the NAFTA TWG on Pesticides. A uniform approach across North America will help reduce the development of pesticide resistance and support joint registration decisions by providing consistency in resistance-management labelling being considered for approval in any or all of the NAFTA countries.

Pesticide resistance, defined for the purpose of this document as a heritable and significant decrease in the sensitivity of a pest population to a pesticide, reduces the field performance of pesticides. Pests include insects, mites, weeds, fungi and bacteria. The management of pesticide resistance development is an important part of sustainable pest-management and this, in conjunction with alternative pest-management strategies and integrated pest-management (IPM) programs, can make significant contributions to reducing risks to humans and the environment. In support of this goal, the purpose of this document is to provide guidance on resistance-management labelling to registrants.

Pesticides are important pest-management tools. Many pesticides have gradually lost their effectiveness due to the development of resistance by pests. An important proactive pesticide resistance-management strategy is to avoid the repeated use of a particular pesticide, or pesticides, that have a similar site of action, in the same field, by rotating pesticides with different sites of action. This approach will slow the development of one important type of resistance, target-site resistance, without resorting to increased rates and frequency of application and will prolong the useful life of pesticides.

A resistance-management strategy should also consider more detailed information regarding cross-resistance between pesticides with different modes of action resulting from the development of other types of resistance (e.g., enhanced metabolism, reduced penetration, or behavior changes). All members of a class may not be cross-resistant based merely on mode of action. However, this labelling initiative will provide pesticide users with easy access to important information regarding target-site resistance, the cornerstone of most resistance-management programs.

To ensure consistency in pesticide grouping and labelling, and to contribute to the management of the pesticide-resistance problem, the following guidelines have been developed for agricultural uses of herbicides, fungicides/bactericides and insecticides/acaricides. The following classification schemes are based on target site of action.

4.0 Site of Action Grouping and Identification Symbol

Herbicides, fungicides/bactericides and insecticides/acaricides are separately grouped according to their primary sites of action (or target site modes of action) by various technical/research committees consisting of representatives of the pesticide industry, researchers, extension specialists and regulatory officials. The industry committees providing guidance on the pesticide groupings were the Herbicide Resistance Action Committee (HRAC), the Fungicide Resistance Action Committee (FRAC) and the Insecticide Resistance Action Committee (IRAC). Primary guidance for herbicides was provided by the Weed Science Society of America (WSSA). The site of action groups plus the identifier numbers for herbicides, fungicides/bactericides and insecticides/acaricides are located in Appendix I, II and III, respectively.

The site of action identification symbol should be shown on all end-use product labels (except products for homeowner/residential uses) in a standard format as outlined below, and should:

- be located on the front panel (preferably at the upper right corner), surrounded by a black rectangle;
- be in black on a white background except the site of action number(s), which is to be white on a black background with a clear white gap between the site of action number(s); and

- include the words “GROUP” and “HERBICIDE” or “FUNGICIDE” or “INSECTICIDE” in capital letters, and between these words the number(s) representing the site of action group(s) of each active ingredient(s). Where a product has two or more active ingredients, and these are represented by two or more sites of action, then two or more appropriate site of action identifier numbers should be used. For products containing an active ingredient that has multiple sites of action, the letter “M” should be used to represent the site of action group. Alternatively, if sites of action are known, specify each site of action by the appropriate number.

Example 1: Product containing one or more active ingredients of the same site of action.

GROUP	1	HERBICIDE

Example 2: Product containing two or more active ingredients represented by two or more sites of action.

GROUP	1	2	3	HERBICIDES

Example 3: Outside label for prepackaged products where each component is in a different container.

GROUP	1	HERBICIDE

GROUP	2	HERBICIDE

Example 4: Premixture of a fungicide and an insecticide.

GROUP	1	FUNGICIDE
GROUP	2	INSECTICIDE

5.0 Resistance-Management Statements

Resistance-management statements are recommended to be included in the use directions for all end-use products for the control of weeds, plant pathogens (diseases), insects and arthropods (except products for homeowner/residential uses) under the heading “Resistance-Management Recommendations”. The section “Resistance-Management Recommendations” should be segregated under the “General” portion of “Use Directions” in the U.S., and under

"Use Directions" in Canada. Product-specific labelling is recommended. The recommended standard resistance-management labelling statements listed below focus on the prevention and mitigation of pest resistance and should be used where applicable. Efforts should be made to include all appropriate active ingredients and products. These recommendations should also be included in any product-specific literature.

5.1 Herbicides

For resistance management, (name of product) is a Group (site of action group number) herbicide. Any weed population may contain or develop plants naturally resistant to (name of product) and other Group (site of action group number) herbicides. The resistant biotypes may dominate the weed population if these herbicides are used repeatedly in the same field. Other resistance mechanisms that are not linked to site of action, but specific for individual chemicals, such as enhanced metabolism, may also exist. Appropriate resistance-management strategies should be followed.

To delay herbicide resistance:

- Where possible, rotate the use of (name of product) or other Group (site of action group number) herbicides with different herbicide groups that control the same weeds in a field.

- Use tank mixtures with herbicides from a different group when such use is permitted.

- Herbicide use should be based on an IPM program that includes scouting, historical information related to herbicide use and crop rotation, and considers tillage (or other mechanical), cultural, biological and other chemical control practices.

- Monitor treated weed populations for resistance development.

- Prevent movement of resistant weed seeds to other fields by cleaning harvesting and tillage equipment and planting clean seed.

- Contact your local extension specialist or certified crop advisors for any additional pesticide resistance-management and/or integrated weed-management recommendations for specific crops and weed biotypes.

- For further information or to report suspected resistance, contact (company representatives) at (toll free number) or at (Internet site).

NOTE The above is a standard statement for products containing one or more active ingredients from the same group. For products containing two or more active ingredients from different groups, the statement should be modified to reflect the situation.

For example:

For resistance management, please note that (name of product) is both a Group (site of action group number) and a Group (site of action group number) herbicide. Any weed population may contain plants naturally resistant to Group (site of action group number) and/or Group (site of action group number) herbicides. The resistant biotypes may dominate the weed population if these herbicides are used repeatedly in the same fields.

5.2 Fungicides and Bactericides

For resistance management, please note that (name of product) contains a Group (group number) (fungicide/bactericide). Any (fungal/bacterial) population may contain individuals naturally resistant to (name of product) and other Group (group number) (fungicides/bactericides). A gradual or total loss of pest control may occur over time if these (fungicides/bactericides) are used repeatedly in the same fields. Other resistance mechanisms that are not linked to site of action but specific for individual chemicals, such as enhanced metabolism, may also exist. Appropriate resistance-management strategies should be followed.

To delay fungicide/bactericide resistance:

- Where possible, rotate the use of (name of product) or other Group (site of action group number) fungicides/bactericides with different groups that control the same pathogens.

NOTE This statement may be modified if repeated application is necessary, e.g., Avoid application of more than (maximum number) and consecutive sprays of (name of product) or other (fungicides/bactericides) in the same group in a season.

- Use tank mixtures with fungicide/bactericides from a different group when such use is permitted.

- Fungicide/bactericide use should be based on an IPM program that includes scouting, historical information related to pesticide use and crop rotation and considers cultural, biological and other chemical control practices.

- Monitor treated fungal/bacterial populations for resistance development.

- If disease continues to progress after treatment with this product, do not increase the use rate. Discontinue use of this product, and switch to another (fungicide/bactericide) with a different target site of action, if available.

- Contact your local extension specialist or certified crop advisors for any additional pesticide resistance-management and/or IPM recommendations for specific crops and pathogens.
- For further information and to report suspected resistance, contact (company representatives) at (toll free number) or at (Internet site).

NOTE The above is a standard statement for products containing one or more active ingredients from the same group. For products containing two or more active ingredients from different groups, the statement should be modified to reflect the situation.

For example:

For resistance management, please note that (name of product) contains both a Group (group number) and Group (group number) fungicide/bactericide. Any fungal/bacterial population may contain individuals naturally resistant to (name of product) and other Group (group number) or Group (group number) fungicides/bactericides. A gradual or total loss of pest control may occur over time if these (fungicides/bactericides) are used repeatedly in the same fields.

5.3 Insecticides and Acaricides

For resistance management, please note that (name of product) contains a Group (group number) insecticide (or acaricide). Any (insect/mite) population may contain individuals naturally resistant to (name of product) and other Group (group number) (insecticides/acaricides). The resistant individuals may dominate the insect/mite population if this group of insecticides/acaricides are used repeatedly in the same fields. Other resistance mechanisms that are not linked to site of action but are specific for individual chemicals, such as enhanced metabolism, may also exist. Appropriate resistance-management strategies should be followed.

To delay insecticide resistance:

- Where possible, rotate the use of (name of product) or other Group (site of action group number) insecticides/acaricides with different groups that control the same pests in a field.

NOTE The above statement may be modified on a pest by pest basis if a number of applications each year are necessary, e.g., Avoid application of more than (maximum

number) and consecutive sprays of (name of product) or other insecticides in the same group in a season.

- Use tank mixtures with insecticides/acaricides from a different group when such use is permitted.

- Insecticide/acaricide use should be based on an IPM program that includes scouting, record keeping, and considers cultural, biological and other chemical control practices.

- Monitor treated pest populations for resistance development.
- Contact your local extension specialist or certified crop advisors for any additional pesticide resistance-management and/or IPM recommendations for the specific site and pest problems in your area.

- For further information or to report suspected resistance contact (company representatives) at (toll free number) or at (Internet site).

NOTE The above is a standard statement for products containing one or more active ingredients from the same group. For products containing two or more active ingredients from different groups, the statement should be modified to reflect the situation.

For example:

For resistance management, please note that (name of product) contains both a Group (group number) and Group (group number) insecticides/acaricides. Any insect/mite population may contain individuals naturally resistant to (name of product) and other Group (group number) or Group (group number) insecticides/ acaricides. The resistant individuals may dominate the insect/mite population if these insecticides/acaricides are used repeatedly in the same fields.

6.0 Pesticides of Unspecified Groups

Some herbicides, fungicides, bactericides, insecticides and acaricides have not been assigned to any particular target site/mode of action group or have not been shown on the lists in this document because of the lack of clear understanding of their target site/mode of action or the absence of a history of resistance development for the product. The registrants should establish the appropriate group identifications for their products in consultation with representatives of the pesticide industry, researchers, extension specialists and regulatory officials. The use directions should include the appropriate resistance-management statements for this product, i.e., herbicides, fungicides/ bactericides and insecticides/acaricides.

The above procedure also applies to new pesticides when they are registered for use. The

pesticide lists (Appendices I–III) will be updated from time to time (approximately annually) to include product names and/or new/revised site/mode of action classification. The revised appendicies will be posted on the Agency's web site under the title of this Regulatory Directive. Hard copies will be made available from the Agency upon request.

Appendix I Herbicide Groups Based on Sites of Action

This list is based on the Herbicide Classification of the Weed Science Society of America (Weed Technology, 1997, 11:384-393). Microbial herbicides are not included.

GROUP	SITE OF ACTION	CHEMICAL FAMILY	ACTIVE INGREDIENT
1	Inhibitors of acetyl CoA carboxylase ACCase	Aryloxyphenoxy propionates	clodinafop-propargyl
			diclofop-methyl
			fenoxaprop-ethyl
			fenoxaprop-p-ethyl
			fluazifop-p-butyl
			fluazifop-butyl
			quizalofop-ethyl
			quizalofop-p-ethyl
		Cyclohexanediones	clethodim
			sethoxydim
			tralkoxydim
2	Inhibition of acetolactate synthase (ALS) and also called aceto-hydroxyacid synthase (AHAS)	Sulfonylureas	chlorimuron
			chlorsulfuron
			ethametsulfuron-methyl
			metsulfuron-methyl
			nicosulfuron
			prosulfuron
			rimsulfuron
			sulfosulfuron
			thifensulfuron-methyl
			triasulfuron
			tribenuron-methyl
			triflusulfuron-methyl
		Imidazolinones	imazamethabenz
			imazamox

GROUP	SITE OF ACTION	CHEMICAL FAMILY	ACTIVE INGREDIENT
			imazapyr
			imazethapyr
		Pyrimidinylthio-benzoate*	
		Triazolopyrimidime	flumetsulam
3	Microtubule assembly inhibitors	Dinitroanilines	ethalfluralin
			pendimethalin
			trifluralin
		Pyridazine	dithiopyr
	Unknown	None	chlorthal-dimethyl (DCPA)
4	Synthetic auxins (action like indoleacetic acid)	Phenoxys	2,4-D
			2,4-DB
			dichlorprop (2,4-DP)
			MCPA
			MCPB
			mecoprop (MCPP)
		Benzoic acids	dicamba
		Carboxylic acids	clopyralid
			fluroxypyr
			picloram
			triclopyr
		Quinoline carboxylic acid	quinclorac
		Semicarbazone	diflufenzopyr
5	Inhibitors of photosynthesis at photosystem II Site A	Triazines	atrazine
			cyanazine
			prometon
			prometryn
			simazine

GROUP	SITE OF ACTION	CHEMICAL FAMILY	ACTIVE INGREDIENT
		Triazinones	hexazinone
			metribuzin
		Uracils	bromacil
			terbacil
		Pyridazinone	pyrazon
		Phenyl-carbamates	desmedipham
			phenmedipham
6	Similar to group 5, but different binding behavior	Nitriles	bromoxynil
		Benzothiadiazoles	bentazon
		Phenyl-pyridazine	pyridate
7	Inhibitors of photosynthesis at photosystem II Site B	Ureas	diuron
			linuron
			metobromuron
			monolinuron
			siduron
			tebuthiuron
		Amide	propanil
8	Inhibition of lipid synthesis, not ACCase inhibition	Thiocarbamates	butylate
			cycloate
			EPTC
			pebulate
			triallate
			vernolate
		None	bensulide
	Unknown	None	difenzoquat

GROUP	SITE OF ACTION	CHEMICAL FAMILY	ACTIVE INGREDIENT
9	Inhibitors of 5-enolpyruvylshikimate-3-phosphate (EPSP) synthase	None	glyphosate
10	Inhibitors of glutamine synthetase	None	glufosinate-ammonium
11	Bleaching: Inhibitors of carotenoid biosynthesis (unknown target)	Triazole	amitrole
12	Bleaching: Inhibitors of carotenoid biosynthesis at the phytoene desaturase step (PDS)	Pyridazinone*	
		Nicotinanilide*	
		Others	fluridone*
			flurochloridone*
13	Bleaching: Inhibition of all diterpenes	Isoxazolidinone	clomazone
14	Inhibitors of proto-porphyrinogen oxidase (PPO)	Diphenylethers	acifluorfen
			fomesafen
			oxyfluorfen
		N-phenylphthalimides*	
		Oxadiazole	oxadiazon
		Triazolinone*	
15	Unknown	Chloroacetamides	metolachlor
			s-metolachlor
			propyzamide
			dimethenamid
		Acetamides	napropamide
		Oxyacetamides*	
16	Unknown	Benzofuran	ethofumesate

GROUP	SITE OF ACTION	CHEMICAL FAMILY	ACTIVE INGREDIENT
17	Unknown	Organoarsenicals	Arsenic, present as monosodium salt of methylarsonic acid (MSMA)
18	Inhibits dihydropteroate (DHP) synthase step	Carbamate	asulam
19	Inhibits indoleacetic acid action	Phthalamate	naptalam
20	Inhibits cell wall synthesis Site A	Nitrile	dichlobenil
21	Inhibits cell wall synthesis Site B	Benzamide	isoxaben
22	Photo system I-electron diverters	Bipyridyliums	diquat
			paraquat
23	Inhibitors of mitosis	Carbamates	chlorpropham
24	Uncoupling membrane disruptors	Dinitrophenol	dinoseb
25	Unknown	Arylaminopropionic acid	flamprop-methyl
26	Unknown	None	trichloroacetic acid (TCA)
27	Unknown	Various	bromobutide*
			cinmethylin*
			dymron*
			flupoxam*
28	Inhibition of 4-hydroxy-phenyl-pyruvate-dioxygenase (4-HPPD)	benzoylisoxazole*	
		Isoxazole*	
		Pyrazole*	
		Triketone*	

* Not registered in Canada at the time of publication of this document.

Appendix II Fungicide/Bactericide Groups Based on Activity Group/Sites of Action

This list is based on the fungicide listing compiled by the Fungicide Resistance Action Committee (FRAC). FRAC is a Specialist Technical Group of the Global Crop Protection Federation (GCPF). Microbial fungicides are not included.

GROUP	ACTIVITY GROUP/ SITE OF ACTION	CHEMICAL GROUP	ACTIVE INGREDIENT
1	Inhibition of tubulin formation	Benzimidazole	benomyl
			carbendazim
			thiabendazole
			thiophanate-methyl
2	Affect cell division, deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) synthesis, and metabolism	Dicarboximide	iprodione
			vinclozolin
3	Demethylation Inhibitor (DMI): Inhibition of demethylation in sterol biosynthesis	Imidazoles*	
		Piperazine	triforine
		Pyridine*	
		Pyrimidines*	
		Triazoles (includes conazoles)	myclobutanil
			difenoconazole
			propiconazole
			triadimenol
4	Phenylamides Affect RNA synthesis	Acylamines	metalaxyl
			metalaxyl M
		Oxazolidinones*	
		Butyrolactones*	
5	Morpholines Inhibition of an isomerase in sterol biosynthesis	Morpholines	dimethomorph
			dodemorph
		Piperidine*	
		Spiroketalamine*	

GROUP	ACTIVITY GROUP/ SITE OF ACTION	CHEMICAL GROUP	ACTIVE INGREDIENT
6	Phosphorothiolate Inhibition of chitin and phospholipid synthesis	Organophosphorous*	
7	Oxathiin Affect mitochondrial transport chain	Anilide (Oxathiin)	carbathiin (carboxin)
			oxycarboxin
8	Hydroxyprimidine	Pyrimidinol*	
9	Anilinopyrimidine Inhibition of amino acid synthesis	Anilinopyrimidine	cyprodinil
10	N-Phenyl carbamates Interfere with cell division	Diethofencarb*	
11	Strobilurin Type Action and Resistance (STAR) Inhibit mitochondrial respiration	Strobilurin*	
		Oxazolidinedione*	
12	Phenylpyrroles	Phenylpyrroles	fludioxonil
13	Quinolines	Quinoline	quinoxyfen
14	Aromatic hydrocarbons	Chlorophenyl	dicloran quintozene (PCNB)
		Thiadiazole	etridiazole
15	Cinnamic acids	Cinnamic acid*	
16	Melanin Biosynthesis Inhibitors (MBI)	Reductase inhibitors*	
		Dehydratase inhibitors*	
17	Hydroxyanilide	Hydroxyanilide*	
18	Antibiotics	Antibiotics	streptomycin
19	Polyoxins	Polyoxin*	
20	Phenylurea	Phenylurea*	
21	Plant host defence inducers	Benzothiadiazole (BTH)*	
U[1]	Unknown Miscellaneous	Amino acid amide*	
		Carbamate	propamocarb
		Cyano-acetamide oxime*	

GROUP	ACTIVITY GROUP/ SITE OF ACTION	CHEMICAL GROUP	ACTIVE INGREDIENT
		Organo-tins	tri-phenyl tins dinocap fenfuram fosetyl-aluminum
M[2]	Multi-site activity	Inorganics	copper (hydroxide)
			copper (oxychloride)
			copper (sulphate)
			sullphur (wettable)
		Dithiocarbamates and relatives	ferbam
			mancozeb
			maneb
			metiram
			thiram
			zineb
			ziram
		Phthalimide	captan
			folpet
		Chloronitrile	chlorothalonil
		Sulphamide*	
		Guanidine	dodine
		Anilazine	anilazine
		Phenyl-pyridinamine*	
		Quinoxaline	chinomethionat (oxythiquinox)

[1] The unknown group, designated by symbol "U," comprises a set of miscellaneous compounds for which that biochemical mode of action may or may not be known, but are not able to be placed with certainty in any other groupings.

[2] The multi-site activity grouping, designated by symbol "M", comprises a collection of various chemicals that act as general toxophores with several sites of action. These sites may differ between group members.

* Not registered in Canada at the time of publication of this document.

Appendix III Insecticide and Acaricide Groups Based on Sites of Action

The classification scheme was developed in consultation with the Insecticide Resistance Action Committee (IRAC). IRAC is a Specialist Technical Group of the Global Crop Protection Federation (GCPF). It is recognized that resistance of insects and mites to insecticides and acaricides can also result from enhanced metabolism, reduced penetration or behavioral changes that are not linked to any site of action classification, but are specific for individual chemicals or chemical groups. All members of a class may not be cross-resistant based merely on site of action. Most biological insecticides are not included in this Appendix because they are thought not to pose a great concern for resistance development. Microbial products involving Bacillus sp. are included as well as products derived from the Neem tree such as azadirachtin.

GROUP	SITE OF ACTION	CHEMICAL GROUP	ACTIVE INGREDIENT
1A[1]	*Acetylcholinesterase inhibitors* Inhibition of the enzyme acetylcholinesterase, interrupting the transmission of nerve impulses	Carbamates	aldicarb
			aminocarb
			bendiocarb
			carbaryl
			carbofuran
			formetanate hydrochloride
			methiocarb
			methomyl
			oxamyl
			pirimicarb
			propoxur
1B[1]		Organophosphates	acephate
			azamethiphos
			azinphos-methyl
			chlorfenvinphos
			chlorpyrifos
			coumaphos
			diazinon
			dichlorvos (DDVP)
			dimethoate
			disulfoton

GROUP	SITE OF ACTION	CHEMICAL GROUP	ACTIVE INGREDIENT
			ethion
			fenitrothion
			fensulfothion
			fenthion
			fonofos
			malathion
			methamidophos
			methidathion
			naled
			oxydemeton-methyl
			parathion
			phorate
			phosalone
			phosmet
			sulfotep
			temephos
			terbufos
			tetrachlorvinphos
			trichlorfon
2A[1]	*Gamma-aminobutyric acid (GABA)-gated chloride channel antagonists* Interferes with GABA receptors of insect neurons, leading to repetitive nervous discharges	Chlorinated cyclodienes	endosulfan
			dienochlor
		Polychlorocycloalkanes	lindane

GROUP	SITE OF ACTION	CHEMICAL GROUP	ACTIVE INGREDIENT
2B[1]	*GABA-gated chloride channel antagonists* Interferes with GABA receptors of insect neurons, leading to repetitive nervous discharges - fiprole site	Phenylpyrazoles*	
3	*Sodium channel modulators* Acts as an axonic poison by interfering with the sodium channels of both the peripheral and central nervous system stimulating repetitive nervous discharges, leading to paralysis	diphenylethanes	dicofol
			methoxychlor
		Synethetic pyrethroids	*d*-allethrin
			d-trans allethrin
			cyfluthrin
			cypermethrin
			deltamethrin
			fenpropathrin
			fenvalerate
			flucythrinate
			tau-fluvalinate
			permethrin
			resmethrin
			tefluthrin
			tetramethrin
		Pyrethrins	pyrethrins
4	*Acetylcholine receptor agonists/antagonists* Binds to nicotinic acetylcholine receptor, disrupting nerve transmission	Chloronicotines (nitro-guanidines)	imidacloprid
		Nicotine Cartap* Bensultap*	nicotine
5	*Acetylcholine receptor modulators* Alters acetylcholine receptor site and disrupts binding	Spinosyns*	

GROUP	SITE OF ACTION	CHEMICAL GROUP	ACTIVE INGREDIENT
6	*Chloride channel activators* Interferes with the GABA nerve receptor of insects.	Avermectin	abamectin
		Milbemycin*	
7	*Juvenile hormone mimics (insect growth regulator)* Mimic juvenile hormones, which prevent moulting from the larval to the adult stage	Juvenile hormone analogues	methoprene
8A[1]	*Unknown or non-specific site of action (fumigants)*	Fumigant	methyl bromide
8B[1]			aluminum phosphide
9A[1]	*Compounds of unknown or non-specific site of action (feeding disruptors)*	Feeding disruptors* (pymetrozine, cryolite)	
9B[1]			
10	*Compounds of unknown or non-specific site of action (mite growth inhibitors)*	Mite growth inhibitors (ovicide)	clofentezine
11	*Microbial disruptors of insect mid-gut membranes (includes Cry proteins expressed in transgenic plants)* Organism has protein inclusions that are released in the gut of the target pest resulting in gut paralysis and a cessation of feeding	Bt Microbials (biological insecticide/larvicide)	*Bacillus thuringiensis* var. *Aizawai*, encapsulated delta endotoxin
			Bacillus thuringiensis var. Tenebrionis
			Bacillus thuringiensis var. Israelensis
			Bacillus thuringiensis var. Kurstaki
12	*Inhibition of oxidative phosphorylation at the site of dinitrophenol uncoupling [disrupt adenosine triphosphate (ATP) formation]*	Organotin matricides	fenbutatin oxide
13	*Uncoupler of oxidative phosphorylation (disrupt H proton gradient formation)*	Pyrrole compound* (broad spectrum contact and stomach poison)	
14	*Inhibit magnesium - stimulated ATPase*	Sulfite ester matricides	propargite

GROUP	SITE OF ACTION	CHEMICAL GROUP	ACTIVE INGREDIENT
15	*Inhibit chitin biosynthesis*	Substituted benzoylurea	diflubenzuron
16	*Inhibit chitin biosynthesis type 1 - Homopteran*	Thiadiazine*	
17	*Inhibit chitin biosynthesis type 2- Dipteran*	Triazine	cyromazine
18	*Ecdysone agonist/disruptor* Disrupts insect molting by antagonizing the insect hormone ecdysone	Benzoic acid hydrazide	tebufenozide
		Botanical* (Neem oil or azadirachtin)	
19	*Octopaminergic agonist*	Triazapentadiene	amitraz
20	*Site II electron transport inhibitors*	None	hydramethylnon
21	*Site I electron transport inhibitors*	Botanical	rotenone
		Pyridazinone	pyridaben

[1] Other resistance mechanisms that are not linked to site of action, such as enhanced metabolism, are common for this group of chemicals. All members of this class may not have developed significant cross-resistance. When only this group of products are available, alternation of compounds from subgroup A and subgroup B are recommended.

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