

# Mode of Action Classification

Edition: 10.6

Now including Nematicides



Insecticide Resistance Action Committee



# The Insecticide Resistance Action Committee

Mode of Action Classification Brochure

Edition: 10.6 – September 2023

Based on the IRAC MoA Classification Version 10.5 and  
Nematicide MoA Classification Version 2.1

**Disclaimer:** While CropLife International and IRAC make every effort to present accurate and reliable information, they do not guarantee the accuracy, completeness, efficacy, timeliness, or correct sequencing of such information. Inclusion of active ingredients on the IRAC Code Lists is based on scientific evaluation of their modes of action; it does not provide any kind of testimonial for the use of a product or a judgment on efficacy. CropLife International and IRAC are not responsible for, and expressly disclaim all liability for, damages of any kind arising out of use, reference to, or reliance on information provided. Listing of chemical classes or modes of action must not be interpreted as approval for use of a compound in a given country. Prior to implementation, each user must determine the current registration status in the country of use and strictly adhere to the uses and instructions approved in that country.

## Foreword

Effective insecticide resistance management (IRM) in conjunction with integrated pest management (IPM) is vital to global crop protection, sustainable agriculture and improved public health, and it is an essential element of responsible product stewardship.

The Insecticide Resistance Action Committee (IRAC) was formed in 1984 and works as a specialist technical group of the industry association CropLife International, to provide a coordinated crop protection industry response to prevent or delay the development of resistance in insect, mite and nematode pests. There are now IRAC country group committees in many parts of the world, researching and responding to local resistance issues, as well as the parent IRAC International group, which provides a coordinating and supporting role at the global level (see also [www.irc-online.org](http://www.irc-online.org)).

Developing new products is becoming increasingly difficult and costly, so it is vital to protect those effective products in the marketplace from the development of resistance. Moreover, with fewer new products being discovered and regulatory pressures reducing the number of older commercial control methods available, the 'toolbox' of usable products is being reduced, making effective IRM more important than ever. The Mode of Action Classification Scheme is a key part of IRAC's global resistance management strategy.

# Insecticide/Acaricide MoA Classification



The CropLife and IRAC member companies support the inclusion of MoA information on product labels which will ensure growers have simple access to critical information to support implementation of resistance management. Further details on MoA Labelling Guidance can be found on the CropLife website under Resources (<https://croplife.org/resources/>)

## Mode of Action Classification

IRAC promotes the use of a Mode of Action (MoA) Classification of insecticides and acaricides as the basis for effective and sustainable resistance management. Actives are allocated to specific groups based on their target site. Reviewed and re-issued periodically, the IRAC MoA Classification Scheme provides farmers, growers, advisors, extension staff, consultants and crop protection professionals with a guide to the selection of acaricides and insecticides in resistance management programs. Effective resistance management of this type preserves the utility and diversity of available insecticides and acaricides. A complete list of the different MoA groups is shown in the following pages, followed by a breakdown of MoAs available for Lepidoptera, aphids, whitefly, plant- and leafhoppers, mites and mosquitoes. For further information, please refer to the full IRAC MoA Classification Scheme on the IRAC website ([www.ircac-online.org](http://www.ircac-online.org)).

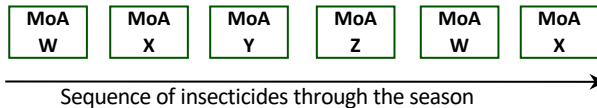
## What is Resistance?

Resistance to insecticides may be defined as *'a heritable change in the sensitivity of a pest population that is reflected in the repeated failure of a product to achieve the expected level of control when used according to the label recommendation for that pest species'* (IRAC). Resistance arises through the over-use or misuse of an insecticide or acaricide against a pest species, and results in the Darwinian selection of resistant forms of the pest and the consequent evolution of populations that are resistant to that insecticide or acaricide.

## Effective IRM Strategies: Sequences or Alternations of MoA

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 insect and mite pests. This ensures that selection from compounds in the same MoA group is minimised, and resistance is less likely to evolve.

Example:



Applications are often arranged into MoA spray windows or blocks that are defined by the stage of crop development, together with the biology and phenology of the species of concern. Local expert advice should always be followed with regard to spray windows and timing. Several sprays may be possible within each spray window, but it is generally essential that successive generations of the pest are not treated with compounds from the same MoA group. IRAC also offers specific recommendations for some MoA groups. Metabolic resistance mechanisms may give cross-resistance between MoA groups; where this is known to occur, the above advice should be modified accordingly. For further information on the use of MoA groups and sub-groups, please see the notes at the end of the brochure and in the full MoA Classification Scheme.

# IRAC Mode of Action Classification Scheme (Classification Version 10.6)

Targeted Physiology: ■ Nerve & Muscle ■ Growth & Development ■ Respiration ■ Midgut ■ Unknown or Non-specific

Note: Rotations for resistance management should be based only on the numbered mode of action groups - see table footnotes for details

| Main Group/Primary Site of Action   | Subgroup, class or Exemplifying active | Active Ingredients   |
|---|--|--|
| <b>1 Acetylcholinesterase (AChE) inhibitors</b><br><br><i>See footnotes for further information on use of compounds between sub-groups.</i> | <b>1A</b> Carbamates                   | Alanycarb, Aldicarb, Bendiocarb, Benfuracarb, Butocarboxim, Butoxycarboxim, Carbaryl, Carbofuran, Carbosulfan, Ethiofencarb, Fenobucarb, Formetanate, Furathiocarb, Isoprocarb, Methiocarb, Methomyl, Metolcarb, Oxamyl, Pirimicarb, Propoxur, Thiodicarb, Thiofanox, Triazamate, Trimethacarb, XMC, Xyllycarb   |
|   | <b>1B</b> Organophosphates             | Acephate, Azamethiphos, Azinphos-ethyl, Azinphos-methyl, Cadusafos, Chlorethoxyfos, Chlorfenvinphos, Chlormephos, Chlorpyrifos, Chlorpyrifos-methyl, Coumaphos, Cyanophos, Demeton-S-methyl, Diazinon, Dichlorvos/DDVP, Dicrotophos, Dimethoate, Dimethylvinphos, Disulfoton, EPN, Ethion, Ethoprophos, Famphur, Fenamiphos, Fenitrothion, Fenthion, Fosthiazate, Heptenophos, Imicyafos, Isofenphos, Isopropyl O-(methoxyaminothiophosphoryl) salicylate, Isoxathion, Malathion, Mecarbam, Methamidophos, Methidathion, Mevinphos, Monocrotophos, Naled, Omethoate, Oxydemeton-methyl, Parathion, Parathion-methyl, Phenthoate, Phorate, Phosalone, Phosmet, Phosphamidon, Phoxim, Pirimiphos-methyl, Profenofos, Propetamphos, Prothiofos, Pyraclofos, Pyridaphenthion, Quinalphos, Sulfotep, Tebupirimfos, Temephos, Terbufos, Tetrachlorvinphos, Thiometon, Triazophos, Trichlorfon, Vamidothion |
| <b>2 GABA-gated chloride channel blockers</b>   | <b>2A</b> Cyclodiene organochlorines   | Chlordane, Endosulfan  |
|   | <b>2B</b> Phenylpyrazoles (Fiproles)   | Ethiprole, Fipronil  |

|   |   |   |
|---|---|---|
| <p><b>3 Sodium channel modulators</b></p> <p><i>See footnotes for further information on use of compounds between sub-groups.</i></p>                                       | <p><b>3A</b> Pyrethroids<br/>Pyrethrins</p> | <p>Acrinathrin, Allethrin, d-<i>cis</i>-trans Allethrin, d-<i>trans</i> Allethrin, Bifenthrin, Bioallethrin, Bioallethrin S-cyclopentenyl, Bioresmethrin, Cycloprothrin, Cyfluthrin, <i>beta</i>-Cyfluthrin, Cyhalothrin, <i>lambda</i>-Cyhalothrin, <i>gamma</i>-Cyhalothrin, Cypermethrin, <i>alpha</i>-Cypermethrin, <i>beta</i>-Cypermethrin, <i>theta</i>-cypermethrin, <i>zeta</i>-Cypermethrin, Cyphenothrin [(1<i>R</i>)-<i>trans</i>- isomers], Deltamethrin, Empenthrin [(<i>EZ</i>)- (1<i>R</i>)- isomers], Esfenvalerate, Etofenprox, Fenpropathrin, Fenvalerate, Flucythrinate, Flumethrin, <i>tau</i>-Fluvalinate, Halfenprox, Imiprothrin, Kadethrin, Permethrin, Phenothrin [(1<i>R</i>)-<i>trans</i>- isomer], Prallethrin, Pyrethrins (pyrethrum), Resmethrin, Silafluofen, Tefluthrin, Tetramethrin, Tetramethrin [(1<i>R</i>)-isomers], Tralomethrin, Transfluthrin</p> |
| <p><b>4 Nicotinic acetylcholine receptor (nAChR) competitive modulators</b></p> <p><i>See footnotes for further information on use of compounds between sub-groups.</i></p> | <p><b>3B</b> DDT<br/>Methoxychlor</p>       | <p>DDT<br/>Methoxychlor</p>   |
| <p><b>5 Nicotinic acetylcholine receptor (nAChR) allosteric modulators - Site I</b></p>   | <p><b>4A</b> Neonicotinoids</p>             | <p>Acetamiprid, Clothianidin, Dinotefuran, Imidacloprid, Nitenpyram, Thiocloprid, Thiamethoxam</p>  |
| <p><b>6 Glutamate-gated chloride channel (GluCl) allosteric modulators</b></p>  | <p><b>4B</b> Nicotine</p>                   | <p>Nicotine</p>   |
| <p></p>   | <p><b>4C</b> Sulfoximines</p>               | <p>Sulfoxaflor</p>  |
| <p></p>   | <p><b>4D</b> Butenolides</p>                | <p>Flupyradifurone</p>  |
| <p></p>   | <p><b>4E</b> Mesoionics</p>                 | <p>Triflumezopyrim, Dicloromezotiaz</p>   |
| <p></p>   | <p><b>4F</b> Pyridylidenes</p>              | <p>Flupyrimin</p>   |
| <p></p>   | <p>Spinosyns</p>                            | <p>Spinetoram, Spinosad</p>   |
| <p></p>   | <p>Avermectins,<br/>Milbemycins</p>         | <p>Abamectin, Emamectin benzoate, Lepimectin, Milbemectin</p>   |

| Main Group/Primary Site of Action   | Subgroup, class or Exemplifying active                 | Active Ingredients   |
|---|--|--|
| <b>7 Juvenile hormone Receptor Modulators</b>   | <b>7A</b> Juvenile hormone analogues                   | Hydroprene, Kinoprene, Methoprene  |
|   | <b>7B</b> Fenoxycarb                                   | Fenoxycarb   |
|   | <b>7C</b> Pyriproxyfen                                 | Pyriproxyfen   |
| <b>8 Miscellaneous non-specific (multi-site) inhibitors</b>   | <b>8A</b> Alkyl halides                                | 1,3 dichloropropene, Methyl bromide and other alkyl halides              |
|   | <b>8B</b> Chloropicrin                                 | Chloropicrin   |
|   | <b>8C</b> Fluorides                                    | Cryolite (Sodium aluminum fluoride), Sulfuryl fluoride                   |
|   | <b>8D</b> Borates                                      | Borax, Boric acid, Disodium octaborate, Sodium borate, Sodium metaborate |
|   | <b>8E</b> Tartar emetic                                | Tartar emetic  |
|   | <b>8F</b> Methyl isothiocyanate generators             | Dazomet, Metam, Methyl isothiocyanate                                    |
| <b>9 Chordotonal organ TRPV channel modulators</b>  | <b>9B</b> Pyridine azomethine derivatives              | Pymetrozine, Pyrfluquinazon  |
|   | <b>9D</b> Pyropenes                                    | Afidopyropen   |
| <b>10 Mite growth inhibitors affecting CHS1</b><br><i>10A Sub-grouping information in footnotes</i> | <b>10A</b> Clofentezine<br>Diflovidazin<br>Hexythiazox | Clofentezine, Diflovidazin, Hexythiazox                                  |
|   | <b>10B</b> Etoxazole                                   | Etoxazole  |

|  |  |   |
|--|--|---|
| <b>11 Microbial disruptors of insect midgut membranes</b>                                | <b>11A</b> <i>Bacillus thuringiensis</i> and the insecticidal proteins they produce<br><br><i>See footnotes for further sub-grouping information</i> | <i>Bacillus thuringiensis</i> subsp. <i>israelensis</i><br><i>Bacillus thuringiensis</i> subsp. <i>aizawai</i><br><i>Bacillus thuringiensis</i> subsp. <i>kurstaki</i><br><i>Bacillus thuringiensis</i> subsp. <i>tenebrionis</i><br><br><i>Bt</i> crop proteins: (see footnote)<br>Cry1Ab, Cry1Ac, Cry1Fa, Cry1A.105, Cry2Ab, Vip3A, mCry3A, Cry3Ab, Cry3Bb, Cry34Ab1/Cry35Ab1 |
|  | <b>11B</b> <i>Bacillus sphaericus</i>  | <i>Bacillus sphaericus</i>  |
| <b>12 Inhibitors of mitochondrial ATP synthase</b>                                       | <b>12A</b> Diafenthiuron   | Diafenthiuron   |
|  | <b>12B</b> Organotin miticides   | Azocyclotin, Cyhexatin, Fenbutatin oxide  |
|  | <b>12C</b> Propargite  | Propargite  |
|  | <b>12D</b> Tetradifon  | Tetradifon  |
| <b>13 Uncouplers of *oxidative phosphorylation via disruption of the proton gradient</b> | Pyrroles<br>Dinitrophenols<br>Sulfluramid  | Chlorfenapyr, DNOC, Sulfluramid   |
| <b>14 Nicotinic acetylcholine receptor (nAChR) channel blockers</b>                      | Nereistoxin analogues  | Bensultap, Cartap hydrochloride, Thiocyclam, Thiosultap-sodium  |

| Main Group/Primary Site of Action                                    | Subgroup, class or Exemplifying active | Active Ingredients   |
|--|--|--|
| 15 Inhibitors of chitin biosynthesis affecting CHS1                  | Benzoylureas                           | Bistrifluron, Chlorfluazuron, Diflubenzuron, Flucycloxuron, Flufenoxuron, Hexaflumuron, Lufenuron, Novaluron, Noviflumuron, Teflubenzuron, Triflumuron |
| 16 Inhibitors of chitin biosynthesis, type 1                         | Buprofezin                             | Buprofezin   |
| 17 Moulting disruptors, Dipteran                                     | Cyromazine                             | Cyromazine   |
| 18 Ecdysone receptor agonists  | Diacylhydrazines                       | Chromafenozide, Halofenozide, Methoxyfenozide, Tebufenozide  |
| 19 Octopamine receptor agonists                                      | Amitraz                                | Amitraz  |
| 20 Mitochondrial complex III electron transport inhibitors – Qo site | 20A Hydramethylnon                     | Hydramethylnon   |
|  | 20B Acequinocyl                        | Acequinocyl  |
|  | 20C Fluacrypyrim                       | Fluacrypyrim   |
|  | 20D Bifenazate                         | Bifenazate   |
| 21 Mitochondrial complex I electron transport inhibitors             | 21A METI acaricides and insecticides   | Fenazaquin, Fenpyroximate, Pyridaben, Pyrimidifen, Tebufenpyrad, Tolfenpyrad   |
|  | 21B Rotenone                           | Rotenone (Derris)  |

|  |   |  |
|--|---|--|
| <b>22 Voltage-dependent sodium channel blockers</b><br><i>See footnotes for further information on sub-grouping</i>              | <b>22A</b> Oxadiazines                          | Indoxacarb   |
|  | <b>22B</b> Semicarbazones                       | Metaflumizone  |
| <b>23 Inhibitors of acetyl CoA carboxylase</b>   | Tetronic and Tetramic acid derivatives          | Spirodiclofen, Spiromesifen, Spiropidion, Spirotetramat                              |
| <b>24 Mitochondrial complex IV electron transport inhibitors</b>   | <b>24A</b> Phosphides                           | Aluminium phosphide, Calcium phosphide, Phosphine, Zinc phosphide                    |
|  | <b>24B</b> Cyanides                             | Calcium cyanide, Potassium cyanide, Sodium cyanide                                   |
| <b>25 Mitochondrial complex II electron transport inhibitors</b><br><i>See footnotes for further information on sub-grouping</i> | <b>25A</b> <i>beta</i> -Ketonitrile derivatives | Cyenopyrafen, Cyflumetofen   |
|  | <b>25B</b> Carboxanilides                       | Pyflubumide  |
| <b>28 Ryanodine receptor modulators</b>  | Diamides  | Chlorantraniliprole, Cyantraniliprole, Cyclaniliprole, Flubendiamide, Tetraniliprole |
| <b>29 Chordotonal organ nicotinamidase inhibitors</b>  | Flonicamid                                      | Flonicamid   |

| Main Group/Primary Site of Action   | Subgroup, class or Exemplifying active                    | Active Ingredients   |
|---|---|--|
| 30 GABA-gated channel allosteric modulators                                 | Meta-diamides<br>Isoxazolines                             | Broflanilide<br>Fluxametamide<br>Isocycloseram   |
| 31 Baculoviruses<br>Host-specific occluded pathogenic viruses               | Granuloviruses (GVs)<br><br>Nucleopolyhedroviruses (NPVs) | <i>Cydia pomonella</i> GV<br><i>Thaumatotibia leucotreta</i> GV<br><i>Anticarsia gemmatalis</i> MNPV<br><i>Heliocoverpa armigera</i> NPV |
| 32 Nicotinic acetylcholine receptor (nAChR) allosteric modulators - Site II | GS-omega/kappa HXTX-Hv1a peptide                          | GS-omega/kappa HXTX-Hv1a peptide   |
| 33 Calcium-activated potassium channel (KCa2) modulators                    | Acynonapyr  | Acynonapyr   |
| 34 Mitochondrial complex III electron transport inhibitors – Qi site        | Flometoquin   | Flometoquin  |
| 36 Chordotonal organ modulators – undefined target site                     | Pyridazine<br>pyrazolecarboxamides                        | Dimpropridaz   |

|   |                |  |
|---|----------------|--|
| <b>UN Compounds</b>   | Azadirachtin   | Azadirachtin   |
|   | Benzoximate    | Benzoximate  |
|   | Benzpyrimoxan  | Benzpyrimoxan  |
|   | Bromopropylate | Bromopropylate   |
|   | Dicofol        | Dicofol  |
|   | Lime sulfur    | Lime sulfur  |
|   | Mancozeb       | Mancozeb   |
|   | Oxazosulfyl    | Oxazosulfyl  |
|   | Pyridalyl      | Pyridalyl  |
|   | Sulfur         | Sulfur   |
| <b>UNB Bacterial agents<br/>* (non-Bt)</b>  |                | <i>Burkholderia spp</i><br><i>Wolbachia pipientis (Zap)</i>  |
| <b>UNE Botanical essence<br/>* including<br/>synthetic, extracts<br/>and unrefined oils</b> |                | <i>Chenopodium ambrosioides near ambrosioides</i> extract, Neem oil<br>Fatty acid monoesters with glycerol or propanediol    |
| <b>UNF Fungal agents</b>  |                | <i>Beauveria bassiana</i> strains, <i>Metarhizium brunneum</i> strain F52, <i>Paecilomyces fumosoroseus</i> Apopka strain 97 |
| <b>UNM Non-specific<br/>* mechanical and<br/>physical disruptors</b>                        |                | Diatomaceous earth, Mineral oil  |
| <b>UNP Peptides</b>   |                |  |

| Main Group/Primary Site of Action          | Subgroup, class or Exemplifying active | Active Ingredients |
|--|--|--------------------|
| UNV<br>*<br>Viral agents (non baculovirus) |  |                    |

Targeted Physiology: ■ Nerve & Muscle ■ Growth & Development ■ Respiration ■ Midgut ■ Unknown or Non-specific

The colour scheme in the table associates mode 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.**

#### Table Notes:

- Inclusion of an insecticidal agent in the classification above does not necessarily signify regulatory approval.
- MoA assignments will usually involve identification of the target protein responsible for the biological effect, although groupings can be made where insecticidal agents share distinctive physiological effects and are structurally related.
- Groups 26 and 27 are unassigned at this time and have therefore been omitted from the table.
- An insecticidal agent with an unknown or controversial MoA or an unknown mode of toxicity will be held in group 'UN' or 'UNB', 'UNE', 'UNF', 'UNM', 'UNP', UNV as applicable until evidence becomes available to enable assignment to a more appropriate MoA class.
- Actives in groups marked with an asterisk 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. These groups are 8, 13, UN, UNB, UNE, UNF, UNM, UNP and UNV.
- Different baculoviruses that target different insect orders may be used together without compromising their resistance management. Rotation between certain specific baculoviruses may provide resistance management benefits for some pests. Consult product-specific recommendations.

### Sub-Groups:

Sub-groups represent distinct chemical classes that are believed to have the same MoA but are different enough in chemical structure or mode of interaction with the target protein that the chance of selection for either metabolic or target-site cross-resistance is reduced compared to close analogs. Sub-groups may also distinguish compounds that are chemically similar but known to bind differently within the target or to have differential selectivity among multiple targets.

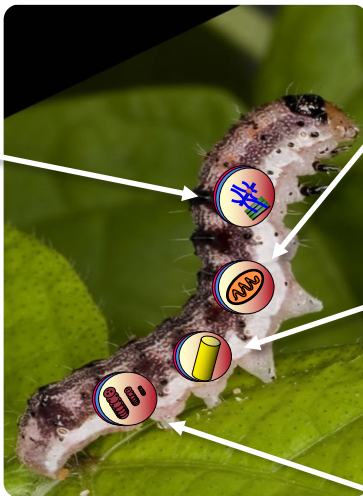
The cross-resistance potential between sub-groups is higher than that between different groups, so rotation between sub-groups should be avoided. In exceptional circumstances (i.e. where effective registered insecticides from other mode of action groups are unavailable) rotation may be considered following consultation with local expert advice and where cross-resistance does not exist. These exceptions should not be considered sustainable resistance management strategies, and alternative options should be sought to maintain pest susceptibility.

| Sub-group              | Notes  |
|------------------------|--|
| 3B                     | Because DDT is no longer used in agriculture, this is only applicable for the control of human disease vectors such as mosquitoes.   |
| 4A, 4B, 4C, 4D, 4E, 4F | Although these compounds are believed to have the same target site, current evidence indicates that the risk of metabolic cross-resistance between subgroups is low.   |
| 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.  |
| 11A                    | Different <i>Bacillus thuringiensis</i> products that target different insect orders may be used together without compromising their resistance management. Rotation between certain specific <i>Bacillus thuringiensis</i> microbial products may provide resistance management benefits for some pests. Consult product-specific recommendations.<br><b>B.t. Crop Proteins:</b> Where there are differences among the specific receptors within the midguts of target insects, transgenic crops containing certain combinations of the listed proteins provide resistance management benefits. |
| 20                     | While there is strong evidence that Bifenazate acts on the Qo site of Mitochondrial Complex III and some Bifenazate resistance mutations confer cross-resistance to Acequinocyl, the sites of action of Flucrypyrim and Hydramethylnon have not been determined.   |
| 22A, 22B               | Although these compounds are believed to have the same target site, current evidence indicates that the risk of metabolic cross-resistance between subgroups is low.   |
| 25A, 25B               | Although these compounds are believed to have the same target site, current evidence indicates that the risk of metabolic cross-resistance between subgroups is low.   |

## Nerve & Muscle Targets

1. Acetylcholinesterase (AChE) inhibitors  
1A: *Carbamates*  
1B: *Organophosphates*
2. GABA-gated chloride channel blockers  
2A: *Cyclodiene Organochlorines*  
2B: *Phenylpyrazoles*
3. Sodium channel modulators  
3A: *Pyrethrins, Pyrethroids*
4. Nicotinic acetylcholine receptor (nAChR) competitive modulators  
4A: *Neonicotinoids*  
4F: *Pyridylidenes*
5. Nicotinic acetylcholine receptor (nAChR) allosteric modulators Site I  
5 *Spinosyns*
6. Glutamate-gated chloride channel (GluCl) allosteric modulators  
6: *Avermectins, Milbemycins*
14. Nicotinic acetylcholine receptor (nAChR) channel blockers  
14: *Nereistoxin analogues*
22. Voltage-dependent sodium channel blockers  
22A: *Oxadiazines*  
22B: *Semicarbazones*
28. Ryanodine receptor modulators  
28: *Diamides*
30. GABA-gated chloride channel allosteric modulators  
30: *Meta-diamides, Isoxazolines*
32. Nicotinic acetylcholine receptor (nAChR) allosteric modulators Site II  
32: *GS-omega/kappa HXTX-HV1a Peptide*

## Lepidoptera - Mode of Action Classification by Target Site



### Unknown or uncertain MoA

*Azadirachtin, Pyridalyl, Beauveria bassiana, Burkholderia spp, Paecilomyces fimosorosus*

## Respiration Targets

13. Uncouplers of oxidative phosphorylation via disruption of the proton gradient  
13: *Chlorfenapyr*
21. Mitochondrial complex I electron transport inhibitors  
21A: *METI acaricides and insecticides (Tolfenpyrad)*
34. Mitochondrial complex III electron transport inhibitors – Qi site  
34: *Flometoquin*

## Midgut Targets

11. Microbial disruptors of insect midgut membranes  
11A: *Bacillus thuringiensis*,  
11B: *Bacillus sphaericus*
31. Baculoviruses  
31: *Host-specific occluded pathogenic viruses*  
*Granuloviruses*,  
*Nucleopolyhedroviruses*

## Growth & Development Targets

7. Juvenile hormone mimics  
7A: *Juvenile hormone analogues (Hydroprene)*  
7B: *Fenoxycarb*
15. Inhibitors of chitin biosynthesis affecting CHS1  
15: *Benzoylureas*
18. Ecdysone receptor agonists  
18: *Diacylhydrazines*

## Nerve & Muscle Targets

1. Acetylcholinesterase (AChE) inhibitors  
1A: *Carbamates*  
1B: *Organophosphates*
2. GABA-gated chloride channel blockers  
2A: *Cyclodiene Organochlorines*  
2B: *Phenylpyrazoles*
3. Sodium channel modulators  
3A: *Pyrethrins, Pyrethroids*
4. Nicotinic acetylcholine receptor (nAChR) competitive modulators  
4A: *Neonicotinoids*  
4C: *Sulfoximines*  
4D: *Butenolides*  
4E: *Mesoionics*  
4F: *Pyridylidenes*
9. Chordotonal organ TRPV channel modulators  
9B: *Pyridine azomethine derivatives*  
9D: *Pyropenes*
22. Voltage-dependent sodium channel blockers  
22A: *Oxadiazines*
28. Ryanodine receptor modulators  
28: *Diamides (Cyantraniliprole)*
29. Chordotonal organ nicotinamidase inhibitors  
29: *Fonicamid*
30. GABA-gated chloride channel allosteric modulators  
30: *Isoxazolines*
32. Nicotinic acetylcholine receptor (nAChR) allosteric modulators Site II  
32: *GS-omega/kappa HXTX-HV1a Peptide*
36. Chordotonal modulators – undefined target site  
36: *Pyridazine pyrazolecarboxamides*

## Aphids, Whiteflies, Planthoppers and Leafhoppers - Mode of Action Classification by Target Site



| MoA Group | Aphids | Whiteflies | Planthoppers Leafhoppers |
|-----------|--------|------------|--------------------------|
| 1A        | X      | X          | X                        |
| 1B        | X      | X          | X                        |
| 2A        | X      | X          | X                        |
| 2B        |        |            | X                        |
| 3A        | X      | X          | X                        |
| 4A        | X      | X          | X                        |
| 4C        | X      | X          | X                        |
| 4D        | X      | X          | X                        |
| 4E        |        |            | X                        |
| 4F        |        |            | X                        |
| 7A        | X      | X          |                          |
| 7C        |        | X          |                          |
| 9B        | X      | X          | X                        |
| 9D        | X      | X          | X                        |
| 12A       | X      | X          |                          |
| 15        |        | X          |                          |
| 16        |        | X          | X                        |
| 21A       |        | X          |                          |
| 22A       |        |            | X                        |
| 23        | X      | X          |                          |
| 28        | X      | X          | X                        |
| 29        | X      | X          | X                        |
| 30        |        | X          |                          |
| 32        | X      | X          |                          |
| 34        |        | X          |                          |
| 36        | X      | X          | X                        |

## Respiration Targets

12. Inhibitors of mitochondrial ATP synthesis  
12A: *Difenthiuron*
21. Mitochondrial complex I electron transport inhibitors  
21A: *METI acaricides and insecticides (Pyridaben, Tolfenpyrad)*
34. Mitochondrial complex III electron transport inhibitors – Qi site  
34: *Flometoquin*

## Growth & Development Targets

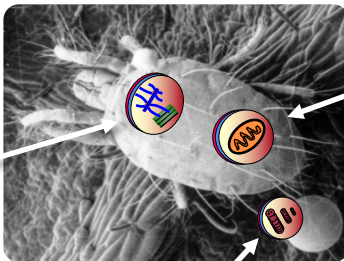
7. Juvenile hormone mimics  
7A: *Kinoprene*  
7C: *Pyriproxyfen*
15. Inhibitors of chitin biosynthesis, affecting CHS1  
15: *Benzoylureas*
16. Inhibitors of chitin biosynthesis, type 1  
16: *Buprofezin*
23. Inhibitors of acetyl CoA carboxylase  
23: *Tetronic & Tetramic acid derivatives*

The table lists the main mode of action groups for the control of aphids, whiteflies and hoppers. However, the availability may differ regionally due to registration status.

## Nerve & Muscle Targets

1. Acetylcholinesterase (AChE) inhibitors  
1A: *Carbamates*  
1B: *Organophosphates*
2. GABA-gated chloride channel blockers  
2A: *Cyclodiene Organochlorines*
3. Sodium channel modulators  
3A: *Pyrethrins, Pyrethroids*
5. Nicotinic acetylcholine receptor (nAChR) allosteric modulators – site I  
5: *Spinosyns*
6. Glutamate-gated chloride channel (GluCl) allosteric modulators  
6: *Avermectins, Milbemycins*
19. Octopamine receptor agonists  
19: *Amitraz*
32. Nicotinic acetylcholine receptor (nAChR) allosteric modulators Site II  
32: *GS-omega/kappa HXTX-HV1a Peptide*
30. GABA-gated chloride channel allosteric modulators  
30: *Isoxazolines*
33. Calcium-activated potassium channel (KCa2) modulators  
33: *Acynonapyr*

## Mites - Mode of Action Classification by Target Site



## Growth & Development Targets

10. Mite growth inhibitors affecting CHS1  
10A: *Clofentezine, Diflovidazin Hexythiazox*  
10B: *Etoxazole*
15. Inhibitors of chitin biosynthesis affecting CHS1  
15: *Benzoylureas*
23. Inhibitors of acetyl CoA carboxylase  
23: *Tetronic & Tetramic acid derivatives*

## Respiration Targets

12. Inhibitors of mitochondrial ATP synthesis  
12A: *Difenthiuron*  
12B: *Organotin miticides*  
12C: *Propargite*
13. Uncouplers of oxidative phosphorylation via disruption of the proton gradient  
13: *Chlorfenapyr*
20. Mitochondrial complex III electron transport inhibitors – Qo site  
20B: *Acequinocyl*  
20C: *Fluacrypyrim*  
20D: *Bifenazate*
21. Mitochondrial complex I electron transport inhibitors  
21A: *METI acaricides*
25. Mitochondrial complex II electron transport inhibitors  
25A: *Cyfenopryafen, Cyflumetofen*  
25B: *Pyflubumide*
34. Mitochondrial complex III electron transport inhibitors – Qi site  
34: *Flometoquin*

## Unknown or uncertain MoA

*Benzoximate, Chinomethionat, Dicofof*

## Mosquitoes - Mode of Action Classification by Target Site

### Nerve & Muscle Targets (Larvae)

1. Acetylcholinesterase (AChE) inhibitors  
*1B: Organophosphates*
5. Nicotinic acetylcholine receptor (nAChR) allosteric modulators – site I  
*5: Spinosyns*



### Growth & Development Targets (Larvae)

7. Juvenile hormone mimics  
*7A: Juvenile hormone analogues*  
*7C: Pyriproxyfen*
15. Inhibitors of chitin biosynthesis, affecting CHS1  
*15: Benzoylureas*

### Midgut Targets (Larvae)

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

### Nerve & Muscle Targets (Adults)

1. Acetylcholinesterase (AChE) inhibitors  
*1A: Carbamates*  
*1B: Organophosphates*
3. Sodium channel modulators  
*3A: Pyrethrins, Pyrethroids*
4. Nicotinic acetylcholine receptor (nAChR) competitive modulators  
*4A: Neonicotinoids*  
*4D: Butenolides*



### Growth & Development Targets (Adults)

7. Juvenile hormone mimics  
*7C: Pyriproxyfen*

### Respiration Targets (Adults)

13. Uncouplers of oxidative phosphorylation via disruption of the proton gradient  
*13: Chlorfenapyr*

## Active Ingredients (Alphabetical Order) with MoA Classification: INSECTICIDES / ACARICIDES

|                                   |     |
|-----------------------------------|-----|
| 1,3-dichloropropene               | 8A  |
| Abamectin                         | 6   |
| Acephate                          | 1B  |
| Acequinocyl                       | 20B |
| Acetamiprid                       | 4A  |
| Acrinathrin                       | 3A  |
| Acynonapyr                        | 33  |
| Afidopropen                       | 9D  |
| Alanycarb                         | 1A  |
| Aldicarb                          | 1A  |
| Allethrin                         | 3A  |
| <i>alpha</i> -Cypermethrin        | 3A  |
| Aluminium phosphide               | 24A |
| Amitraz                           | 19  |
| <i>Anticarsia gemmatilis</i> MNPV | 31  |
| Azadirachtin                      | UN  |
| Azamethiphos                      | 1B  |
| Azinphos-ethyl                    | 1B  |
| Azinphos-methyl                   | 1B  |
| Azocyclotin                       | 12B |
| <i>Bacillus thuringiensis</i>     | 11A |
| <i>Bacillus sphaericus</i>        | 11B |
| <i>Beauveria bassiana</i> strains | UNF |
| Bendiocarb                        | 1A  |
| Benfuracarb                       | 1A  |
| Bensultap                         | 14  |
| Benzoximate                       | UN  |
| Benzpyrimoxan                     | UN  |
| <i>beta</i> -Cyfluthrin           | 3A  |
| <i>beta</i> -Cypermethrin         | 3A  |

|  |     |
|--|-----|
| Bifenazate   | 20D |
| Bifenthrin   | 3A  |
| Bioallethrin   | 3A  |
| Bioallethrin S-cyclopentenyl isomer                              | 3A  |
| Bioresmethrin  | 3A  |
| Bistrifluron   | 15  |
| Borax  | 8D  |
| Boric acid   | 8D  |
| Broflanilide   | 30  |
| Bromopropylate   | UN  |
| Buprofezin   | 16  |
| <i>Burkholderia spp.</i>   | UNB |
| Butocarboxim   | 1A  |
| Cadusafos  | 1B  |
| Calcium cyanide  | 24B |
| Calcium phosphide  | 24A |
| Carbaryl   | 1A  |
| Carbofuran   | 1A  |
| Carbosulfan  | 1A  |
| Cartap hydrochloride   | 14  |
| <i>Chenopodium ambrosioides</i> near <i>ambrosioides</i> extract | UNE |
| Chinomethionat   | UN  |
| Chlorantraniliprole  | 28  |
| Chlordane  | 2A  |
| Chlorethoxyfos   | 1B  |
| Chlorfenapyr   | 13  |
| Chlorfenvinphos  | 1B  |
| Chlorfluazuron   | 15  |

|  |     |
|--|-----|
| Chlormephos  | 1B  |
| Chloropicrin                                       | 8B  |
| Chlorpyrifos                                       | 1B  |
| Chlorpyrifos-methyl                                | 1B  |
| Chromafenozide                                     | 18  |
| Clofentezine                                       | 10A |
| Clothianidin                                       | 4A  |
| Coumaphos  | 1B  |
| Cryolite   | 8C  |
| Cyanide  | 24B |
| Cyanophos  | 1B  |
| Cyantraniliprole                                   | 28  |
| Cycloprothrin                                      | 3A  |
| <i>Cydia pomonella</i> GV                          | 31  |
| Cyfenoprafen                                       | 25A |
| Cyflumetofen                                       | 25A |
| Cyfluthrin   | 3A  |
| Cyhalothrin  | 3A  |
| Cyhexatin  | 12B |
| Cypermethrin                                       | 3A  |
| Cyphenothrin (1 <i>R</i> )- <i>trans</i> -isomers] | 3A  |
| Cyromazine   | 17  |
| <i>d-cis-trans</i> Allethrin                       | 3A  |
| Dazomet  | 8F  |
| DDT  | 3B  |
| Deltamethrin                                       | 3A  |
| Demeton-S-methyl                                   | 1B  |
| Diafenthiuron                                      | 12A |
| Diatomaceous earth                                 | UNM |
| Diazinon   | 1B  |

|  |     |
|--|-----|
| Dichlorvos/ DDVP                                   | 1B  |
| Dicofol  | UN  |
| Dicrotophos  | 1B  |
| Dicloromezotiaz                                    | 4E  |
| Diflovidazin                                       | 10A |
| Diflubenzuron                                      | 15  |
| Dimethoate   | 1B  |
| Dimethylvinphos                                    | 1B  |
| Dimpropridaz                                       | 36  |
| Dinotefuran  | 4A  |
| Disodium octaborate                                | 8D  |
| Disulfoton   | 1B  |
| DNOC   | 13  |
| <i>d-trans</i> Allethrin                           | 3A  |
| Emamectin benzoate                                 | 6   |
| Empenthrin [(EZ)-(1 <i>R</i> )-isomers]            | 3A  |
| Endosulfan   | 2A  |
| EPN  | 1B  |
| Esfenvalerate                                      | 3A  |
| Ethiofencarb                                       | 1A  |
| Ethion   | 1B  |
| Ethiprole  | 2B  |
| Ethoprophos  | 1B  |
| Etofenprox   | 3A  |
| Etoazole   | 10B |
| Famphur  | 1B  |
| Fatty acid monoesters with glycerol or propanediol | UNE |

## Active Ingredients (Alphabetical Order) with MoA Classification: INSECTICIDES / ACARICIDES

|                                 |     |
|---------------------------------|-----|
| Fenamiphos                      | 1B  |
| Fenazaquin                      | 21A |
| Fenbutatin oxide                | 12B |
| Fenitrothion                    | 1B  |
| Fenobucarb                      | 1A  |
| Fenoxycarb                      | 7B  |
| Fenpropathrin                   | 3A  |
| Fenpyroximate                   | 21A |
| Fenthion                        | 1B  |
| Fenvalerate                     | 3A  |
| Fipronil                        | 2B  |
| Flonicamid                      | 29  |
| Flometoquin                     | 34  |
| Fluacrypyrim                    | 20C |
| Flubendimide                    | 28  |
| Flucycloxuron                   | 15  |
| Flucythrinate                   | 3A  |
| Flufenoxuron                    | 15  |
| Flumethrin                      | 3A  |
| Flupyradifurone                 | 4D  |
| Fluxametamide                   | 30  |
| Flupyrimin                      | 4F  |
| <i>gamma</i> -Cyhalothrin       | 3A  |
| GS-omega/kappa HXTX-Hv1a        | 32  |
| Halfenprox                      | 3A  |
| Halofenozide                    | 18  |
| <i>Helicoverpa armigera</i> NPV | 31  |
| Heptenophos                     | 1B  |
| Hexaflumuron                    | 15  |

|  |     |
|--|-----|
| Hexythiazox  | 10A |
| Hydramethylnon   | 20A |
| Hydroprene   | 7A  |
| Imicyafos  | 1B  |
| Imidacloprid   | 4A  |
| Imiprothrin  | 3A  |
| Indoxacarb   | 22A |
| Isocylcoseram  | 30  |
| Isofenphos   | 1B  |
| Isoprocarb   | 1A  |
| Isopropyl O- (methoxy-aminothio-phosphoryl) salicylate | 1B  |
| Isoxathion   | 1B  |
| Kadethrin  | 3A  |
| Kinoprene  | 7A  |
| <i>lambda</i> -Cyhalothrin                             | 3A  |
| Lepimectin   | 6   |
| Lime sulfur  | UN  |
| Lufenuron  | 15  |
| Malathion  | 1B  |
| Mancozeb   | UN  |
| Mecarbam   | 1B  |
| Metaflumizone  | 22B |
| Metam  | 8F  |
| <i>Metarhizium brunneum</i> strain F52                 | UNF |
| Methamidophos  | 1B  |
| Methidathion   | 1B  |
| Methiocarb   | 1A  |

|   |     |
|---|-----|
| Methomyl  | 1A  |
| Methoprene  | 7A  |
| Methoxychlor                                      | 3B  |
| Methoxyfenozide                                   | 18  |
| Methyl bromide                                    | 8A  |
| Metolcarb   | 1A  |
| Methyl isocyanate                                 | 8F  |
| Mevinphos   | 1B  |
| Milbemectin                                       | 6   |
| Mineral Oil                                       | UNM |
| Monocrotophos                                     | 1B  |
| Naled   | 1B  |
| Neem Oil  | UNE |
| Nicotine  | 4B  |
| Nitenpyram  | 4A  |
| Novaluron   | 15  |
| Noviflumuron                                      | 15  |
| Omethoate   | 1B  |
| Oxamyl  | 1A  |
| Oxazosulfyl                                       | UN  |
| Oxydemeton-methyl                                 | 1B  |
| <i>Paecilomyces fumosoroseus</i> Apopka strain 97 | UNF |
| Parathion   | 1B  |
| Parathion-methyl                                  | 1B  |
| Permethrin  | 3A  |
| Phenothrin [(1R)- <i>trans</i> - isomer]          | 3A  |
| Phenthoate  | 1B  |

|                        |     |
|------------------------|-----|
| Phorate                | 1B  |
| Phosalone              | 1B  |
| Phosmet                | 1B  |
| Phosphamidon           | 1B  |
| Phosphine              | 24A |
| Phoxim                 | 1B  |
| Pirimicarb             | 1A  |
| Pirimiphos- methyl     | 1B  |
| Potassium cyanide      | 24B |
| Prallethrin            | 3A  |
| Profenofos             | 1B  |
| Propargite             | 12C |
| Propetamphos           | 1B  |
| Propoxur               | 1A  |
| Prothiofos             | 1B  |
| Pyflubumide            | 25B |
| Pymetrozine            | 9B  |
| Pyraclufos             | 1B  |
| Pyrethrins (pyrethrum) | 3A  |
| Pyridaben              | 21A |
| Pyridalyl              | UN  |
| Pyridaphenthion        | 1B  |
| Pyrifluquinazon        | 9B  |
| Pyrimidifen            | 21A |
| Pyriproxyfen           | 7C  |
| Quinalphos             | 1B  |
| Resmethrin             | 3A  |
| Rotenone (Derris)      | 21B |
| Silafluofen            | 3A  |

## Active Ingredients (Alphabetical Order) with MoA Classification: INSECTICIDES / ACARICIDES

|                         |     |
|-------------------------|-----|
| Sodium borate           | 8D  |
| Sodium cyanide          | 24B |
| Sodium metaborate       | 8D  |
| Spinetoram              | 5   |
| Spinosad                | 5   |
| Spirodiclofen           | 23  |
| Spiromesifen            | 23  |
| Spiropidion             | 23  |
| Spirotetramat           | 23  |
| Sulfotep                | 1B  |
| Sulfoxaflor             | 4C  |
| Sulfur                  | UN  |
| Sulfuramid              | 13  |
| Sulfuryl fluoride       | 8C  |
| Tartar emetic           | 8E  |
| <i>tau</i> -Fluvalinate | 3A  |

|                                      |     |
|--------------------------------------|-----|
| Tebufenozide                         | 18  |
| Tebufenpyrad                         | 21A |
| Tebupirimfos                         | 1B  |
| Teflubenzuron                        | 15  |
| Tefluthrin                           | 3A  |
| Temephos                             | 1B  |
| Terbufos                             | 1B  |
| Tetrachlorvinphos                    | 1B  |
| Tetradifon                           | 12D |
| Tetramethrin                         | 3A  |
| Tetramethrin [(1 <i>R</i> )-isomers] | 3A  |
| Tetraniliprole                       | 28  |

|                                    |     |
|------------------------------------|-----|
| <i>Thaumatotibia leucotreta</i> GV | 31  |
| <i>theta</i> -cypermethrin         | 3A  |
| Thiacloprid                        | 4A  |
| Thiamethoxam                       | 4A  |
| Thiocyclam                         | 14  |
| Thiodicarb                         | 1A  |
| Thiofanox                          | 1A  |
| Thiometon                          | 1B  |
| Thiosultap-sodium                  | 14  |
| Tolfenpyrad                        | 21A |
| Tralomethrin                       | 3A  |
| Transfluthrin                      | 3A  |

|                                  |     |
|----------------------------------|-----|
| Triazamate                       | 1A  |
| Triazophos                       | 1B  |
| Trichlorfon                      | 1B  |
| Triflumuron                      | 15  |
| Triflumezopyrim                  | 4E  |
| Trimethacarb                     | 1A  |
| Vamidotion                       | 1B  |
| <i>Wolbachia pipientis</i> (Zap) | UNB |
| XMC                              | 1A  |
| Xylcarb                          | 1A  |
| <i>zeta</i> -Cypermethrin        | 3A  |
| Zinc phosphide                   | 24A |

# Nematicide MoA Classification

This is the first edition to include the newly created Nematicide Mode of Action Classification Scheme. The development of this scheme enables visibility of the modes of action available to control plant-parasitic nematodes. Additionally, the numbering scheme allows clarity of product labelling, supporting the principles of rotation of mode-of-action for resistance management. See the IRAC International website for further information (<https://irac-online.org/teams/nematodes/>) – including a poster and a statement on nematicide resistance risk.



# Nematicide Mode of Action Classification Scheme (Version 2.1)

Targeted Physiology: ■ Nerve & Muscle ■ Growth & Development ■ Respiration ■ Unknown or Non-specific

| Main Group/Primary Site of Action |   | Class or Exemplifying active                         | Active Ingredients   | IRAC/FRAC Group |
|-----------------------------------|---|--|--|-----------------|
| N-1                               | Acetylcholinesterase (AChE) inhibitors  | A Carbamates   | Aldicarb, Benfuracarb, Carbofuran, Carbosulfan, Oxamyl   | IRAC: 1A        |
|                                   |   | B Organophosphates                                   | Cadusafos, Ethoprophos, Fenamiphos, Fosthiazate, Imicyafos, Phorate, Terbufos  | IRAC: 1B        |
| N-2                               | Glutamate-gated chloride channel (GluCl) allosteric modulators                          | Avermectins  | Abamectin  | IRAC: 6         |
| N-3                               | Mitochondrial complex II electron transport inhibitors. Succinate-coenzyme Q reductase. | Pyridinyl-ethyl benzamides; Phenethyl pyridineamides | Fluopyram, Cyclobutrifluram  | FRAC: 7         |
| N-4                               | Inhibitors of acetyl CoA carboxylase  | Tetronic and Tetramic acid derivatives               | Spirotetramat  | IRAC: 23        |
| N-UN                              | Compounds with unknown Mode of Action   |  | Furfural, Fluensulfone, Fluazaindolizine, Iprodione  |                 |
| N-UNX                             | Presumed multi-site inhibitors  |  | 1,2-Dibromo-3-chloropropane (DBCP), 1,3-Dichloropropene, Allyl isothiocyanate, Carbon Disulfide, Chloropicrin, Dazomet, Dimethyl Disulfide (DMDS), Ethylene Dibromide, Metam Potassium, Metam Sodium, Methyl Bromide, Methyl Iodide (Iodomethane), Sodium tetrathiocarbonate | IRAC: 8         |

|   |  |   |  |
|---|--|---|--|
| <b>N-UNB Bacterial agents (non-Bt) *</b>  |  | <i>Bacillus spp., Burkholderia spp., Pasteuria spp., Pseudomonas spp., Streptomyces spp.</i>  |  |
| <b>N-UNF Fungal agents *</b>  |  | <i>Actinomyces spp., Arthrobotrys spp., Aspergillus spp., Muscodor spp., Myrothecium spp., Pochonia spp., Purpureocillium lilacinum (syn. Paecilomyces lilacinus), Trichoderma spp.</i> |  |
| <b>N-UNE Botanical or animal derived agents including synthetic, extracts and un-refined oils</b> |  | Azadirachtin, Camellia Seed Cake, Essential oils, Garlic extract, Pongamia oil, <i>Quillaja saponaria</i> extract, Chitin, Terpenes   |  |

\* Only species with proven nematocidal activity

## Nematodes - Mode of Action Classification by Target Site

### Nerve & Muscle Targets

N-1 Acetylcholinesterase (AChE) inhibitors

1A: *Carbamates*

1B: *Organophosphates*

N-2 Glutamate-gated chloride channel (GluCl) allosteric modulators

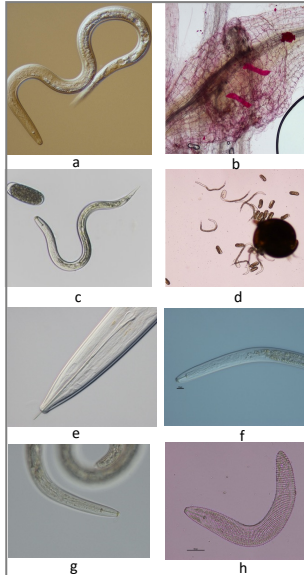
*Avermectins*

### Respiration Targets

N-3 Mitochondrial complex II electron transport inhibitors. Succinate-coenzyme Q reductase.

*Fluopyram, Cyclobutrifluram*

a – Root-knot nematode J2, b – Root-knot nematode J3's in root galls, c – SCN J2 and egg, d – PCN cyst, eggs and J2's, e – Dagger nematode, f – Root lesion nematode, g – Spiral nematode, h – Ring nematode



### Growth & Development Targets

N-4 Inhibitors of acetyl CoA carboxylase  
*Tetronic & Tetramic acid derivatives*

### Unknown or uncertain MoA

N-UN Compounds with unknown Mode of Action

N-UNX Presumed multi-site inhibitors

N-UNB Bacterial agents (non-Bt)

N-UNF Fungal agents

N-UNE Botanical or animal derived agents including synthetic, extracts and unrefined oils

## Active Ingredients (Alphabetical Order) with MoA Classification: NEMATOCIDES

|                                    |       |
|------------------------------------|-------|
| Benfuracarb                        | N-1A  |
| 1,2-Dibromo-3-chloropropane (DBCP) | N-UNX |
| 1,3-Dichloropropene                | N-UNX |
| Abamectin                          | N-2   |
| <i>Actinomyces spp.</i>            | N-UNF |
| Aldicarb                           | N-1A  |
| Allyl isothiocyanate               | N-UNX |
| <i>Arthrobotrys spp.</i>           | N-UNF |
| <i>Aspergillus spp.</i>            | N-UNF |
| Azadirachtin                       | N-UNE |
| <i>Bacillus spp.</i>               | N-UNB |
| <i>Burkholderia spp.</i>           | N-UNB |
| Cadusafos                          | N-1B  |
| Camellia Seed Cake                 | N-UNE |
| Carbofuran                         | N-1A  |

|                           |       |
|---------------------------|-------|
| Carbon Disulfide          | N-UNX |
| Carbosulfan               | N-1A  |
| Chloropicrin              | N-UNX |
| Cyclobutrifluram          | N-3   |
| Dazomet                   | N-UNX |
| Dimethyl Disulfide (DMDS) | N-UNX |
| Essential oils            | N-UNE |
| Ethoprophos               | N-1B  |
| Ethylene Dibromide        | N-UNX |
| Fenamiphos                | N-1B  |
| Fluazaindolizine          | N-UN  |
| Fluensulfone              | N-UN  |
| Fluopyram                 | N-3   |
| Fosthiazate               | N-1B  |
| Furfural                  | N-UN  |

|  |       |
|--|-------|
| Garlic extract   | N-UNE |
| Imicyafos  | N-1B  |
| Iprodione  | N-UN  |
| Metam Potassium  | N-UNX |
| Metam Sodium   | N-UNX |
| Methyl Bromide   | N-UNX |
| Methyl Iodide (Iodomethane)                                    | N-UNX |
| <i>Muscodor spp.</i>   | N-UNF |
| <i>Myrothecium spp.</i>  | N-UNF |
| Oxamyl   | N-1A  |
| <i>Purpureocillium lilacinum (syn. Paecilomyces lilacinus)</i> | N-UNF |
| <i>Pasteuria spp.</i>  | N-UNB |
| Phorate  | N-1B  |

|                                   |       |
|-----------------------------------|-------|
| <i>Pochonia spp.</i>              | N-UNF |
| Pongamia oil                      | N-UNE |
| <i>Pseudomonas spp.</i>           | N-UNB |
| <i>Quillaja saponaria</i> extract | N-UNE |
| Chitin                            | N-UNE |
| Sodium tetrathiocarbonate         | N-UNX |
| Spirotetramat                     | N-4   |
| <i>Streptomyces spp.</i>          | N-UNB |
| Terbufos                          | N-1B  |
| Terpenes                          | N-UNE |
| <i>Trichoderma spp.</i>           | N-UNF |

### Table Notes:

- Inclusion of a nematode control agent in the table above does not necessarily signify regulatory approval.
- The list is not aimed at being comprehensive but gives key representatives by group.
- N-UNB and N-UNF includes only species with proven nematocidal activity.

Photograph Acknowledgements:

Page 16: N. Armes, BASF

Page 17: F. Haile Corteva Agriscience, S. Bauer USDA, A. McCaffery

Page 18: Syngenta

Page 19: Syngenta & J. Gathany, CDC

Page 26: Corteva Agriscience, T. Thoden various nematodes & R.M. Dickenson SCN nematode

Photograph details and credits are accurate to the best of our knowledge

Further information is available from the IRAC website at:  
[www.irac-online.org](http://www.irac-online.org)

or by email at:  
[enquiries@irac-online.org](mailto:enquiries@irac-online.org)



IRAC Insecticide/Acaricide  
Mode of Action Classification



IRAC Nematicide Mode of  
Action Classification

# IRAC



Insecticide Resistance Action Committee



visit us @ [irac-online.org](http://irac-online.org)