



**Effective resistance management  
for the neonicotinoids:**

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

**IRAC Symposium on Insecticide Sustainability: Neonicotinoids  
ESA Annual Meeting, December 2005**

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# Outline

Why effective Resistance Management is essential

What industry is doing:

- **Company level**
  - Resistance Management Strategy for a Neonicotinoid – A typical responsible company approach to IRM
- **Inter-company level**
  - Collaborative Industrial Approach to IRM for Neonicotinoids
    - An industry partnership to ensure sustainability
- **All-industry level**
  - Role of Insecticide Resistance Action Committee (IRAC)



# Why Effective Resistance Management is essential

- Sustaining effective commercial life of current insecticides requires intelligent use of presently available compounds
  - Insecticide Resistance Management (IRM)
- For any crop / pest situation, effective IRM requires the availability of a broad range of modes of action
- IRM is made much more difficult by loss of modes of action through resistance development caused by misuse or overuse of insecticides
- We can no longer rely on having a steady stream of new modes of action to circumvent resistance problems.....



# Protecting current AIs from resistance is crucial !

- Finding and developing new insecticides is extremely costly & difficult
- We cannot accept losing them to resistance!

Cost of developing and registering a new chemical crop protection AI in year 2000 (\$M) [Source: ECPA, 2003]

Category	Sub-category	Costs	Total Cost
Research	Chemistry	41	94
	Biology	44	
	Toxicology / Environmental Chemistry	9	
Development	Chemistry	20	79
	Field Trials	25	
	Toxicology	18	
	Environmental Chemistry	16	
Registration			11
Total			<b>184</b>

## What industry is doing at a company level



# Resistance Management Strategy for a Neonicotinoid

Responsible companies have clear guidelines to manage resistance to Neonicotinoids:

'To prevent the development and spread of resistance, applications of Thiamethoxam and other Neonicotinoid insecticides should be applied in 'block' applications where:

The total duration of the neo-nicotinoid 'blocks' does not exceed more than half of the crop cycle (vegetative period). The duration of a block application should be based on either:

- The generation time of the target pest (Where possible each block should treat a single generation of the target pest)
- The period of insect control that is provided by a single application of the insecticide (Applicable to insects with a short generation time).

Wherever possible it is recommended that the application of an insecticide 'block' should not immediately be followed by an application of an insecticide 'block' of the same chemical class.

# Example of Whitefly RM Strategy

## Transplanting

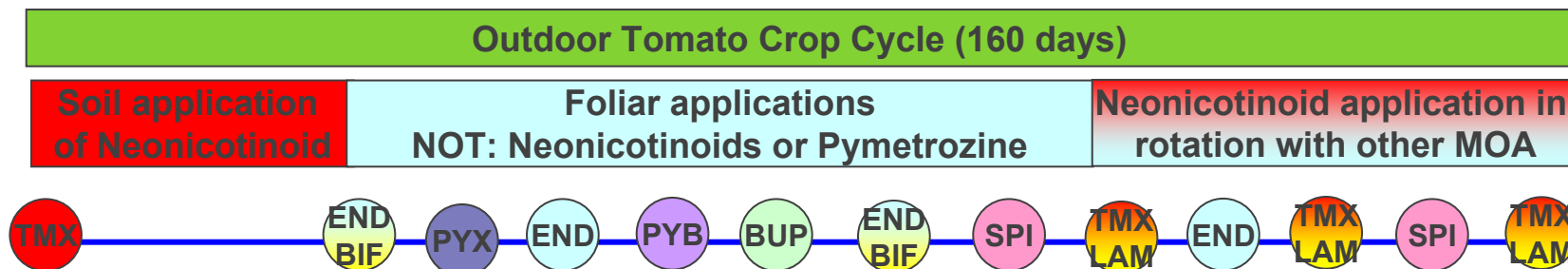
- Soil application of Neonicotinoid provides good control for an extended period - with limited selection for resistance

## First foliar applications made after soil application

- Avoid applications of Neonicotinoids or Pymetrozine in this period
- Rotate other available AIs

## Foliar applications at end of crop cycle

- Rotate available insecticides with different MoA including Neonicotinoids and Pymetrozine.
- Avoid consecutive applications of same chemical class
- Total number of Neonicotinoid and Pymetrozine applications should be < half crop cycle (based on 15d duration for foliar and 30day for soil)



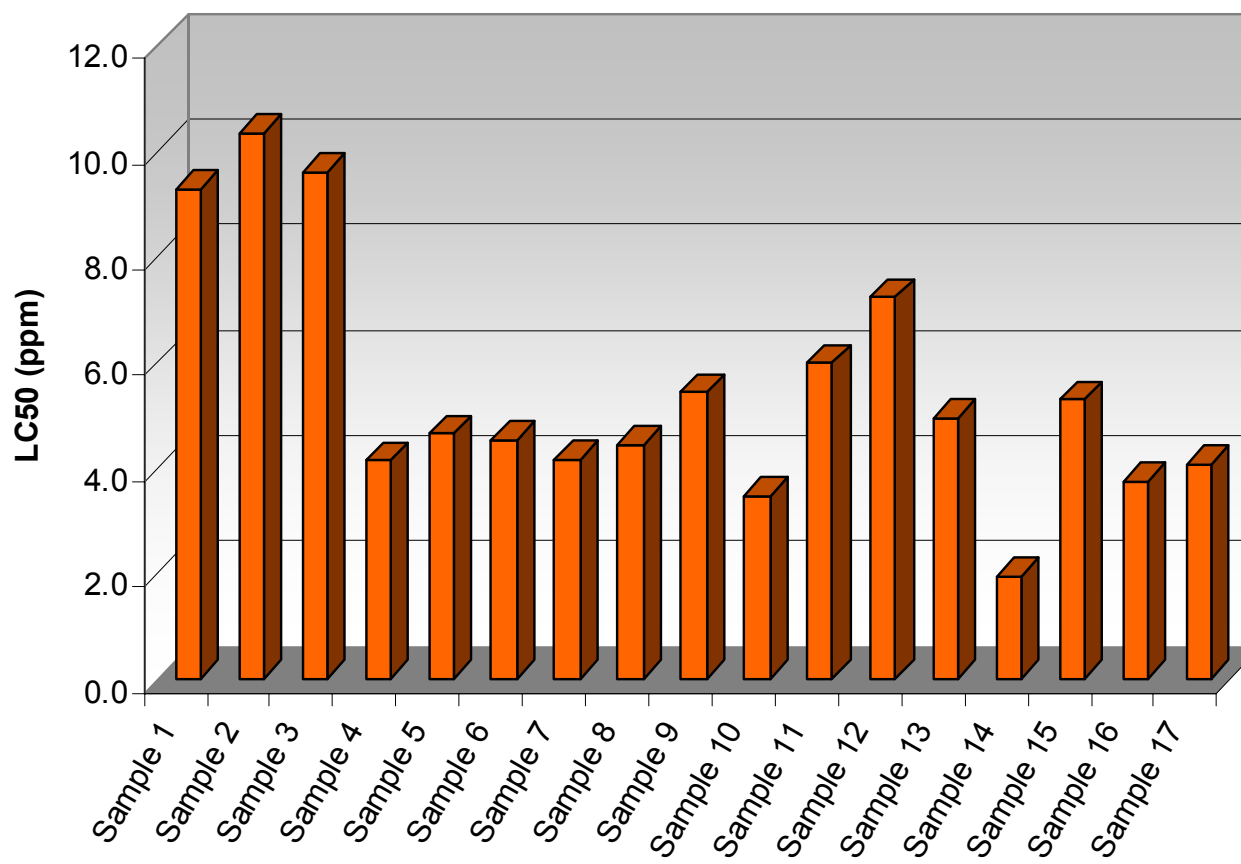
# Baselines and Resistance Monitoring

- Establishment of clear baselines followed by appropriate susceptibility monitoring ensures we know current status of susceptibility to key insecticides
  - **Timely awareness of any emerging problems**
- As indicated in Ralf Nauen's presentation each company establishes baselines for its products e.g. :
  - **Thiamethoxam against Soybean Aphid**
  - **Emamectin benzoate against Grape Berry Moth**
- And undertakes regular susceptibility monitoring for key at-risk pests e.g. :
  - **Cotton Aphid, Peach Potato Aphid, Glasshouse Whitefly, etc**
  - **Diamondback Moth, Fall Armyworm, Cotton Bollworm, etc**
  - **Colorado Potato Beetle, Pollen Beetle, Spider Mites, etc**



## Example of Susceptibility Monitoring

- Adult Western Corn Rootworm 'baseline' susceptibility to thiamethoxam
- Independent samples collected from USA Corn Belt.



## Sponsorship of Resistance Research

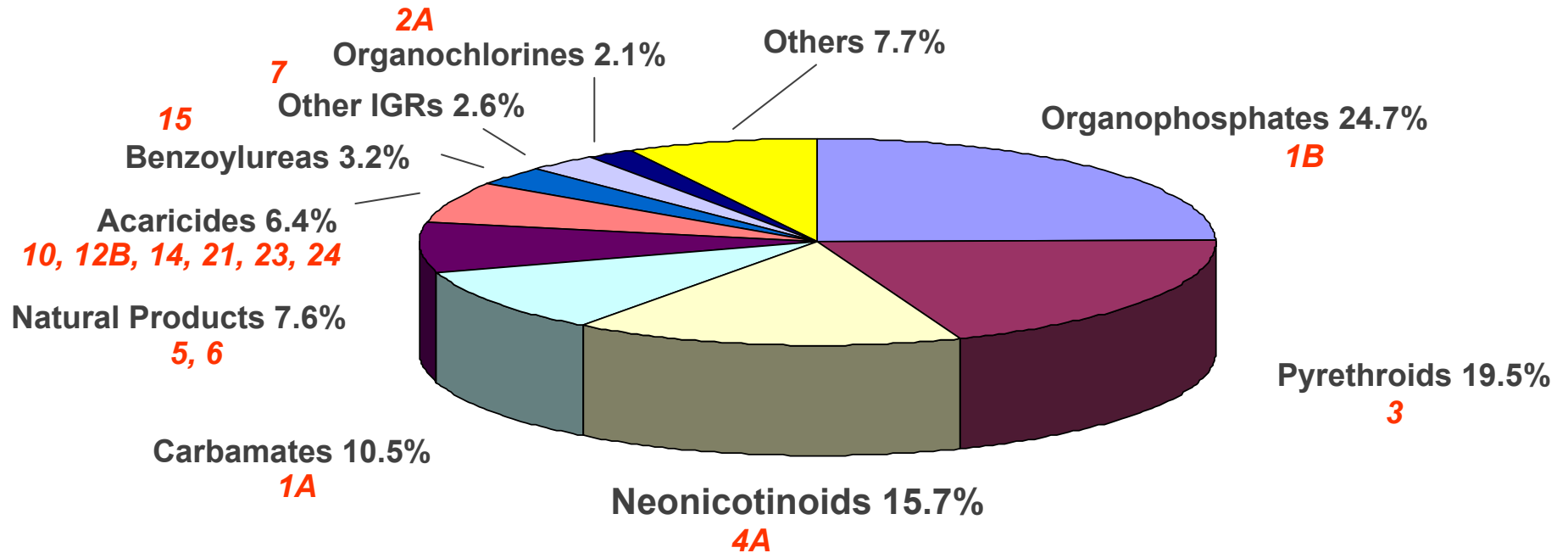
- Sponsorship of various research projects on resistance to Neonicotinoids including:
- ‘Characterisation and management of Neonicotinoid resistance in *Bemisia tabaci*’
- At Rothamsted Research, UK (Ian Denholm, Kevin Gorman)



## What industry is doing at an inter-company level



# Global Insecticide sales



**Total Global Insecticide Sales 2003 = \$6,650 million**

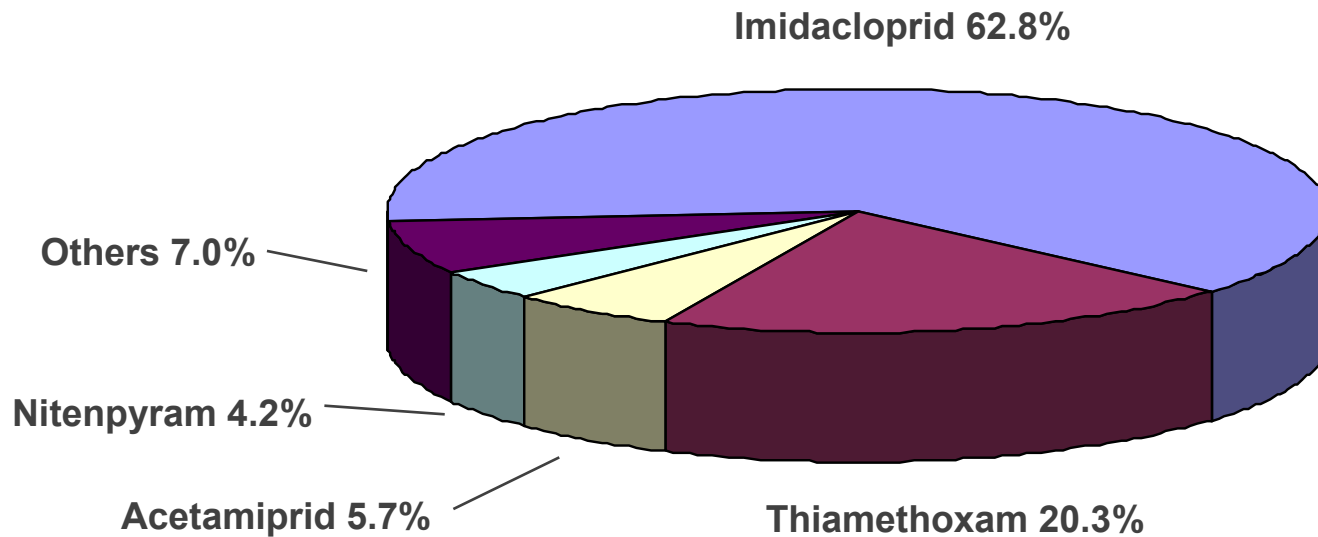
[Source Phillips McDougall, November 2004]

[Natural products includes avermectins and spinosyns]

**IRAC Mode of Action Classification Number**

Neonicotinoids now 3<sup>rd</sup> largest group of insecticides based on global sales

# Global Neonicotinoid sales



**Global Neonicotinoid Sales 2003 = \$1,059 million**

[Source Phillips McDougall, November 2004]

***IRAC Mode of Action Classification Number 4A***

**Imidacloprid and Thiamethoxam account for >80% of market**

# Bayer CropScience and Syngenta – Collaborative Neonicotinoid Stewardship Project

- Together, sales of Bayer CropScience and Syngenta Neonicotinoid products total c. \$930M – 88% of Neonicotinoids
  - Bayer CropScience: Imidacloprid, Thiacloprid, Clothianidin
  - Syngenta: Thiamethoxam
- Two companies uniquely placed to take a lead in developing and delivering coherent and effective IRM strategies at both a global and local level
- March 2005: Bayer CropScience and Syngenta agreed a joint global stewardship project to manage Neonicotinoids, focussing on key at-risk pests
- Other [Japanese] companies invited to join – but declined



# Bayer CropScience / Syngenta – Collaborative Neonicotinoid Stewardship Project

- Aim: To intensify the implementation of IRM by working together through contacts at country level
- Proposal to develop local IRM recommendations based on the two company global IRM recommendations for Neonicotinoids
  - Syngenta: Maximal exposure to Neonicotinoids is limited to 50% of the cropping cycle
  - Bayer CropScience: Neonicotinoids are limited to maximum of 3 applications per pest species and crop cycle
- Although slightly different, in practice expected in most situations that time periods covered by neonicotinoids are similar for both company recommendations
- Agreed that local guidelines can be stricter than the global guidelines, but should not be more flexible

# Bayer CropScience and Syngenta - Collaborative Neonicotinoid Stewardship Project – Targets

Agreed first list of key at-risk targets for co-operation:

Country	Target	Crop
Mexico	Whitefly	Vegetables
Guatemala	Whitefly	Melons & Tomatoes
India	Brown planthopper	Rice
Brazil	Whitefly	Beans
Morocco	Whitefly	Covered vegetables
Italy	Whitefly	Covered vegetables
Turkey	Whitefly	Covered vegetables
Japan	Thrips	Vegetables



# Bayer CropScience and Syngenta - Collaborative Neonicotinoid Stewardship Project

## Key actions:

- Establish local contacts between nominated persons from both companies and set up joint meetings
- Establish agreed local IRM Neonicotinoid strategies taking into account the general guidelines of both companies
  - Agree and adopt positioning in high risk crops
  - Adapt for local conditions, positioning and availability of products
- Involve local regulatory authorities and encourage them to take ownership
- Involve key local academic groups and influencers
- Involve local IRAC groups
- Approach other local neonicotinoid companies
- Check possibility of implementing a labelling scheme (similar to US)



## BCS and Syngenta sponsor UK Neonicotinoid LINK project

- Bayer CropScience and Syngenta are jointly sponsoring [with others] :

### UK Department of Environment, Food and Rural Affairs, SA-LINK Project: Sustainability of Neonicotinoid Insecticides

- To assess and manage increasing risk of resistance to Neonicotinoids in *Myzus persicae* (and other aphids)
- Risk arises from rapid recent increase in uses of neonicotinoids in multiple host crops for *M. persicae*
- Co-ordinating laboratory Rothamsted Research (Dr Ian Denholm et al)

## What industry is doing at an all-industry level



# Insecticide Resistance Action Committee - IRAC

- IRAC formed in 1984 to provide a co-ordinated industry response to the development of resistance in insect and mite pests

- Currently 6 IRAC International members:

**BASF**

**DuPont**

**FMC**

**Bayer CropScience**

**Dow AgroSciences**

**Syngenta**

## IRAC Objectives:

- Facilitate communication and education on insecticide and acaricide resistance
- Promote the development of resistance management strategies in crop protection and vector control to maintain efficacy and support sustainable agriculture and improved public health

## IRAC, US - Members

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

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

# IRAC Country Groups

- IRAC Country groups deal with key resistance issues at local level – supported by IRAC International
  - Multi-company cooperation and coordinated IRM
  - IRAC Country groups often include additional companies not involved in IRAC International
  - Country groups may include or involve others from Academia and Research Institutes and Regulatory bodies (IRAG groups)
- Current IRAC Country groups:
  - IRAC Australia (AIRMG)
  - IRAC Brazil
  - IRAC India
  - IRAC South Africa
  - IRAC Spain
  - IRAC US
  - IRAC China (proposed)



# IRAC Mode of Action Classification



Insecticide Resistance Action Committee  
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
- A key tool for selection of insecticides in effective IRM programs
- Updated as required
- Latest version Sept 2005

# IRAC Mode of Action Classification

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, Butocarb, Butoxyacarb, Carbaryl, Carbofuran, Carbosulfan, Ethiofencarb, Fenobucarb, Formetanate, Furathiocarb, Isoprocarb, Methiocarb, Methomyl, Metolcarb, Oxamyl, Pirimicarb, Propoxur, Thiodicarb, Thiofanox, Trimethacarb, XMC, Xylcarb
	Triazemate	Triazemate
	1B Organophosphates	Acephate, Acemethiphos, Acephos-ethyl, Acephos-methyl, Cadusafos, Chlorothoxyfos, Chlorfenvinphos, Chlomephos, Chlorpyrifos, Chlorpyrifos-methyl, Coumaphos, Cyanophos, Demeton-S-methyl, Diazinon, Dichlorvos/ DDVP, Dicrotophos, Dimethoate, Dimethylvinphos, Disulfoton, EPN, Ethion, Ethoprophos, Famphur, Fenamiphos, Fenitrothion, Fenthion, Fosthiazate, Heptenophos, Isufenphos, Isopropyl O-methoxyaminothio-phosphonyl salicylate, Isoxathion, Malathion, Mecarbam, Methamidophos, Methidathion, Mevinphos, Monocrotophos, Naled, Omethoate, Oxydemeton-methyl, Parathion, Parathion-methyl, Phenthoate, Phorate, Phosalone, Phosmet, Phosphamidon, Phoxim, Pirimiphos-ethyl, Profenofos, Propetamphos, Prothiofos, Pyraclofos, Pyridaphenthion, Quinalphos, Sulfotep, Tebupirimfos, 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, d-trans 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
	Cartap hydrochloride Nereistoxin analogues	Cartap hydrochloride Thiocyclam, Thiosultap-sodium
5 Nicotinic Acetylcholine receptor agonists (steric) (not group 4)	Spinosyns	Spinosad
6 Glycine receptor channel modulators	Avermectins, Milbemycins	Abamectin, Enamectin benzoate, Milbemectin
7 Juvenile hormone mimics	7A Juvenile hormone analogues	Hydroprene, Kinoprene, Methoprene
	7B Fenoxycarb	Fenoxycarb
	7C Pyriproxyfen	Pyriproxyfen
8 Compounds of unknown or non-specific mode of action (fumigants)	8A Alkyl halides	Methyl bromide and other alkyl halides
	8B Chloropicrin	Chloropicrin



# Using the IRAC MoA Classification

- The IRAC Mode of action scheme is central to developing effective IRM strategies
- Sequences, rotations or alternations of different MoA groups help prevent or delay resistance, or deal with existing resistance problems
- Modify locally to take account of known metabolic mechanisms conferring cross-resistance between MoA groups or insect populations with multiple resistances
- In the absence of any information, intelligent sequences of MoA groups will always reduce selection pressures and help prevent or delay resistance, and help regain susceptibility
- IRAC strongly supports MoA labeling schemes – e.g. US, Australia
  - And IRAC campaigns for wider use of such schemes
- Use of symbols and colors for MoA groups can help e.g. Brazil

# IRAC MoA Posters and Wallchart

**IRAC** Insecticide Resistance Action Committee

## Insecticide Mode of Action Classification: A key to effective insecticide resistance management

IRAC website: [www.irac-online.org](http://www.irac-online.org)

**Introduction**  
IRAC promotes the use of a Mode of Action (MoA) classification of insecticides as the basis for effective and sustainable insecticide resistance management (IRM). Insecticides are allocated to specific groups based on their target site. Reviewed and reassessed periodically, the IRAC MoA classification list provides farmers, growers, advisors, extension staff, consultants and crop protection professionals with a guide to the selection of insecticides or acaricides in IRM programs. Effective IRM of this type preserves the utility and diversity of available insecticides and acaricides. A selection of MoA groups is shown below.

**Use Mode of Action wisely for good IRM!**

**Effective IRM strategies: Alternations or sequences of MoA**  
All effective insecticide (and acaricide) resistance management (IRM) strategies seek to minimize the selection for resistance from any one type of insecticide or acaricide. In practice, alternations, sequences or rotations of compounds from different MoA groups provide sustainable and effective IRM. This ensures that selection from compounds in the same MoA group is minimised. Applications are often arranged into MoA spray windows or blocks that are defined by the stage of crop development and the biology of the pest(s) of concern. Local expert advice should always be followed with regard to spray windows and timings. Several sprays of a compound may be possible within each spray window but it is generally essential to ensure that successive generations of the pest are not treated with compounds from the same MoA group. Metabolic resistance mechanisms may give cross-resistance between MoA groups, and where this is known to occur, the above advice must be modified accordingly.

**Moultng & Metamorphosis**  
Group 16: Ecdyson agonist / di-ruptor  
Disrupts the moult process.  
Group 7: Juvenile hormone inhibitors  
Disrupts the moult process by blocking the synthesis of Juvenile Hormone (JH).  
Group 17: Moulting disruptor  
Disrupts the moult process by blocking the synthesis of Juvenile Hormone (JH).  
Group 21: Coupling site II electron transport inhibitors (Couple II)  
Disrupts the moult process by blocking the synthesis of Juvenile Hormone (JH).

**Midgut**  
Group 7: Juvenile hormone inhibitors  
Disrupts the moult process by blocking the synthesis of Juvenile Hormone (JH).  
Group 17: Moulting disruptor  
Disrupts the moult process by blocking the synthesis of Juvenile Hormone (JH).

**Nervous System**  
Groups 1A, B & A: Insect cholinesterase (AChE) inhibitors  
Carbamates and Organophosphates  
Group 28: Nicotinic acetylcholine receptor agonists/antagonists  
Group 3: GABA-gated chloride channel antagonists  
Group 4: Nicotinic acetylcholine receptor agonists/antagonists  
Group 5: Nicotinic acetylcholine receptor agonists/antagonists  
Group 6: Chloride channel activators  
Group 7: Juvenile hormone inhibitors  
Group 11: Microbial disruptors of insect mid-gut membranes - Includes transgenic crop expressing Bacillus thuringiensis (Bt) protein  
Group 12: Inhibitors of insect mid-gut membrane ATP formation inhibitors of ATP synthase  
Group 15: Uncouplers of oxidative phosphorylation via disruption of H proton gradient  
Group 16: Inhibitors of chitin biosynthesis (Type II, Lepidopteran)  
Group 18: Ecdyson agonist / di-ruptor  
Group 19: Octopamine agonists  
Group 20: Coupling site I electron transport inhibitors (Couple I)  
Group 22: Voltage dependent sodium channel blockers  
Group 24: Mitochondrial complex IV electron transport inhibitors  
Group 25: Neuronal inhibitors (unknown mode of action)  
Group 26: Aconitine inhibitors  
Group 27: Synergists  
Group 28: Nicotinic acetylcholine receptor agonists/antagonists  
Group UN: Compounds with unknown mode of action  
Group NS: Miscellaneous non-specific (multi-MoA) inhibitors

**Non-specific MoA**  
Group 9: Compounds of non-specific mode of action

**Metabolic Processes**  
Many groups acting on a wide range of metabolic processes including:  
Group 12: Inhibitors of oxidative phosphorylation, disruptors of ATP formation  
Group 15: Uncouplers of oxidative phosphorylation via disruption of H proton gradient - Chlorfenvinpyr

**Cuticle Synthesis**  
Groups 7 and 18: Inhibitors of chitin biosynthesis  
Bioresolins (Lepidoptera and others), Ruprofosin (Homoptera)

## Conference Posters

**IRAC** Insecticide Resistance Action Committee

## Insecticide Mode of Action Classification: A Key to Effective Insecticide Resistance Management in Whiteflies

**Introduction**  
IRAC has developed a key to effective insecticide resistance management (IRM) for whiteflies. This key is based on the mode of action (MoA) of insecticides and is intended to provide a guide to the selection of insecticides for IRM programs. The key is based on the MoA of insecticides and is intended to provide a guide to the selection of insecticides for IRM programs. The key is based on the MoA of insecticides and is intended to provide a guide to the selection of insecticides for IRM programs.

**Insecticides acting on the nervous system**  
The nervous system is the target for many current insecticides, but when this system is many target sites. Insecticides with specific mode of action act on these target sites.  
Group 1: Organophosphates (OP) inhibit acetylcholinesterase (AChE), disrupting the transmission of nerve impulses.  
Group 2: Carbamates (CA) act as inhibitors of AChE at nerve synapses. This results in hyperactivity in the nervous system.  
Group 3: GABA-gated chloride channel antagonists (GABA-gated chloride channel complex) and inhibit the action of GABA causing neuronal hyperactivity.  
Group 4: Nicotinic acetylcholine receptor agonists  
The insecticide (IA) acts as agonist of acetylcholine at the post-synaptic membrane Nicotinic acetylcholine receptor (nAChR). This leads to overstimulation and hyperactivity.  
Group 5: Nicotinic acetylcholine receptor antagonists  
The insecticide (IA) acts as antagonist of acetylcholine at the post-synaptic membrane Nicotinic acetylcholine receptor (nAChR). This leads to overstimulation and hyperactivity.  
Group 6: Chloride channel activators  
The insecticide (IA) acts as activator of chloride channels in the nervous system, causing hyperactivity and neural block.  
Group 7: Juvenile hormone inhibitors  
Disrupts the moult process by blocking the synthesis of Juvenile Hormone (JH).

**Insecticides inhibiting cuticle synthesis (Type I)**  
New cuticle is synthesized during the moult cycle and insecticides which interfere with this process stop the moult cycle leading to death of the insect.  
Group 7: Juvenile hormone inhibitors  
Disrupts the moult process by blocking the synthesis of Juvenile Hormone (JH).

**Insecticides acting as feeding blockers**  
Group 9: Compounds of unknown action  
Pyriproxyfen (PY) has a non-specific mode of action which appears to involve a selective inhibition of mid-gut feeding. Feeds as a result of starvation.

**Insecticide classes for whitefly control**  
IRAC lists 28 modes of action groups (42 including sub-groups). 19 of these are currently used for whitefly control.

Group	Insecticide Class	Target Site / Mode of Action
1A	Organophosphates	Cholinesterase
1B	Carbamates	Cholinesterase
2	GABA-gated chloride channel antagonists	Chloride channels
3	Nicotinic acetylcholine receptor agonists	Nicotinic acetylcholine receptors
4	Nicotinic acetylcholine receptor antagonists	Nicotinic acetylcholine receptors
5	Nicotinic acetylcholine receptor agonists	Nicotinic acetylcholine receptors
6	Chloride channel activators	Chloride channels
7	Juvenile hormone inhibitors	Juvenile hormone synthesis
8	Bioresolins	Chitin biosynthesis
9	Compounds of unknown mode of action	Unknown
10	Unknown mode of action	Unknown
11	Microbial disruptors of insect mid-gut membranes	Mid-gut membranes
12	Inhibitors of insect mid-gut membrane ATP formation	ATP synthase
13	Uncouplers of oxidative phosphorylation	Oxidative phosphorylation
14	Uncouplers of oxidative phosphorylation	Oxidative phosphorylation
15	Uncouplers of oxidative phosphorylation	Oxidative phosphorylation
16	Inhibitors of chitin biosynthesis (Type II)	Chitin biosynthesis
17	Moulting disruptors	Juvenile hormone synthesis
18	Ecdyson agonists	Ecdyson synthesis
19	Octopamine agonists	Octopamine receptors
20	Coupling site II electron transport inhibitors	Coupling site II
21	Coupling site I electron transport inhibitors	Coupling site I
22	Voltage dependent sodium channel blockers	Sodium channels
23	Inhibitors of lipid synthesis	Lipid synthesis
24	Mitochondrial complex IV electron transport inhibitors	Mitochondrial complex IV
25	Neuronal inhibitors (unknown mode of action)	Unknown
26	Aconitine inhibitors	Aconitine
27	Synergists	Synergists
28	Nicotinic acetylcholine receptor agonists/antagonists	Nicotinic acetylcholine receptors
UN	Compounds with unknown mode of action	Unknown
NS	Miscellaneous non-specific (multi-MoA) inhibitors	Multiple sites

## IRAC Mode of Action Wallchart: MoA Classification Groups & Structures

A1 printed versions available

# eClassification – interactive MoA

New interactive online tool

[www.irac-online.org](http://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
  - Subgroup: A
    - Chemical Class: Neonicotinoids
      - Acetamidrid
      - Clothianidin
      - Dinotofuran
      - Imidacloprid
      - Nitenpyram
      - Thiacloprid
      - Thiamethoxam
  - Subgroup: B
  - Subgroup: C
- 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) inhibitors3

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

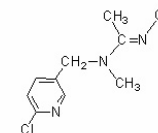
**Drop down menus >>options**

**IRAC**  
Insecticide Resistance Action Committee

**eClassification**

[Back to Group Index](#)

Cas No	135410-20-7
Common Name	Acetamidrid
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 Lepidoptera
Relevant Crops	Wide range of crops, especially vegetables, fruit and tea
Use Patterns	Soil or foliar
Comments	



# IRAC Website – [www.irac-online.org](http://www.irac-online.org)

**IRAC** Resistance Management for Sustainable Agriculture & improved Public Health  
Insecticide Resistance Action Committee

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## 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.

We would encourage you to further explore the site using the drop-down menus at the top of the page or via the other links. Further background on IRAC, its Constitution and Mission along with the IRAC newsletter eConnection can be located under the About IRAC heading. The majority of the IRAC documents can be located under Resources. This includes Mode of Action Classification, Test Methods, Resistance Management Guidelines, Posters and Publications along with other Educational and Regulatory Material. The headings, IRAC International and IRAC Country Groups, provide information on these different Teams some of which is only available to Team Members. The final drop-down menu provides Grower information in the form of links to Publications, Associations and Magazines. We hope you find the site a useful resource.

**Links to New Resistance Management Information**

- General Principles of Insecticide RM from IRAC
- IRAC Test Methods - Overview and Summary
- IRAC Paper and Poster on MOA at ICE Meeting Brisbane, August 2004
- Neonicotinoid IRM Guidelines, September 2004
- New IRAC Logo and Branding material - September 2004
- EWSN Meeting, Croatia 5-9th October 2004 - Whitefly MOA Poster
- IRAC eConnection - Issues 5, December 2004
- IRAC Intl. Conference Call - Action Log, January 2005 (Members only)
- Website Traffic and Activity Report March 2005
- Latest IRAC eConnection - Issues 6, April 2005
- IRAC US Meeting Minutes, April 2005 (Members only)
- IRAC Intl. Spring Meeting Minutes, Florence, April 2005 (Members only)
- Work on resistance in Italy on Codling Moth and the new Italian group GIRIF
- JUST RELEASED - New IRAC MoA Classification Scheme (ver 4.2, May 2005)
- IRAC Website - Update and Review, May 2005

**quicklinks**

- MOA Scheme 05
- New Group Guide
- EPPC Guidelines
- IRAC Methods
- IRAC Posters
- IRAC Website
- FRAC Website
- MSU Database
- IRAC Website
- PM Newsletter

**upcoming events**

- IRAC Conf Calls
- IRAC C & E Team
- IRAC CM Team
- IRAC US Meeting
- IRAC Intl. Meetings
- IRAC ZA Meeting
- ESA Meeting
- BCPC, Glasgow

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- IRAC's key communication vehicle
- Av. 150 hits, 30 visits a day (09.05)
- Accessed by over 80 countries
- Search terms - #1 'IRAC', #2 'Insecticide Resistance'
- 190 pages including public, protected & utility pages
- 160 docs. & 92 image files
- Information on IRAC, Mode of Action, advice on IRM
- Education modules
- Resources incl. key papers, documents, posters
- Links for growers
- IRAC Country group information

# IRAC Susceptibility Test Methods



Insecticide Resistance Action Committee  
[www.ircac-online.org](http://www.ircac-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	
Status:	Approved	
Species:	<i>Panonychus ulmi</i> <i>Tetranychus spp.</i>	
Species Stage:	<i>P. ulmi</i> (summer eggs) <i>Tetranychus</i> (eggs)	
Product Class:	<del>clofenteperin</del> <del>bexxyliazox</del> <del>tetradiolon</del>	
Comments:	None	

Photograph Courtesy of  
 Whitney Chonka, Colorado State University  
 Tetranychus spp.

**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  
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IRAC Susceptibility Test Methods Series  
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- 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 live mainly on the lower leaf surface, the leaf sections may need to be placed lower surface uppermost. Leaves of kidney beans are particularly suitable.

- IRAC provides validated test methods of proven ability to detect changes in susceptibility
- IRAC currently has a program to update the methods
- Intention to include methods for all pests in new EPPO guidelines
- New methods will include biochemical and molecular methods

# Communication & Education IRAC Activities

- **eConnection** – Free electronic IRAC newsletter raises awareness of resistance issues, existence of country groups, raises profile of IRAC
- **eLearning** - extensive, interactive web-based education and training modules being developed



**IRAC**  
Insecticide Resistance Action Committee

eConnection

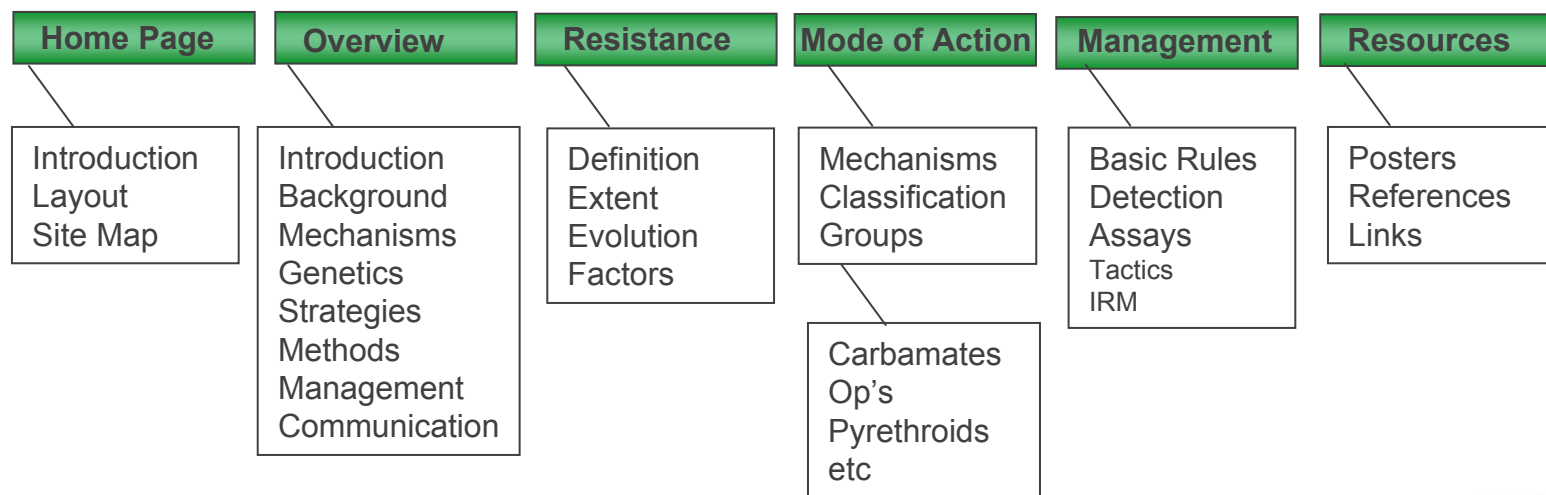
**Issue 8**  
September, 2005  
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**News Categories this Issue:**

- eConnection and Website update
- IRAC News
- Conferences and Symposia

■ **Issue 8 of eConnection**  
Welcome to the latest eConnection, a free newsletter prepared in conjunction with the IRAC website. In this issue we report on the response from the IRAC International Regulatory Team to a recent ECPA release outlining the impact of reduced numbers of products for the treatment of minor crops. Also included is an article on the control of the brown plant hopper with neonicotinoids describing initiatives such as those being taken by IRAC India to monitor the resistance status. Finally there is a brief report on the recent IRAC International Meeting at CropLife International in Brussels and advance notice of an IRAC Symposium in the US on Neonicotinoid Sustainability. We hope you find the information interesting.



## Conclusions

- The major Neonicotinoid companies undertake extensive research to understand factors influencing the effectiveness of their compounds
- There is a large body of ongoing work to maintain awareness of susceptibility in key at-risk pests
- Key companies like Bayer CropScience and Syngenta are collaborating at a local level to harmonise their guidelines for IRM for the neonicotinoids
- IRAC works for the industry to promote awareness of and solutions to resistance
  - Communication and education on IRM are vital
  - IRAC provides key resources such as the MoA scheme, methodologies, IRM advice to help manage resistance
  - IRAC country groups work to tackle local problems