Mode of Action Classification

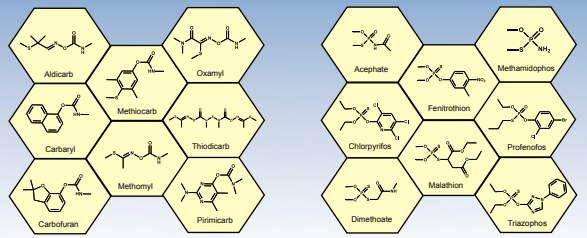
IRAC

Insecticide Resistance Action Committee

The Key to Resistance Management

- Successive generations of a pest should not be treated with compounds from the same MoA Group.
- Not all of the current groupings are based on knowledge of a shared target protein. For further information, please refer to the IRAC Mode of Action Classification document.
- 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.

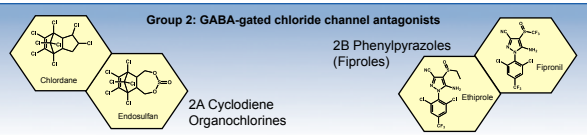
Group 1: Acetylcholinesterase (AChE) inhibitors (Only major representatives of the groups are shown)



1A Carbamates

1B Organophosphates

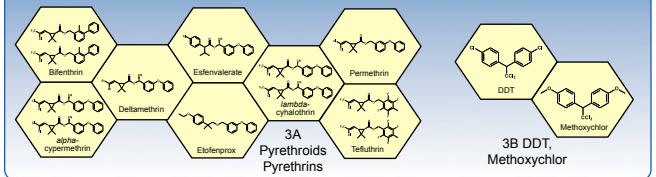
Group 2: GABA-gated chloride channel antagonists



2A Cyclodiene Organochlorines

2B Phenylpyrazoles (Fiproles)

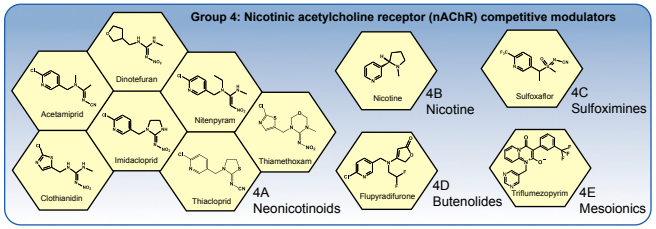
Group 3: Sodium channel modulators (Only major representatives of group 3A are shown)



3A Pyrethroids Pyrethrins

3B DDT, Methoxychlor

Group 4: Nicotinic acetylcholine receptor (nAChR) competitive modulators



4A Neonicotinoids

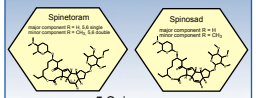
4B Nicotine

4C Sulfoximines

4D Butenolides

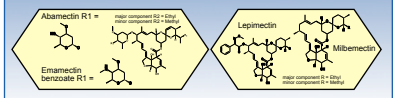
4E Mesoionics

Group 5: Nicotinic acetylcholine receptor (nAChR) allosteric modulators



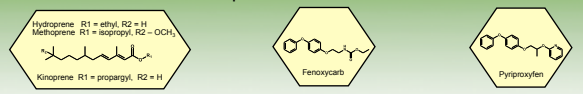
5 Spinosyns

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



6 Avermectins, Milbemycins

Group 7: Juvenile hormone mimics

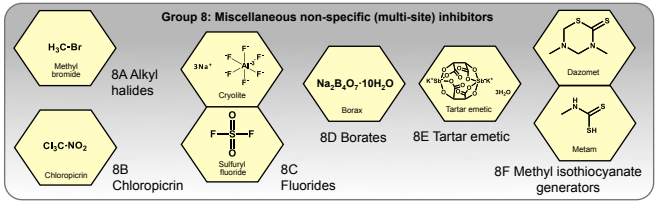


7A Juvenile hormone analogues

7B Fenoxycarb

7C Pyriproxyfen

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



8A Alkyl halides

8B Chloropicrin

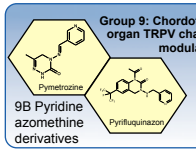
8C Fluorides

8D Borates

8E Tartar emetic

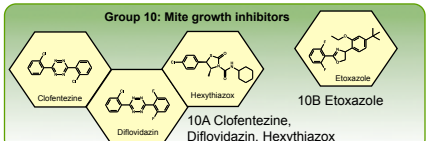
8F Methyl isothiocyanate generators

Group 9: Chordotonal organ TRPV channel modulators



9B Pyridine azomethine derivatives

Group 10: Mite growth inhibitors



10A Clofentezine, Diflovidazin, Hexythiazox

10B Etoxazole

Group 11: Microbial disruptors of insect midgut

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)

Different *B.t.* products that target different insect orders may be used together without compromising their resistance management.

Rotation between certain specific *B.t.* microbial products may provide 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.

Bacillus thuringiensis and the insecticidal proteins produced *B.t. israelensis*, *B.t. aizawai*, *B.t. kurstaki*, *B.t. tenebrionis*

Bt crop proteins *

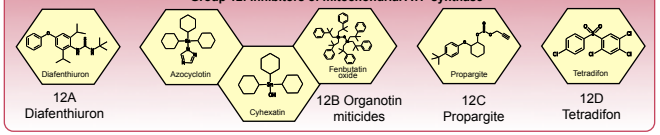
Cry1Ab, Cry1Ac, Cry1Fa, Cry1A.105, Cry2Ab, Vip3A, mCry3A, Cry3Ab, Cry 3Bb, Cry34Ab1/Cry35Ab1

11A *Bacillus thuringiensis*

Bacillus sphaericus

11B *Bacillus sphaericus*

Group 12: Inhibitors of mitochondrial ATP synthase



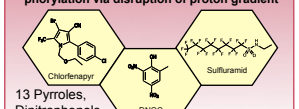
12A Diafenthiuron

12B Organotin miticides

12C Propargite

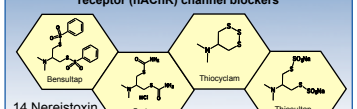
12D Tetradifon

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



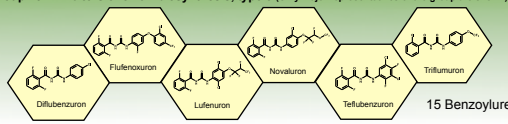
13 Pyrroles, Dinitrophenols, Sulfluramid

Group 14: Nicotinic acetylcholine receptor (nAChR) channel blockers



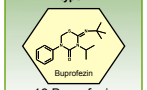
14 Nereistoxin analogues

Group 15: Inhibitors of chitin biosynthesis, type 0 (Only major representatives of the group are shown)



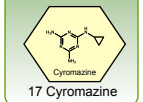
15 Benzoylureas

Group 16: Inhibitors of chitin biosynthesis, type 1



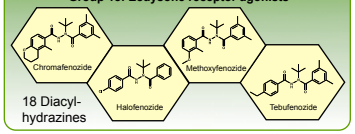
16 Buprofezin

Group 17: Moulting disruptors, Dipteran



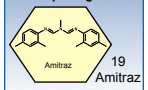
17 Cyromazine

Group 18: Ecdysone receptor agonists



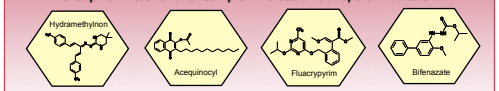
18 Diacylhydrazines

Group 19: Octopamine receptor agonists



19 Amitraz

Group 20: Mitochondrial complex III electron transport inhibitors



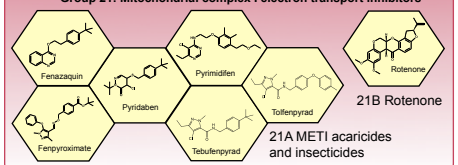
20A Hydramethylnon

20B Acequinocyl

20C Fluacrypyrim

20D Bifenazate

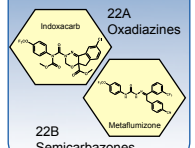
Group 21: Mitochondrial complex I electron transport inhibitors



21A METI acaricides and insecticides

21B Rotenone

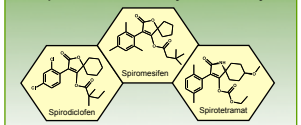
Group 22: Voltage-dependent sodium channel blockers



22A Oxadiazines

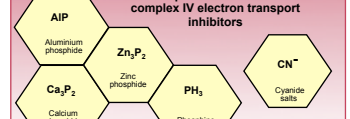
22B Semicarbazones

Group 23: Inhibitors of acetyl CoA carboxylase



23 Tetronic & Tetramic acid derivatives

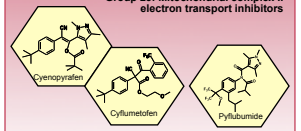
Group 24: Mitochondrial complex IV electron transport inhibitors



24A Phosphides

24B Cyanides

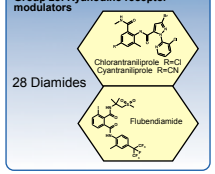
Group 25: Mitochondrial complex II electron transport inhibitors



25A *beta*-Ketonitrile derivatives

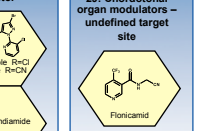
25B Carboxanilides

Group 28: Ryanodine receptor modulators

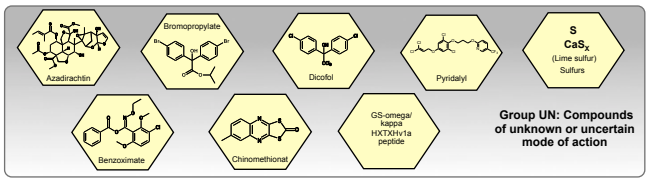


28 Diamides

29: Chordotonal organ modulators – undefined target site



29 Flonicamid



Group UN: Compounds of unknown or uncertain mode of action

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 reduces 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.
- Actives in groups 8 (Miscellaneous non-specific multi-site inhibitors), 13 (Uncouplers) and UN 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.
- Sub-groups represent distinct structural classes 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-group10A: Hexythiazox is grouped with clofentezine because they exhibit cross-resistance even though they are structurally distinct, and the target site for these compounds is unknown. 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.

Poster Notes:

- Groups 26 and 27 are unassigned.
- The 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.
- Representative compounds are shown. Please visit www.irac-online.org for the complete IRAC classification.

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