BASF

The Chemical Company

Complete IRAC Classification of Insecticide Modes of Action

Grouping of insecticides by mode of action is the cornerstone of effective resistance management. The Insecticide Resistance Action Committee (IRAC) is an international group of experts from the crop protection industry that was formed in 1984 to provide advice on the prevention and management of resistance in arthropod pests. IRAC publishes and maintains a classification of insecticides and miticides, based on mode of action, that has become the de facto standard, and provides the framework for this guide. As of 2013, there are 27 insecticide MoA groups, numbered 1-25, 28 and UN. The current version of the classification can be obtained from the IRAC Web site: *www.irac-online.org.*

Neuromuscular Disruptors

1* AChE inhibitors

- **1a Carbamates**: Aldicarb, Benfuracarb, Carbaryl, Carbofuran, Carbosulfan, Fenobucarb, Methiocarb, Methomyl, Oxamyl, Thiodicarb, Triazamate
- **1b Organophosphates**: Acephate, Chlorpyrifos, Dimethoate, Diazinon, Malathion, Methamidophos, Monocrotophos, Parathion-methyl, Profenofos, Terbufos

2* GABA-gated chloride channel antagonists

- **2a Cyclodiene Organochlorines**: Chlordane, Endosulfan
- **2b Phenylpyrazoles (Fiproles)**: Ethiprole, Fipronil

3* Sodium channel modulators

- **3a Pyrethroids Pyrethrins**: Bifenthrin, Cyfluthrin, Cypermethrin, *Alpha*-cypermethrin, *Zeta*-cypermethrin, Deltamethrin, Esfenvalerate, Etofenprox, *Lambda*-cyhalothrin, Tefluthrin, Pyrethrins (Pyrethrum)
- **3b DDT, Methoxychlor**: DDT, Methoxychlor

4* Nicotinic acetylcholine receptor (nAChR) agonists

- **4a Neonicotinoids**: Acetamiprid, Clothianidin, Dinotefuran, Imidacloprid, Nitenpyram, Thiacloprid, Thiamethoxam
- **4b Nicotine**
- **4c Sulfoxaflor**

5* Nicotinic acetylcholine receptor (nAChR) allosteric modulators - spinosyns

Spinetoram, Spinosad

6* Chloride channel activators - avermectins, milbemycins

Abamectin, Emamectin benzoate, Lepimectin, Milbemectin

9 Selective homopteran feeding blockers

- **9b Pymetrozine**: Pymetrozine
- **9c Flonicamid**

14 Nicotinic acetylcholine receptor (nAChR) channel blockers

Bensultap, Cartap hydrochloride, Thiocyclam, Thiosultap-sodium

19 Octopamine receptor agonists

Amitraz

22 Voltage-dependent sodium channel blockers

- **22a Indoxacarb**
- **22b Metaflumizone**

28* Ryanodine receptor modulators

Diamides: Cyantraniliprole, Chlorantraniliprole, Flubendiamide

Growth and Development Disruptors

7* Juvenile hormone mimics

- **7a Juvenile hormone analogues**: Hydroprene, Methoprene, Kinoprene
- **7b Fenoxycarb**
- **7c Pyriproxyfen**

10* Mite growth inhibitors

- **10a Clofentezine Hexythiazox**: Clofentezine, Hexythiazox, Diflovidazin
- **10b Etoxazole**

15 Inhibitors of chitin biosynthesis, type 0

Benzoylureas: Bistrifluron, Chlorfluazuron, Diflubenzuron, Flucycloxuron, Flufenoxuron, Hexaflumuron, Lufenuron, Novaluron, Noviflumuron, Teflubenzuron,Triflumuron

16 Inhibitors of chitin biosynthesis, type 1

Buprofezin

17 Molting disruptor, dipteran

Cyromazine

18 Ecdysone receptor agonists

Diacylhydrazines: Chromafenozide, Halofenozide, Methoxyfenozide, Tebufenozide

23* Inhibitors of acetyl CoA carboxylase

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

Respiration Disruptors

12 Inhibitors of mitochondrial ATP synthase

- **12a Diafenthiuron**
- **12b Organotin miticides**: Azocyclotin, Cyhexatin, Fenbutatin oxide
- **12c Propargite**
- **12d Tetradifon**

13 Uncouplers of oxidative phosphorylation via disruption of the proton gradient

Chlorfenapyr, DNOC, Sulfluramid

20* Mitochondrial complex III electron transport inhibitors

- **20a Hydramethylnon**
- **20b Acequinocyl**
- **20c Fluacrypyrim**

21 Mitochondrial complex I electron transport inhibitors

- **21a METI acaricides and insecticides**: Fenazaquin, Fenpyroximate, Pyridaben, Pyrimidifen, Tebufenpyrad, Tolfenpyrad
- **21b Rotenone**

24 Mitochondrial complex IV electron transport inhibitors

- **24a Phosphine**: Aluminum Phosphide, Calcium Phosphide, Zinc Phosphide, Phosphine
- **24b Cyanide**

25 Mitochondrial complex II electron transport inhibitors

24a beta-Ketonitrile derivatives: Cyenopyrafen, Cyflumetofen

Gut Disruptors

11* Microbial disruptors of insect midgut membranes

- **11a *Bacillus thuringiensis***
- **11b *Bacillus sphaericus***

Miscellaneous

8 Miscellaneous non-specific (multi-site) inhibitors

- **8a Alkyl halides**: Methyl bromide
- **8b Chloropicrin**
- **8c Sulfuryl fluoride**
- **8d Borates**
- **8e Tartar emetic**

UN. Compounds of unknown or uncertain mode of action

- Azadirachtin
- Bifenazate
- Benzoximate
- Chinomethionat
- Cryolite
- Dicofol
- Pyridalyl
- Pyrifluquinazon

Type of Target Protein

- Ion Channel
- Enzyme
- G-Protein-Coupled Receptor
- Nuclear Receptor
- Ionophore (no target)
- Unknown Target
- Cell Adhesion Proteins (for Bt)

*** Indicates groups where target site resistance is known**

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