Mode of Action Classification

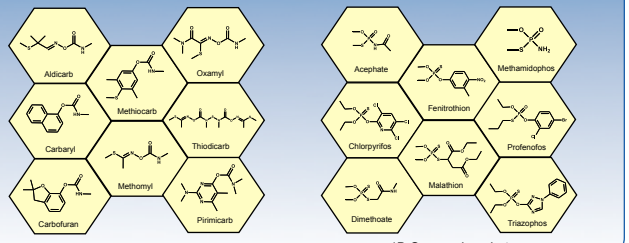
IRAC

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.

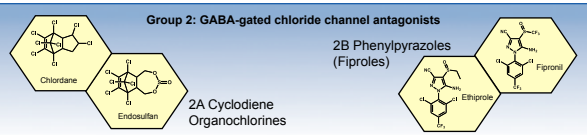
Group 1: Acetylcholinesterase (AChE) inhibitors (Only major representatives of the groups are shown)



1A Carbamates

1B Organophosphates

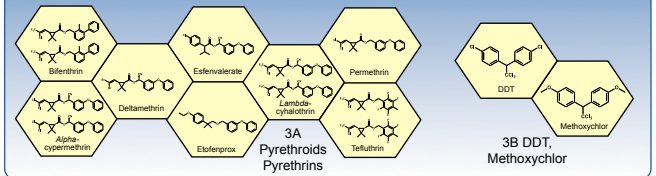
Group 2: GABA-gated chloride channel antagonists



2A Cyclodiene Organochlorines

2B Phenylpyrazoles (Fiproles)

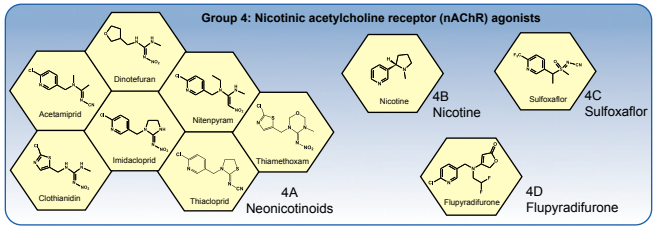
Group 3: Sodium channel modulators (Only major representatives of group 3A are shown)



3A Pyrethroids Pyrethrins

3B DDT, Methoxychlor

Group 4: Nicotinic acetylcholine receptor (nAChR) agonists



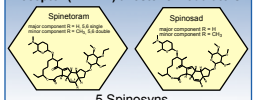
4A Neonicotinoids

4B Nicotine

4C Sulfoxaflor

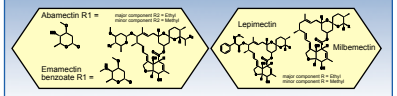
4D Flupyradifurone

Group 5: Nicotinic acetylcholine receptor (nAChR) allosteric modulators



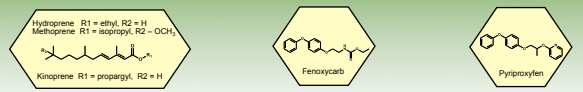
5 Spinosyns

Group 6: Chloride channel activators



6 Avermectins, Milbemycins

Group 7: Juvenile hormone mimics

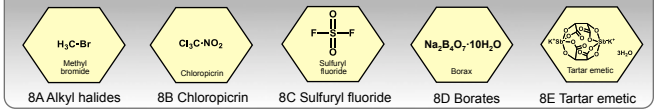


7A Juvenile hormone analogues

7B Fenoxycarb

7C Pyriproxyfen

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



8A Alkyl halides

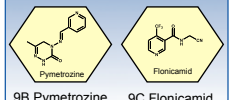
8B Chloropicrin

8C Sulfuryl fluoride

8D Borates

8E Tartar emetic

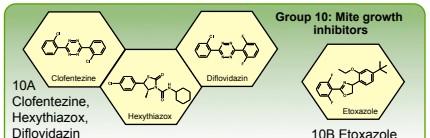
Group 9: Modulators of Chordotonal Organs



9B Pymetrozine

9C Flonicamid

Group 10: Mite growth inhibitors



10A Clofentezine, Hexythiazox, Diflovidazin

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 *

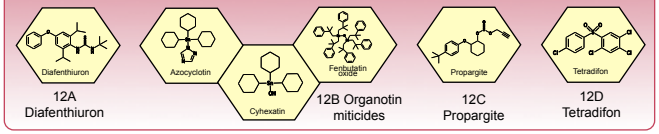
Cry1Ab, Cry1Ac, Cry1Fa, Cry1A.105, Cry2Ab, Vip3A, mCry3A, Cry3Ab, Cry 3Bb, Cry34Ab1/Cry35Ab1

11A *Bacillus thuringiensis*

Bacillus sphaericus

11B *Bacillus sphaericus*

Group 12: Inhibitors of mitochondrial ATP synthase



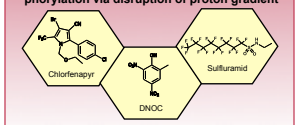
12A Diafenthiuron

12B Organotin miticides

12C Propargite

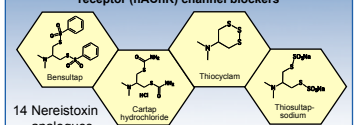
12D Tetradifon

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



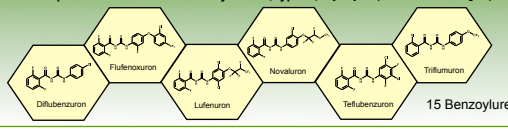
13 Pyrroles, Dinitrophenols, Sulfluramid

Group 14: Nicotinic acetylcholine receptor (nAChR) channel blockers



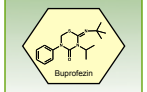
14 Nereistoxin analogues

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



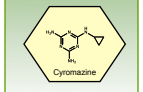
15 Benzoylureas

Group 16: Inhibitors of chitin biosynthesis, type 1



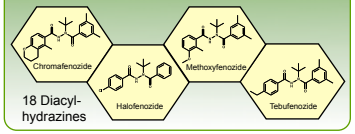
16 Buprofezin

Group 17: Moulting disruptor, Dipteran



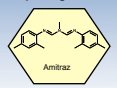
17 Cyromazine

Group 18: Ecdysone receptor agonists



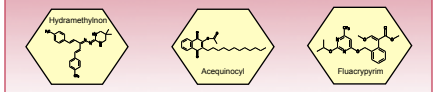
18 Diacylhydrazines

Group 19: Octopamine receptor agonists



19 Amitraz

Group 20: Mitochondrial complex III electron transport inhibitors

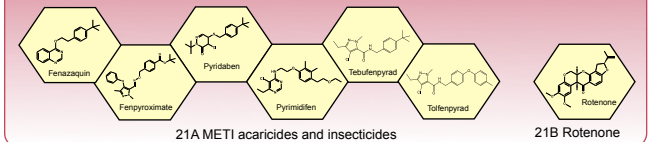


20A Hydramethylnon

20B Acequinocyl

20C Fluacrypyrim

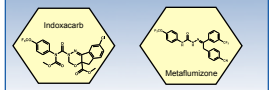
Group 21: Mitochondrial complex I electron transport inhibitors



21A METI acaricides and insecticides

21B Rotenone

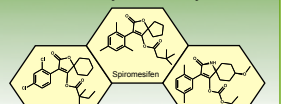
Group 22: Voltage-dependent sodium channel blockers



22A Indoxacarb

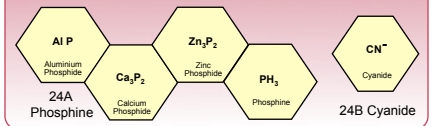
22B Metaflumizone

Group 23: Inhibitors of acetyl CoA carboxylase



23 Tetronic & Tetramic acid derivatives

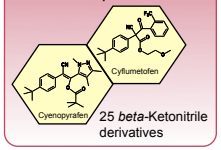
Group 24: Mitochondrial complex IV electron transport inhibitors



24A Phosphine

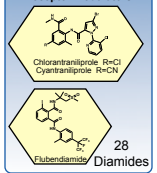
24B Cyanide

Group 25: Mitochondrial complex II electron transport inhibitors



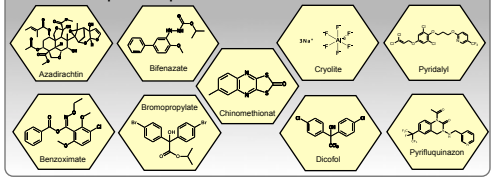
25 *beta*-Ketonitrile derivatives

Group 28: Ryanodine receptor modulators



28 Diamides

Group UN: Compounds of unknown or uncertain mode of action



Targeted Physiology

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

Guidance on the use of Sub-Groups:

- Represent distinct structural classes believed to have the same mode of action.
- 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.
- 3B: DDT is no longer used in agriculture and therefore this is only applicable for the control of human disease vectors such as mosquitoes, because of a lack of alternatives.
- 4A, 4B, 4C, 4D: Although these compounds are believed to have the same target site, current evidence indicates that the risk of metabolic cross-resistance between sub-groups is low.
- 10A - 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.
- 22A & 22B - Although these compounds are believed to have the same target site, they have been sub-grouped because they are chemically distinct, and current evidence indicates that the risk of metabolic cross-resistance is low.
- 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.

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.
- For further information visit the IRAC website: www.irac-online.org

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CropLife