Insecticide Resistance Mode of Action Classification

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.

**Introduction**

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**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 concerned. 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).

**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: Cyclodiene Organochlorines (e.g. Endosulfan),
2B: Phenylpyrazoles (e.g. Fipronil),
2C: Pyrethroids (e.g. Cypermethrin),
2D: DDT, Methoxychlor

**Group 3** Sodium channel modulators
3A: Pyrethrins, Pyrethroids (e.g. Cypermethrin),
3B: SOD, GST, SARMs

**Group 4** Nicotinic acetylcholine receptor (nAChR) competitive modulators
4A: Neonicotinoids (e.g. Imidacloprid, Thiamethoxam),
4B: Pyrethroids (e.g. Sufloxaflor),
4C: pyrethroids (e.g. Sufloxaflor),
4D: Butoxide, Ruboxyl, Fluoro-1

**Group 5** Nicotinic acetylcholine receptor (nAChR) allosteric modulators
5: Pyrethrins (e.g. Spinosad, Spiretrolan)

**Group 6** Glutamate-gated chloride channel (GluCl) allosteric modulators
6: Avermectins, Milbemycins (e.g. Abamectin, Emamectin benzoate)

**Group 7** Chordotonal organ TRP channel modulators
7B: Pyridine azemethine derivatives (e.g. Pyrethrinone, Pyrflquinazone)

**Group 8** Nicotinic acetylcholine receptor (nAChR) channel blockers
8: Nereistoxin analogs (e.g. Cartap hydrochloride),
8B: Octopamine receptor agonists
8C: GABA-B, Alpha-7

**MIDGUT TARGETS**

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

**Group 12** Mitochondrial complex II electron transport inhibitors
12A: Dieldrin, Diflubenzuron, Hexythiazox
12B: Etoxazole

**Group 13** Mitochondrial complex I electron transport inhibitors
13A: METI amines & insecticides (e.g. Pyridaben),
13B: Roflubenzamide

**Group 14** Mitochondrial complex III electron transport inhibitors
14: Pyrethroids (e.g. Chlorfenapyr),
14A: Fluoracetamide,
14B: Pyridalyl

**Group 15** Mitochondrial complex IV electron transport inhibitors
15: Organophosphates (e.g. Phosmet)
15A: Chitin inhibitors (e.g. Chlorfenapyr),
15B: Fipronil

**Group 16** Inhibitors of chitin synthesis, type 1
16: Benzoxazoles (e.g. Flupyradifurone),
16A: Pyriproxyfen

**Group 17** Inhibitors of chitin synthesis, type 2
17: Pymetrozine

**Group 18** GABA-B, Alpha, 7 receptor agonists
18: Tebufenozide

**GROUP 19** Organics of unknown or uncertain mode of action (e.g. Azadirachtin,
19: Azadirachtin,
19A: Pyproxifen

**GROUP 20** Organics of uncertain mode of action (e.g. Benzoxazoles,
20A: Pyflunolvin,
20B: Benoxazol

**GROUP 21** Organics of uncertain mode of action (e.g. Benoxazol,
21A: Pyproxifen,
21B: Pymetrozine

**GROUP 22** Organics of uncertain mode of action (e.g. Pyflunolvin,
22A: Pyroxifen,
22B: Pyproxifen

**GROUP 23** Organics of uncertain mode of action (e.g. Pyproxifen,
23A: Pyproxifen,
23B: Pyproxifen

**GROUP 24** Organics of uncertain mode of action (e.g. Pyproxifen,
24A: Pyproxifen,
24B: Pyproxifen

**GROUP 25** Organics of uncertain mode of action (e.g. Pyproxifen,
25A: Pyproxifen,
25B: Pyproxifen

**GROUP 26** Organics of uncertain mode of action (e.g. Pyproxifen,
26A: Pyproxifen,
26B: Pyproxifen

**GROUP 27** Organics of uncertain mode of action (e.g. Pyproxifen,
27A: Pyproxifen,
27B: Pyproxifen

**GROUP 28** Organics of uncertain mode of action (e.g. Pyproxifen,
28A: Pyproxifen,
28B: Pyproxifen

**GROUP 29** Organics of uncertain mode of action (e.g. Pyproxifen,
29A: Pyproxifen,
29B: Pyproxifen

**GROUP 30** Organics of uncertain mode of action (e.g. Pyproxifen,
30A: Pyproxifen,
30B: Pyproxifen

**Unknown**

**Group UN** Compounds of unknown or uncertain mode of action (e.g. Azadirachtin,
UNA: Azadirachtin,
UNB: Azadirachtin

**Midgut Targets**

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

**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.