

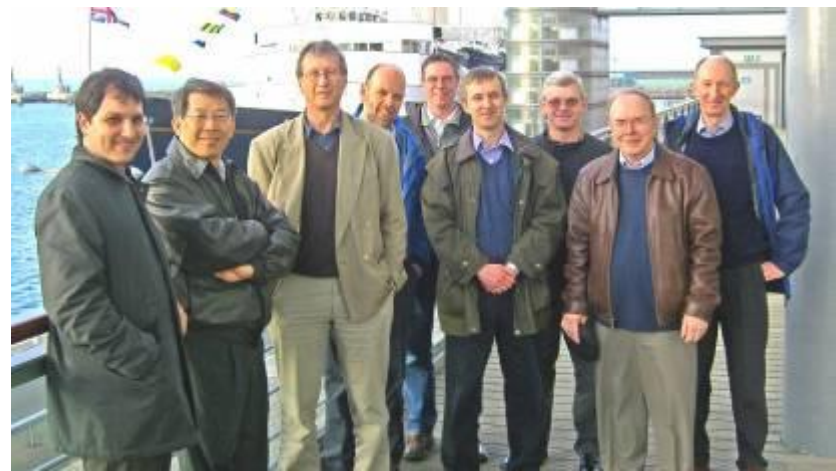


**Insecticide Resistance Action Committee:  
A coordinated industry commitment to product  
stewardship and sustainability**

CropLife International Chemicals Committee  
CropLife International, Avenue Louise 143, Brussels  
14 September 2006



- IRAC formed in 1984 to provide a coordinated industry response to the development of resistance in insect and mite pests
- IRAC is a technical group affiliated to CropLife
- Currently 7 IRAC International members:
  - BASF
  - Dow AgroSciences
  - FMC
  - Syngenta
  - Bayer CropScience
  - DuPont
  - Sumitomo
- Allows companies to successfully pool expertise and resources to develop effective insecticide resistance management (IRM) strategies



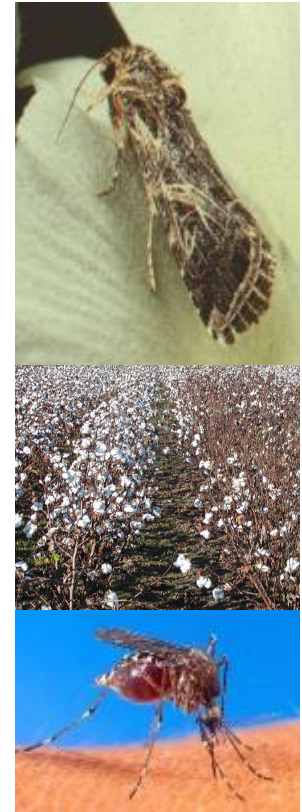
- *“Promote the development of resistance management strategies in crop protection and vector control to maintain efficacy and support sustainable agriculture and improved public health”*
- *“Keep all classes of insecticides and acaricides as viable control options”*
- *“Facilitate communication and education on insecticide and acaricide resistance”*

Core Activities

Crop protection

Biotechnology

Public health



Name	Company/Group	Country	Role/Responsibility
Alan Porter	APA (Consultant)	UK	International Coordinator, Website, C&E, PH & Reg teams
Nigel Armes	BASF	US	Communication & Education team leader, Methods team
Jamin Huang	Bayer CropScience	US	Regulatory Liaison team leader
Ralf Nauen	Bayer CropScience	Germany	Treasurer, Vice Chair, PH team leader, C&E & NNic teams
Nick Storer	Dow AgroSciences	US	Biotechnology team
Gary Thompson	Dow AgroSciences	US	MSU Database & RPMN Liaison, IRAC-US Liaison
Andrea Bassi	DuPont	Italy	Regulatory Liaison team
Chuck Staetz	FMC	US	IRAC-US liaison, Public Health team
Robin Slatter	Sumitomo	US	Public Health team
Max Angst	Syngenta	Switzerland	Codling Moth team leader, Neonicotinoid team
Alan McCaffery	Syngenta	UK	Chairman, Mode of Action, C&E, Reg. & Biotech teams

- Member companies parallel the CropLife International Core Companies, except for Monsanto
- IRAC working to recruit additional members, especially from SE Asia
- Generics are not CropLife members, and do not participate in IRAC

- Actively promote and support work of IRAC Country groups
- Interact effectively with and support IRAGs
- Liaise and cooperate with CropLife International
- Interact with regulatory authorities responsible for insecticide registration

### *Liaison and coordination activities*



## IRAC International

A comprehensive approach to tackling resistance



### *Technical outputs*

- Help to identify the scope and nature of resistance problems
- Provide methods for detecting and monitoring resistance
- Provide key resources to aid in developing effective IRM e.g. Mode of action scheme



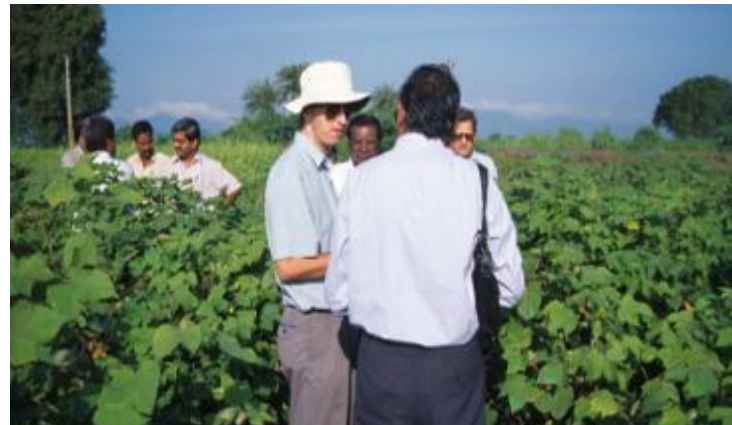
### *Communication and education*

- Develop IRAC website to provide communication and education on resistance to all stakeholders
- Develop educational resources to improve understanding of IRM
- Act as key global communicator on topical resistance issues

- Deal with key resistance issues at local level – supported by IRAC Intl. (liaison officer affiliated to each country group)
- Often include additional companies not involved in IRAC International
- May involve others from academia, research institutes & regulatory bodies
- Develop projects to support local problems –
  - e.g. IRAC-US neonicotinoid sub-committee harmonizing IRM guidelines
  - e.g. IRAC-India developing project to tackle resistance in BPH
  - e.g. IRAC-Brazil developed local Mode of Action based IRM scheme

### Current IRAC Country groups:

- IRAC Australia (IRMRG)
- IRAC Brazil
- IRAC India
- IRAC South Africa
- IRAC Spain
- IRAC US



- IRAC is keen to see the formation of an IRAC regional or country group in SE Asia



IRAC Country groups work with additional companies reflecting local resistance issues.

Two examples:

## IRAC-US membership

- AMVAC
- Arysta LifeScience
- BASF
- Bayer CropScience
- Cerexagri
- Chemtura
- Dow AgroSciences
- DuPont
- FMC
- Mitsui
- Monsanto
- Nisso America
- Syngenta
- Valent



## IRAC-Spain membership

- Agrodan
- Arago
- BASF
- Bayer CropScience
- Cequisa
- Dow AgroSciences
- DuPont
- IQV
- Kenogard
- Nufarm
- Sipcam Inagra
- Syngenta

Functional Teams:

- Communication & Education
- Regulatory Liaison

Expert Teams:

- Biotechnology
- Methods
- Mode of Action
- MSU Database & RPMN
- Public Health

Current Project Teams:

- Codling Moth
- Neonicotinoids



- Promote IRM to support sustainable agriculture and improved public health
- Emphasis on communication and education
- Development of international resources for IRM



Communication and Education is vital !  
A key role of IRAC



IRAC Communication and Education team responsibility



Resistance Management for Sustainable Agriculture & improved Public Health

Insecticide Resistance Action Committee

About IRAC

Resources

IRAC International

Country Groups










## Resistance Management from IRAC

The Insecticide Resistance Action Committee (IRAC) is an inter company group formed in 1984 to provide insecticide and acaricide resistance management strategies to help reduce the development of resistance in insect and mite pests. IRAC believes that Resistance Management should be an integral part of Integrated Pest Management and provides for Sustainable Agriculture and improved Public Health.



This new IRAC website has been designed to make it easier to navigate and locate Resistance Management information - the "drop-down" menus above lead to further details. We hope the site a useful resource.

### Links to recent Insecticide Resistance Management Information

-  [General Principles of Insecticide RM from IRAC](#)
-  [New IRAC Posters](#)
-  [IRAC Test Methods - New format, July 2005](#)
-  [IRAC Intl. Meeting, Florence April 2005 \(Members only\)](#)
-  [IRAC Information used at the BCPC, Glasgow, November 2005](#)
-  [IRAC Intl. Regulatory Team Minutes, January 2006 \(Members Only\)](#)
-  [IRAC Intl. C & E Team Minutes, March 2006 \(Members Only\)](#)
-  [IRAC Intl. Conference Call - Action Log, March 2006 \(Members only\)](#)
-  [IRAC US Meeting Minutes, April 2006 \(Members only\)](#)

### IRAC & IRM in the Spotlight

-  [Latest IRAC eConnection - Issue 11](#)

- IRAC's key communication vehicle
- Accessed by over 129 countries
- Av. 1,169 hits, 212 visits, 330 page views per day (Q1, 2006)
- Ranked 1<sup>st</sup> in Google and Yahoo for Insecticide Resistance and IRM
- IRAC Country group information
- Information on IRAC, Mode of Action, advice on IRM
- Education modules
- Resources - key papers, posters, etc.
- Links for growers
- Home, diary and other general pages
- Team and group areas
- 215 coded pages, 100 viewable pages, 3 databases. 157 document files, 135 image/graphic files

# Search Engine Ranking

Keyword	Google (SE) – March (Number of hits)		
	2004	2005	2006
IRAC & Resistance	1 (2K)	1 (4K)	1 (30K)
Insecticide Resistance Action Committee	1 (55K)	1 (257K)	1 (1,680K)
Insecticide Resistance Management	10 (70K)	1 (174K)	1 (854K)
IRAC *	1 (85K)	3 (127K)	2 (612K)
Insecticide Resistance	60 (103K)	1 (278K)	1 (1,450K)
Insecticide	>100	5 (969K)	6 (8,680K)

\* Top rank is irac.org which is the Israel Religious Action Centre

## Issue 11

September, 2006

[Subscribe](#) | [Unsubscribe](#)

### In this Issue:

- Introduction to eConnection
- IRAC News
- Resistance News
- Conferences and Symposia

### Introduction to eConnection

#### ■ eConnection Update

Welcome to the eleventh issue of IRAC eConnection, which covers activities over the last 6 months. IRAC International and the Country Committees have been busy on various IRM initiatives as well as representing IRAC at a number of international conferences. Details are covered briefly in this eConnection but further information can be found on the website. [See the site »](#)

A few of you have reported problems with the formatting of the eConnection when received by email. We have now re-coded the page to improve this but if you are still having difficulties we have also included links to html and pdf version at the top of the page and these can be opened up within your browser. Remember to update your details if your email address changes and you want to continue to receive copies of the newsletter. You can do this using the links above by "unsubscribing" your old address and "subscribing" with your new address.

We are always pleased to receive your feedback so keep it coming. As always past issues of eConnection can be located on the website under the heading "About IRAC" [or via this link](#)

- Free IRAC newsletter distributed by e-mail - part of IRAC Communications Plan
- Raises awareness of importance of IRM
- Promotes IRAC's reputation, expertise & resources
- Publicises and encourages visit to IRAC website
- 3 to 4 issues a year (10 to date)
- Current distribution 550 - 650

### Issue 10

March 2006

[Subscribe](#) | [Unsubscribe](#)

 [PDF Version](#)

#### News Categories this Issue:

- eConnection Update
- IRAC News
- Resistance News
- Conferences and Symposia

#### eConnection Update

##### ■ Issue 10 of eConnection

Welcome to the first issue of eConnection for 2006. IRAC has had a busy three months so in this issue we report on some of the IRAC meetings and Team Conference Calls that have taken place over the last quarter, the upcoming IRAC International Spring Meeting in Edinburgh, a report on the newly formed German Expert Committee on Pesticide Resistance – Working Group Insecticides, Acaricides (ECPR-I) and an early announcement of the Resistance Conference at Rothamsted (R2007).

As always past issues of eConnection and further details on the items reported can be found on the IRAC website. [More »](#)

##### ■ How to Subscribe or Unsubscribe from eConnection

New subscribers are able to add their name to the distribution list using the "subscribe" link at the top of the page and are also able to add names of interested colleagues. If you wish to remove your name from the distribution please use the "Unsubscribe" link also at the top of the page. Remember to update your details if your email address changes and you want to continue to receive copies of the newsletter. You can do this by "unsubscribing" your old address and re-subscribing with your new address. If you have any problems please contact the IRAC Coordinator at [aporter@intraspin.com](mailto:aporter@intraspin.com)

If you have a colleague who would be interested in the IRAC eConnection and website please forward this link to them so they can subscribe free of charge at: <http://www.irac-online.org/about/econnection.asp>

##### ■ Spread the Word

If you have Resistance Management information that you think should appear in eConnection or on the IRAC website contact us with details at: [aporter@intraspin.com](mailto:aporter@intraspin.com)

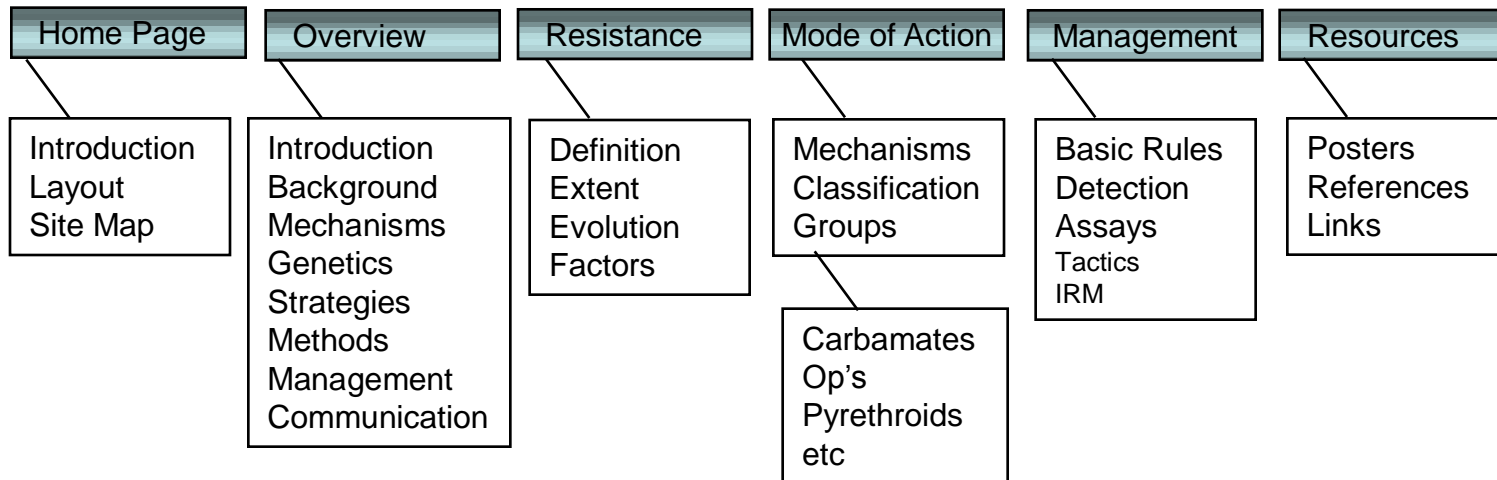
### 2005 / 2006 articles included:

- EPPO standard on RRA
- New MoA Scheme
- MoA scheme for US cotton
- Loss of AIs in EU for minor crops
- Brown Planthopper & neonicotinoids
- IRAC US neonicotinoids symposium
- *Bemisia tabaci* biotype Q on the move
- New IRAC communications pack

- New IRAC resource still in development
- Education and Training modules on resistance & IRM
- Graphic provides diagrammatic representation of layout and content



## Proposed Website Menu Headings and Sub-Headings



## Awareness, understanding and expert technical inputs on global regulatory matters and issues that concern insecticide resistance

- Provide technical advice and inputs on IRM matters to CropLife, FAO, EPPO, ECPA (Efficacy expert group), US-EPA, and other regulatory bodies, etc.
  - Lobby and influence on issues that relate to effective resistance management
  - Area for cooperation with CropLife
  - Liaison and collaboration with FRAC and HRAC
- Develop awareness and understanding [for both Conventional chemistry (Ag and non-Ag) and GMO's] of current status of and forthcoming developments in:
  - Resistance risk assessments in different countries & technical data requirements needed to support them
  - IRM labelling, Mode of Action labelling

## Awareness, understanding and expert technical inputs on global regulatory matters and issues that concern insecticide resistance

- Guide intelligent interpretation and implementation of technical aspects of guidelines on resistance risk assessment
  - Provide lists of pests and resistance risks
  - Develop and provide methods to support Resistance Risk Assessment
  - Membership of EPPO permanent panel on insecticide resistance
- Developing IRAC-International regulatory policy paper - harmonised with IRAC-US





## European and Mediterranean Plant Protection Organization



### EPPO standard on Resistance Risk Assessment PP 1/213(2)

Specific scope:

This standard describes how the risk of resistance to plant protection products can be assessed and, if appropriate, systems for risk management can be proposed, in the context of official registration of plant protection products



Examples of species in the EPPO region which have developed resistance and for which sensitivity data should be normally provided

*Aphis gossypii*  
*Myzus persicae*  
*Phorodon humuli*  
*Bemisia tabaci*  
*Trialeurodes vaporariorum*  
*Frankliniella occidentalis*  
*Spodoptera exigua*  
*Cydia pomonella*  
*Leptinotarsa decemlineata*  
*Tetranychus urticae*  
*Panonychus ulmi*

### Why?

- Resistance evolves readily when a specific target site is put under continuous selection pressure through the use of a single insecticidal mode of action

### What?

- Effective Insecticide Resistance Management (IRM) is essential
- IRAC has led the way in promoting selection and use of insecticides based on mode of action (MoA) and the use of a range of modes of action in IRM programmes
- Developed definitive, globally recognized Mode of Action scheme

### What works?

Proactive - Prevention or delay of evolution of resistance – Easiest

Reactive - Cure of resistance and recovery of susceptibility - Harder



Insecticides with different modes of action



Sequences  
Programmes  
Alternations  
Rotations  
Mixtures  
Mosaics



Insecticide Resistance Action Committee  
[www.irc-online.org](http://www.irc-online.org)

## IRAC Mode of Action Classification

Fully revised & re-issued, September 2005

Version: 5.1

The IRAC Mode of Action (MoA) classification provides farmers, growers, advisors, extension staff, consultants and crop protection professionals with a guide to the selection of insecticides or acaricides for use in an effective and sustainable insecticide or acaricide resistance management (IRM) strategy. In addition to presenting the MoA classification, this document outlines the background to, and purposes of, the classification list and provides guidance on how it is used for IRM purposes. The list is reviewed and re-issued at intervals as required.

### 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). This definition differs slightly from others in the literature, but IRAC believes it represents the most accurate, practical definition of relevance to farmers and growers. Resistance arises through the over-use or mis-use of an insecticide or acaricide against a pest species and results in the selection of resistant forms of the pest and the consequent evolution of populations that are resistant to that insecticide or acaricide.

### MoA, Target-site resistance and Cross-resistance

In the majority of cases, not only does resistance render the selecting compound ineffective but it often also confers cross-resistance to other chemically related compounds. This is

- Definitive scheme developed and endorsed by IRAC in consultation with key researchers
- Worldwide distribution
- All current insecticides allocated to a Mode of Action group or sub-group
  - MoA groups 1-28
- A key tool for selection of insecticides in effective IRM programs
- Updated as required
- Latest version Sept 2005
- Next revision, Q3, 2006

IRAC Mode of Action Classification Version: 5.1

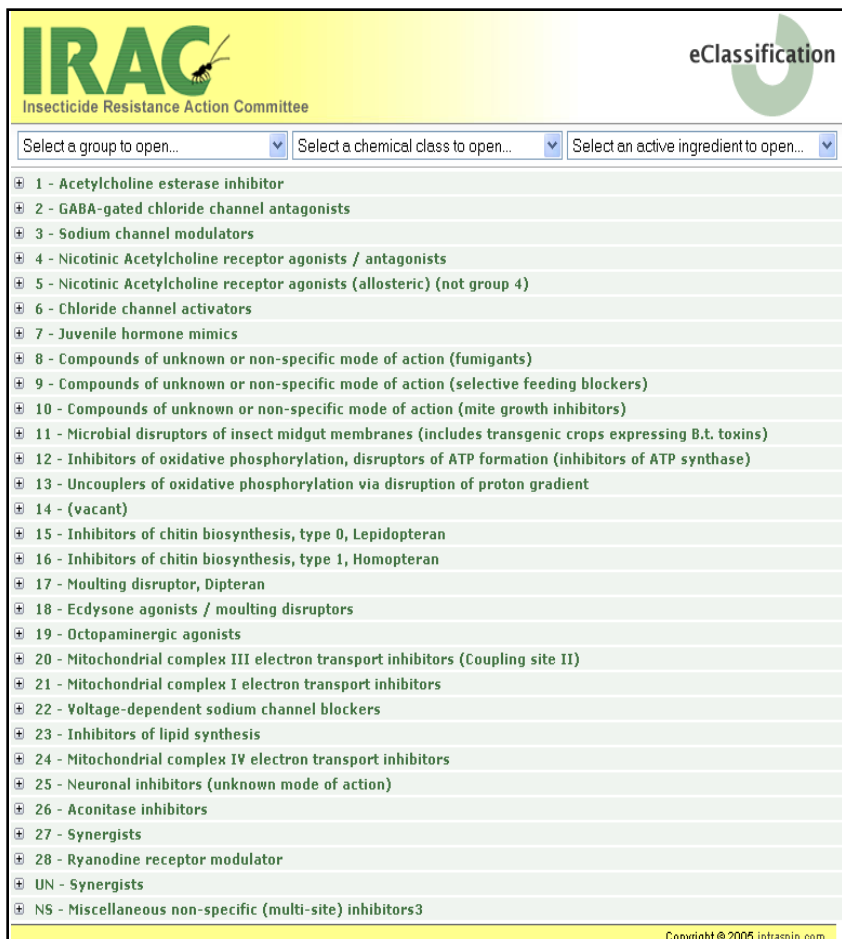
**IRAC Mode of Action Classification v5, September 2005<sup>1</sup>**

Main Group and Primary Site of Action	Chemical Sub-group or exemplifying Active Ingredient	Active Ingredients
1 Acetylcholine esterase inhibitors	1A Carbamates	Aldicarb, Alanycarb, Bendiocarb, Benfuracarb, Butocarboxim, Butoxycarboxim, Carbaryl, Carbofuran, Carbosulfan, Ethiofencarb, Fenobucarb, Formetanate, Furathiocarb, Isoprocarb, Methiocarb, Methomyl, Metolcarb, Oxamyl, Pirimicarb, Propoxur, Thiodicarb, Thiofanox, Trimethacarb, XMC, Xylcarb
	Triazemate	Triazemate
	1B Organophosphates	Acephate, Acamethiphos, Acinphos-ethyl, Acinphos-methyl, Cadusafos, Chlorothoxyfos, 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, Isofenphos, Isopropyl O-methoxyaminothio-phosphoryl salicylate, Isoxathion, Malathion, Mecarbam, Methamidophos, Methidathion, Mevinphos, Monoerotophos, Naled, Omethoate, Oxydemeton-methyl, Parathion, Parathion-methyl, Phenthoate, Phorate, Phosalone, Phosmet, Phosphamidon, Phoxim, Pirimiphos-ethyl, Profenofos, Propetamphos, Prothiofos, Pyraclofos, Pyridaphenthion, Quinalphos, Sulfotep, Tebupirifos, Temephos, Terbufos, Tetrachlorvinphos, Thiometon, Triazophos, Trichlorfon, Vamidathion
2 GABA-gated chloride channel antagonists	2A Cyclodiene organochlorines	Chlordane, Endosulfan, gamma-HCH (Lindane)
	2B Phenylpyrazoles (Fiproles)	Ethiprole, Fipronil
3 Sodium channel modulators	DDT	DDT
	Methoxychlor	Methoxychlor
	Pyrethroids	Acinathrin, Allethrin, d-cis-trans Allethrin, dtrans Allethrin,

## Example pages

Main Group and Primary Site of Action	Chemical Sub-group or exemplifying Active Ingredient	Active Ingredients
4 Nicotinic Acetylcholine receptor agonists / agonists	4A Neonicotinoids	Acetamiprid, Clothianidin, Dinotefuran, Imidacloprid, Nitenpyram, Thiacloprid, Thiamethoxam
	4B Nicotine	Nicotine
	4C Bensultap	Bensultap
5 Nicotinic Acetylcholine receptor agonists (steric) (not group 4)	Cartap hydrochloride	Cartap hydrochloride
	Nereistoxin analogues	Thiocyclam, Thiosultap-sodium
6 GABA-gated chloride channel antagonists	Spinosyns	Spinosad
7 Voltage-gated sodium channel blockers	Avemectins, Milbemycins	Abamectin, Enamectin benzoate, Milbemectin
8 Juvenile hormone mimics	7A Juvenile hormone analogues	Hydroprene, Kinoprene, Methoprene
	7B Fenoxycarb	Fenoxycarb
	7C Pyriproxyfen	Pyriproxyfen
9 Compounds of unknown or non-specific mode of action (fumigants)	8A Alkyl halides	Methyl bromide and other alkyl halides
	8B Chloropicrin	Chloropicrin

## New MoA interactive online tool www.irac-online.org



**IRAC**  
Insecticide Resistance Action Committee

**eClassification**

Select a group to open... Select a chemical class to open... Select an active ingredient to open...

- 1 - Acetylcholine esterase inhibitor
- 2 - GABA-gated chloride channel antagonists
- 3 - Sodium channel modulators
- 4 - Nicotinic Acetylcholine receptor agonists / antagonists
- 5 - Nicotinic Acetylcholine receptor agonists (allosteric) (not group 4)
- 6 - Chloride channel activators
- 7 - Juvenile hormone mimics
- 8 - Compounds of unknown or non-specific mode of action (fumigants)
- 9 - Compounds of unknown or non-specific mode of action (selective feeding blockers)
- 10 - Compounds of unknown or non-specific mode of action (mite growth inhibitors)
- 11 - Microbial disruptors of insect midgut membranes (includes transgenic crops expressing B.t. toxins)
- 12 - Inhibitors of oxidative phosphorylation, disruptors of ATP formation (inhibitors of ATP synthase)
- 13 - Uncouplers of oxidative phosphorylation via disruption of proton gradient
- 14 - (vacant)
- 15 - Inhibitors of chitin biosynthesis, type 0, Lepidopteran
- 16 - Inhibitors of chitin biosynthesis, type 1, Homopteran
- 17 - Moulting disruptor, Dipteran
- 18 - Ecdysone agonists / moulting disruptors
- 19 - Octopaminergic agonists
- 20 - Mitochondrial complex III electron transport inhibitors (Coupling site II)
- 21 - Mitochondrial complex I electron transport inhibitors
- 22 - Voltage-dependent sodium channel blockers
- 23 - Inhibitors of lipid synthesis
- 24 - Mitochondrial complex IV electron transport inhibitors
- 25 - Neuronal inhibitors (unknown mode of action)
- 26 - Aconitase inhibitors
- 27 - Synergists
- 28 - Ryanodine receptor modulator
- UN - Synergists
- NS - Miscellaneous non-specific (multi-site) inhibitors

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Select a group to open...

- (vacant)
- Acetylcholine esterase inhibitor
- Aconitase inhibitors
- Chloride channel activators
- Compounds of unknown or non-specific mode of action (fumigants)
- Compounds of unknown or non-specific mode of action (selective feeding blockers)
- Compounds of unknown or non-specific mode of action (mite growth inhibitors)
- Ecdysone agonists / moulting disruptors
- GABA-gated chloride channel antagonist
- Inhibitors of chitin biosynthesis, type 0, Lepidopteran
- Inhibitors of chitin biosynthesis, type 1, Homopteran
- Inhibitors of lipid synthesis
- Inhibitors of oxidative phosphorylation, disruptors of ATP formation (inhibitors of ATP synthase)
- Juvenile hormone mimics
- Microbial disruptors of insect midgut membranes (includes transgenic crops expressing B.t. toxins)
- Miscellaneous non-specific (multi-site) inhibitors
- Mitochondrial complex I electron transport inhibitors
- Mitochondrial complex III electron transport inhibitors (Coupling site II)
- Mitochondrial complex IV electron transport inhibitors
- Moulting disruptor, Dipteran
- Neuronal inhibitors (unknown mode of action)
- Nicotinic Acetylcholine receptor agonists
- Nicotinic Acetylcholine receptor agonists (allosteric) (not group 4)
- Octopaminergic agonists
- Ryanodine receptor modulator
- Sodium channel modulators
- Synergists
- Synergists
- Uncouplers of oxidative phosphorylation via disruption of proton gradient
- Voltage-dependent sodium channel blockers

Select a chemical class to open...

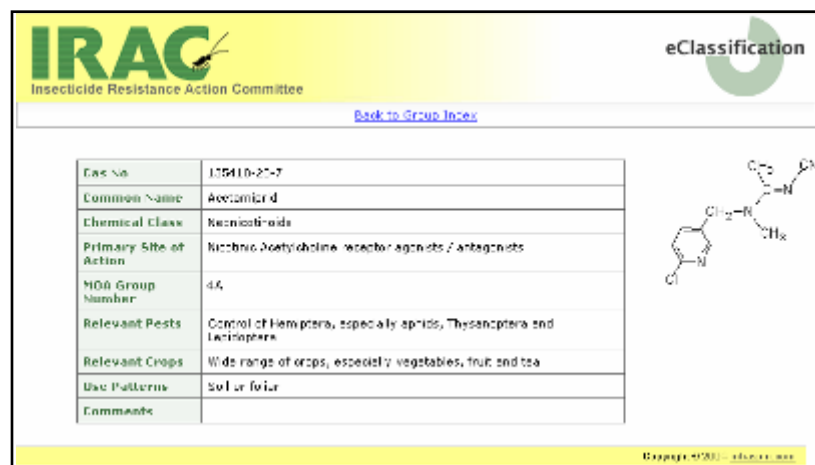
- Avermectins, Milbemycins
- Benzoylureas
- Carbamates
- Cyclodiene organochlorines
- Esterase inhibitors
- Fipronil (or Phenylpyrazoles)
- Juvenile hormone analogues
- METI acaricides, Rotenone
- Methyl bromide
- Neonicotinoids
- Organophosphates
- Organotin miticides
- P450 monoxygenase inhibitors
- Pyrethroids
- Tetronic acid derivatives

Select an active ingredient to open...

- Abamectin
- Accephate
- Acequinocyl
- Acetamiprid
- Acrinathrin
- Alarycarb
- Aldicarb
- Allethrin
- Aluminium phosphide
- Aminocarb
- Amitraz
- Azadirachtin
- Azamethiphos
- Azinphos-methyl
- Azinphos-methyl
- Azocyclotin
- B.t. var. aizawai
- B.t. var. israelensis
- B.t. var. kurstaki
- B.t. var. sphaericus
- B.t. var. tenebrionensis
- Bendiocarb
- Benfuracarb
- Bensultap
- Benzoate
- Bifenazate
- Bifenthrin
- Bioallethrin
- Bioallethrin S-cyclopentyl

Drop down menu  
>> options

Data Sheets



**IRAC**  
Insecticide Resistance Action Committee

**eClassification**

[Back to Group Index](#)

IRAC No.	105110-27-7
Common Name	Acetamiprid
Chemical Class	Neonicotinoids
Primary Site of Action	Nicotinic Acetylcholine receptor agonists / antagonists
MoA Group Number	4A
Relevant Pests	Control of Hemiptera, especially aphids, Thysanoptera and Lecynoptera
Relevant Crops	Wide range of crops, especially vegetables, fruit and tea
Use Patterns	Sol or foliar
Comments	

CC1=NC(=NC=C1)C(=O)N(C)C(=O)N

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life



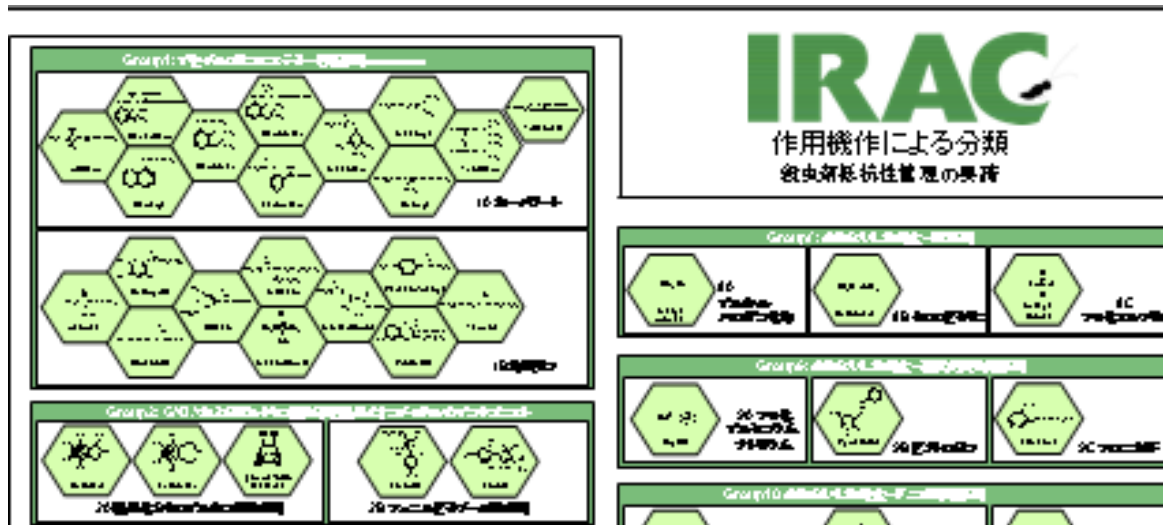
## New in 2006 - IRAC Mode of Action Classification Groups and Structures

**Mode of Action Classification**  
The key to Insecticide Resistance Management

For more information on the Insecticide Resistance Action Committee and the Insecticide Action Classification is available from [www.iraconline.org](http://www.iraconline.org) or [inquiries@iraconline.org](mailto:inquiries@iraconline.org)

- Available as A1 posters
- First batch of 3000 printed
- Extremely high demand for copies!
- Recently translated into Japanese

- Successful IRM needs widespread distribution of the resources IRAC International has developed
- As part of IRAC's communication and education remit, work underway to develop translations of key IRAC documents, posters & papers
- Local company offices and IRAC Country groups e.g. IRAC-Spain are helping
- MoA structure poster has been translated into Japanese and other key documents will follow



Part of Japanese version of MoA poster





### Almeria region SE Spain

- Intensive, widespread vegetable production in plastic houses
- Continuous production cycles + favourable climatic conditions → Severe Bemisia tabaci infestations → direct damage and virus transmission
- Zero or extremely low virus tolerance
- Insecticides applied every 2-3 days!
- Neonicotinoids used to be highly effective - until recently
- But intensive use = very high levels of selection → development of resistance to all neonicotinoids
- Cause - Lack of effective IRM programmes with available AIs
- Similar problems in other Mediterranean basin countries
- Resistance due to enhanced monooxygenase activity

IRAC lists 9 compound types commonly used for whitefly control:

**Carbamates**

**Organophosphates**

**Cyclodienes**

**Neonicotinoids**

**Pyriproxyfen**

**Pymetrozine**

**Diafenthiuron**

**Buprofezin**

**Spiromesifen**

*So why is resistance a problem?*



Outlooks on Pest Management, 2006:

## INSECTICIDE RESISTANCE ACTION COMMITTEE

THE INSECTICIDE RESISTANCE ACTION COMMITTEE (IRAC):  
PUBLIC RESPONSIBILITY AND ENLIGHTENED INDUSTRIAL  
SELF-INTEREST

Alan McCaffery<sup>1</sup> and Ralf Nauen<sup>2</sup>

<sup>1</sup> Chairman, Insecticide Resistance Action Committee, Syngenta, Jealotts Hill International Research Station, Bracknell, UK

<sup>2</sup> Vice-Chairman, Insecticide Resistance Action Committee Bayer CropScience AG, Research Insecticides, Monheim, Germany

## Insecticide Resistance Management A Monograph

(in preparation)

*Written and published by:  
Insecticide Resistance Action Committee  
(IRAC) 2007*

Text for CLI / IRAC publication:

## Insecticide Resistance Management for Sustainable Agriculture and Improved Public Health

(in preparation)

*Written and published by:  
CropLife International in conjunction with the  
Insecticide Resistance Action Committee (IRAC)  
2006*

Wiley book (2007) chapter: (in press)

## 4.1. IRAC, Insecticide Resistance and Mode of Action Classification of Insecticides

A. Elbert, R. Nauen and A. R. McCaffery

...inated crop  
... delay the  
...s. The main  
...ication and  
...y to promote  
...ies in crop

## Prevention and Management of Insecticide Resistance in Vectors and Pests of Public Health Importance

A manual produced by:

Insecticide Resistance Action Committee (IRAC)

(in press)



### Effective insecticide resistance management

The agrochemical industry's approach to ensure sustained efficacy of insecticides

Alan McCaffery<sup>1</sup> and Ralf Nauen<sup>2</sup>

<sup>1</sup>Syngenta, Bracknell, UK

Chairman, Insecticide Resistance Action Committee

<sup>2</sup>Bayer CropScience, Monheim, Germany

Vice-Chairman, Insecticide Resistance Action Committee

Effective resistance management for the neonicotinoids:

Industry's approach to ensure the continued efficacy of a key insecticide class



Switzerland



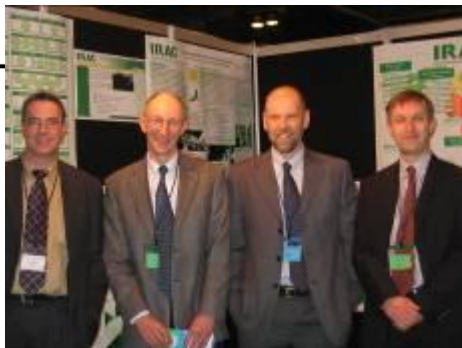
### Insecticide Resistance Action Committee: What does it do?

Joint RAC & RAG Open Forum  
Combating Pesticide Resistance  
BCPC International Congress  
Crop Science & Technology 2005

Alan McCaffery

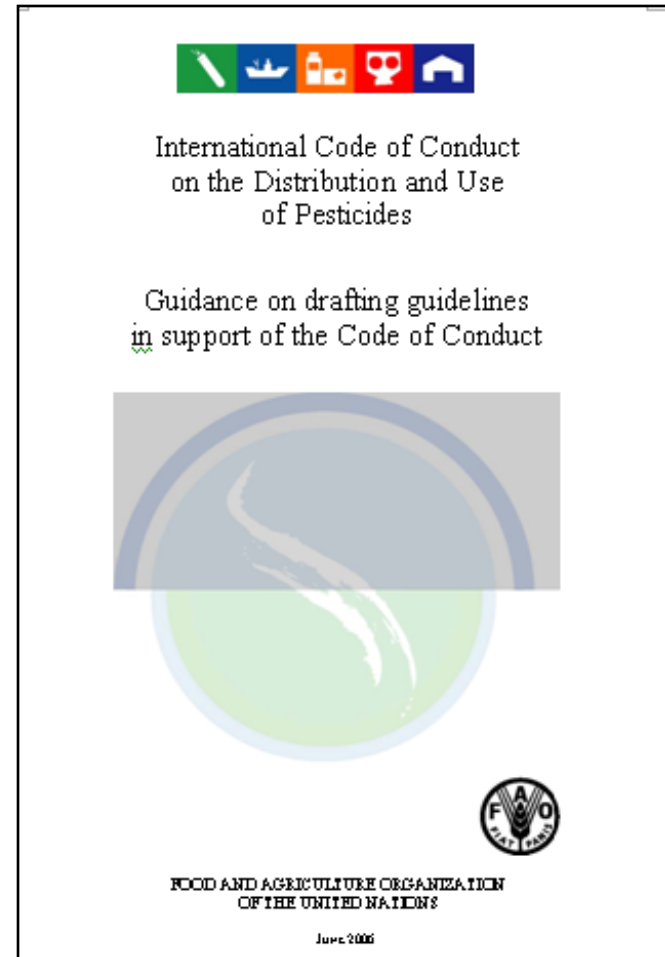


IUPAC, Kobe, August 10, 2006: Resistance Management and





- IRAC provides expert advice, guidance and education (via website) on effective IRM
- Provides resources to help develop IRM programmes
- Directly helps and encourages IRAC Country Groups to develop IRM programmes
- Inputs to EPPO guidelines
- Inputs to new initiatives e.g. will be helping CropLife to develop resistance management sections of FAO International Code of Conduct

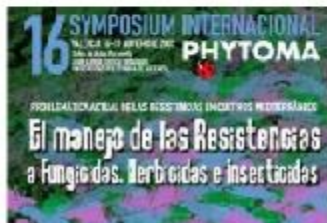




### Principales dificultades en el control de plagas

Resultados de las encuestas IRAC España  
(Insecticide Resistance Action Committee)

2002-2004



Jose Luis Collar Ure  
Doctor Ingeniero Agrónomo

Aragonesas Agro S.L.  
Miembro de IRAC España



### LA RESISTENCIA DE LOS TRIPS EN CULTIVOS INTENSIVOS

“Un problema que requiere la colaboración de todos”



## IRAC, Neonicotinoid Subcommittee

The Neonicotinoid Subcommittee of Insecticide Resistance Action Committee (IRAC-US) was created in 2003 with the charter to act as the official industry body for coordinating information and resources on resistance management for the neonicotinoid chemical class. Recent public interest in insecticide resistance issues as well as the public

### GENERAL GUIDELINES FOR USE OF NEONICOTINOID INSECTICIDES (IRAC Mode of Action Classification Group 4A)

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IRAC

Resistance management begins with good agricultural practices including crop rotation, utilization of resistant varieties, sanitation, healthy seed, as well as pest monitoring and forecasting. For resistance management to be effective, a concerted effort.

The following guidelines have been accepted by the IRAC Neonicotinoid Subcommittee.

These guidelines focus on both soil and/or foliar applications.

IRAC-US initiative to form a specialist sub-committee to provide guidance on use and IRM of this valuable class of insecticides

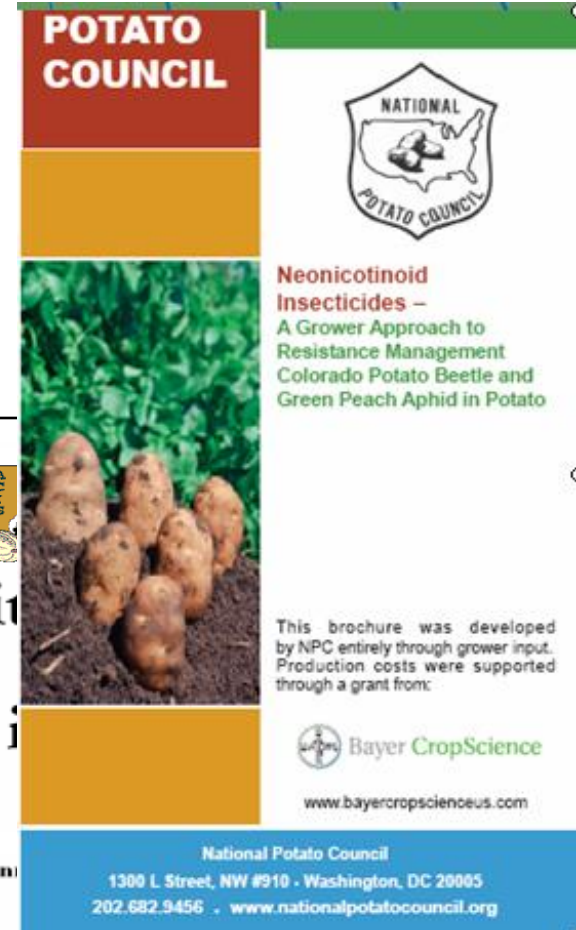
Group worked with advisory bodies and grower organisations




## Cross-commodity Guidelines for Neonicotinoids in Arizona

John Palumbo, Peter C. Ellsworth, Timothy J. Demaree  
*University of Arizona*

*Developed in collaboration with*  
Arizona Crop Protection Association  
Arizona Cotton Growers Association  
Cotton Incorporated  
Western Growers Association




**POTATO COUNCIL**



**Neonicotinoid Insecticides – A Grower Approach to Resistance Management**  
Colorado Potato Beetle and Green Peach Aphid in Potato

This brochure was developed by NPC entirely through grower input. Production costs were supported through a grant from:



[www.bayercropscienceus.com](http://www.bayercropscienceus.com)

National Potato Council  
1300 L Street, NW #910 - Washington, DC 20005  
202.682.9456 · [www.nationalpotatocouncil.org](http://www.nationalpotatocouncil.org)



US:  
IRAC-US

### Insecticide Resistance Management Strategies

*Developed by the CropLife Australia Insecticide Resistance Management Group and Industry Researchers*

Current as at 25 November 2005

Australia:  
Insecticide Resistance Management Review Group (IRMRG)  
(formerly AIRAC, AIRMG)

### Insecticide Resistance: Causes and Action



A joint effort between the Southern Region Integrated Pest Management Center and the Insecticide Resistance Action Committee

Mode of Action (MOA) Initiative





*Effective Insecticide Resistance Management (IRM) is possible but....  
A broad range of different insecticidal modes of action is essential*





# The need for new AIs – Pollen beetle

In many European countries the pyrethroids are the only insecticides registered for use on oilseed rape – particularly for control of pollen beetle – and we have resistance!!



Resistance to pyrethroids  
in *Meligethes*

**Poland**

**France**

**Germany**

**Belgium**

**Austria**

**Scandinavia**

Loss of effective OP's in EU - de-registration or lack of re-registration (not just a problem in minor crops)

Reliance on a single MoA class – the pyrethroids

New MoA classes urgently required!

- No new insecticides for adult mosquito control have been produced in 30 years.
- Loss of insecticides for mosquito control
  - Resistance issues
  - Regulatory hurdles
  - Economic reasons
- WHO has highlighted urgent need for new mosquito adulticide

Available chemistry – just two targets

- OP's and carbamates – acetylcholinesterase
- DDT and pyrethroids – sodium channel

Insecticide treated bednets contribute in a major way to malaria control but are reliant on pyrethroids

Resistance is increasingly a major problem in many countries and it is spreading





#### Recomendações para o manejo no controle da lagarta-do-cartucho do milho (*Spodoptera frugiperda*)

Baseado no mapeamento de risco potencial e nas informações obtidas nos estudos, sugere-se a rotação de inseticidas considerando-se o mecanismo de ação, a frequência de resistência observada para os diferentes grupos químicos e a época de plantio.

#### Áreas críticas e potenciais

Época de Plantio	Verão	Safra seca	Inverno
1ª Mudas de Plantação III	2 a 3	2 a 3	5 a 7
1ª Aplicação	[Color dots]	[Color dots]	[Color dots]
2ª Aplicação	[Color dots]	[Color dots]	[Color dots]
3ª Aplicação	[Color dots]	[Color dots]	[Color dots]
Quarta	[Color dots]	[Color dots]	[Color dots]

III data de pesquisa de campo  
\* usar somente inseticidas registrados no Brasil

#### Recomendações gerais:

Dar preferência a produtos seletivos a inimigos naturais nas primeiras aplicações.

Não repetir o uso de produtos do mesmo grupo químico utilizada aplicação anterior.

As pulverizações devem ser realizadas seguindo-se a recomendação técnica do nível de controle desta praga na cultura. Em caso de dúvida consulte um engenheiro agrônomo.

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IRAC-Brazil worked with academics, government including regulators, and grower groups to implement effective IRM using MoA coding and guidelines on product use

#### Ingredientes ativos registrados para lagarta-do-cartucho (*Spodoptera frugiperda*) em milho

Grupo Químico	Mecanismo de Ação Primário	Princípio Ativo
Piratróides	Inibidores de síntese de ácidos	Chlorantranilipropina Methoxyfenoxipropina Nixafent Deltamethrina Etofenprox Efenprox Fenoxipropina Sulfofenoxipropina Permethrina Zeta-cypermethrina
Organofosforados	Inibidores da síntese de acetilcolina	Chlorpyrifos Difentozina Diazinofos Difentozina Etofenprox Fenoxipropina Triazofos
Carbamatos	Inibidores da síntese de acetilcolina	Carbaryl Bifenthrin Triazofos
Natural/lyfe	Inibidores de receptores da acetilcolina	Spinosad
Dinilhidrozinóis	Agregados de esteroides (acetylcholinesterase)	Imidacloprid Triazofos
Derivados de uréia	Inibidores da síntese de ácidos	Chlorantranilipropina Methoxyfenoxipropina Nixafent Deltamethrina Etofenprox Triazofos

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### Mode of Action Labeling



IRAC-US initiative to ensure clear MoA labelling of products




**GROUP 4A INSECTICIDE**

**INSECT-BE-GONE<sup>®</sup> Insecticide**

For uses in pest management applications.

ACTIVE INGREDIENT: XXXXXXXXXXXX, XXXXXXXX XXXXXXXX  
 ..... XX.X%

OTHER INGREDIENTS .....  
 ..... XX.X%

EPA Reg. No. XXXX-XXXX  
 Contains 7 pounds of XXXXXX per gallon.  
 SHAKE WELL BEFORE USE

100.0%

**MODE OF ACTION  
 IRAC-International Classification**

**Will be added to labels.**

CropLife INTERNATIONAL

- IRAC provides validated test methods of proven ability to detect changes in susceptibility
  - Baselines
  - Early detection of resistance
  - Evaluation of success of IRM strategies
- IRAC currently has a program to update the methods
- Intention to include methods for all pests in regulatory guidelines
  - e.g. EPPO Standard PP 1/213 Resistance Risk Analysis
- New methods will also include biochemical and molecular methods
- IRAC intends to develop interactive versions in the future





Insecticide Resistance Action Committee

[www.irc-online.org](http://www.irc-online.org)

Resistance Management for Sustainable Agriculture and Improved Public Health

## IRAC Susceptibility Test Methods Series

Version: 2

Method No: 3

### Details:

Method:	No: 3	 <p>Photograph Courtesy of Whitney Chapman, Colorado State University Tetranychus spp.</p>
Status:	Approved	
Species:	<i>Panonychus ulmi</i> <i>Tetranychus</i> spp.	
Species Stage:	<i>P. ulmi</i> (summer eggs) <i>Tetranychus</i> (eggs)	
Product Class:	clofentezine hexythiazox tetradiolon	
Comments:	None	

### Description:

#### Materials:

Petri dishes (9-cm diameter), filter paper to fit Petri dishes, cotton wool, untreated apple or plum leaves, small scissors, small forceps, fine pointed brush or cocktail stick, beakers or glass jars (ca. 100-ml capacity) for test liquids, 1-ml disposable plastic syringes for liquids for weighing balance for solids, hand lens (minimum 10 x) or binocular microscope, maximum/minimum thermometer.

#### Methods:

- Cut square sections about 1.5 x 1.5 cm from chemically untreated apple or plum leaves. Use young leaves, but not before they are fully expanded. Leaves must be in good condition. Use a minimum of four replicates (leaf sections) per treatment.
- Place these sections, upper surface uppermost, on a sheet of moist filter paper on moist cotton wool in open Petri dishes.
- Collect apple leaves with adult mites, and with the fine pointed brush or cocktail stick transfer 10 - 15 females onto each leaf section. Maintain at a minimum temperature of 20°C, minimum photoperiod 16 h and a high light intensity, but not in direct sunlight.
- After 24 h, check that the female mites have laid eggs. Aim for at least 20 eggs per leaf section. If there are not enough eggs, leave for a further 24 h. Do not leave longer than 48 h.
- When sufficient egg numbers have been obtained, remove the mites with the fine pointed brush or cocktail stick. Record the time when this is done.
- Prepare appropriate test dilutions of formulations in water. The use of a wetter is not

For further information please contact: Alan Porter, IRAC International Coordinator  
[www.irc-online.org](http://www.irc-online.org), e-mail: [aporter@intrasdn.com](mailto:aporter@intrasdn.com)

## IRAC Susceptibility Test Methods Series

Version: 2

Method No: 3

- recommended.
- Agitate test liquids and then dip the leaf sections for 5 sec. Dip equal number of control leaf sections in water only.
  - Record the number of eggs per leaf section.
  - Return leaf sections to Petri dishes and maintain in conditions described above. Record maximum and minimum temperatures. Moisten cotton wool daily.
  - Using a hand lens or binocular microscope observe leaf sections daily until there has been complete (or nearly complete) hatch on the untreated (water only) leaf sections. Record numbers of un-hatched eggs on treated and untreated leaf sections.
  - Express results as percentage mortality and correct for untreated mortality using Abbott's formula. Untreated mortality should be recorded.

### Precautions & Notes:

If the lids are left off, the leaf sections may dry out and, unless the cotton wool can be moistened at least daily, the test may be invalidated by excessive control mortality. In such circumstances, the method may have to be modified to suit the local conditions, e.g. use lids with holes cut in them to reduce water loss without creating a condensation problem.

For *Tetranychus* spp. which lay mainly on the lower leaf surface, the leaf sections may need to be placed lower surface uppermost. Leaves of kidney beans are particularly suitable.

### References & Acknowledgements:

None

For further information please contact: Alan Porter, IRAC International Coordinator  
[www.irc-online.org](http://www.irc-online.org), e-mail: [aporter@intrasdn.com](mailto:aporter@intrasdn.com)



## Example new definitive method



Adult vial test for Pollen beetle *Meligethes aeneus*  
 For OPs and pyrethroids  
 Especially relevant for resistance to pyrethroids in Europe





- Public Health team reformed May 2006 with membership including WHO and Gates Foundation
- First face-to-face meeting held at WHO HQ in Geneva in August
- Team is working to understand status of vector resistance, nature of resistance, options for control and availability of test insects and methods
- Team is addressing need for overall vector control strategy and how to manage insecticide resistance
- Vector Control Manual was completed in August and IRAC will publish it



### **Prevention and Management of Insecticide Resistance in Vectors and Pests of Public Health Importance**

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- IRAC is now involved in IRM for GM crops expressing insect-control traits – new Biotechnology team formed 2005
- Reflects realities of modern pest insect management and need for multiple inputs

### Objectives:

- Influence development of regional or country IRM plans away from one-size-fits-all approach
- Advise CropLife on biotechnology IRM issues
  - Parallels increasing involvement of CLI in Biotechnology
- Provide uniform guidance to IRAC or non-IRAC country groups on appropriate resistance management practices and regulations
- Provide unified global industry position on IRM regulation
- Coordinate development of education programmes
- Support research with international dimensions



Photo: JR Bradley, 2004

# IRAC needs help !

## *IRAC is increasingly successful - but also being required to do a much bigger job*

- IRAC's influence is increasing rapidly – a result of a major commitment to education and communication on the need for effective IRM
- Demands on IRAC have increased markedly
  - Broader remit - Crop Protection, Biotechnology, Public Health
  - Increasing regulatory demands for IRM and related activities
  - Increasing recognition that we need to preserve what we have - finding new AIs is ever-more costly and time-consuming

## *But we need help in:*

- Increasing awareness of the importance of resistance management stewardship activities within member companies
  - Expanding remit and participation – more manpower needed
  - Less challenge for financial support for IRAC and its initiatives
- Increased coordination within CropLife – particularly across the RACs
- Support for communication and education projects including:
  - Developing better messages on the value of crop protection and biotechnology products - and why we and others should support IRM to preserve this value

# Some final thoughts

- IRAC has a key focus on Communication and Education – a major effort in recent years
- The IRAC website is central to this effort – resources, education, advice
- IRAC is supporting the Country group network with appropriate resources to tackle local resistance problems
- IRAC is working with regulatory bodies to represent and champion effective IRM
- IRAC has key projects to support worldwide IRM for major MoA groups like Neonicotinoids
- The IRAC Public Health team is working with WHO & Gates Foundation on vector resistance
- IRAC is increasingly involved in IRM in insect-control transgenic crops
- Industry is facing key problems of resistance in Brown planthopper, Whiteflies, Pollen beetle, and other pests – IRAC is dedicated to help solve these problems

***Resistance is everyone's problem - managing it is vital!  
The agrochemical industry is playing its part***



*Thank you*