MODE OF ACTION CLASSIFICATION SCHEME

VERSION 11.4, MAY 2025

PREPARED IRAC International MoA Working Group

APPROVED IRAC Executive

IRAC

Insecticide Resistance Action Committee

CropLife INTERNATIONAL

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1. Scope

The IRAC classification is intended to cover all materials, chemical, biological or other, that are used to control insects or acarines on crops, in structures or in the environment. Some insecticides and acaricides also control nematodes, but selective nematicides are covered in a separate Nematicide MoA classification document available at https://www.irac-online.org/. Behaviour-modifying agents and predatory insects/mites are not included. Products used only by direct application to animals or humans for control of parasites are likewise not included.

Note: Inclusion in the MoA list does not necessarily signify regulatory approval.

2. Purpose

The IRAC Mode of Action (MoA) classification provides growers, advisors, extension staff, consultants and crop protection professionals with a guide to the selection of acaricides or insecticides for use in an effective and sustainable acaricide or insecticide resistance management (IRM) strategy. In addition to presenting the MoA classification, this document outlines the background to, and purposes of, the classification list, and provides guidance on how it is used for IRM purposes. Many countries now require the IRAC MoA group code included on labels and this is recommended even if not required. Labeling guidelines are given in Appendix 1 and require that the active ingredient be listed in Appendix 5. Procedures for requesting IRAC classification of a new/unlisted active ingredient are found in Appendix 4. This document is reviewed and re-issued as needed.

3. What is resistance?

Resistance to insecticides may be defined as '*a heritable change in the sensitivity of a pest population that is reflected in the repeated failure of a product to achieve the expected level of control when used according to the label recommendation for that pest species'* (IRAC). This definition differs slightly from others in the literature, but IRAC believes it represents the most accurate practical definition of relevance to growers. Resistance arises through the over-use or misuse of an insecticide or acaricide against a pest species and results from the Darwinian selection of resistant forms of the pest and the consequent evolution of populations that are resistant to that insecticide or acaricide.

4. MoA, Target-site resistance and Cross-resistance

In many cases, not only does resistance render the selecting insecticidal or acaricidal agent ineffective, it also confers cross-resistance to other structurally related agents. This is because agents with structural similarity

usually share a common target site within the pest, and thus share a common MoA. It is common for resistance to develop that is based on a genetic modification of this target site. When this happens, the interaction of the selecting insecticidal or acaricidal agent with its target site is impaired and the agent loses its pesticidal efficacy. Because all insecticidal and acaricidal agents with structural similarity share a common MoA, there is a high risk that existing or developing target-site resistance will confer cross-resistance to all agents in the same group. It is this concept of cross-resistance within a family of structurally related insecticides or acaricides that is the basis of the IRAC MoA classification.

5. Use of alternations or sequences of different MoAs

The objective of successful Insecticide Resistance Management (IRM) is to prevent or delay the evolution of resistance to insecticides, or to help regain susceptibility in insect pest populations in which resistance has already arisen. Effective IRM is thus an important element in maintaining the efficacy of valuable insecticides. It is important to recognize that it is usually easier to proactively prevent resistance from occurring than it is to reactively regain susceptibility. Nevertheless, the IRAC MoA classification will always provide valuable guidance to the design of effective IRM strategies.

Experience has shown that all effective insecticide or acaricide resistance management strategies seek to minimise the selection for resistance from any one type of insecticide or acaricide. In practice, alternations, sequences or rotations of insecticidal or acaricidal agents from different MoA groups provide a sustainable and effective approach to IRM. This ensures that selection from insecticidal agents in any one MoA group is minimised. The IRAC classification in this document is provided as an aid to insecticide selection for these types of IRM strategies. Applications are often arranged into MoA spray windows or blocks that are defined by the stage of crop development and the biology of the pest(s) of concern. Local expert advice should always be followed regarding spray windows and timings. Several sprays of an insecticidal agent may be possible within each spray window, but successive generations of a pest should not be treated with insecticidal agents from the same MoA group.

Groups in the classification whose members do not act at a common target site are exempt from the proscription against rotation within the group. These are Group 8, Miscellaneous non-specific (multi-site) inhibitors; Group 13, Uncouplers of oxidative phosphorylation via disruption of the proton gradient; and all the UN groups: UN, UNB, UNE, UNF, UNM, UNP and UNV.

To help delay resistance, it is strongly recommended that growers also integrate other control methods into insect or mite control programmes. Further advice is given in Appendix 2.

6. Non-target-site resistance mechanisms

It is fully recognized that resistance of insects and mites to insecticides and acaricides can, and frequently does, result from enhanced metabolism by enzymes within the pest. Such metabolic resistance mechanisms are not linked to any specific site of action classification and therefore they may confer

resistance to insecticides in more than one IRAC MoA group. Where such metabolic resistance has been characterized and the cross-resistance spectrum is known, it is possible that certain alternations, sequences or rotations of MoA groups cannot be used. Similarly, mechanisms of reduced penetration of the pesticide into the pest, or behavioural changes of the pest may also confer resistance to multiple MoA groups. Where such mechanisms are known to give cross-resistance between MoA groups, the use of insecticides should be modified appropriately.

Where the resistance mechanism(s) is unknown, the intelligent use of alternations, sequences or rotations of insecticidal agents from different MoA classes remains an entirely viable resistance management technique, since such a practice will always minimise selection pressures.

7. The MoA Classification Scheme

The IRAC MOA classification scheme is based on the best available evidence of the MoA of available insecticidal and acaricidal agents. Details of the classification have been agreed upon by IRAC member companies and approved by internationally recognized industrial and academic insect toxicologists and biochemists.

Insecticidal and acaricidal agents are classified into two types of MoA groups: numbered groups whose members are known or thought to act at specific target sites, and UN groups of undefined or unknown mode of action. The only exceptions are the numbered groups 8, Miscellaneous non-specific (multi-site) inhibitors and 13, Uncouplers of oxidative phosphorylation via disruption of the proton gradient, which for historical reasons retain their legacy group numbers even though they are not acting at specific target sites. Nevertheless, it is the intention of the IRAC MoA working group going forward to only assign group numbers where there is good evidence of a common target site.

Insecticidal compounds, bacterial agents, extracts and crude oils, fungal agents, mechanical disruptors, peptides and viruses of unknown Mode of Action are classified in groups UN, UNB, UNE, UNF, UNM, UNP and UNV, respectively.

7.1 Rules for inclusion of an insecticidal agent in the MoA list

- Chemical nomenclature is generally based on ISO accepted common names.
- To be included in the active list, insecticidal agents must have a minimum of one registered use in at least one country.
- In any one MoA classification sub-group, where more than one active ingredient in that sub-group is registered for use, the sub-group name is used.
- In any one MoA classification sub-group, where only one active ingredient is registered for use, the name of that exemplifying active ingredient may be used

7.2 The Classification Table

IRAC MoA Classification Version 11.4, May 2025 *See section 7.4 for further information on sub-groups.* *See section 7.3 for criteria for descriptors of the quality of MoA information.*		
Main Group and Primary Site of Action	Sub-group, class or exemplifying Active Ingredient	Active Ingredients
1 **Acetylcholinesterase (AChE) inhibitors** Nerve action {Strong evidence that action at this protein is responsible for insecticidal effects}	**1A** Carbamates	Alanycarb, Aldicarb, Bendiocarb, Benfuracarb, Butocarboxim, Butoxycarboxim, Carbaryl, Carbofuran, Carbosulfan, Ethiofencarb, Fenobucarb, Formetanate, Furathiocarb, Isoprocarb, Methiocarb, Methomyl, Metolcarb, Oxamyl, Pirimicarb, Propoxur, Thiodicarb, Thiofanox, Triazamate,Trimethacarb, XMC, Xylylcarb
	1B Organophosphates	Acephate, Azamethiphos, Azinphos-ethyl, Azinphos-methyl, Cadusafos, Chlorethoxyfos, Chlorfenvinphos, Chlormephos, Chlorpyrifos, Chlorpyrifos-methyl, Coumaphos, Cyanophos, Demeton-S-methyl, Diazinon, Dichlorvos/ DDVP, Dicrotophos, Dimethoate, Dimethylvinphos, Disulfoton, EPN, Ethion, Ethoprophos, Famphur, Fenamiphos, Fenitrothion, Fenthion, Fosthiazate, Heptenophos, Imicyafos, Isofenphos, Isopropyl *O*-(methoxyaminothio-phosphoryl) salicylate, Isoxathion, Malathion, Mecarbam, Methamidophos, Methidathion, Mevinphos, Monocrotophos, Naled, Omethoate, Oxydemeton-methyl, Parathion, Parathion-methyl, Phenthoate, Phorate, Phosalone, Phosmet, Phosphamidon, Phoxim, Pirimiphos-methyl, Profenofos, Propetamphos, Prothiofos, Pyraclofos, Pyridaphenthion, Quinalphos, Sulfotep, Tebupirimfos, Temephos, Terbufos, Tetrachlorvinphos, Thiometon, Triazophos, Trichlorfon, Vamidothion
2 **GABA-gated chloride channel blockers** Nerve action {Strong evidence that action at this protein is responsible for insecticidal effects}	**2A** Cyclodiene Organochlorines	Chlordane, Endosulfan
	2B Phenylpyrazoles (Fiproles)	Ethiprole, Fipronil

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3 **Sodium channel modulators** Nerve action {Strong evidence that action at this protein is responsible for insecticidal effects}	**3A** Pyrethroids Pyrethrins	Acrinathrin, Allethrin, d-*cis-trans* Allethrin, d-*trans* Allethrin, Bifenthrin, Bioallethrin, Bioallethrin S-cyclopentenyl isomer , Bioresmethrin, Cycloprothrin, Cyfluthrin, *beta*-Cyfluthrin, Cyhalothrin, *lambda*-Cyhalothrin, *gamma*-Cyhalothrin, Cypermethrin, *alpha*-Cypermethrin, *beta*-Cypermethrin, *theta*-cypermethrin, *zeta*-Cypermethrin, Cyphenothrin , (1*R*)-*trans*- isomers], Deltamethrin, Empenthrin (*EZ*)- (1*R*)- isomers], Esfenvalerate, Etofenprox, Fenpropathrin, Fenvalerate, Flucythrinate, Flumethrin, *tau*-Fluvalinate, Halfenprox, Imiprothrin, Kadethrin, Permethrin, Phenothrin [(1*R*)-*trans*- isomer], Prallethrin, Pyrethrins (pyrethrum), Resmethrin, Silafluofen, Tefluthrin, Tetramethrin, Tetramethrin [(1*R*)-isomers], Tralomethrin, Transfluthrin,
	3B DDT Methoxychlor	DDT Methoxychlor
4 **Nicotinic acetylcholine receptor (nAChR) competitive modulators** Nerve action {Strong evidence that action at one or more of this class of protein is responsible for insecticidal effects}	**4A** Neonicotinoids	Acetamiprid, Clothianidin, Dinotefuran, Imidacloprid, Nitenpyram, Thiacloprid, Thiamethoxam,
	4B Nicotine	Nicotine
	4C Sulfoximines	Sulfoxaflor
	4D Butenolides	Flupyradifurone
	4E Mesoionics	Dicloromezotiaz, Fenmezoditiaz, Triflumezopyrim
	4F Pyridylidenes	Flupyrimin
5 **Nicotinic acetylcholine receptor (nAChR) allosteric modulators – Site I** Nerve action {Strong evidence that action at one or more of this class of protein is responsible for insecticidal effects}	Spinosyns	Spinetoram, Spinosad

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6 **Glutamate-gated chloride channel (GluCl) allosteric modulators** Nerve and muscle action {Strong evidence that action at one or more of this class of protein is responsible for insecticidal effects}	Avermectins, Milbemycins	Abamectin, Emamectin benzoate, Lepimectin, Milbemectin
7 **Juvenile hormone receptor modulators** Growth regulation {Strong evidence that action at one or more of this class of protein is responsible for insecticidal effects}	**7A** Juvenile hormone analogues	Hydroprene, Kinoprene, Methoprene
	7B Fenoxycarb	Fenoxycarb
	7C Pyriproxyfen	Pyriproxyfen
8 * **Miscellaneous non-specific (multi-site) inhibitors**	**8A** Alkyl halides	1,3-Dichloropropene, Methyl bromide and other alkyl halides
	8B Chloropicrin	Chloropicrin
	8C Fluorides	Cryolite (Sodium aluminum fluoride), Sulfuryl fluoride
	8D Borates	Borax, Boric acid, Disodium octaborate, Sodium borate, Sodium metaborate
	8E Tartar emetic	Tartar emetic
	8F Methyl isothiocyanate generators	Dazomet, Metam, Methyl isothiocyanate
9 **Chordotonal organ TRPV channel modulators** Nerve action {Strong evidence that action at one or more of this class of proteins is responsible for insecticidal effects}	**9B** Pyridine azomethine derivatives	Pymetrozine, Pyrifluquinazon
	9D Pyropenes	Afidopyropen

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10 **Mite growth inhibitors affecting CHS1** Growth regulation {Strong evidence that action at one or more of this class of proteins is responsible for insecticidal effects}	**10A** Clofentezine Diflovidazin Hexythiazox	Clofentezine, Diflovidazin, Hexythiazox
	10B Etoxazole	Etoxazole
11 **Microbial disruptors of insect midgut membranes** (Includes transgenic crops expressing *Bacillus thuringiensis* toxins, however specific guidance for resistance management of transgenic crops is not based on rotation of modes of action)	**11A** *Bacillus thuringiensis* and the insecticidal proteins they produce	*Bacillus thuringiensis* subsp. *israelensis* *Bacillus thuringiensis* subsp. *aizawai* *Bacillus thuringiensis* subsp. *kurstaki* *Bacillus thuringiensis* subsp. *tenebrionis* *B.t.* crop proteins: (* Please see footnote) Cry1Ab, Cry1Ac, Cry1Fa, Cry1A.105, Cry2Ab, Vip3A, mCry3A, Cry3Ab, Cry3Bb, Cry34Ab1/Cry35Ab1
	11B *Bacillus sphaericus*	*Bacillus sphaericus*
12 **Inhibitors of mitochondrial ATP synthase** Energy metabolism {Compounds affect the function of this protein, but it is not clear that this is what leads to biological activity}	**12A** Diafenthiuron	Diafenthiuron
	12B Organotin miticides	Azocyclotin, Cyhexatin, Fenbutatin oxide
	12C Propargite	Propargite
	12D Tetradifon	Tetradifon
13 * **Uncouplers of oxidative phosphorylation via disruption of the proton gradient** Energy metabolism	Pyrroles Dinitrophenols Sulfluramid	Chlorfenapyr DNOC Sulfluramid

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14 **Nicotinic acetylcholine receptor (nAChR) channel blockers** Nerve action {Compounds affect the function of this protein, but it is not clear that this is what leads to biological activity}	Nereistoxin analogues	Bensultap, Cartap hydrochloride, Thiocyclam, Thiosultap-sodium
15 **Inhibitors of chitin biosynthesis affecting CHS1** Growth regulation {Strong evidence that action at one or more of this class of proteins is responsible for insecticidal effects}	Benzoylureas	Bistrifluron, Chlorfluazuron, Diflubenzuron, Flucycloxuron, Flufenoxuron, Hexaflumuron, Lufenuron, Novaluron, Noviflumuron, Teflubenzuron, Triflumuron
16 **Inhibitors of chitin biosynthesis, type 1** Growth regulation {Target protein responsible for biological activity is unknown, or uncharacterized}	Buprofezin	Buprofezin
17 **Moulting disruptors, Dipteran** Growth regulation {Target protein responsible for biological activity is unknown, or uncharacterized}	Cyromazine	Cyromazine
18 **Ecdysone receptor agonists** Growth regulation {Strong evidence that action at this protein is responsible for insecticidal effects}	Diacylhydrazines	Chromafenozide, Halofenozide, Methoxyfenozide, Tebufenozide

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19 **Octopamine receptor agonists** Nerve action {Good evidence that action at one or more of this class of protein is responsible for insecticidal effects}	Amitraz	Amitraz
20 **Mitochondrial complex III electron transport inhibitors – Qo site** Energy metabolism {Good evidence that action at this protein complex is responsible for insecticidal effects}	**20A** Hydramethylnon	Hydramethylnon
	20B Acequinocyl	Acequinocyl
	20C Fluacrypyrim	Fluacrypyrim
	20D Bifenazate	Bifenazate
21 **Mitochondrial complex I electron transport inhibitors** Energy metabolism {Good evidence that action at this protein complex is responsible for insecticidal effects}	**21A** METI acaricides and insecticides	Fenazaquin, Fenpyroximate, Pyridaben, Pyrimidifen, Tebufenpyrad, Tolfenpyrad
	21B Rotenone	Rotenone (Derris)
22 **Voltage-dependent sodium channel blockers** Nerve action {Good evidence that action at this protein complex is responsible for insecticidal effects}	**22A** Oxadiazines	Indoxacarb
	22B Semicarbazones	Metaflumizone

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Main Group and Primary Site of Action	Sub-group, class or exemplifying Active Ingredient	Active Ingredients
23 **Inhibitors of acetyl-CoA carboxylase** Lipid synthesis, growth regulation {Good evidence that action at this protein is responsible for insecticidal effects}	Tetronic and Tetramic acid derivatives	Spidoxamat Spirodiclofen, Spiromesifen, Spiropidion, Spirotetramat
24 **Mitochondrial complex IV electron transport inhibitors** Energy metabolism {Good evidence that action at this protein complex is responsible for insecticidal effects}	**24A** Phosphides	Aluminium phosphide, Calcium phosphide, Phosphine, Zinc phosphide
	24B Cyanides	Calcium cyanide, Potassium cyanide, Sodium cyanide
25 **Mitochondrial complex II electron transport inhibitors** Energy metabolism {Good evidence that action at this protein complex is responsible for insecticidal effects}	**25A** *Beta*-ketonitrile derivatives	Cyenopyrafen, Cyflumetofen
	25B Carboxanilides	Pyflubumide
28 **Ryanodine receptor modulators** Nerve and muscle action {Strong evidence that action at this protein complex is responsible for insecticidal effects}	Diamides	Chlorantraniliprole, Cyantraniliprole, Cyclaniliprole Flubendiamide, Tetraniliprole
29 **Chordotonal organ nicotinamidase inhibitors** Nerve action {Strong evidence that action at this protein is responsible for insecticidal effects}	Flonicamid	Flonicamid

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Main Group and Primary Site of Action	Sub-group, class or exemplifying Active Ingredient	Active Ingredients
30 **GABA-gated chloride channel allosteric modulators** Nerve action {Strong evidence that action at this protein complex is responsible for insecticidal effects}	Isoxazolines Meta-diamides	Isocycloseram Broflanilide, Cyproflanilide, Fluxametamide,
31 **Baculoviruses** Host-specific occluded pathogenic viruses {Midgut epithelial columnar cell membrane target site – undefined}	Granuloviruses (GVs) Nucleopolyhedroviruses (NPVs)	*Cydia pomonella* GV *Thaumatotibia leucotreta* GV *Anticarsia gemmatalis* MNPV *Helicoverpa armigera* NPV
32 **Nicotinic Acetylcholine Receptor (nAChR) Allosteric Modulators - Site II** Nerve action {Strong evidence that action at one or more of this class of protein is responsible for insecticidal effects}	GS-omega/kappa HXTX-Hv1a peptide	GS-omega/kappa HXTX-Hv1a peptide
33 **Calcium-activated potassium channel (KCa2) modulators** Nerve action {Strong evidence that action at this protein is responsible for insecticidal effects}	Acynonapyr	Acynonapyr
34 **Mitochondrial complex III electron transport inhibitors – Qi site** Energy metabolism {Modulation of this protein complex has been clearly demonstrated and the specific target site responsible for biological activity is distinct from Group 20}	Flometoquin	Flometoquin

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Main Group and Primary Site of Action	Sub-group, class or exemplifying Active Ingredient	Active Ingredients
35 **RNA Interference mediated target suppressors** Activation of the RNAi mechanism which specifically reduces abundance of the target messenger RNA (mRNA) resulting in the reduction of the protein encoded by the mRNA.	Ledprona	Ledprona
36 **Chordotonal organ modulators – undefined target site** Nerve action {Modulation of chordotonal organ function has been clearly demonstrated, but the specific target protein(s) responsible for biological activity are distinct from Group 9 and Group 29 and remain undefined}	Pyridazine pyrazolecarboxamides	Dimpropyridaz
37 **Vesicular acetylcholine transporter (VAChT) inhibitor** Nerve action Bind to VAChTs, causing cholinergic synaptic transmission block resulting in nervous system shutdown and paralysis. VAChTs are involved in loading acetylcholine into synaptic vesicles	Oxazosulfyl	Oxazosulfyl
UN* **Compounds of unknown or uncertain MoA** {Target protein responsible for biological activity is unknown, or uncharacterized}	Azadirachtin	Azadirachtin
	Benzoximate	Benzoximate
	Benzpyrimoxan	Benzpyrimoxan
	Bromopropylate	Bromopropylate
	Chinomethionat	Chinomethionat
	Dicofol	Dicofol
	Lime sulfur	Lime sulfur
	Mancozeb	Mancozeb

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Main Group and Primary Site of Action	Sub-group, class or exemplifying Active Ingredient	Active Ingredients
	Pyridalyl	Pyridalyl
	Sulfur	Sulfur
UNB* **Bacterial agents (non-Bt) of unknown or uncertain MoA** {Target protein responsible for biological activity is unknown or uncharacterized}		*Burkholderia* spp *Wolbachia pipientis* (Zap)
UNE* **Botanical essence including synthetic, extracts and unrefined oils with unknown or uncertain MoA** {Target protein responsible for biological activity is unknown, or uncharacterized}		*Chenopodium ambrosioides near ambrosioides* extract, *Clitoria ternatea* extract, Fatty acid monoesters with glycerol or propanediol, Neem oil, Nonanoic acid, Sabadilla extract
UNF* **Fungal agents of unknown or uncertain MoA** {Target protein responsible for biological activity is unknown, or uncharacterized}		*Akanthomyces muscarius* Ve6 *Beauveria bassiana strains* *Metarhizium brunneum* strain F52 *Paecilomyces fumosoroseus* Apopka strain 97
UNM* **Non-specific mechanical and physical disruptors** {Target protein responsible for biological activity is unknown, or uncharacterized}		Diatomaceous earth Mineral oil Polydimethylsiloxane (PDMS)
UNP* **Peptides of unknown or uncertain MoA** {Target protein responsible for biological activity is unknown, or uncharacterized}		
UNV* **Viral agents (non-baculovirus) of unknown or uncertain MoA** {Target protein responsible for biological activity is unknown, or uncharacterized}		

Targeted Physiology: Nerve & Muscle | Growth & Development | Respiration | Midgut | Protein Suppressor | Unknown or Non-specific

Table Notes

a) The color scheme used associates modes of action into broad categories based on the physiological functions affected, as an aid to understanding symptomology, speed of action and other properties of the insecticides, and not for any resistance management purpose. Rotations for resistance management should be based only on the numbered mode of action groups.
b) Inclusion of an insecticidal agent in the classification above does not necessarily signify regulatory approval.
c) MoA assignments will usually involve identification of the target protein responsible for the biological effect, although groupings can be made where insecticidal agents share distinctive physiological effects and are structurally related.
d) Groups 26 and 27 are unassigned at this time and have therefore been omitted from the table.
e) An insecticidal agent with an unknown or controversial MoA or an unknown mode of toxicity will be held in group 'UN' or 'UNB', 'UNE', 'UNF', 'UNM', 'UNP', 'UNV' as applicable until evidence becomes available to enable assignment to a more appropriate MoA class.
f) Actives in groups marked with an asterisk are thought not to share a common target site and therefore may be freely rotated with each other unless there is reason to expect cross-resistance. These groups are 8, 13, UN, UNB, UNE, UNF, UNM, UNP and UNV.
g) Different baculoviruses that target different insect orders may be used together without compromising their resistance management. Rotation between certain specific baculoviruses may provide resistance management benefits for some pests. Consult product-specific recommendations.
h) While there is strong evidence that Bifenazate acts on the Qo site of Mitochondrial Complex III and some Bifenazate resistance mutations confer cross-resistance to acequinocyl, the sites of action of Fluacrypyrim and Hydramethylnon have not been determined.
i) Because of documented cross-resistance between dicofol, bromopropylate and abamectin, these active ingredients should not be rotated after each other in an IRM program.

7.3. Criteria for descriptors of the quality of MoA information

{Strong evidence that action at this protein (or protein complex) is responsible for insecticidal effects}	Potent effects on the function of the target protein and either resistance due to mutation / overexpression / removal of this protein or correlation of potency between effects on the protein and biological activity for a set of related insecticidal agents.
{Good evidence that action at this protein (or protein complex) is responsible for insecticidal effects}	Highly potent effects on the function of the protein combined with clearly consistent physiological effects
{Insecticidal agents affect the function of this protein, but it is not clear that this is what leads to biological activity}	Insecticidal agents (or their active principles) have moderate or low potency on the function of the protein, and there is little or no evidence associating this effect with biological activity. Insecticidal agents may be grouped because of similarity of structure and distinctive physiological effect.
{Target protein responsible for biological activity is unknown, or uncharacterized}	Insecticidal agents may be grouped because of similarity of structure and distinctive physiological effect.

7.4. Notes regarding sub-groups

Sub-groups represent distinct classes of insecticidal agents that are believed to have the same MoA but are different enough in structure or mode of interaction with the target protein that the chance of selection for either metabolic or target-site cross-resistance is reduced compared to closely related insecticidal agents. Sub-groups may also distinguish insecticidal agents that are structurally similar but known to bind differently within the target or to have differential selectivity among multiple targets. Evidence supporting lack of cross-resistance between existing compounds within the Group and the new active ingredient submission must be provided to support sub-grouping. This should include bioassay-based studies and provide quantifiable resistance ratios between susceptible and resistant strains.

The cross-resistance potential between sub-groups is higher than that between different groups, so rotation between sub-groups should be avoided. In exceptional circumstances (i.e. where effective registered insecticides from other mode of action groups are unavailable) rotation may be considered following consultation with local expert advice and where cross-resistance does not exist. These exceptions should not be considered sustainable resistance management strategies, and alternative options should be sought to maintain pest susceptibility.

The following notes provide additional information about particular sub-groups.

Sub-groups	Notes
3A & 3B	Because DDT is no longer used in agriculture, this is only applicable for the control of insect vectors of human disease such as mosquitoes.
4A, 4B, 4C, 4D, 4E & 4F	Although these compounds are believed to have the same target site, current evidence indicates that the risk of metabolic cross-resistance between subgroups is low.
10A	Hexythiazox is grouped with clofentezine because they exhibit cross-resistance, even though they are structurally distinct. Diflovidazin has been added to this group because it is a close analogue of clofentezine and is expected to have the same mode of action.
11A	Different *Bacillus thuringiensis* products that target different insect orders may be used together without compromising their resistance management. Rotation between certain specific *Bacillus thuringiensis* microbial products may provide resistance management benefits for some pests. Consult product-specific recommendations. *B.t.* Crop Proteins: Where there are differences among the specific receptors within the midguts of target insects, transgenic crops containing certain combinations of the listed proteins provide resistance management benefits.
22A & 22B	Although these compounds are believed to have the same target site, current evidence indicates that the risk of metabolic cross-resistance between subgroups is low.
25A & 25B	Although these compounds are believed to have the same target site, current evidence indicates that the risk of metabolic cross-resistance between subgroups is low.

7.5. General notes & MoA Classification Scheme updates

- Further details on the MoA Group Descriptors are given in Appendix 3.
- A list of active ingredients in alphabetical order with their respective MoA classification is given in Appendix 5.
- The Classification Scheme has been prepared using the most up-to-date information available to IRAC. It is provided to user groups, grower organisations, extension personnel, regulatory authorities such as the US EPA and all those involved in resistance management, as an agreed definitive statement by the plant protection industry on the MoA of insecticides currently in use.
- The IRAC MoA classification is reviewed and reissued at intervals as required. The latest version is always available for reference via the IRAC website (www.irac-online.org).
- Submissions for new active ingredients together with recommendations for their inclusion in specific new or existing MoA classes, together with citations or evidence for classification should be made to IRAC through the website.
- IRAC member companies review draft versions before an agreed final version of any update is published. In addition, several internationally well-known insect toxicologists and biochemists can be consulted regarding additions, deletions or other changes to the list. Details of the procedures followed for allocation of new insecticidal materials to the MoA classification are given in Appendix 4.
- Changes to the listing may have serious consequences. In those countries where insecticide labels display the IRAC MoA number or class name as an aid to good IRM (see Appendix 1), changes may be especially costly to implement. In general, changes are therefore only endorsed when the scientific evidence supporting the change is compelling.
- Superseded, obsolete or withdrawn insecticidal agents for which no current registration exists, and that are no longer in common usage, are not listed.
- In a continued effort to refine the list, readers are kindly asked to inform IRAC of factual errors or omissions, citing definitive evidence wherever possible. Such submissions should be directed to IRAC via the website. Suggestions for improvements are likewise welcome.

Appendix 1

Product labels: Indication of MoA of active ingredient and accompanying IRM advice

To assist users in the selection of insecticides for use in IRM strategies employing sequences, rotations or alternations of MoA groups, IRAC is encouraging producers to clearly indicate the IRAC MoA group number and description on the product label, and to accompany this with appropriate advice of the type indicated below. Thus, in addition to the detailed product information, handling, and safety information required by local regulations, a typical label should clearly indicate the IRAC MoA Group number & description, and minimal, brief advice on IRM as indicated in the example below.

Inclusion of the IRAC group on the label is a warrant from the manufacturer that the insecticide has been classified by IRAC and is listed in Appendix 5 of this document, the only authoritative and comprehensive list of IRAC-classified insecticides. If an insecticide is not listed in Appendix 5 and falls within the scope of the IRAC classification as stated at the beginning of this document, please petition IRAC for classification of the product, as directed in Appendix 4, before drafting a label. Insecticidal materials falling outside the scope of the classification may be labeled as "Exempt from IRAC Classification".

For resistance management purposes, Product XXX insecticide is an IRAC MoA Group 15 insecticide. Any insect population may contain individuals naturally resistant to Product XXX and other Group 15 insecticides. If these insecticides are used repeatedly, the resistant individuals may eventually dominate the pest insect population. These resistant insects may not be controlled by Product XXX insecticide or by other Group 15 insecticides. To delay the development of resistance:

- Avoid exclusive repeated use of insecticides from the same chemical sub-group, (indicated by the IRAC MoA Group number).
- Alternate with products from other IRAC MoA Groups
- Integrate other control methods (chemical, cultural, biological) into insect control programs.

For further information on resistance management and advice on IRM programmes contact your local distributor.

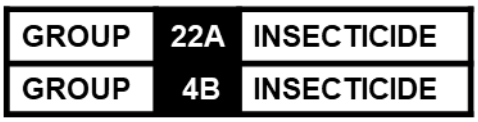
LABELLING SPECIFICS

It is recommended that the MoA icon is displayed in a prominent position on the label. A position at the top right of the front panel of the label is strongly recommended as shown in the example above. A clearly defined font should be used, e.g., Arial or Calibri for users of Latin script. A black and white colour scheme is recommended. The icon uses the word GROUP in capital letters in black font on a white background; the mode of action letter or numeral should be in white font on a black background; the word INSECTICIDE in capital letters in black font on a white background. Both lines, and the whole indicator, are contained within black rectangles. See example below.

The words GROUP and INSECTICIDE in capital letters which should not be less than one-quarter of the height of the largest letter or numeral on the label and be between 2 mm and 12.5 mm high. If more than one insecticide is included in a product then the icon should be written in plural e.g. INSECTICIDES not INSECTICIDE. The appropriate letter(s) or number(s) representing the Mode of Action (MoA) group(s) of each active constituent(s) are to be inserted between the words GROUP and INSECTICIDE. The width of the white line that separates the groups for the pesticides in a product with more than one active ingredient should be defined. It should be wide enough so that when the icon is printed on small packets the line is clear. The letter(s) representing the mode of action should be written in capital letters which should not be less than one-half the height of the largest letter or numeral on the label and between 4 mm and 25 mm high. The words GROUP and INSECTICIDE must be no less than half, and no more than the actual size of the group number or letter.

Note that where a product has two or more active constituents, and these are represented by two or more modes of action, you must use two or more appropriate MoA identifier letters or numbers in a single statement. Alternatively, each individual active ingredient can be placed in a stacked format (see examples below).

OR



If the product contains two or more active constituents which perform different functions, for example, an insecticide and a fungicide, you must show each function separately (that is, one indicator panel for the insecticide and another for the fungicide component). See examples below.

Where required, appropriate translation should be used to ensure MoA labels are clear to product users. Labelling should also consider the FAO/WHO Guidelines on Good Labelling Practice for Pesticides. MoA labelling must follow all country regulations and may vary.

RESISTANCE MANAGEMENT LANGUAGE FOR PRODUCT LABELS

In addition to mode of action number labelling, it is strongly recommended by CLI and the Resistance Action Committees (RACs) to include guidance on the management of resistance on the product label. Where possible companies will voluntarily add resistance management language to their product labels that explains how to use MoA information in resistance management recommendations.

IRAC recommends that resistance management guidelines be presented under a headed section titled: "RESISTANCE MANAGEMENT" on all insecticide labels and the following three IRM elements be incorporated in the text.

- The name of the active ingredient(s) and mode of action identifier (IRAC Mode of Action groups).
- A statement that the product should be rotated with different modes of action using mode of action treatment windows.
- Guidance to avoid treating consecutive generations with the same mode of action

EXAMPLE OF AN IRM RECOMMENDATION ON AN INSECTICIDE PRODUCT LABEL:

> ***PRODUCT NAME*** contains the ***ACTIVE INGREDIENT NAME*** and is an ***IRAC GROUP X*** insecticide. Do not exclusively use ***PRODUCT NAME*** or other ***GROUP X*** insecticides to control the same pest throughout the season. Avoid exposing consecutive generations of a pest to the same mode of action by using the "application window" approach which rotates products from different mode of action groups.
>
> An "application window" is the period of residual activity that a single application or sequential applications of products from the same mode of action provide. It can also be defined as the duration of an insect generation or if unknown, then use an approximate 30 day period. Rotate windows with treatments of ***PRODUCT NAME*** and *other* ***Group X*** products followed by windows of treatments with other effective products with different modes of action. Multiple applications (recommend no more than two) of the same MoA insecticide are acceptable if they are used within the same application window.

Reference: CropLife International Mode of Action Labelling Guidance

Appendix 2

IRM principles recommended and endorsed by IRAC

- Consult a local agricultural advisor or extension services in the area for up-to-date recommendations and advice on IPM and IRM programmes.
- Consider options for minimizing insecticide use by selecting early maturing or pest-tolerant varieties of crop plants.
- Include effective cultural and biological control practices that work in harmony with effective IRM programmes. Adopt all non-chemical techniques known to control or suppress pest populations, including biological sprays such as Bt's, resistant varieties, within-field refugia (untreated areas) and crop rotation.
- Where possible select insecticides and other pest management tools that preserve beneficial insects.
- Use products at their full, recommended doses. Reduced (sub-lethal) doses quickly select populations with average levels of tolerance, whilst doses that are too high may impose excessive selection pressures.
- Appropriate, well-maintained equipment should be used to apply insecticides. Recommended water volumes, spray pressures and optimal temperatures should be used to obtain optimal coverage.
- Where larval stages are being controlled, target younger larval instars where possible because these are usually much more susceptible and therefore much more effectively controlled by insecticides than older stages.
- Use appropriate local economic thresholds and spray intervals.
- Follow label recommendations or local expert advice for use of alternations or sequences of different classes of insecticide with differing modes of action as part of an IRM strategy.
- Where there are multiple applications per year or growing season, alternate products of different MoA classes.
- In the event of a control failure, do not reapply the same insecticide but change the class of insecticides to one having a different MoA and to which there is no [locally] known cross-resistance.
- Mixtures may offer a short-term solution to resistance problems, but it is essential to ensure that each component of a mixture belongs to a different insecticide MoA class, and that each component is used at its full rate.
- Consideration should be given to monitoring for the incidence of resistance in the most commercially important situations and gauge levels of control obtained.
- Withholding use of a product to which resistance has developed until susceptibility returns may be a valid tactic if sufficient alternative chemical classes remain to provide effective control.

Appendix 3

MoA Group Descriptors

NERVE AND MUSCLE TARGETS

Most current insecticides act on nerve and muscle targets. Insecticides that act on these targets are generally fast acting.

Group 1: Acetylcholinesterase (AChE) inhibitors

Inhibit AChE, causing hyperexcitation. AChE is the enzyme that terminates the action of the excitatory neurotransmitter acetylcholine at nerve synapses.

Group 2: GABA-gated chloride channel blockers

Block the GABA-activated chloride channel, causing hyperexcitation and convulsions. GABA is the major inhibitory neurotransmitter in insects.

Group 3: Sodium channel modulators

Keep sodium channels open, causing hyperexcitation and, in some cases, nerve block. Sodium channels are involved in the propagation of action potentials along nerve axons.

Group 4: Nicotinic acetylcholine receptor (nAChR) competitive modulators

Bind to the acetylcholine site on nAChRs, causing a range of symptoms from hyper-excitation to lethargy and paralysis. Acetylcholine is the major excitatory neurotransmitter in the insect central nervous system.

Group 5: Nicotinic acetylcholine receptor (nAChR) allosteric modulators – Site I

Allosterically activate nAChRs (at a site distinct from Group 32 - Site II), causing hyperexcitation of the nervous system. Acetylcholine is the major excitatory neurotransmitter in the insect central nervous system.

Group 6: Glutamate-gated chloride channel (GluCl) allosteric modulators

Allosterically activate glutamate-gated chloride channels (GluCls), causing paralysis. Glutamate is an important inhibitory neurotransmitter in insect.

Group 9: Chordotonal organ TRPV channel modulators

Bind to and disrupt the gating of Nan-Iav TRPV (Transient Receptor Potential Vanilloid) channel complexes in chordotonal stretch receptor organs, which are critical for the senses of hearing, gravity, balance, acceleration, proprioception and kinesthesia. This disrupts feeding and other behaviors in target insects.

Group 14: Nicotinic acetylcholine receptor (nAChR) channel blockers

Block the nAChR ion channel, resulting in nervous system block and paralysis. Acetylcholine is the major excitatory neurotransmitter in the insect central nervous system.

Group 19: Octopamine receptor agonists

Activate octopamine receptors, leading to hyperexcitation. Octopamine is the insect equivalent of adrenaline, the fight-or-flight neurohormone

Group 22: Voltage-dependent sodium channel blockers

Block sodium channels, causing nervous system shutdown and paralysis. Sodium channels are involved in the propagation of action potentials along nerve axons.

Group 28: Ryanodine receptor modulators

Activate muscle ryanodine receptors, leading to contraction and paralysis. Ryanodine receptors mediate calcium release into the cytoplasm from intracellular stores.

Group 29: Chordotonal organ nicotinamidase inhibitors

Disrupt the function of chordotonal stretch receptor organs, which are critical for the senses of hearing, gravity, balance, acceleration, proprioception and kinesthesia. This disrupts feeding and other behaviors in target insects. Group 29 insecticides inhibit the enzyme nicotinamidase, which degrades the endogenous TRPV modulator nicotinamide.

Group 30: GABA-gated chloride channel allosteric modulators

Allosterically inhibit the GABA-activated chloride channel, causing hyperexcitation and convulsions. GABA is the major inhibitory neurotransmitter in insects.

Group 32: Nicotinic acetylcholine receptor (nAChR) allosteric modulators – Site II

Allosterically activate nAChRs (at a site distinct from Group 5 - Site I), causing hyperexcitation of the nervous system. Acetylcholine is the major excitatory neurotransmitter in the insect central nervous system.

Group 33: Calcium-activated potassium channel (KCa2) modulators

Negative modulation of KCa2 causes hyperexcitation and convulsions. KCa2 channels are activated by increase of the intracellular calcium concentration and are involved in the regulation of action potentials.

Group 36: Chordotonal organ modulators – undefined target site

Disrupt the function of chordotonal stretch receptor organs, which are critical for the senses of hearing, gravity, balance, acceleration, proprioception and kinesthesia. This disrupts feeding and other behaviors in target insects. Group 36 insecticides act at a site different from Group 9 and Group 29 insecticides and are neither affecting TRPV channels nor nicotinamidase.

Group 37: Vesicular acetylcholine transporter (VAChT) inhibitor

Bind to VAChTs, causing cholinergic synaptic transmission block resulting in nervous system shutdown and paralysis. VAChTs are involved in loading acetylcholine into synaptic vesicles

GROWTH AND DEVELOPMENT TARGETS

Insect development is controlled by the balance of two principal hormones: juvenile hormone and ecdysone. Insect growth regulators act by mimicking one of these hormones or directly perturbing cuticle formation/deposition or lipid biosynthesis. Insecticides that act on individual targets in this system are generally slow to moderately slow acting.

Group 7: Juvenile hormone mimics

Applied in the pre-metamorphic instar, these compounds disrupt and prevent metamorphosis.

Group 10: Mite growth inhibitors affecting CHS1

Inhibit the enzyme that catalyzes the polymerization of chitin.

Group 15: Inhibitors of chitin biosynthesis affecting CHS1

Inhibit the enzyme that catalyzes the polymerization of chitin.

Group 16: Inhibitors of chitin biosynthesis, type 1

Incompletely defined MoA leading to inhibition of chitin biosynthesis in a number of insect species, including whiteflies.

Group 17: Moulting disruptors, Dipteran

Incompletely defined MoA that leads to moult disruption.

Group 18: Ecdysone receptor agonists

Mimic the moulting hormone, ecdysone, inducing a precocious moult.

Group 23: Inhibitors of acetyl-CoA carboxylase

Inhibit acetyl coenzyme A carboxylase, part of the first step in lipid biosynthesis, leading to insect death.

RESPIRATION TARGETS

Mitochondrial respiration produces ATP, the molecule that energizes all vital cellular processes. In mitochondria, an electron transport chain stores the energy released by oxidation in the form of a proton gradient, which drives ATP synthesis. Several insecticides are known to interfere with mitochondrial respiration by the inhibition of electron transport and/or oxidative phosphorylation. Insecticides that act on individual targets in this system are generally fast to moderately fast acting.

Group 12: Inhibitors of mitochondrial ATP synthase

Inhibit the enzyme that synthesizes ATP.

Group 13: Uncouplers of oxidative phosphorylation via disruption of the proton gradient

Protonophores that short-circuit the mitochondrial proton gradient so that ATP cannot be synthesized.

Group 20; Mitochondrial complex III electron transport inhibitors – Qo site

Inhibit electron transport complex III, preventing the utilization of energy by cells by binding to the Qo site.

Group 21: Mitochondrial complex I electron transport inhibitors

Inhibit electron transport complex I, preventing the utilization of energy by cells.

Group 24: Mitochondrial complex IV electron transport inhibitors

Inhibit electron transport complex IV, preventing the utilization of energy by cells.

Group 25: Mitochondrial complex II electron transport inhibitors

Inhibit electron transport complex II, preventing utilization of energy by cells.

Group 34: Mitochondrial complex III electron transport inhibitors – Qi site

Inhibit electron transport complex III, preventing the utilization of energy by cells. In contrast to Group 20, Group 34 insecticides bind to the Qi site.

MIDGUT TARGETS

Lepidopteran-specific microbial toxins that are sprayed or expressed in transgenic crop varieties, and baculoviruses.

Group 11: Microbial disruptors of insect midgut membranes

Protein toxins that bind to receptors on the midgut membrane and induce pore formation, resulting in ionic imbalance and septicemia.

Group 31: Host-specific occluded pathogenic viruses

A baculovirus-unique Per os Infectivity Factor (PIF) protein complex on the virus promotes host-specific infection by binding to PIF targets on midgut cells that are unknown but believed to be unique for each baculovirus type. Infection is ultimately lethal.

TARGETED PROTEIN SUPPRESSORS

Multiple biological processes govern the accumulation of proteins critical to supporting a wide variety of functions within insects. Protein suppressors act through reduction of specific protein levels in the pest species. Insecticides that act in this manner are generally moderately slow acting.

Group 35: RNA interference mediated target suppressors

Activation of the RNAi mechanism which specifically reduces abundance of the target messenger RNA (mRNA) resulting in the reduction of the protein encoded by the mRNA.

UNKNOWN OR NON-SPECIFIC TARGETS

Several insecticides are known to affect less well-described target-sites or functions, or to act non-specifically on multiple targets.

Group 8: Miscellaneous non-specific (multi-site) inhibitors

Group UN: Compounds of unknown or uncertain MoA

Group UNB: Bacterial agents of unknown or uncertain MoA

Group UNE: Botanical essence including synthetic, extracts and unrefined oils with unknown or uncertain MoA

Group UNF: Fungal agents of unknown or uncertain MoA

Group UNM: Non-specific mechanical and physical disruptors

Group UNP: Peptides of unknown or uncertain MoA

Group UNV: Viral agents of unknown or uncertain MoA

Appendix 4

Procedure for allocation of new insecticidal materials to the MoA classification

IRAC maintains the MoA Classification scheme as the definitive, globally recognised, ultimate authority on insecticide modes of action. In order to provide the best possible information for resistance management purposes, IRAC also issues regular updates of the scheme, in which newly introduced insecticides are allocated to an appropriate MoA classification group and structural sub-group, and in which re-classification or the correction of errors or anomalies for specific insecticidal agents is undertaken considering definitive new information. This document details how these processes are administered by IRAC.

Who is responsible for the process within IRAC?

The IRAC MoA Team comprises technical representatives of the member companies with expertise in insect toxicology, pharmacology or biochemistry. All IRAC companies are eligible to contribute technical expertise to the group. The group meets regularly to consider the content and detail of the MoA scheme and makes proposals on significant additions, deletions or reallocations of insecticidal agents within the scheme for consideration by the IRAC Executive.

Why and how often is the scheme updated?

New versions of the scheme are issued periodically as necessary, as a result of the MoA Team's consideration of new information. The introduction of major new MoA groups or the reallocation of insecticidal agents or groups would merit the issue of a new version (vN). Minor changes or corrections that do not significantly impact the scheme are undertaken automatically at intervals as necessary, and sub-versions are issued (vN.n). New sub-versions may be issued up to several times per year as required, while new full versions are not anticipated more than once per year. The potential impact of proposed significant changes on derived versions of the scheme around the world is fully appreciated, especially in countries where MoA labelling of products is used. The MoA team is cognisant of these impacts and revisions are only proposed when the evidence for change is scientifically compelling.

What evidence is needed to support MoA classification of an insecticidal agent?

Proposals for additions to the MoA scheme or for amendments to the current scheme should be submitted to the IRAC MoA team (details below). These proposals will be considered by the Team and a

decision on the outcome will be provided to the proposer in due course. Published material in high quality, front line, peer-reviewed, scientific journals is especially useful as a source of information for consideration by the team, and those companies, bodies or individuals submitting proposals for consideration by the team are strongly encouraged to provide such information wherever possible. Corroborating information is also especially welcome. Unpublished material may be submitted in evidence, and the MoA team will interpret this appropriately.

Several types of data can be used to establish MoA (including the activation of pro-insecticides to their actives). Convincing evidence to support the MoA hypothesis is needed. This includes the demonstration of a clear target effect (activation, inhibition, or modulation) at concentrations that can reasonably be expected in the intoxicated organism. Preferably, these data may be corroborated by physiological and/or symptomology studies to link insect mortality to the effect on the target site. A positive structure-activity correlation of *in vitro* efficacy with insecticidal potency, and/or target site mutations conferring resistance are required to further substantiate the proposed MoA.

What are the criteria for establishing MoA Sub-groups?

Sub-groups represent distinct chemical classes that are believed to have the same MoA but are different enough in chemical structure or mode of interaction with the target protein that the chance of selection for either metabolic or target-site cross-resistance is reduced compared to close analogs. Sub-groups may also distinguish insecticidal agents that are structurally similar but known to bind differently within the target or to have differential selectivity among multiple targets. Evidence supporting lack of cross-resistance between existing compounds within the Group and the new active ingredient submission must be provided to support sub-grouping. This should include bioassay-based studies and provide quantifiable resistance ratios between susceptible and resistant strains.

The cross-resistance potential between sub-groups is higher than that between different groups, so rotation between sub-groups should be avoided. In exceptional circumstances (i.e., where effective registered insecticides from other mode of action groups are unavailable) rotation may be considered following consultation with local expert advice and where cross-resistance does not exist. These exceptions should not be considered sustainable resistance management strategies, and alternative options should be sought to maintain pest susceptibility.

How are decisions made by the MoA Team?

Given the definitive nature of the IRAC MoA scheme, the MoA Team regards it as an absolute priority that the highest levels of scientific integrity are always employed in the consideration and discussion of allocation of insecticidal agents. In general, agreement on allocation of an insecticidal agent is usually arrived at through consensus within the Team, following detailed discussion. Major decisions, for example the introduction of new MoA classes or sub-classes are proposed to the IRAC Executive for ratification. If the Team cannot agree it may choose to place the case with a panel of external MoA experts to gain their written opinion before reconsidering the case. The composition of the expert panel

is agreed in advance by the Team. If after reconsidering the particular case the team is still in disagreement, the matter will be passed to the IRAC Executive for further consideration. Where individual members of the Team are subject to a conflict of interests through company affiliation or other interests, they may choose to withdraw from discussion of particular insecticidal agents as they consider appropriate.

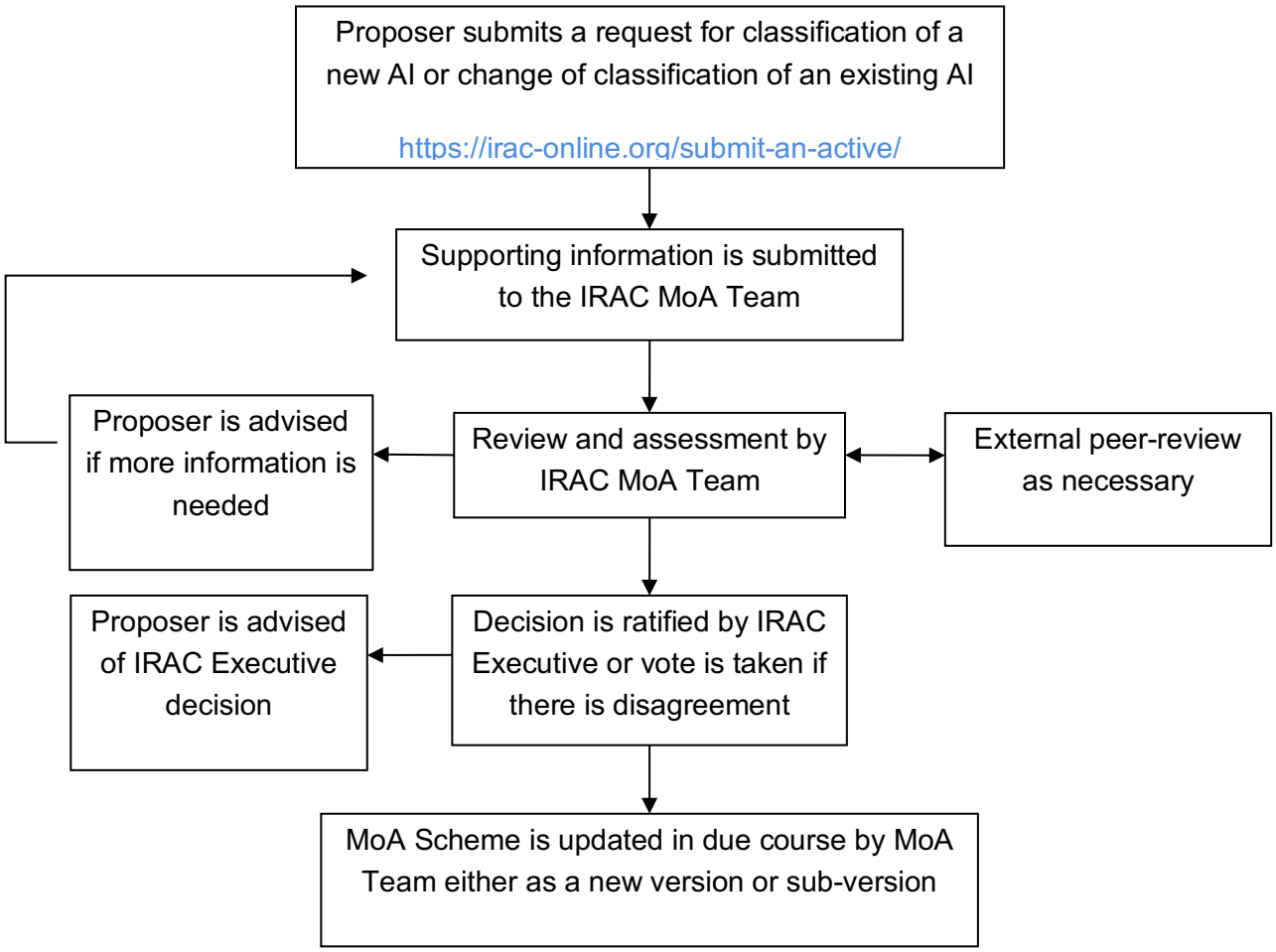
How long does this process take?

The MoA Team has a duty to make a definitive decision on allocation of an insecticidal agent as quickly as possible following receipt of appropriate supporting evidence. For straightforward cases that do not require external consultation it should generally be expected that the Team could provide feedback to proposers within 3 months. The need for external consultants may extend the process to 6 months.

To whom should proposals be sent?

Proposals for new insecticidal agents or for changes to the current IRAC MoA scheme should be submitted to the IRAC MoA Team via the IRAC International Coordinator. A link to the coordinator is provided on the IRAC website (www.irac-online.org) at the bottom of each page under 'Contact'. Alternatively, the online request can be completed at http://www.irac-online.org/submit-an-active/

Procedure for updates to IRAC MoA Classification Scheme



MoA Classification Guidance Matrix

Supporting Evidence for Classification	Links
1. Existing Group	
a. Existing Subgroup / no Subgroup	
• Demonstration of a clear effect (activation, inhibition, or modulation) on the target / signal transduction pathway at concentrations that can reasonably be expected in the intoxicated organism	
• A positive structure-activity correlation of *in vitro* efficacy with insecticidal potency and/or • Target site mutation(s) supporting the proposed MoA	https://irac-online.org/documents/established-insecticide-target-site-mutations/?ext=xlsx
• Physiological and/or symptomology studies to link insect mortality to the effect on the target site / signal transduction pathway	
b. New Subgroup (additional evidence required)	
• Distinct chemical / biological class*	
Evidence supporting lack of cross-resistance between existing compounds within the Group and the new active ingredient: • Quantifiable resistance ratios between field-relevant susceptible and resistant strains • *In vitro* studies (optional)	resistance profiles of relevant pests incl. references https://irac-online.org/pests/
* Sub-groups may also distinguish insecticidal agents that are structurally similar but known to bind differently within the target or to have differential selectivity among multiple targets.	
2. New Group	
• New chemical / biological class	
• Demonstration of a clear effect (activation, inhibition, or modulation) on the target / signal transduction pathway at concentrations that can reasonably be expected in the intoxicated organism	
• A positive structure-activity correlation of *in vitro* efficacy with insecticidal potency and/or • Target site mutation(s) supporting the proposed MoA	
• Physiological and/or symptomology studies to link insect mortality to the effect on the target site / signal transduction pathway	
• Clear differentiation from existing sites in a known target / signal transduction pathway is required if activity on a new site in an existing target / signal transduction pathway is claimed: this might include experimental evidence that the insecticidal agent binds to a unique site of an existing target which is not impacted by mutations conferring resistance to the existing target	searchable online version of the MoA Classification https://www.irac-online.org/modes-of-action/
3. Unknown Mode of Action	
If there is insufficient evidence supporting a defined Mode of Action, insecticidal / acaricidal agents can be included in the classification scheme in the Unknown Mode of Action category they fall under: compounds, UN; bacterial agents, UNB; extracts and crude oils, UNE; fungal agents, UNF; mechanical and physical disruptors, UNM; peptides, UNP; viruses UNV	

Appendix 5

ACTIVE INGREDIENTS (ALPHABETICAL ORDER) WITH MOA CLASSIFICATION.

This is the comprehensive reference list of IRAC-classified insecticides. If your active ingredient is not on this list and falls within the scope of this classification as defined in section 1, please contact IRAC as directed in Appendix 4.

Active Ingredient	MOA No.
1,3-dichloropropene	8A
Abamectin	6
Acephate	1B
Acequinocyl	20B
Acetamiprid	4A
Acrinathrin	3A
Acynonapyr	33
Afidopyropen	9D
Akanthomyces muscarius Ve6	UNF
Alanycarb	1A
Aldicarb	1A
Allethrin	3A
alpha-Cypermethrin	3A
Aluminium phosphide	24A
Amitraz	19
Anticarsia gemmatalis MNPV	31
Azadirachtin	UN

Active Ingredient	MOA No.
Azamethiphos	1B
Azinphos-ethyl	1B
Azinphos-methyl	1B
Azocyclotin	12B
Bacillus thuringiensis	11A
Bacillus sphaericus	11B
Beauveria bassiana strains	UNF
Bendiocarb	1A
Benfuracarb	1A
Bensultap	14
Benzoximate	UN
Benzpyrimoxan	UN
beta-Cyfluthrin	3A
beta-Cypermethrin	3A
Bifenazate	20D
Bifenthrin	3A
Bioallethrin	3A

Active Ingredient	MOA No.
Bioallethrin S-cyclopentenyl isomer	3A
Bioresmethrin	3A
Bistrifluron	15
Borax	8D
Boric acid	8D
Broflanilide	30
Bromopropylate	UN
Buprofezin	16
Burkholderia spp,	UNB
Butocarboxim	1A
Butoxycarboxim	1A
Cadusafos	1B
Calcium cyanide	24B
Calcium phosphide	24A
Carbaryl	1A
Carbofuran	1A
Carbosulfan	1A
Cartap hydrochloride	14
Chenopodium ambrosioides near ambrosioides extract	UNE
Chinomethionat	UN

Active Ingredient	MOA No.
Chlorantraniliprole	28
Chlordane	2A
Chlorethoxyfos	1B
Chlorfenapyr	13
Chlorfenvinphos	1B
Chlorfluazuron	15
Chlormephos	1B
Chloropicrin	8B
Chlorpyrifos	1B
Chlorpyrifos-methyl	1B
Chromafenozide	18
Clitoria ternatea extract	UNE
Clofentezine	10A
Clothianidin	4A
Coumaphos	1B
Cryolite	8C
Cyanide	24B
Cyanophos	1B
Cyantraniliprole	28
Cyclaniliprole	28
Cycloprothrin	3A

Active Ingredient	MOA No.
Cydia pomonella GV	31
Cyenopyrafen	25A
Cyflumetofen	25A
Cyfluthrin	3A
Cyhalothrin	3A
Cyhexatin	12B
Cypermethrin	3A
Cyphenothrin (1*R*)-*trans*-isomers]	3A
Cyproflanilide	30
Cyromazine	17
d-*cis*-*trans* Allethrin	3A
Dazomet	8F
DDT	3B
Deltamethrin	3A
Demeton-S-methyl	1B
Diafenthiuron	12A
Diatomaceous earth	UNM
Diazinon	1B
Dichlorvos/ DDVP	1B
Dicloromezotiaz	4E

Active Ingredient	MOA No.
Dicofol	UN
Dicrotophos	1B
Diflovidazin	10A
Diflubenzuron	15
Dimethoate	1B
Dimethylvinphos	1B
Dimpropyridaz	36
Dinotefuran	4A
Disodium octaborate	8D
Disulfoton	1B
DNOC	13
d-*trans* Allethrin	3A
Emamectin benzoate	6
Empenthrin [(EZ)-(1*R*)-isomers]	3A
Endosulfan	2A
EPN	1B
Esfenvalerate	3A
Ethiofencarb Ethion	1A 1B
Ethiprole	2B
Ethoprophos	1B

Active Ingredient	MOA No.
Etofenprox	3A
Etoxazole	10B
Famphur	1B
Fatty acid monoesters with glycerol or propanediol	UNE
Fenamiphos	1B
Fenazaquin	21A
Fenbutatin oxide	12B
Fenitrothion	1B
Fenmezoditiaz	4E
Fenobucarb	1A
Fenoxycarb	7B
Fenpropathrin	3A
Fenpyroximate	21A
Fenthion	1B
Fenvalerate	3A
Fipronil	2B
Flometoquin	34
Flonicamid	29
Fluacrypyrim	20C
Flubendimide	28

Active Ingredient	MOA No.
Flucycloxuron	15
Flucythrinate	3A
Flufenoxuron	15
Flumethrin	3A
Flupyradifurone	4D
Flupyrimin	4F
Fluxametamide	30
Formetanate	1A
Fosthiazate	1B
Furathiocarb	1A
gamma-Cyhalothrin	3A
GS-omega/kappa HXTX-Hv1a	32
Halfenprox	3A
Halofenozide	18
Helicoverpa armigera NPV	31
Heptenophos	1B
Hexaflumuron	15
Hexythiazox	10A
Hydramethylnon	20A
Hydroprene	7A
Imicyafos	1B

Active Ingredient	MOA No.
Imidacloprid	4A
Imiprothrin	3A
Indoxacarb	22A
Isocycloseram	30
Isofenphos	1B
Isoprocarb	1A
Isopropyl O- (methoxyaminothio-phosphoryl) salicylate	1B
Isoxathion	1B
Kadethrin	3A
Kinoprene	7A
lambda-Cyhalothrin	3A
Ledprona	35
Lepimectin	6
Lime sulfur	UN
Lufenuron	15
Malathion	1B
Mancozeb	UN
Mecarbam	1B
Metaflumizone	22B
Metam	8F

Active Ingredient	MOA No.
Metarhizium brunneum strain F52	UNF
Methamidophos	1B
Methidathion	1B
Methiocarb	1A
Methomyl	1A
Methoprene	7A
Methoxychlor	3B
Methoxyfenozide	18
Methyl bromide	8A
Methyl isocyanate	8F
Metolcarb	1A
Mevinphos	1B
Milbemectin	6
Mineral oil	UNM
Monocrotophos	1B
Naled	1B
Neem oil	UNE
Nicotine	4B
Nitenpyram	4A
Nonanoic acid	UNE

Active Ingredient	MOA No.
Novaluron	15
Noviflumuron	15
Omethoate	1B
Oxamyl	1A
Oxazosulfyl	37
Oxydemeton-methyl	1B
Paecilomyces fumosoroseus Apopka strain 97	UNF
Parathion	1B
Parathion-methyl	1B
Permethrin	3A
Phenothrin [(1*R*)- *trans*- isomer]	3A
Phenthoate	1B
Phorate	1B
Phosalone	1B
Phosmet	1B
Phosphamidon	1B
Phosphine	24A
Phoxim	1B
Pirimicarb	1A
Pirimiphos- methyl	1B

Active Ingredient	MOA No.
Polydimethylsiloxane (PDMS)	UNM
Potassium cyanide	24B
Prallethrin	3A
Profenofos	1B
Propargite	12C
Propetamphos	1B
Propoxur	1A
Prothiofos	1B
Pyflubumide	25B
Pymetrozine	9B
Pyraclofos	1B
Pyrethrins (pyrethrum)	3A
Pyridaben	21A
Pyridalyl	UN
Pyridaphenthion	1B
Pyrifluquinazon	9B
Pyrimidifen	21A
Pyriproxyfen	7C
Quinalphos	1B
Resmethrin	3A
Rotenone (Derris)	21B

Active Ingredient	MOA No.
Sabadilla extract	UNE
Silafluofen	3A
Sodium borate	8D
Sodium cyanide	24B
Sodium metaborate	8D
Spidoxamat	23
Spinetoram	5
Spinosad	5
Spirodiclofen	23
Spiromesifen	23
Spriropidion	23
Spirotetramat	23
Sulfotep	1B
Sulfoxaflor	4C
Sulfur	UN
Sulfuramid	13
Sulfuryl fluoride	8C
Tartar emetic	8E
tau-Fluvalinate	3A
Tebufenozide	18
Tebufenpyrad	21A

Active Ingredient	MOA No.
Tebupirimfos	1B
Teflubenzuron	15
Tefluthrin	3A
Temephos	1B
Terbufos	1B
Tetrachlorvinphos	1B
Tetradifon	12D
Tetramethrin	3A
Tetramethrin [(1*R*)- isomers]	3A
Tetraniliprole	28
Thaumatotibia leucotreta GV	31
theta-cypermethrin	3A
Thiacloprid	4A
Thiamethoxam	4A
Thiocyclam	14
Thiodicarb	1A
Thiofanox	1A
Thiometon	1B
Thiosultap-sodium	14
Tolfenpyrad	21A
Tralomethrin	3A

Active Ingredient	MOA No.
Transfluthrin	3A
Triazamate	1A
Triazophos	1B
Trichlorfon	1B
Triflumezopyrim	4E
Triflumuron	15
Trimethacarb	1A
Vamidothion	1B
Wolbachia pipientis (Zap)	UNB
XMC	1A
Xylylcarb	1A
zeta-Cypermethrin	3A
Zinc phosphide	24A

Appendix 6

Active Ingredients Pending Registration

Group numbers are proposed at this stage - the final number will be confirmed following the first registration.

Main Group and Primary Site of Action	Sub-group, class or exemplifying Active Ingredient	Active Ingredient
UNP Peptides of unknown or uncertain MoA {Target protein responsible for biological activity is unknown, or uncharacterized	U1-AGTX-Ta1b-QA Peptide	U1-AGTX-Ta1b-QA Peptide
UNM Group UNM: Non-specific mechanical and physical disruptors	Perlite	Perlite
35 RNA Interference mediated target suppressors Activation of the RNAi mechanism which specifically reduces abundance of the target messenger RNA (mRNA) resulting in the reduction of the protein encoded by the mRNA.	Vadescana	Vadescana