General Introduction to the Insecticide Resistance Action Committee

Insecticide Resistance Action Committee (IRAC)

Verónica Companys, Ph.D.
Chair, Diamide Working Group (Group 28 Insecticides) in IRAC

Insecticide Resistance Action Committee

Introductory statement

- **Insecticide Resistance Action Committee (IRAC)**
  - Formed in 1984 – now in its 27th year and still growing
  - Specialist technical expert group of the agrochemical industry
  - Provides a coordinated industry response to the development of resistance in insect and mite pests
  - Around 70 industry representatives and specialist members in different working groups
  - 7 Country/Regional Groups with a further 70-80 representatives
  - Association with CropLife International (Formal part of CLI´s Stewardship Committee since June 2010)




IRAC Mission

IRAC Mission:

- Facilitate communication and education on insecticide and acaricide resistance
- Promote development of resistance management strategies to maintain efficacy and support sustainable agriculture and improved public health
  - Pool expertise
  - Industry commitment to product stewardship and sustainability
  - Foster communication and education on IRM

IRAC and its members

Insecticide Resistance Action Committee

- **Currently 15 IRAC Executive member companies**

FMC syngenta
DUPONT Chemtura
Bayer CropScience
Nihon Nohyaku
BASF The Chemical Company
Dow AgroSciences
BELCHIM Crop Protection
CHEMINOVA
SUMITOMO CHEMICAL
Nufarm
MONSANTO imagine
VESTERGAARD FRANDSEN DISEASE CONTROL TEXTILES

45th IRAC Annual Meeting, Washington DC, April 2010

- **Plus an international coordinator**

apa alan porter associates

IRAC INTERNATIONAL

EXECUTIVE Committee

Crop Protection

Public Health

Plant Biotechnology

15 Companies

13 International Working Groups

Working Groups

- Steering Group
- Public Health
- Biotechnology
- Methods
- Mode of Action
- Comm./Education
- Stakeholder Relations
- R. Database (MSU)
- Oilseed Rape
- Sucking Pest
- Codling Moth
- Lepidoptera
- Diamide

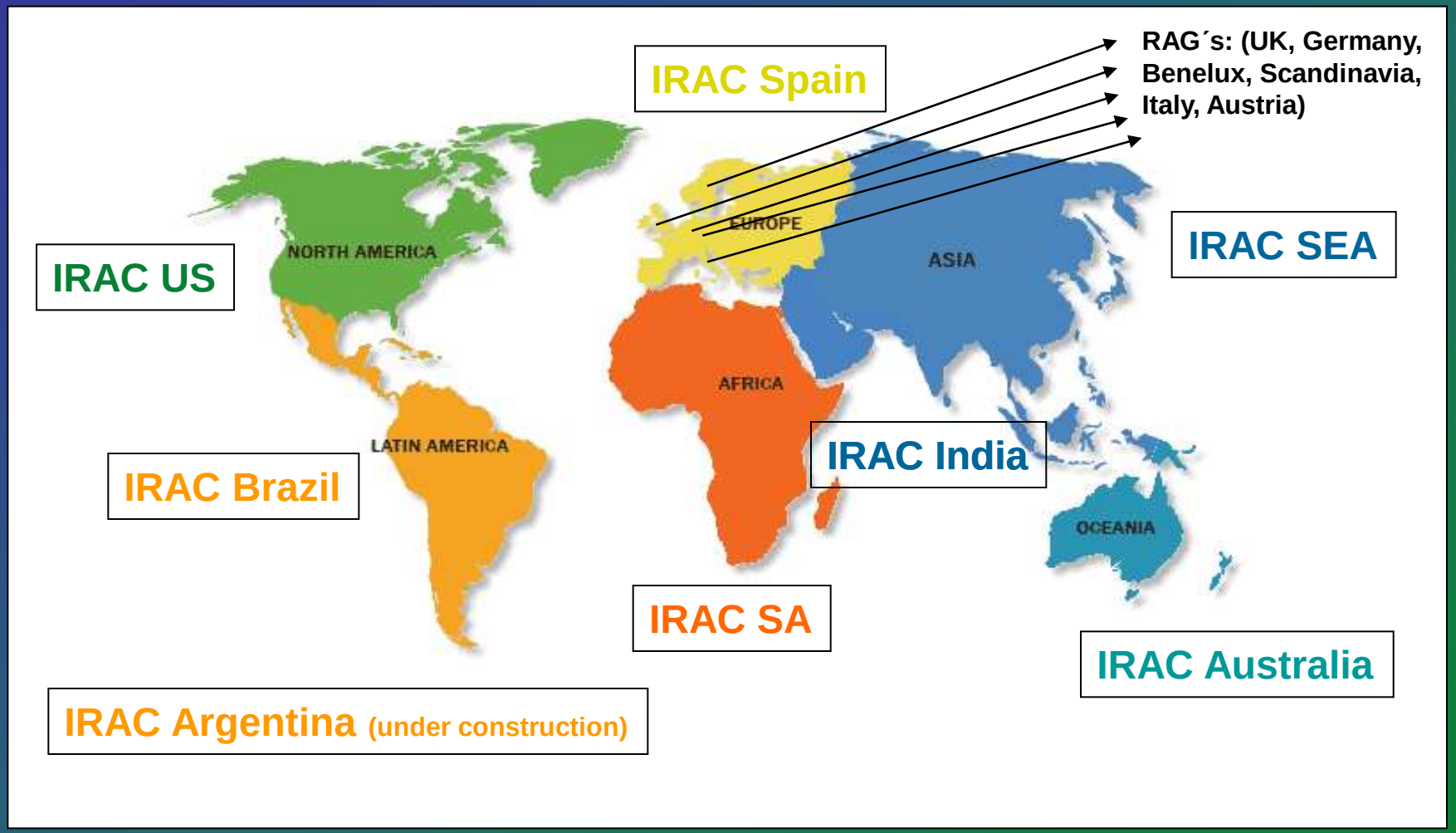
Country/Regional Groups

- IRAC Spain
- IRAC US
- IRAC S.E. Asia
- IRAC Australia
- IRAC Brazil
- IRAC India
- IRAC S. Africa

CropLife INTERNATIONAL

Insecticide Resistance Action Committee

IRAC Country Groups



IRAC Executive

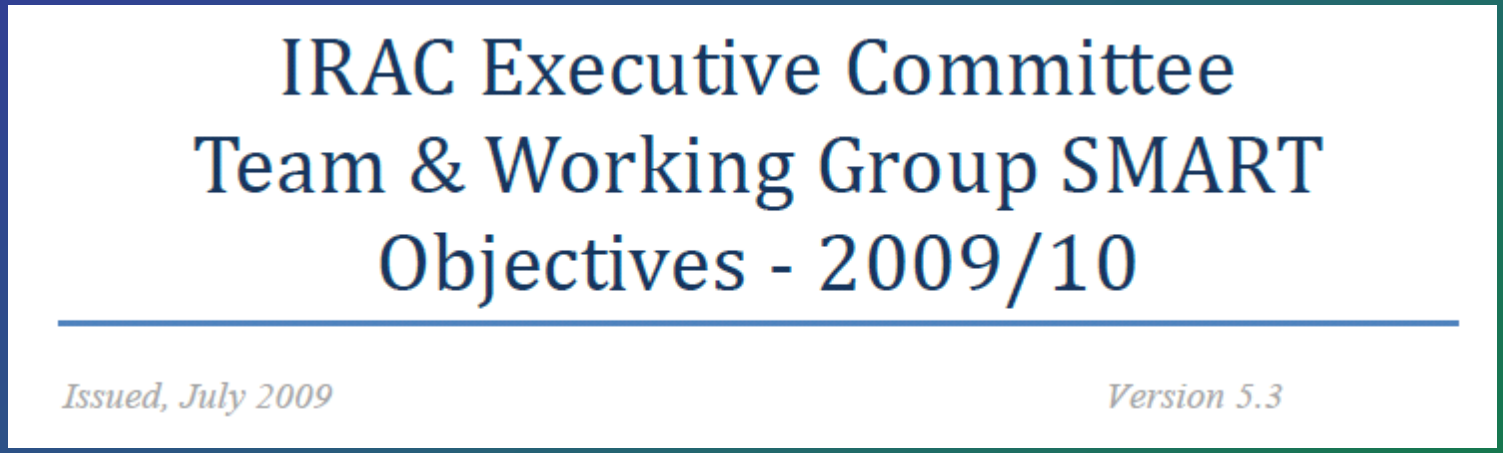
Insecticide Resistance Action Committee

Incl. Alan Porter

- BASF
  - Nigel Armes (Treasurer)
  - Tatjana Sikuljak
- Bayer CropScience
  - Ralf Nauen (Chair)
  - Verónica Companys (Diamide)
- Belchim Crop Protection
  - Jens-Peter Vollmers Hansen
- Cheminova
  - Eric Andersen
- Chemtura
  - Alasdair Haley
- Dow AgroSciences
  - Gary Thompson (MSU Database)
  - Tom Sparks (MoA WG)
  - Nick Storer (Biotech WG)
- DuPont
  - Paula Marcon
  - John Andaloro
- FMC
  - Thomas Anderson
- Makhteshim Agan
  - Jonathan Henen (Vice Chair)
- Monsanto
  - Graham Head (IRAC US)
- Nihon Nohyaku
  - Glyn Jones
  - Ken Chisholm
- Nufarm
  - Jean-Paul Genay
- Sumitomo
  - John Lucas
- Syngenta
  - Philippe Camblin
  - Russell Slater (Vice Chair)
  - Mark Hoppe (PH Team)
- Vestergaard Frandsen
  - Michael Pedersen

Insecticide Resistance Action Committee

Goals & SMART Objectives



- 13 Teams and WGs with Goals & SMART* objectives
- Reviewed and updated every year by WG´s

*SMART: **S**pecific, **M**easurable, **A**chievable, **R**ealistic and **T**ime-bound

Insecticide Resistance Action Committee

WG diversity & members

❑ Steering Group:	8	(fixed)
❑ Public Health:	15	(incl. 3 non-industrial members)
❑ Biotech:	8	(all US)
❑ Methods:	8	
❑ MoA:	12	
❑ C&E:	8	
❑ EU Liaison:	10	
❑ MSU Database:	7	
❑ Pollen Beetle:	12	(incl. 3 non-industrial members)
❑ Sucking Pest:	13	
❑ Codling Moth:	11	
❑ Lepidoptera:	8	
❑ Diamide:	12	

IRAC

Insecticide Resistance Action Committee

Key successes 2009/2010

Public Health

- 2nd edition of Vector Manual close to publishing
- Participation in huge WHO resistance project

Biotechnology

- White paper published in PMS
- Mode of action classification finalized

Methods

- eMethods fully established
- New methods approved & draft methods poster

Mode of Action

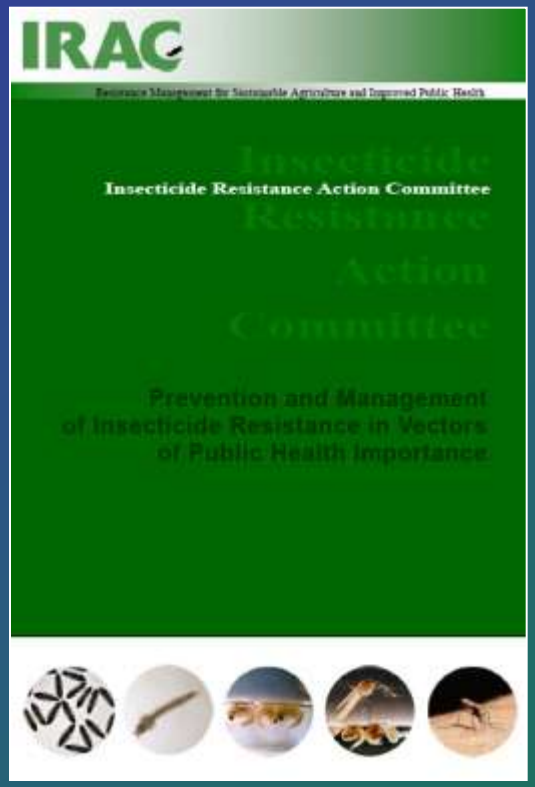
- MoA classification scheme v7.0 completed
- MoA brochure (pocket size) completed

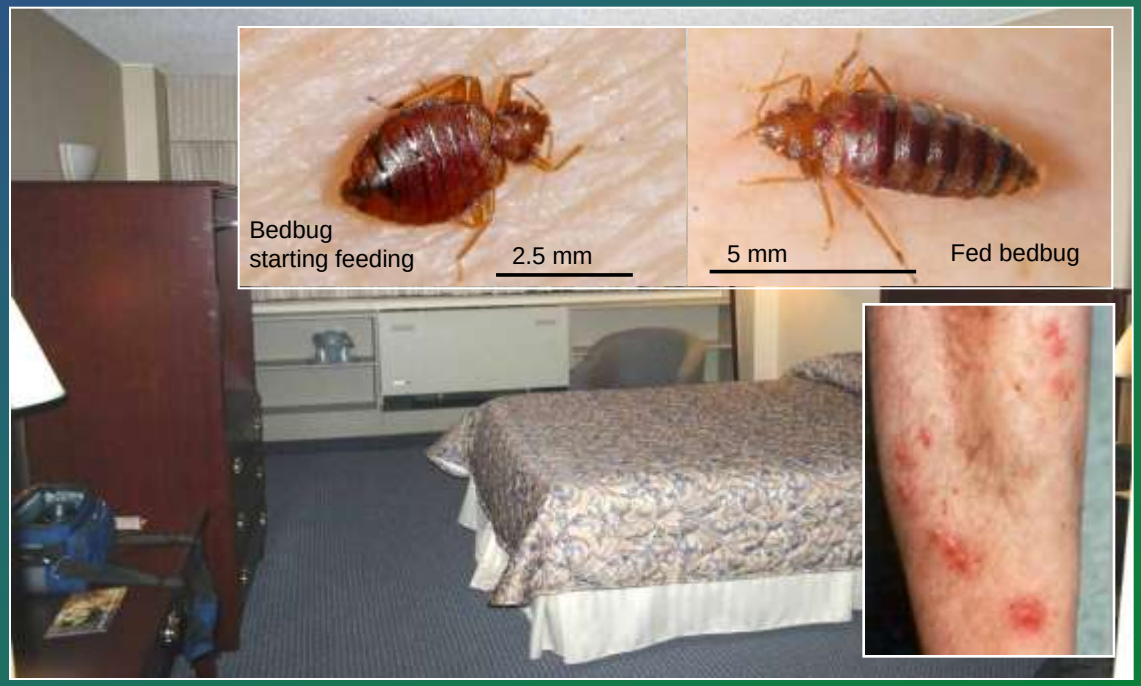
Public Health Team

Key successes 2009/2010 (examples)

Public Health

- 2nd edition of Vector Manual published (Nov 1st)
- Participation in huge WHO resistance project





Biotech Team

Key successes 2009/2010 (examples)

Biotechnology

- White paper published in PMS
- Mode of action classification finalized

Research Article

SCI

Received: 27 March 2009 Revised: 15 July 2009 Accepted: 15 July 2009 Published online in Wiley Interscience: 23 October 2009

(www.interscience.wiley.com) DOI 10.1002/ps.1854

Managing the risk of insect resistance to transgenic insect control traits: practical approaches in local environments

Susan C MacIntosh*

Abstract

BACKGROUND: Growers have enthusiastically embraced crops genetically modified to express *Bacillus thuringiensis* (Bt) proteins for insect control because they provide excellent protection from key damaging insect pests around the world. Bt crops also offer superior environmental and health benefits while increasing grower income. However, insect resistance development is an important concern for all stakeholders, including growers, technology providers and seed companies that develop these genetically modified crops. Given the marked benefits associated with Bt crops, insect resistance management (IRM) must be a consideration when cultivating these crops.

Susceptibility Test Methods For Resistance Monitoring

Insecticide Resistance Action Committee

www.irac-online.org

Methods Team Objectives and Goals

Methods team consist of 6 representatives from different chemical companies.

The goals of the team are:

- To develop a single point of contact for researchers to gain information on how to conduct insecticide resistance bioassays
- To provide IRAC approved methods, so that data generated by independent researchers can be directly compared

What does a team do to meet these goals:

- We have developed a searchable database containing IRAC approved methods and those used by researchers (referred to as references) but not yet confirmed by IRAC

To be able to continue providing additional methods we would like to encourage you to submit your testing methods to us.

Full information on Susceptability Test Methods can be found on the IRAC website: www.irac-online.org

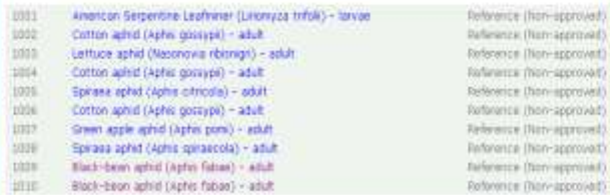
IRAC eMethods Tool

Required method can be searched in two different ways, by Species or Mode of Action:

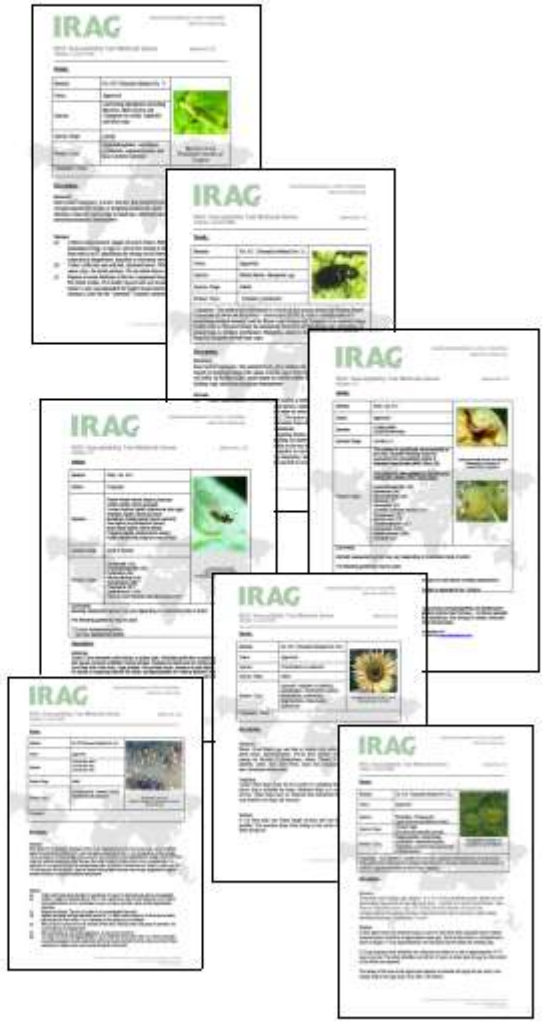
For example – by Species:

And/or Mode of action:

If available for a given species or mode of action the list of references will also show:



Some of the IRAC Methods available:



Designed & produced by IRAC Methods WG, April 2010, Poster Ver. 2
For further information visit the IRAC website: www.irac-online.org

Method for *Plutella xylostella*

Insecticide Resistance Action Committee

IRAC Susceptibility Test Methods Series

Version: 3.4

Method No: 018

Details:

Method:	IRAC No. 018
Status:	Approved
Species:	Diamondback Moth *(Plutella xylostella)*
Species Stage	Larvae (L2/L3)
Product Class:	This method is specifically recommended by the IRAC Diamide Working Group for evaluating the susceptibility status of **diamide insecticides (IRAC MoA 28)**** This method is also suitable for the following insecticide classes (IRAC MoA class): Carbamate (1A)* Organophosphate (1B)* Organochlorine (2A)* Fiprole (2B)* Pyrethroid (3A)* Spinosyn (5)* Avermectin (6)* Benzyl urea (15)** Diacylhydrazine (18)*** Indoxacarb (22A)* Metaflumizone (22B)* Pyridalyl (un)*

Plutella xylostella larvae
Courtesy of BASF

Check susceptibility of DBM to different insecticides

Available at www.irac-online.org

Method for *Plutella xylostella*

Method:

(a) Collect a representative sample of insects from a field. These may be larvae suitable for immediate testing, or eggs/L1 larvae for rearing to the appropriate stage or material from which an F1 population for testing can be reared. The insects should not be subjected to temperature, humidity or starvation stress after collection.

(b) Collect sufficient non-infested, untreated host plant leaves. Whole leaves are preferred or, for some crops, the distal portions. Do not allow leaves to wilt by keeping them in a humid environment (plastic bag). *Brassica oleracea* (cabbages, cauliflowers & collards) are the recommended choice of host plant; however *Brassica rapa* (chinese cabbage, turnip) is also suitable. Choice of host plant should be recorded for future reference.

(c) Prepare accurate dilutions of the test compound from the identified commercial product. For initial studies, six widely spaced rates are recommended. The use of additional wetter is only recommended for highly waxed leaf material, in which case this wetter solution is used for the "untreated" (control) solution in place of water alone. As the addition of a wetting agent can significantly affect the performance of an insecticide product in a bioassay, it is essential that details of the wetting agent are recorded with any summary data and that only data generated with the same agent and concentration are compared for susceptibility measurements.

(d) Dip leaves individually in the test liquid for 10 seconds with gentle agitation and place to surface-dry on paper toweling (abaxial surface facing skywards). Ensure the entire leaf surface is emerged equally and do not allow the leaves to wilt. Dip the same number of leaves per treatment (a minimum of four replicate leaves per concentration is recommended), and treat sufficient leaf material to avoid starvation stress in the "untreated" during the test. Commence dipping the "untreated" first and work up through the test dilutions (lowest to highest).

(e) Place the treated surface-dry leaves in the labeled test containers, which must be suitable for holding enough leaf material in good condition for up to 96 hours.

Sampling

Host plant

Dilutions of test compound

Dip leaves

Container

Insecticide Resistance Action Committee

Method for *Plutella xylostella*

(f) Add equal numbers of L2 larvae to each container, so that a minimum total of 40 larvae are used per treatment, divided between at least four replicate containers. Seal the containers with the container lid.

As development time can vary between populations of *Plutella xylostella*. The following length measurement can be used to classify L2/L3 larvae: 3-5mm.

Add larvae

(g) Store the containers in an area where they are not exposed to direct sunlight or extremes of temperature. Record maximum and minimum temperatures. If possible a mean temperature of 25°C, 60% RH and 16:8 light/dark regime is preferred.

Store

(h) In the case of diamide insecticides, a final assessment of larval mortalities (dead and live) is made after 96 hours. For other insecticides please see guidelines provided at the top of this document. Larvae which are unable to make coordinated movement away from gentle stimulus with a seeking pin or fine pointed forceps to the posterior body segment are to be considered as dead (combination of dead and seriously affected). Anti-feeding effects (percentage damage to the leaf or larval growth) may also be recorded for additional information.

Assessment

(i) Express results as percentage mortalities, correcting for "untreated" (control) mortalities using Abbott's formula. Untreated mortality should be recorded. It is recommended that the mortality data is utilised to perform a probit or logit dose response analysis to provide LD50 and LD90 estimates for each insecticide or insect population tested.

Results

Please submit your methods to www.irac-online.org

Insecticide Resistance Action Committee

Key successes 2009/2010

Comm./Education

- 4 issues of IRAC eConnection published
- New website launched in March 2010

EU Liaison

- No activities in 2009
- Restarting activities as Stakeholder Relations WG

R. Database (MSU)

- Further work on resistance mapping tool
- Presentation at BCPC Conference on database

Pollen Beetle

- Pyrethroid resistance monitoring expanded (>800)
- Neonicotinoid method drafted and posted

Communication & Education

Insecticide Resistance Action Committee

New IRAC website launched in March 2010

IRAC newsletter eConnection (latest issue 24; eg MSU Database article)

www.irac-online.org

IRAC
Insecticide Resistance Action Committee

Key successes 2009/2010

Codling Moth

- Regional CM resistance survey evaluated
- Literature collection and expert list

Lepidoptera

- Kick-off in Dec 2009
- Two posters drafted on Tuta and Plutella

Diamide

- Development of diamide bioassay methods
- Formation of 15 Diamide Country Groups

Sucking Pest

- Merger with Neonic WG and poster development
- Myzus questionnaire circulated

Insecticide Resistance Action Committee

IRAC Conference Contributions

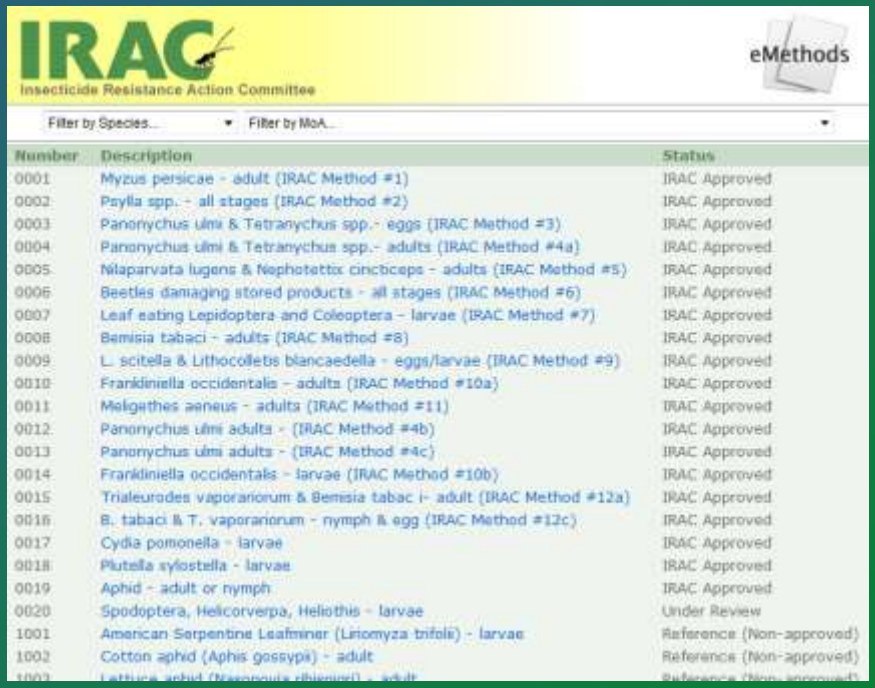
- **IRAC representation at:**
  - National Congress of Entomology, Brazil, August 2008
  - AgChem Forum, Berlin, Sept 2008
  - European Whitefly Conference, Almeria, October 2008
  - Expert CM Workshop, Nov 2008
  - ESA Meeting, December 2008
  - Annual SW Ag Summit, March 2009
  - 6th Intl. IPM Symposium, March 2009
  - BCPC Meeting, Glasgow, November 2009
  - 5th Bemisia Workshop, November 2009
  - CropLife Malaysia, December 2009
  - ESA Meeting, December 2009
  - Japan PPA, January 2010
  - Crop Conference, Barcelona, May 2010
  - ESA Meeting, USA, December 2010
  - 6th Intl DBM Workshop, Thailand, March 2011

Setting up the IRAC S. Africa stand at the ICE, Durban

Posters & eTools

Insecticide Resistance Action Committee

- A number of new & updated posters in the pipeline
- Work on posters generally carried out by Working Groups
- 2000 copies of a new version of MoA poster printed in 2010 (v6.4)
- eTools, e.g. eMethods



The Diamondback Moth, *Plutella xylostella:*
Resistance Management is Key for Sustainable Control

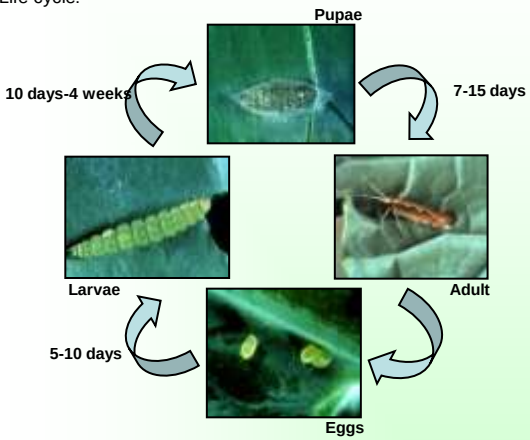
Insecticide Resistance Action Committee

www.irac-online.org

Introduction and Biological

Diamondback moth (*Plutella xylostella* L.) is a highly migratory, cosmopolitan species and one of the most important pest of cruciferous crops worldwide. Globally, direct losses and control costs are estimated to be US$ 1 billion (1).

Life cycle:



Annual outbreaks of *P. xylostella* in temperate regions are contributed to migrations due to low over-wintering ability, while in tropical and subtropical regions it can have a high number of continuous generations per year (e.g. up to 21 in Taiwan) (2) .

P. xylostella is considered to be one of the most difficult pests to control. For many years continuous insecticide applications have been and continue to be the main tool for it's control.

However first cases of insecticide resistance were reported in 1950´s. Today this species shows resistance to almost all insecticides, including compounds of new mode of action classes only recently introduced (3).

References

1: Gryzwacz, D., A. Rossbach, D. Russell, R. Srinivasan, A.M. Shelton. 2010. Current control methods for diamondback moth and other brassica insect pests and the prospects for improved management with lepidopteran-resistant *Bt* vegetable brassicas in Asia and Africa. *Crop Protection* 29 (1): 68-79

2. Chapman, J.W., D.R. Reynolds, A.D. Smith, J.R. Riley, D.E. Pedgley, I.P. Woiwod. 2002. High-altitude migration of the diamondback moth *Plutella xylostella* to the UK: a study using radar, aerial netting, and ground trapping. *Ecol. Entomol*. 27: 641-650

3. Zaho, J.Z., L.H. Collins, X.Y. Li, R.F.L Mau, G.D. Thompson et al. 2006. Monitoring of diamondback moth (resistance to spinosad, indoxacarb and emamectin benzoate. *J. Econ. Entomol*. 99: 176-181

4. Hung, C.F., C.H. Kao. C.C. Liu, J.G. Lin, and C.N. Sun. 1990. Detoxifying enzymes of selected insect species with chewing and sucking habits. *J.Econ.Entomol*. 83: 361-365

5. Liu, Y.B., B.E. Tabashnik, L. Mason, B. Escriche, and J. Ferre. 2000. Binding and toxicity of *Bacillus thuringiensis* Protein Cry1C to susceptible and resistant diamondback moth (Lepidoptera: Plutellidae). *J. Econ. Entomol*. 93: 1-6

6. Li, A., Y.Yang, S. Wu, C. Li., and Y. Wu. 2006. Investigation of resistance mechanisms to fipronil in diamondback moth (Lepidoptera: Plutellidae). *J.Econ.Entomol*. 99: 914-919

Plutella xylostella resistance around the globe

Resistance Mechanisms

Several biochemical mechanisms were described to confer resistance to insecticides in diamondback moths. Many of the mechanisms listed below are acting in concert and sometimes provide resistance factors of 1000-fold or greater.

1. **Enhanced metabolic detoxification mechanisms**:
   -**microsomal monooxygenases** – different forms of cytochrome P450 play a major role in *P. xylostella* resistance to pyrethroids,
   organophosphates, abamectin and benzoylphenyl ureas (4)
   -**glutathione S-transferases** – for example reported to confer organophosphate resistance (3, 4)
   -**carboxylesterases** – involved in resistance to organophosphates and other chemical classes of insecticides (3)

2. **Insensitive acetylcholinesterase** – proven to play a role in *P. xylostella* resistance development to organophosphates and carbamates

3. **Reduced Cry1C binding to target site in midgut membrane and**
   reduced conversion of Cry1C protoxin to toxin – factors in resistance development to *Bacillus thuringiensis* protein Cry1C (5)

4. **Knock-down resistance** – mutation(s) in voltage-gated sodium channels providing pyrethroid resistance

5. **Other mechanisms** – include modified GABA-gated chloride channels and reduced penetration and reported to confer fiprole resistance (6)

Management Strategy

A combination of all available tools for *P. xylostella* management should be used to prevent the development of insecticide resistance:

- resistant varieties
- refuge crops
- biological control with natural enemies, e.g. *Cotesia plutellae*
- insecticide applications
  mode of action rotation, window approach
- crop hygiene

Plutella xylostella method (No. 018) for resistance monitoring is available on IRAC website under e-methods tool and should be used to evaluate insecticide susceptibility.

Chemical Control of *P. xylostella*

- Select insecticides based on known local effectiveness and selectivity
- Rotate insecticides by mode of action group, using a window approach
- Use only insecticides registered for diamondback moth control
- Always follow the directions for use on the label of each product

MOA GROUP	PRIMARY SITE OF ACTION	CHEMICAL SUB-GROUP OR EXEMPLIFYING ACTIVE INGREDIENT
1	Acetylcholinesterase inhibitors	1A: Carbamates 1B: Organophosphates
2	GABA-gated Cl channel antagonists	2B: Phenylpyrazoles (Fiproles)
3	Sodium channel modulators	3A: Pyrethroids, Pyrethrins
4	Nicotinic acetylcholine receptor agonists	4A: Neonicotinoids
5	Nicotinic acetylcholine receptor allosteric modulators	Spinosyns
6	Chloride channel activators	Avermectins, Milbemycins
11	Microbial disruptors of insect midgut membranes and derived toxins	*Bacillus thuringiensis* var. kurstaki
13	Uncouplers of oxidative phosphorylation via disruption of the proton gradient	Pyrrols
15	Inhibitors of chitin biosynthesis, type 0	Benzoylureas
18	Ecdysone receptor agonists	Diacylhydrazines
22	Voltage-dependent sodium channel blockers	22A: Indoxacarb 22B: Metaflumizone
28	Ryanodine receptor modulators	Diamides
UN	Compounds of unknown or uncertain mode of action	Azadirachtin Pyridalyl

Designed & produced by IRAC Lepidoptera WG, August 2010, Poster Ver. 1.1
For further information visit the IRAC website: www.irac-online.org

Mode of Action Classification

IRAC

Insecticide Resistance Action Committee

The Key to Resistance Management

More information on IRAC and the Mode of Action Classification is available from:
www.irac-online.org or enquiries@irac-online.org

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 (A) are shown)

3A Pyrethroids Pyrethrins

3B DDT, Methoxychlor

Group 4: Nicotinic acetylcholine receptor (nAChR) agonists

4A Neonicotinoids

4B Nicotine

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 Borax

8E Tartar emetic

Group 9: Selective homopteran feeding blockers

9B Pymetrozine

9C Flonicamid

Group 10: Mite growth inhibitors

10A Clofentezine 10A Hexythiazox

10B Etoxazole

Group 11: Microbial disruptors of insect midgut membranes and derived toxins

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

Group 14: Nicotinic acetylcholine receptor (nAChR) channel blockers

14 Nereistoxin analogues

Group 15: Inhibitors of chitin biosynthesis, type 0

15 Benzoylureas

Group 16: Inhibitors of chitin biosynthesis, type 1

16 Buprofezin

Group 17: Moulting disruptor, Dipteran

17 Cryomazine

Group 18: Ecdysone receptor agonists

18 Diacylhydrazines

Group 19: Octopamine receptor agonists

19 Amitraz

Group 20: Mitochondrial complex III electron transport inhibitors

20A

20B

20C

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 Cyenopyrafen

Group 28: Ryanodine receptor modulators

28 Diamides

Group UN: Compounds of unknown or uncertain mode of action

Guidance on the use of Sub-Groups:

- Represent distinct structural classes believed to have the same mode of action
- Provides differentiation between compounds that may bind at the same target site
- Are structurally different such that risk of metabolic cross-resistance is lower than for close chemical analogs
- Are likely to be metabolized by different enzymes - may bind differently enough within the target site that the chance of selection for metabolic/target-site resistance is reduced compared to close analogs.

- In the absence of other alternatives, it may be possible to rotate compounds between sub-groups if it is clear that cross resistance mechanisms do not exist in the target populations.
- 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.
- 1A & 1B - If there are no other alternatives, compounds may be rotated in situations where cross-resistance mechanisms are known to be absent in the insect populations to be treated.

- 3A & 3B - If there are no other alternatives, compounds may be rotated in situations where cross-resistance mechanisms (e.g. kdr) are known to be absent in the insect populations to be treated. 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.
- 10A - Clofentezine & Hexythiazox are grouped because they commonly exhibit cross-resistance even though they are structurally distinct, and the target site for neither compound is known.
- 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.

Poster Version 2.5, July 2006 Based on the Mode of Action Classification - Version 6.3

杀虫剂作用机制分类

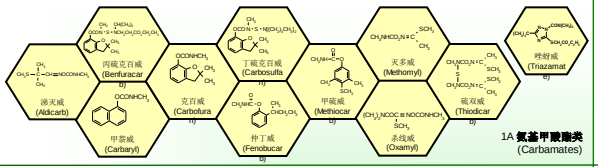
IRAC

Insecticide Resistance Action Committee

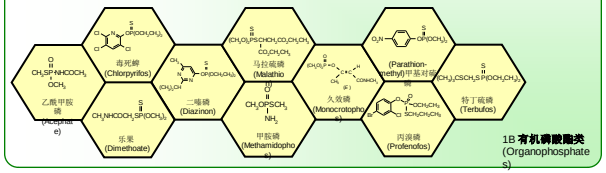
抗药性治理的关键

欲获取更多有关杀虫剂抗药性工作委员会(IRAC)和杀虫剂作用机制分类信息
登陆 www.irac-online.org 或电邮 enquiries@irac-online.org

第1组: 乙酰胆碱酯酶（AChE）抑制剂 (仅列出该组主要代表性化合物)



1A **氨基甲酸酯类** (Carbamates)



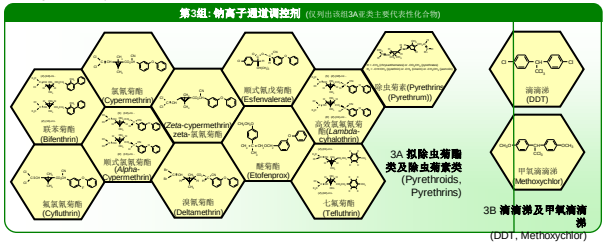
1B **有机磷酸酯类** (Organophosphate s)

第2组: γ-氨基丁酸（GABA）门控氯离子通道拮抗剂

2A **环戊二烯有机氯化合物** (Cyclodiene Organochlorines)

2B **苯基吡唑类** (Phenylpyrazoles (Fiproles))

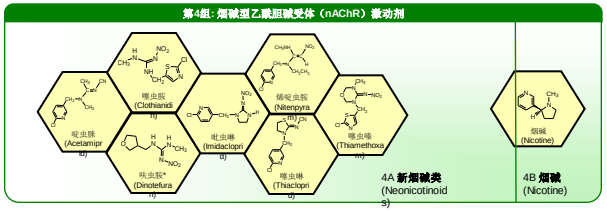
第3组: 钠离子通道调控剂 (仅列出该组3A亚类主要代表性化合物)



3A **拟除虫菊酯类及除虫菊素类** (Pyrethroids, Pyrethrins)

3B **滴滴涕及甲氧滴滴涕** (DDT, Methoxychlor)

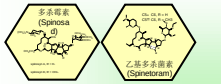
第4组: 烟碱型乙酰胆碱受体（nAChR）激动剂



4A **新烟碱类** (Neonicotinoid s)

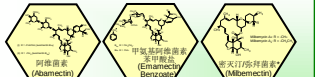
4B **烟碱** (Nicotine)

第5组: 烟碱型乙酰胆碱受体（nAChR）别构调节剂



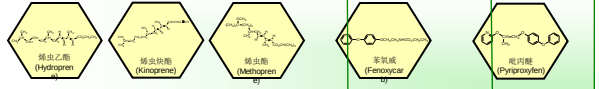
5 **多杀菌素类** (Spinosyns)

第6组: 氯离子通道激动剂



6 **阿维菌素类，米尔贝霉素类** (Avermectins, Milbemycins)

第7组: 仿生保幼激素



7A **保幼激素类似物** (Juvenile hormone analogues)

7B **苯氧威** (Fenoxycarb)

7C **吡丙醚** (Pyriproxyfen)

杀虫剂作用机制分类

IRAC

Insecticide Resistance Action Committee

抗药性治理的关键

欲获取更多有关杀虫剂抗药性工作委员会(IRAC)和杀虫剂作用机制分类信息
登陆 www.irac-online.org 或电邮 enquiries@irac-online.org

第8组: 其它非特异（多位点）抑制剂

8A **卤化烷类** (Alkyl halides)

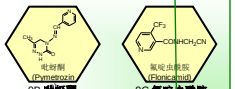
8B **氯化苦** (Chloropicrin)

8C **硫酰氟** (Sulfuryl fluoride)

8D **硼砂** (Borax)

8E **酒石酸锑钾** (Tartar emetic)

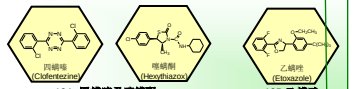
第9组: 选择性同翅目昆虫摄食阻滞剂



9B **吡蚜酮** (Pymetrozin e)

9C **氟啶虫酰胺** (Flonicamid)

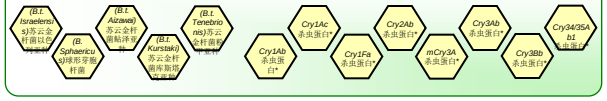
第10组: 螨虫生长抑制剂



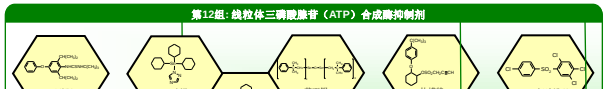
10A **四螨嗪及噻螨酮** (Clofentezine, Hexythiazox)

10B **乙螨唑** (Etoxazole)

第11组: 干扰昆虫中肠肠膜功能的微生物及其衍生毒素



第12组: 线粒体ΔATP合成酶抑制剂



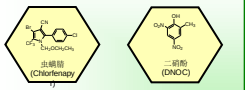
12A **丁醚脲** (Diafenthiuron)

12B **有机锡杀螨剂** (Organotin Miticides)

12C **炔螨特** (Propargite)

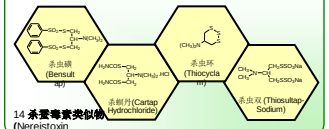
12D **三氯杀螨砜** (Tetradifon)

第13组: 通过干扰质子梯度影响氧化磷酸化的解偶联剂



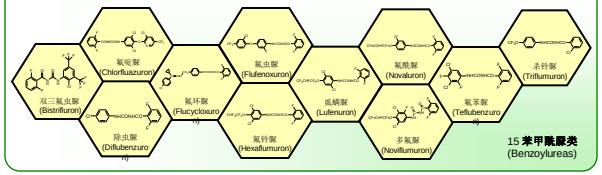
13 **吡咯及二硝酚类**(Pyrroles, Dinitrophenols)

第14组: 烟碱型乙酰胆碱受体（nAChR）通道阻滞剂



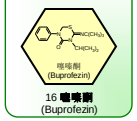
14 **杀蜚喜素类似物** (Nereistoxin analogues)

第15组: 几丁质生物合成抑制剂，0型



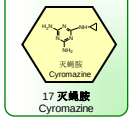
15 **苯甲酰脲类** (Benzoylureas)

第16组: 几丁质生物合成抑制剂，1型



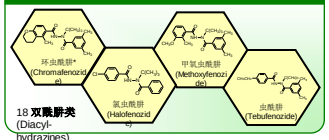
16 **噻嗪酮** (Buprofezin)

第17组: 双翅目昆虫蜕皮干扰物



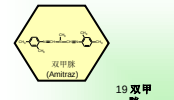
17 **灭蝇胺** Cyromazine

第18组: 蜕皮激素受体激动剂



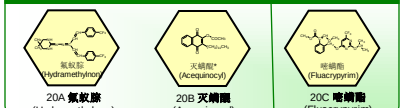
18 **双酰肼类** (Diacyl-hydrazines)

第19组: 章胺(Octopamine)受体激动剂



19 **双甲脒** (Amitraz)

第20组: 线粒体电子传递链复合体（Ⅲ）抑制剂

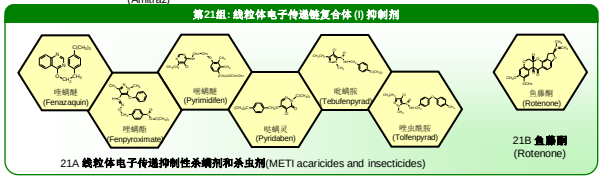


20A **氢胺腙** (Hydramethylnon)

20B **灭螨醌** (Acequinocyl)

20C **喹螨酚** (Fluacrypyrim)

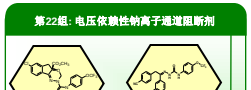
第21组: 线粒体电子传递链复合体（I）抑制剂



21A **线粒体电子传递抑制性杀螨剂和杀虫剂**(METI acaricides and insecticides)

21B **鱼藤酮** (Rotenone)

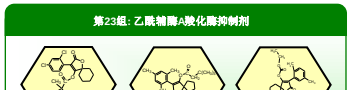
第22组: 电压依赖性钠离子通道阻断剂



22A **茚虫威** (Indoxacarb)

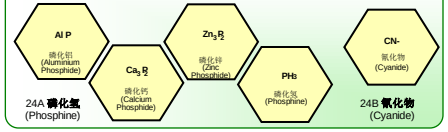
22B **氰氟虫腙** (Metaflumizone)

第23组: 乙酰辅酶A羧化酶抑制剂



23 **特雷酮和特拉姆酸衍生物** (Tetronic & Tetramic acid derivatives)

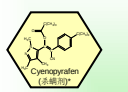
第24组: 线粒体电子传递链复合体（Ⅳ）抑制剂



24A **磷化氢** (Phosphine)

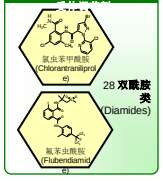
24B **氰化物** (Cyanide)

第25组: 线粒体电子传递链 复合体（Ⅱ）抑制剂



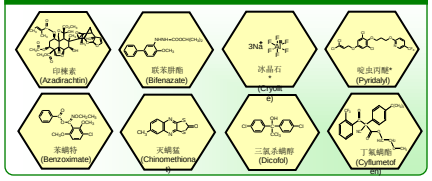
25 **Cyenopyrafen (杀螨剂)**

第28组: 尼鱼丁 (Ryanodine)



28 **双酰胺类** (Diamides)

UN组: 作用机制未知或未确定的化合物



* 目前为非标准化中文通用名称。同一化合物可能存在不同非标准化中文名称。

亚组使用指南:

- 亚组代表具有相同作用机制而化学结构类别不同的化合物。
- 亚组是用来区分那些可能结合于相同作用靶位的化合物。
- 由于亚组化合物化学结构不同，其产生代谢性交叉抗药性的风险低于那些结构相近的化学同系物。
- 亚组化合物可能经不同酶系代谢。与结构相近的同系物相比，其对同一靶位的不同结合方式会减少产生代谢性及靶标抗药性的机会。
- 无其它选择时，如果已知亚组化合物在靶标昆虫群落中无交叉抗药性作用，则可以将其轮转施用。
- 目前的亚组分类并非全部依据化合物对共同靶标蛋白的作用。欲了解更多信息，请参阅 **IRAC**有关“作用机制分类”文件资料。
- **1A**和**1B**亚组：如果无其它选择，已知靶标昆虫群落中无交叉抗药性时，两亚类化合物可以轮转施用。
- 3A和3B亚组：如果无其它选择，并且已知在靶标昆虫群落中无交叉抗药性作用（如击倒抗性）时，则两类亚组化合物间可轮转施用。
- 滴滴涕不再用于农业生产。但是，由于缺少其它替代物，因此只可应用于人类病源虫媒（如蚊虫）的防控。
- 10A亚组：尽管四螨嗪与噻螨酮的化学结构不同，但是通常存在交叉抗药性，因此将其并为同一亚组。而两种化合物的作用靶位均不明确。
- 22A和22B亚组：虽然这些化合物被认为具有相同的作用靶点，但是由于其化学结构不同，并且现有证据显示存在代谢交叉抗药性的风险较低，因此将其分为两个不同亚组。

海报版 2，2009年10月，以“作用机制分类” 6.3版本为基础制作。

Insecticide Resistance Action Committee

Mobile MoA scheme

MOA 24 page Booklet – 4,000 copies

Thanks for your attention