Mode of Action Classification

7th Edition

Now including Nematicides

IRAC

Insecticide Resistance Action Committee

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

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

* Only species with proven nematicidal activity

Nematodes - Mode of Action Classification by Target Site

Nerve & Muscle Targets

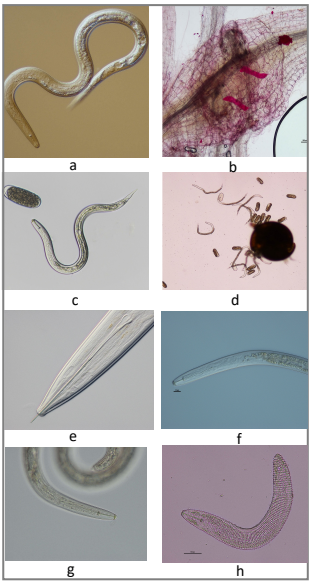
N-1 Acetylcholinesterase (AChE) inhibitors
1A: Carbamates
1B: Organophosphates

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: NEMATICIDES

Benfuracarb	N-1A
1,2-Dibromo-3-chloropropane (DBCP)	N-UNX
1,3-Dichloropropene	N-UNX
Abamectin	N-2
Actinomyces spp.	N-UNF
Aldicarb	N-1A
Allyl isothiocyanate	N-UNX
Arthrobotrys spp.	N-UNF
Aspergillus spp.	N-UNF
Azadirachtin	N-UNE
Bacillus spp.	N-UNB
Burkholderia spp.	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
Muscodor spp.	N-UNF
Myrothecium spp.	N-UNF
Oxamyl	N-1A
Purpureocillium lilacinum (syn. Paecilomyces lilacinus)	N-UNF
Pasteuria spp.	N-UNB
Phorate	N-1B

Pochonia spp.	N-UNF
Pongamia oil	N-UNE
Pseudomonas spp.	N-UNB
Quillaja saponaria extract	N-UNE
Chitin	N-UNE
Sodium tetrathiocarbonate	N-UNX
Spirotetramat	N-4
Streptomyces spp.	N-UNB
Terbufos	N-1B
Terpenes	N-UNE
Trichoderma spp.	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 nematicidal activity.

Further information is available from the IRAC website at:
www.irac-online.org

or by email at:
enquiries@irac-online.org

IRAC Insecticide/Acaricide
Mode of Action Classification

IRAC Nematicide Mode of
Action Classification

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IRAC

Insecticide Resistance Action Committee

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