IRAC

Insecticide Resistance Action Committee

Mode of Action Classification

Group 1: Acetylcholinesterase (AChE) inhibitors (Only major representatives of the chemical sub-groups)

1A Carbamates: Aldicarb, Oxamyl, Methiocarb, Carbaryl, Thiodicarb, Methomyl, Carbofuran, Pirimicarb

1B Organophosphates: Acephate, Methamidophos, Fenitrothion, Chlorpyrifos, Profenofos, Malathion, Dimethoate, Triazophos

Group 2: GABA-gated chloride channel antagonists

2A Cyclodiene Organochlorines: Chlordane, Endosulfan

2B Phenylpyrazoles (Fiprole): Ethiprole, Fipronil

Group 3: Sodium channel modulators (Only major representatives of group 3A shown)

3A Pyrethroids Pyrethrins: Bifenthrin, Esfenvalerate, Permethrin, Deltamethrin, *lambda*-cyhalothrin, alpha-cypermethrin, Etofenprox, Tefluthrin

3B DDT, Methoxychlor: DDT, Methoxychlor

Group 4: Nicotinic acetylcholine receptor (nAChR) competitive modulators

4A Neonicotinoids: Acetamiprid, Dinotefuran, Nitenpyram, Imidacloprid, Thiamethoxam, Clothianidin, Thiacloprid

4B Nicotine: Nicotine

4C Sulfoximines: Sulfoxaflor

4D Butenolides: Flupyradifurone

4E Mesoionics: Triflumezopyrim

Group 5: Nicotinic acetylcholine receptor (nAChR) allosteric modulators - site I

5 Spinosyns: Spinetoram (Mixture of 1 2-Major and 1 2-Minor), Spinosad (Mixture of 1 2-Major and 1 2-Minor)

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

6 Avermectins & Milbemycins: Abamectin R1 = (Mixture of 1 2a, 1 2b), Emamectin benzoate R1 = (Mixture of 1 2a, 1 2b), Lepimectin, Milbemectin

Group 7: Juvenile hormone mimics

7A Juvenile hormone analogues: Hydroprene R1 = ethyl, R2 = H; Methoprene R1 = isopropyl, R2 = OCH3; Kinoprene R1 = propargyl, R2 = H

7B Fenoxycarb: Fenoxycarb

7C Pyriproxyfen: Pyriproxyfen

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

8A Alkyl halides: Methyl bromide (H_3C-Br), Chloropicrin (Cl_3C-NO_2)

8B Chloropicrin

8C Fluorides: Cryolite, Sulfuryl fluoride

8D Borates: Borax ($Na_2B_4O_7 \cdot 10H_2O$)

8E Tartar emetic

8F Methyl isothiocyanate generators: Dazomet, Metam

Group 9: Chordotonal organ TRPV channel modulators

9B Pyridine azomethine derivatives: Pymetrozine, Pyrifluquinazon

9D Pyropenes: Afidopyropen

Group 10: Mite growth inhibitors affecting CHS1

10A Clofentezine, Diflovidazin, Hexythiazox: Clofentezine, Diflovidazin, Hexythiazox

10B Etoxazole: Etoxazole

Group 11: Microbial disrupters of insect midgut membranes

{Includes transgenic crops expressing *Bacillus thuringiensis* toxins (however, specific genetics for resistance management strategies may be found in extension at means of action)}

Different *B.t.* products, strains and/or toxins within mixtures and/or rotations may be used together without compromising risk management.

Contact between certain species, *B.t.* microbial products and certain resistance management benefits for some pests. Consult product-specific recommendations.

* Where there are differences among the specific receptors within the midguts of target insects, transgenic crops containing certain combinations of these proteins provide resistance management benefits.

11A *Bacillus thuringiensis* and the insecticidal proteins produced: *B.t. israelensis*, *B.t. aizawai*, *B.t. kurstaki*, *B.t. tenebrionis*; Bt crop proteins*: Cry1Ab, Cry1Ac, Cry1Fa, Cry1A.105, Cry2Ab, Vip3A, mCry3A, Cry3Ab, Cry 3Bb, Cry34Ab1/Cry35Ab1

11B *Bacillus sphaericus*

Group 12: Inhibitors of mitochondrial ATP synthase

12A Diafenthiuron

12B Organotin miticides: Azocyclotin, Cyhexatin, Fenbutatin oxide

12C Propargite

12D Tetradifon

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

13 Pyrroles, Dinitrophenols, Sulfluramid: Chlorfenapyr, DNOC, Sulfluramid

Group 14: Nicotinic acetylcholine receptor (nAChR) channel blockers

14 Nereistoxin analogues: Bensultap, Cartap hydrochloride, Thiocyclam, Thiosultap-sodium

Group 15: Inhibitors of chitin biosynthesis affecting CHS1

(Only major representatives of group are shown)

15 Benzoylureas: Diflubenzuron, Flufenoxuron, Lufenuron, Novaluron, Teflubenzuron

Group 16: Inhibitors of chitin biosynthesis type 1

16 Buprofezin: Buprofezin

Group 17: Moulting disrupter, Dipteran

17 Cyromazine: Cyromazine

Group 18: Ecdysone receptor agonists

18 Diacylhydrazines: Chromafenozide, Halofenozide, Methoxyfenozide, Tebufenozide

Group 19: Octopamine receptor agonists

19 Amitraz: Amitraz

Group 20: Mitochondrial complex III electron transport inhibitors

20A Hydramethylnon: Hydramethylnon

20B Acequinocyl: Acequinocyl

20C Fluacrypyrim: Fluacrypyrim

20D Bifenazate: Bifenazate

Group 21: Mitochondrial complex I electron transport inhibitors

21A METI acaricides and insecticides: Fenazaquin, Pyridaben, Pyrimidifen, Tebufenpyrad, Tolfenpyrad, Fenpyroximate

21B Rotenone: Rotenone

Group 22: Voltage-dependent sodium channel blockers

22A Oxadiazines: Indoxacarb

22B Semicarbazones: Metaflumizone

Group 23: Inhibitors of acetyl CoA carboxylase

23 Tetronic & Tetramic acid derivatives: Spirodiclofen, Spiromesifen, Spirotetramat, Spiropidion

Group 24: Mitochondrial complex IV electron transport inhibitors

24A Phosphides: Aluminium phosphide (AlP), Calcium phosphide (Ca_3P_2), Zinc phosphide (Zn_3P_2), Phosphine (PH_3)

24B Cyanides: Calcium cyanide (CN-)

Group 25: Mitochondrial complex II electron transport inhibitors

25A beta-Ketonitrile derivatives: Cyenopyrafen

25B Carboxanilides: Cyflumetofen, Pyflubumide

Group 28: Ryanodine receptor modulators

28 Diamides: Chlorantraniliprole R=Cl, Cyantraniliprole R=CN, Flubendiamide, Cyclaniliprole, Tetraniliprole

29: Chordotonal organ modulators - undefined target site

29 Flonicamid: Flonicamid

30: GABA-gated chloride channel allosteric modulators

Meta-diamides & isoxazolines: Broflanilide, Fluxametamide

31 Baculoviruses

Granuloviruses & Nucleopolyhedroviruses: *Cydia pomonella* GV, *Thaumatotibia leucotreta* GV, *Anticarsia gemmatalis* MNPV, *Helicoverpa armigera* NPV

32 Nicotinic Acetylcholine Receptor (nAChR) Allosteric Modulators Site II

GS-omega/kappa HXTX-Hv1a peptide

Group UN: Compounds of unknown or uncertain mode of action

Azadirachtin, Bromopropylate, Chinomethionat, Dicofol, Benzoximate, Mancozeb, Pyridalyl, S (Lime sulfur) CaSx Sulfurs

UNB	UNE	UNF	UNM
Bacterial agents (non-Bt) of unknown or uncertain MoA	Botanical essence including synthetic, extracts and crude/red oils with unknown or uncertain MoA	Fungal agents of unknown or uncertain MoA	Non-specific mechanical disruptors
Burkholderia spp, *Wolbachia pipientis* (Zap)	*Chenopodium ambrosioides near ambrosioides* extract; Fatty acid monoesters with glycerol or propanediol; Neem oil	*Beauveria bassiana* strains; *Metarhizium anisopliae* strain F52; *Paecilomyces fumosoroseus* Apopka strain 97	Diatomaceous earth

Key to Targeted Physiology

Nerve & Muscle; Growth & Development; Respiration; Midgut; Unknown or Non-specific

Use of Groups and Sub-Groups:

- Alternations, sequences or rotations of compounds between MoA groups reduce selection for target site resistance.
- Applications are arranged into MoA spray windows defined by crop growth stage and pest biology.
- Several sprays of a compound may be possible within each spray window, but successive generations of a pest should not be treated with compounds from the same MoA group.
- Local expert advice should always be followed with regard to spray windows and timing.
- Groups in the classification whose members do not act at a common target site are exempt from the presumption against rotation within the group. These are: Group 8, Group 13 and all the UN groups: UNB, UNE, UNF, UNM.
- Sub-groups represent distinct structural classes which are believed to have the same mode of action.
- Sub-groups provide differentiation between compounds that may bind at the same target site but are structurally different enough that risk of metabolic cross-resistance is lower than for close chemical analogs.
- Cross-resistance potential between sub-groups is higher than between groups, so rotation between sub-groups should be considered only when there are no alternatives, and only if cross resistance does not exist, following consultation with local expert advice. These exceptions are not sustainable, and alternative options should be sought.
- Sub group 3B: DDT is no longer used in agriculture and therefore this is only applicable for the control of insect vectors of human disease, such as mosquitoes, because of a lack of alternatives.
- Sub group 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.

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Poster Notes:

- Groups 26 and 27 are unassigned.
- This poster is for educational purposes only. Information presented is accurate to the best of our knowledge at the time of publication, but IRAC or its member companies cannot accept responsibility for how this information is used or interpreted. Advice should always be sought from local experts or advisors, and health and safety recommendations followed.
- In some cases only representative compounds in Groups are shown where indicated.
- Please visit www.irac-online.org for the complete IRAC classification.

CropLife International

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