

## Introduction

Insecticide Resistance Action Committee [IRAC] promotes the use of a Mode of Action (MoA) classification of insecticides as the basis for effective and sustainable insecticide resistance management (IRM). Insecticides are allocated to specific groups based on their target site. Reviewed and re-issued periodically, the IRAC MoA classification list provides farmers, growers, advisors, extension staff, consultants and crop protection professionals with a guide to the selection of insecticides or acaricides in IRM programs. Effective IRM of this type preserves the utility and diversity of available insecticides and acaricides.

## Nerve & Muscle Targets

- Group 1 Acetylcholinesterase (AChE) inhibitors
  - 1A: Carbamates (e.g. Thiodicarb),
  - 1B: Organophosphates (e.g. Chlorpyrifos)
- Group 2 GABA-gated chloride channel blockers
  - 2A: Cyclo-diene Organochlorines (e.g. Endosulfan)
  - 2B: Phenylpyrazoles (e.g. Fipronil)
- Group 3 Sodium channel modulators
  - 3A: Pyrethrins, Pyrethroids (e.g. Cypermethrin)
  - 3B: DDT, Methoxychlor
- Group 4 Nicotinic acetylcholine receptor (nAChR) competitive modulators
  - 4A: Neonicotinoids (e.g. Imidacloprid, Thiamethoxam)
  - 4B: Nicotine
  - 4C: Sulfoximines (e.g. Sulfoxaflor)
  - 4D: Butenolides (e.g. Flupyradifurone)
- Group 5 Nicotinic acetylcholine receptor (nAChR) allosteric modulators
  - 5: Spinosyns (e.g. Spinosad, Spinetoram)
- Group 6 Glutamate-gated chloride channel (GluCl) allosteric modulators
  - 6: Avermectins, Milbemycins (e.g. Abamectin, Emamectin benzoate)
- Group 9 Chordotonal organ TRPV channel modulators
  - 9B: Pyridine azomethine derivatives (e.g. Pymetrozine, Pyflquinazon)
- Group 14 Nicotinic acetylcholine receptor (nAChR) channel blockers
  - 14: Nereistoxin analogs (e.g. Cartap hydrochloride)
- Group 19 Octopamine receptor agonists
  - 19: Amitraz
- Group 22 Voltage dependent sodium channel blockers
  - 22A: Oxadiazines (e.g. Indoxacarb)
  - 22B: Semicarbazones (e.g. Metaflumizone)
- Group 28 Ryanodine receptor modulators
  - 28: Diamides (e.g. Chlorantraniliprole, Cyantraniliprole, Flubendiamide)
- Group 29 Chordotonal organ modulators – undefined target site
  - 29: Fonicamid

## Midgut Targets

- Group 11 Microbial disruptors of insect midgut membranes
  - 11A: *Bacillus thuringiensis*
  - 11B: *Bacillus sphaericus*

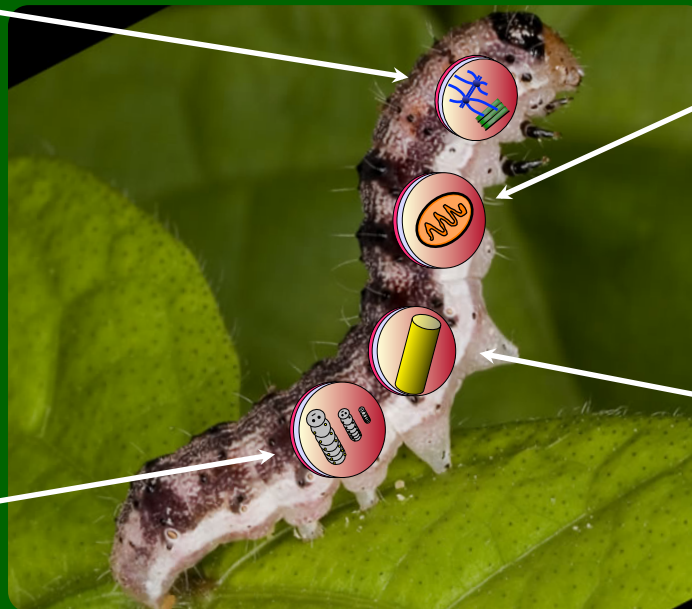
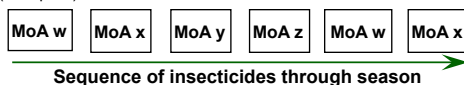
## Miscellaneous non-specific (multi-site) inhibitors

- Group 8 8A: Alkyl halides, 8B: Chloropicrin, 8C: Fluorides, 8D: Borates, 8E: Tartar emetic, 8F: Methyl isothiocyanate generators

## Effective IRM strategies: MoA Sequences & alternations

All effective insecticide resistance management (IRM) strategies seek to minimise the selection of resistance to any one type of insecticide. In practice, alternations, sequences or rotations of compounds from different MoA groups provide sustainable and effective IRM for pest insects. This ensures that selection from compounds in the same MoA group is minimised, and resistance is less likely to evolve.

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 species of concern. Local expert advice should always be followed with regard to spray windows and timings. Several sprays may be possible within each spray window but it is generally essential to ensure that successive generations of the pest are not treated with compounds from the same MoA group. Metabolic resistance mechanisms may give cross-resistance between MoA groups, and where this is known to occur, the above advice must be modified accordingly. IRAC also provides general recommendations for resistance management tactics regarding specific MoA groups, e.g. neonicotinoids (Group 4A).



## MoA Sequences & alternations – Exceptions

IRAC recommends alternations, sequences or rotations of compounds from different MoA groups to provide a sustainable and effective approach to IRM. Three groups (8, 13 and UN) are exempt from the recommendations as they do not contain compounds acting at a common target site

## Color Scheme Notes:

The color scheme used here 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.** The cross-resistance potential between sub-groups is higher than that between different groups, so rotation between sub-groups should only be used where effective registered insecticides from other MoA groups are unavailable.

## Respiration targets

- Group 12 Inhibitors of mitochondrial ATP synthesis
  - 12A: Diafenthiuron
  - 12B: Organotin miticides (e.g. Cyhexatin)
  - 12C: Propargite
  - 12D: Tetradifon
- Group 13 Uncouplers of oxidative phosphorylation via disruption of the proton gradient
  - 13: Pyroles (e.g. Chlorfenapyr), Dinitrophenols, (e.g. DNOC), Sulfuramid
- Group 20 Mitochondrial complex III electron transport inhibitors
  - 20A: Hydramethylnon
  - 20B: Acequinocyl
  - 20C: Fluacrypyrim
  - 20D: Bifenazate
- Group 21 Mitochondrial complex I electron transport inhibitors
  - 21A: METI acaricides & insecticides (e.g. Pyridaben)
  - 21B: Rotenone (Derris)
- Group 24 Mitochondrial complex IV electron transport inhibitors
  - 24A: Phosphides (e.g. Phosphine)
  - 24B: Cyanides (e.g. Sodium cyanide)
- Group 25 Mitochondrial complex II electron transport inhibitors
  - 25A: Beta-ketonitrile derivatives (e.g. Cyenopyrafen, Cyflumetofen)
  - 25B: Carboxanilides, (e.g. Pyflubumide)

## Growth & Development targets

- Group 7 Juvenile hormone mimics
  - 7A: Juvenile hormone analogues (e.g. Methoprene)
  - 7B: Fenoxycarb
  - 7C: Pyriproxyfen
- Group 10 Mite growth inhibitors
  - 10A: Clofentazine, Diflovidazin, Hexythiazox
  - 10B: Etoxazole
- Group 15 Inhibitors of chitin biosynthesis, Type 0
  - 15: Benzoylureas (e.g. Flufenoxuron, Novaluron)
- Group 16 Inhibitors of chitin biosynthesis, type 1
  - 16: Buprofezin
- Group 17 Moulting disruptors, Dipteran
  - 17: Cyromazine
- Group 18 Ecdysone receptor agonists
  - 18: Diacylhydrazines (e.g. Methoxyfenozide, Tebufenozide)
- Group 23 Inhibitors of acetyl CoA carboxylase
  - 23: Tetrionic & Tetramic acid derivatives (e.g. Spirodiclofen)

## Unknown

- Group UN Compounds of unknown or uncertain mode of action (e.g. Azadiractin, Benzoximate, Bromopropylate, Chinomethionat, Dicofof, Lime sulfur, Pyridalyl, Sulfur)