



Insecticide Resistance Action Committee

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## **IRAC overview & update on activities.**

33rd Insecticide Resistance Action Group (IRAG) meeting  
Rothamsted Research, Harpenden, UK.  
4th Novemeber 2014

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# 30 years of IRAC

## The 1st „IRAC“ – Brussels, Belgium

March 13<sup>th</sup>, 1984

People attending: 6

6 company members:

Voss / Ciba Geigy (Chair)

Lindley / Cyanamide

Cronin / FMC

Davies / ICI

Knauf / Hoechst

Zoebelein / Bayer



## 48th Meeting - Jealott's Hill, Berkshire, UK

March 2013 - with 13 members

People attending: 45

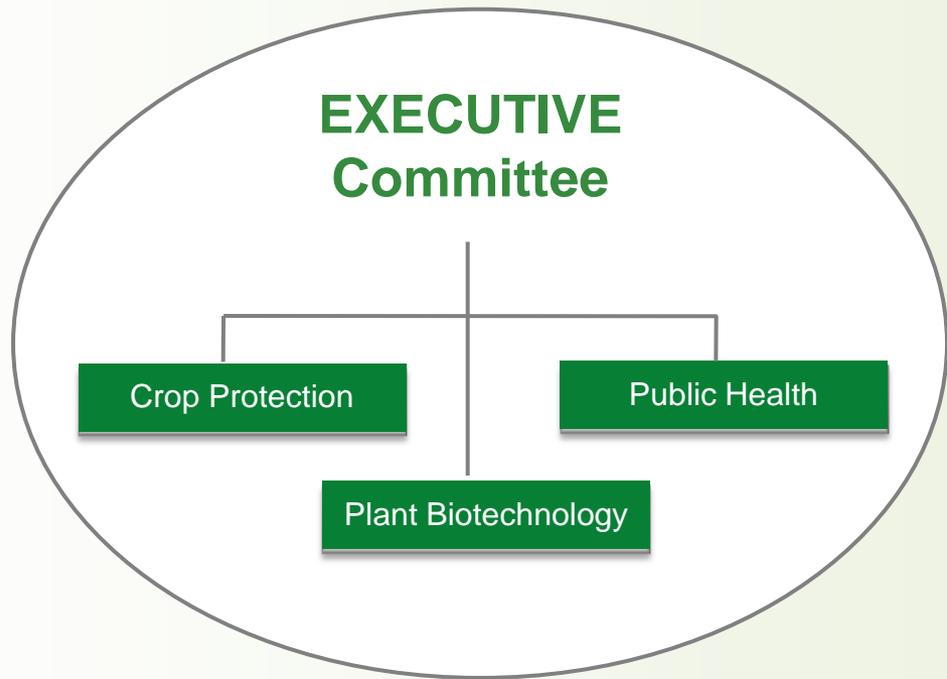


## 49th Meeting – RTP North Carolina, USA

March 2014 - with 13 members

People attending: 50

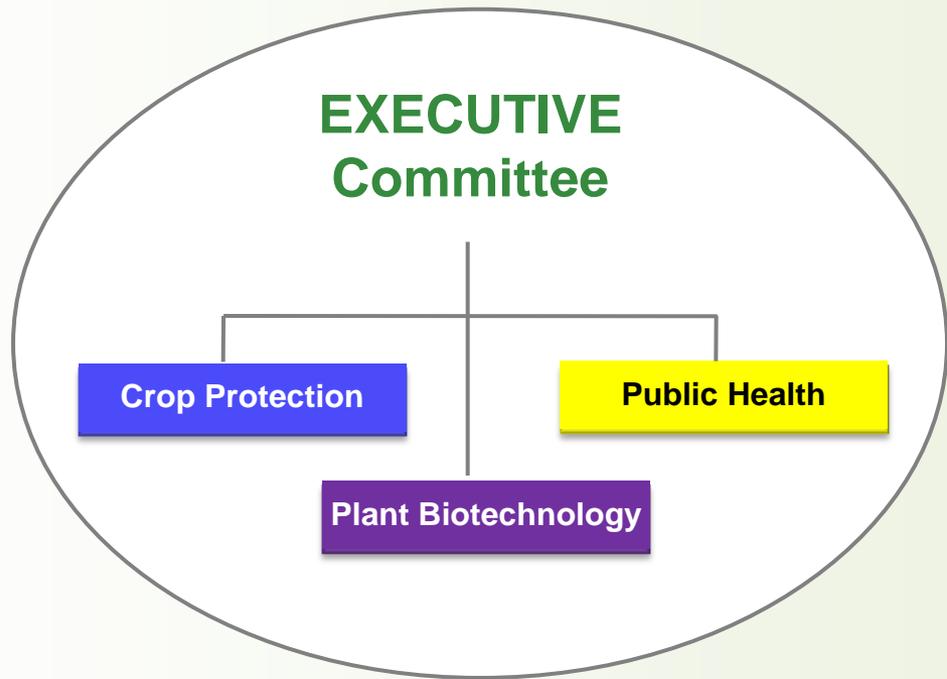




- Steering Group
- Comm./Education
- R. Database (MSU)
- Methods
- Mode of Action
- Public Health
- Biotechnology
- Coleoptera
- Sucking Pest
- Lepidoptera

## IRAC Country Groups

IRAC Spain	IRAC Brazil	IRAC S.Africa
IRAC Australia	IRAC SE Asia	IRAC India
IRAC USA	IRAC Philippines	IRAC Argentina



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# IRAC web-site: communicating knowledge & education

**IRAC**  
Resistance Management for Sustainable Agriculture and Improved Public Health

HOME ABOUT NEWS EVENTS TEAMS COUNTRIES PESTS CROPS RESOURCES

WELCOME TO THE INSECTICIDE RESISTANCE ACTION COMMITTEE WEBSITE

**THE IRAC NEWSLETTER**  
FREE INDUSTRY NEWS ONCE A QUARTER, DIRECT TO YOUR INBOX ON ANY DEVICE

**SUBSCRIBE >**

**ABOUT IRAC**  
IRAC is an international group of more than 150 members of the Crop Protection Industry organised by sector and region to advise on the prevention and management of insecticide resistance.  
[Launch Presentation](#)

**RESISTANCE MANAGEMENT RESOURCES**  
Resistance is 'a heritable change in the sensitivity of a pest population, reflected in the repeated failure of a product to achieve the expected level of control when used as instructed for that product.'

**CROP PROTECTION**

**BIOTECHNOLOGY**

**PUBLIC HEALTH**

**MODE OF ACTION**

**METHODS**

**PEST LIBRARY**

IRAC #32  
IRAC RESISTANCE ACTION COMMITTEE

IRAC #33  
IRAC RESISTANCE ACTION COMMITTEE

IRAC

# IRAC web-site: Pest Pages



Resistance Management for Sustainable Agriculture and Improved Public Health

Login

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SEARCH

WELCOME TO THE INSECTICIDE RESISTANCE ACTION COMMITTEE WEBSITE

## PEST INFORMATION

Clicking on the pest images will take you to specific pest pages. Presented for each pest is information on biology, distribution, resistance status and links to relevant IRAC resources. In addition there are links to useful non-IRAC material and published papers.



**Aedes MOSQUITO**

*Aedes spp*



**ANOPHELINE MOSQUITOES**

*Anopheles spp*



**MELON & COTTON APHID**

*Aphis gossypii*



**TOBACCO WHITEFLY**

*Bemisia tabaci*



**COCKROACHES**

*Cockroach Species*



**CODLING MOTH**

*Cydia pomonella*



**ASIAN CITRUS PSYLLID**

*Diaphorina citri*



**STINK BUG**

*Euschistus Heros*



**WESTERN FLOWER THIRPS**

*Frankliniella occidentalis*



**COLORADO POTATO BEETLE**

*Leptinotarsa decemlineata*



**EUROPEAN GRAPEVINE MOTH**

*Lobesia botrana*



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Credit: Chantler Australia

## TOBACCO WHITEFLY

*Bemisia tabaci*

*B. tabaci* is found on over 900 host plants on all continents except Antarctica. It reportedly transmits over a hundred virus species. The whitefly thrives in tropical, subtropical, and is predominantly in temperate habitats. It is also a major pest of glasshouses. The adults are about 1 mm long; their body is sulphur-yellow in color, the wings are white, and the animal is entirely coated with a white, wax-like powder. The first instar nymph is about 0.3 mm in length and it moves about in search of a place to insert its mouthparts into the phloem.

Infestation is easily recognized by examining the undersides of leaves, where all stages of the insect can usually be found. At first, the damage consists of chlorotic spots. The leaves will start to show a yellow mosaic, with the green areas becoming ever smaller. Twisting of stems and curling of leaves may occur, and the plants may become stunted. Heavily-infested leaves often wilt and fall off. In addition to direct feeding, all stages damage the plants through abundant production of honeydew, which encourages the growth of sooty molds, and, most importantly, by the transmission of viruses.

The two most damaging biotypes of *B. tabaci* are the 'B' and 'Q' biotypes. The B-type has a worldwide distribution. The Q-type was largely restricted to the Mediterranean area but has recently been detected in the U.S.A and some regions of China. Biotype status can be diagnosed from esterase banding patterns using polyacrylamide gel electrophoresis (PAGE). *B. tabaci* has been shown to possess a high potential for resistance development.

### KNOWN RESISTANCE

Organophosphates – Group 1B  
 Organochlorines Group 2A  
 Pyrethroids – Group 3A  
 Neonicotinoids – Group 4A  
 Pyriproxyfen – Group 7C  
 Pymetozin – Group 9B  
 Buprofezin – Group 16

### IRAC SUSCEPTIBILITY TEST METHODS

Method No. 008 – *Bemisia tabaci* (adults)

### EXTERNAL LINKS

- Bayer CropScience Crop Compendium
- Biotype Dynamics and Resistance to Insecticides in Israel During the Years 2008–2010
- Age-specific expression of a P450 monooxygenase (CYP6CM1) correlates with neonicotinoid resistance in *Bemisia tabaci*. *Pesticide Biochemistry and Physiology*, 101 (1), 53-58 (2011)
- Age-specific expression of resistance to a neonicotinoid insecticide in the whitefly *Bemisia tabaci*. *Pest Management Science* 64: 1100-1110 (2008).



Pest Distribution

### Posters

- Sucking Pests MoA Poster  
V6.3 – JAN 12
- Neonicotinoids and Whitefly IRM Poster  
V2.1 – OCT 08

# IRAC web-site: Methods & Method videos



Resistance Management for Sustainable Agriculture and Improved Public Health

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METHODS: NEWS

## METHODS TEAM

Team Leader	Frank Wessels, DOW AGROSCIENCE
Deputy Leader	Harald Kohler, BAYER CROPSCIENCE
Linxi Mao	Magali Gravouil
Russell Slater	

## METHODS TEAM

The availability of standard, validated and easy-to-run methods for resistance detection in the world's major insect pests is crucial for successful monitoring of resistance problems. The IRAC Methods Team has worked to develop, validate and collate approved methods and make these available via the IRAC website and the online tool, eMethods. The work of the Methods Team involves interaction with other IRAC Teams and Working Groups as well as cooperation with external experts in academia and institutes. The Methods Team also has the objective to make available biochemical and molecular methodologies as well as references to other methods in peer reviewed journals which have not been validated by IRAC.

A search of available IRAC Methods can be carried out using the filter on the right hand side and a list of all the methods (IRAC and references) can be found using the link in the same green box which takes you to the eMethods tool. Videos of the more popular methods are gradually being developed and those available can be viewed via the links below.

### TEAM OBJECTIVES:

- > Establish single contact point for insecticide and acaricide resistance monitoring methods (core activities)
- > To provide IRAC approved methods, so that data generated by independent researchers can be directly compared
- > Improve communication to our target audience (promotional activities)

### IRAC VIDEOS



### SEARCH FOR AN IRAC METHOD:

Use IRAC's online eMethods tool to search for the method you need:

Search by species...

Search by MoA...

[See all Methods](#)

### Posters

IRAC Methods Poster  
V5.0 - NOV 13

### Presentations

Methods Team Update (2014)  
V1.0 - MAR 14

Methods Team Update (2013)  
V1.0 - APR 13

Methods Team Update (2012)  
V1.0 - APR 12

Methods Team Update (2011)  
V1.0 - APR 11

Methods Data Recording Form  
V3.0 - JUN 09

### Spreadsheets

eMethods References Template  
V1.0 - JUN 11

### Documents

Method Team Objectives (2014)  
V1.0 - AUG 14

### WHO Test Method Information

- WHO Test Procedures
- Discriminating Concentrations
- Procurement of WHO Test Kits

### CDC Vector resistance Assays

- Bottle Bioassay

### External Links

- Leora POLO software - probit and logit



# IRAC web-site: Mode of action classification tools



Resistance Management for Sustainable Agriculture and Improved Public Health

HOME ABOUT NEWS EVENTS TEAMS COUNTRIES PESTS CROPS RESOURCES

MODE OF ACTION: NEWS

## MODE OF ACTION TEAM



**Team Leader** Vince Salgado, BASF

Andrew Crossthwaite Dan Cordova  
 Danny Karmon Jerry Watson  
 Peter Luemmen Ralf Nauen  
 Shigero Saito Tom Sparks

The IRAC mode of action classification is considered as the definitive global authority on the target site of insecticides and acical to this is the scientific integrity of the scheme. It is used globally to classify insecticides, as the basis for mode of action labelling, and is an essential tool for the development of IRM strategies involving multiple modes of action in a window-based approach.

The MoA Team, which is largely composed of technical experts, is charged with maintaining the scheme and its status, carrying out updates as required as well as developing educational resources such as posters to promote the correct use of the scheme. The team considers data to support new submissions for entries to the scheme and acts as an arbiter on questions of MOA.

### TEAM OBJECTIVES

- Continue to review and update the MOA scheme as required.
- Develop new versions of the MOA Structure Poster as needed
- Target site mutation table
- Develop new MoA posters and update existing posters as required
- Develop MoA training slides
- MoA page – IRAC Website
- Provide additional information on topics important to MoA and IRM
- Update of MoA Charter
- Address issue of DIY classification
- Implement MoA Classification update notification list

## IRAC MODE OF ACTION CLASSIFICATION



### SEARCH THE MOA DATABASE

The MoA Classification is available as an interactive searchable eTool allowing you to browse and filter chemical groups, classes and actives.



### DOWNLOAD THE MOA APP

Download the IRAC MoA application from the Apple iTunes or Google Play App Stores for quick access to reference information on the move.



### Posters

- General MoA Poster V2.2 - APR 12
- Lepidoptera MoA Poster V4.0 - FEB 12
- Sucking Pests MoA Poster V3.3 - JAN 12
- Mosquitoes MoA Poster V2.0 - APR 14
- Mites MoA Poster V1.7 - MAR 12
- MOA Structures Poster (English) V3.0 - MAR 13
- MOA Structures Poster (Spanish) V3.0 - MAR 13
- MOA Structures Poster (Portuguese) V3.0 - MAR 13
- MoA Structures Poster (French) V3.0 - MAR 13
- MOA Structures Poster (Japanese) V3.0 - MAR 13
- MOA Structures Poster (Chinese) V3.0 - MAR 13

### Presentations

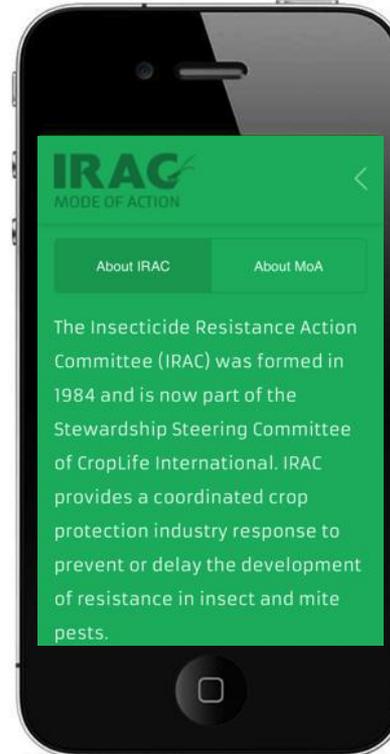
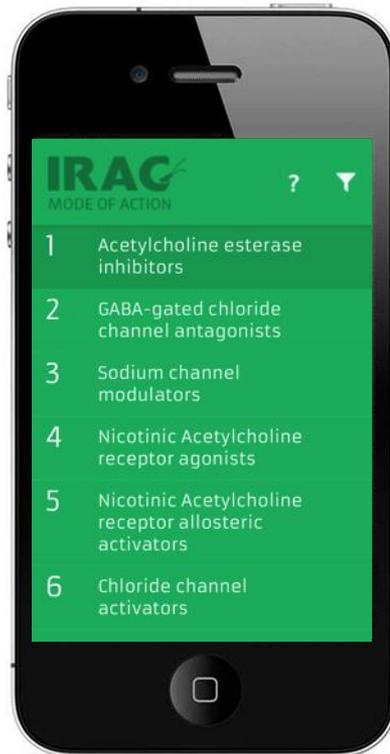
- MoA Team Update (2014) V1.0 - MAR 14
- MoA Team Update (2013) V1.0 - APR 13
- MoA Team Update (2012) V1.0 - APR 12
- MOA Team Update (2011) V1.0 - APR 11

### Publications

- MoA Classification V7.3 - MAY 14
- MoA brochure V3.6 - MAY 14
- MoA Classification: Mosquito Disease Vectors



# Mode of Action classification: Phone/Tablet App



# UNL Educational Modules

Plant & Soil Sciences eLibrary

Plant & Soil Sciences eLibrary<sup>PRO</sup>

<http://passel.unl.edu/pages/index.php?>

Contents: 120 Lessons and 116 Animations



UNIVERSITY OF  
**Nebraska**  
Lincoln  
*Placering nye fremtids.*

**Pesticide Resistance Management**  
Insects: Biological and Ecological Factors Affecting Development

How To Use this Activity
How to Get Continuing Education Credits
Acknowledgements

**Abstract:**

In many systems, the development of insecticide resistance has created serious pest management constraints. Managing the development of insecticide resistance requires understanding the factors that interact to impact resistance development.

In this module you will gain an understanding of what biological and ecological factors influence the development of insecticide resistance in insects. Biological factors, such as an insect's reproductive success, can influence the intensity of selection pressure on an insect population. The genetic diversity of a population will determine how that population can respond to selection pressures. Ecological factors, such as an insect's movement capabilities or its feeding behavior will impact an insect population's exposure to insecticides. Finally, you will begin to be introduced to operational factors that are the mainstay in actions that can be taken to reduce selection pressure and manage the development of resistance.



Introduction



Insect Life Cycles



Population Growth



Genetic Factors



Movement



Exposure



Operational



Summary





UNIVERSITY OF NEBRASKA-LINCOLN

**IRAC**

**PESTICIDE RESISTANCE MANAGEMENT**  
Understanding Resistance Mechanisms

How To use this Activity
How To Get Continuing Education Credits
Acknowledgements

**Abstract:**

Understanding details of various insecticide resistance mechanisms is critically important to developing and implementing effective and efficient resistance management programs. The objective of this educational module is to provide an understanding of these insecticide resistance mechanisms. Categories of different resistance mechanisms are described and explained, with specific examples of many also presented. In order to understand the details of some of the mechanisms, information on the modes of action of the insecticide groups affected by these mechanisms are also provided.

*Click on the green links below to proceed through the module.*

INTRODUCTION



RESISTANCE MECHANISMS

BEHAVIORAL

PHYSIOLOGICAL - REDUCE PENETRATION

PHYSIOLOGICAL - METABOLIC DETOXIFICATION

PHYSIOLOGICAL - TARGET SITE INSENSITIVITY

OTHER INSECTICIDE TARGETS

SUMMARY



 Home





UNIVERSITY OF NEBRASKA-LINCOLN

**IRAC**

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How To Get Continuing Education Credits
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PHYSIOLOGICAL - TARGET SITE INSENSITIVITY

OTHER INSECTICIDE TARGETS

SUMMARY



 Home





<http://passel.unl.edu/communities/pesticiderm>



Funding for the development of materials found in this site has been provided by the Insecticide Resistance Action Committee (IRAC)

# E-Connection: IRAC news letter

IRAC NEWSLETTER ISSUE 35 OCTOBER 2014

# IRAC

Insecticide Resistance Action Committee

eConnection

**FEATURED IRAC MEMBER:**  
Clint Pilcher (DuPont Pioneer) joined the IRAC Plant Biotechnology Team in 2011, and became Team Leader earlier this year. He also represents the Team on the IRAC Steering Group.



**IN THIS ISSUE:**  
**WHITE PAPERS FROM THE IRAC PLANT BIOTECH TEAM**  
Summary of three white papers covering IRM for transgenic crops in small-holder systems, Industry perspectives on IRM for transgenic crops and IRM for seed blends.  
**RECENTLY UPDATED IRAC POSTERS**  
New posters covering insecticide resistance mechanisms for *Myzus persicae* and IRM for *Diuraphis citri*.  
**RESISTANCE STATUS OF CEREAL APHIDS**  
A challenge for cereal growers in Northern Europe from pyrethroid resistance in *Sitobion avenae*.  
**IRM VALUE USING TRAITS AND TRADITIONAL CHEMISTRY**  
A statement from IRAC International outlining key considerations.  
**NEWS SNIPPETS & CONFERENCES**  
[www.irac-online.org](http://www.irac-online.org)

**About This Issue**  
Welcome to another IRAC eConnection Newsletter. As always we try to bring you interesting and informative articles about the work of IRAC and insecticide resistance news from around the world.  
In this issue we have summaries of position papers from the Biotechnology Team, details of two updated posters from the Sucking Pest Team on *Myzus persicae* and *Diuraphis citri*, the resistance status of cereal aphids in Northern Europe and a statement from IRAC International on IRM considerations when using both traditional chemistries and traits.  
Remember, if you have any news or resistance topics of interest, please let us know so that we can inform others in the IRAC Network. We hope you enjoy the issue.

**IRAC Plant Biotechnology Team White Papers**  
The IRAC Biotechnology Team recently produced three white papers covering different aspects of insect resistance management for biotech crops which can be downloaded from the IRAC website. Team members summarize the key points from these papers below.  
**Insect Resistance Management (IRM) for Transgenic Crops in Small-Holder Agricultural Systems**  
Insects are capable of developing resistance to any pest management tactic, transgenic insect-protected crops are no exception. The consequences of insects developing resistance to transgenic crops will include: loss of revenue to growers due to yield loss, increased costs associated with more aggressive management measures and alteration to crop practices. It is incumbent on technology providers to take proactive measures to delay its onset and develop insect resistance management programs for transgenic crops.  
Developing IRM programs in agricultural systems that are dominated by small holders where the economic and practical considerations vary from industrial agricultural systems deserve special consideration. This guide provides an overview of important elements to a proactive IRM program and includes recommendations for IRM in small-holder agriculture systems. These elements include: 1) refuge guidelines, 2) best management practices, 3) education and communication, 4) monitoring, and 5) on-going research.  
Critical to small-holder agriculture systems, economic and practical realities are especially important and should complement the scientific basis of any recommended IRM program. Developers must take into account the economic, social and rural agricultural community. In addition, regulators should encourage technology providers to simplify and harmonize IRM programs for similar transgenic products. The full paper can be found at: <http://www.irac-online.org/documents/irm-in-small-holder-systems?ext=pdf>.

IRAC NEWSLETTER ISSUE 35 OCTOBER 2014

## Pyrethroid resistant grain aphids – a challenge for cereal growers in Northern Europe.

Recent surveys of the grain aphid (*Sitobion avenae*) in the United Kingdom and Ireland have revealed the presence of pyrethroid resistant aphids. If they spread, these resistant aphids could present a new challenge to cereal growers in other parts of Europe.

The grain aphids have been identified as being resistant by an adaption of the sodium channel which forms part of the nervous system in insects and is the site of action of the pyrethroid insecticides. This modification at the target site of pyrethroids is known as the L1014F *kdr* mutation. The mutation is well known in other agricultural and public health pests such as the green peach aphid (*Myzus persicae*) and house fly (*Musca domestica*). What is different to other species is that in this case all the aphids have been found to be heterozygous (single copy) for the resistance allele.

Although the aphids have been demonstrated as having only a relatively low level of resistance to pyrethroid insecticides (up to 40 times less susceptible than insects without the mutation) this shift in sensitivity has been shown to reduce the performance of pyrethroid sprays when the percentage of resistant aphids reach high enough levels. Since their first detection in 2011, resistant aphids have been identified in several English and Irish counties, but the frequency of resistant individuals has not been high enough to cause problems everywhere. Control problems have mainly been focused around Suffolk, Norfolk and Cambridgeshire. Surveys in other European countries have shown that resistant aphids are much rarer in mainland Europe, with only a small number of resistant grain aphids found in parts of Germany and none found in limited surveys of France and Denmark.

The grain aphid is only one of the key species of aphid considered to be pests of cereal crops in Europe. There is currently no indication of pyrethroid resistance in the other species, which include the bird-cherry oat aphid (*Rhopalosiphum padi*), the rose-grain aphid (*Metopolophium dirhodum*) and further eastwards in Europe, the Russian wheat aphid, (*Diuraphis noxia*) and the Spring green aphid (*Schizaphis graminum*).

The resistant grain aphids currently present a challenge to farmers in the UK and Ireland and the concern is that the problem may spread to other areas of Europe. At present, there are few registered insecticides with different modes of action available to farmers (seed treatment or foliar applications) for the control of cereal aphids. This makes it difficult to rotate insecticides with different modes of action, which is the most commonly recommended form of resistance and pest management. In the UK the only other foliar applied insecticides apart from the pyrethroids are organophosphates and carbamates which share the same mode of action (IRAC Group 1). In other countries other insecticide modes of action such as chlordotonal organ modulators (IRAC Group 9) and nicotinic acetylcholine receptor agonists (IRAC Group 4) are available. The situation might get more difficult, if further uses are restricted or insecticides are banned from the market.

**If you observe the reduced performance of pyrethroid insecticides against cereal aphids in your region, please work with either your local plant protection organization or pyrethroid manufacturer to determine whether resistance is the cause of the problem and encourage them to report their findings to IRAC.**

Resistance management advice for the UK is provided by the Insecticide Resistance Action Group (IRAG) and can be found at [www.pesticides.gov.uk/Resources/CRD/Migrated-Resources/Documents/I/IRAG\\_Grain\\_Aphid\\_Guidance\\_Sept\\_2012.pdf](http://www.pesticides.gov.uk/Resources/CRD/Migrated-Resources/Documents/I/IRAG_Grain_Aphid_Guidance_Sept_2012.pdf), whilst more details on the mechanisms of resistance can be found in: Foster *et al.* A mutation (L1014F) in the voltage-gated sodium channel of the grain aphid, *Sitobion avenae*, is associated with resistance to pyrethroid insecticides. Pest Management Science (2013) DOI 10.1002/ps.3683 (<http://onlinelibrary.wiley.com/doi/10.1002/ps.3683/abstract>)

Links to French and German language versions of this document can be found on the IRAC Sucking Pest Team page at: <http://www.irac-online.org/teams/sucking-pests/>



Grain aphid (*Sitobion avenae*)  
Photo courtesy of Kansas Department of Agriculture Archive, bugwood.org



## **Working Group Activities**

RESISTANCE MONITORING

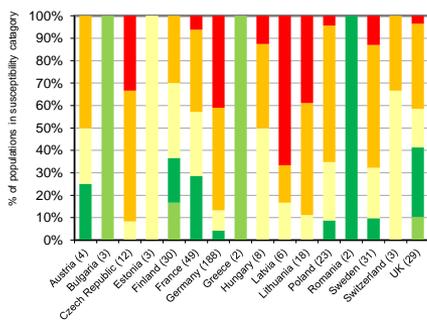


### Introduction and Background

Pyrethroid resistance has been recorded in European populations of the pollen beetle (*Meligethes aeneus*) since 1999, when it was first reported in Eastern France. The IRAC Coleopteran Working Group brings together expertise from agrochemical companies and independent researchers in order to monitor the development and spread of resistance in pollen beetles and other coleopteran pests of oilseed rape.

Pyrethroid, neonicotinoid, indoxacarb and organophosphate susceptibility is measured by the use of insecticide coated glass vial assays. Results of the 2013 susceptibility monitoring program are presented in this poster. More details of the methods used in this survey can be found on the IRAC website ([www.irac-online.org](http://www.irac-online.org)).

### 2013 pyrethroid resistance monitoring: *Meligethes aeneus*



- IRAC method #11
- 0.075 & 0.015 ug/cm<sup>2</sup> lambda-cyhalothrin doses
- Scoring system based on mortality at both doses indicates susceptibility status.

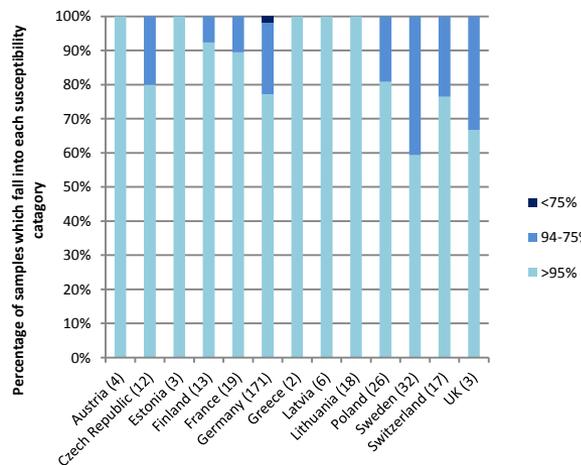
Pyrethroid resistant populations of pollen beetle dominate in most of the European countries surveyed.

3A  
IRAC MoA

4A  
IRAC MoA

### 2013 neonicotinoid susceptibility monitoring: *Meligethes aeneus*

- IRAC method # 21
- 1.44ug/cm<sup>2</sup> thiacloprid dose: > 95% mortality indicates susceptibility.



22A  
IRAC MoA

1B  
IRAC MoA

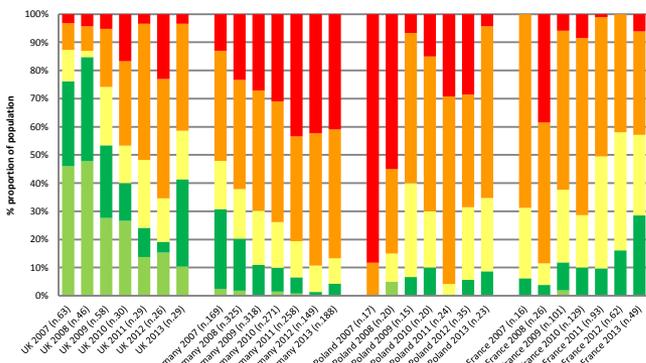
### Indoxacarb & Organophosphate susceptibility

- IRAC method # 25 (Chlorpyrifos-ethyl)
- IRAC Method # 27 (Indoxacarb)

All European populations of pollen beetle tested were susceptible to both Indoxacarb and organophosphates based on the IRAC recommended discriminating dose.

Country	No. of populations tested	
	Indoxacarb	OP
United Kingdom	4	0
Czech Republic	0	1
France	7	9
Germany	30	1
Hungary	1	2
Poland	2	5
Greece	0	2
Sweden	1	0

### Changes in the pyrethroid susceptibility of pollen beetle populations 2007 - 2013



Susceptibility surveys conducted between 2007 & 2013 suggest that in general pyrethroid resistant populations of pollen beetle have been on the increase in Europe. However, there are suggestions that since 2011, the number of resistant populations could be decreasing.

3A  
IRAC MoA

### Summary & Recommendations

- In the majority of countries surveyed, pyrethroid resistant populations of pollen beetle dominate (> 60% are resistant).
- 14% of pollen beetle populations surveyed in Europe can be classified as pyrethroid susceptible (2012= 7%).
- Across the UK, France, Germany and Poland there was evidence for an increase in the percentage of susceptible populations compared with 2012, with changes most noticeable in the UK and France.
- From the countries surveyed in Greece, Bulgaria, Romania, most populations were susceptible.
- The majority of populations tested across Europe remained susceptible to neonicotinoids, with only a small number of populations from Germany indicating a reduced susceptibility (<1% total samples).
- There was no evidence of changes in indoxacarb or organophosphate susceptibility observed in all countries surveyed.
- In order to prevent further insecticide resistance development, it is recommended that insecticides with different modes of action are utilised in an effective resistance management program, dependent on local insecticide availability and national use guidelines. IRAC guidelines for resistance management in oilseed rape can be found on the IRAC website ([www.irac-online.org](http://www.irac-online.org)).
- IRAC would like to thank all of those who contributed to the survey. Participants are too numerous to name, but their contributions are very much appreciated.

# IRAC US: Funded research projects 2013-14

Research	Investigators	Timeline
<ul style="list-style-type: none"> <li>Management of Insecticide Resistance in Asian Citrus Psyllid (ACP) Populations</li> </ul>	<ul style="list-style-type: none"> <li>Phil Stansly, University of Florida</li> </ul>	<ul style="list-style-type: none"> <li>Year 2 of 3 Year Study</li> </ul>
<ul style="list-style-type: none"> <li>Resistance risk assessment in populations of the Asian citrus psyllid (<i>Diaphorina citri</i>) to recommended insecticides: resistance monitoring in Texas and Florida, and establishment of the Asian Citrus Psyllid (ACP) resistance website portal.</li> </ul>	<ul style="list-style-type: none"> <li>Patricia V. Pietrantonio &amp; Cecilia Tamborindeguy, Texas A&amp;M University</li> </ul>	<ul style="list-style-type: none"> <li>Year 2 of 3 Year Study</li> </ul>
<ul style="list-style-type: none"> <li>Assessment of Southern Chinch Bug Insecticide Resistance Prevention</li> </ul>	<ul style="list-style-type: none"> <li>Eileen Buss, University of Florida</li> </ul>	<ul style="list-style-type: none"> <li>Year 2 of 2 Year Study</li> </ul>

# Research Projects

- *Spodoptera frugiperda*
- *Tuta absoluta*
- *Alabama argillacea*<sup>1</sup>
- *Grapholita molesta*<sup>1</sup>
- *Bemisia tabaci*
- *Euschistus heros*
- *Chrysodeixis includens*
- *Helicoverpa armigera*
- *Tetranychus urticae*<sup>2</sup>



<sup>1</sup> Concluded

<sup>2</sup> Institutional



## **Working Group Activities**

EDUCATIONAL MATERIAL

### Objectives

#### Introduction and background

Mosquitoes are vectors of many human diseases, including malaria. The emergence of species resistant to insecticides widely used in vector control has the potential to severely impact on the control of these disease vectors.



The lack of available suitable alternative insecticides for vector control is becoming a serious issue. It is therefore vital that effective insecticide resistance management (IRM) strategies are implemented to ensure that the efficacy of existing compounds can be maintained for as long as possible. There are several larvicides which have totally different modes of action to currently available adulticides and therefore offer the opportunity to control resistant mosquitoes where the major classes of adulticide insecticides are resisted. For details on application of larvicides see IRAC Poster 'Larviciding and Insecticide Resistance Management'.

This MoA (Modes of Action) is available at the IRAC website [www.irc-online.org](http://www.irc-online.org).

#### Malaria Control

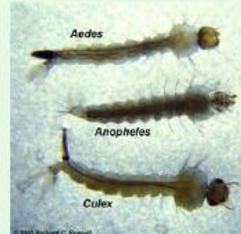
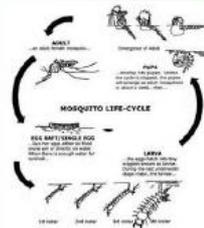
As malaria declines in many African countries there is a growing realization that new interventions need to be added to the front-line vector control tools of LLINs (long-lasting impregnated nets) and IRS (indoor residual spraying) that both target adult mosquitoes indoors. Larviciding provides the dual benefits of not only reducing numbers of house-entering mosquitoes, but, importantly, also those that bite outdoors and therefore are not vulnerable to LLINs or IRS. Of the larvicides that are recommended by the WHO Pesticide Evaluation Scheme (WHOPES), many have never been used to kill adult mosquitoes (except organophosphates) and are unaffected by the resistance mechanisms currently spreading through malaria vector populations in Africa. (Interim Position Statement - The role of larviciding for malaria control in sub-Saharan Africa WHO/GMP 2012). It is recommended that the impact of larval control on malaria is monitored through adult catches.

### Objectives (Contd.)

#### Dengue Control

The role of larviciding in Dengue control is more defined and is one of the major interventions in the control of the dengue vectors *Aedes aegypti* and *Aedes albopictus*, as their breeding sites are peri-domestic, well-defined, easier to find and not so widespread as for Anophelines. Before commencing treatment good surveys should be conducted to identify key breeding sites. Environmental management is also important with the removal of discarded containers, used tyres and regular emptying of plant containers and ant traps.

**Note:** When applying larvicides (especially in dengue control) it may be necessary to treat water storage containers used for drinking (potable water). If this is required only use products which have a WHO approval for use in potable water.



#### Nuisance mosquitoes

In many urban environments some mosquito species such as *Culex quinquefasciatus* can be a biting nuisance and not always a disease vector. However many authorities wish to control them to alleviate suffering of the local population or for example in tourist areas. These species usually have well defined breeding sites that can be located and treated to control the larvae.

#### Further information:

IRAC publication: Prevention and management of insecticide resistance in vectors of public health importance [www.irc-online.org](http://www.irc-online.org)

WHO (2006): Pesticides and their application WHO/CDC/NTD/WHOPES/GCDPP 6<sup>th</sup> edition, 114pp. [www.who.int/whopes/en/](http://www.who.int/whopes/en/)

### Application strategies

#### Dengue

The larviciding of breeding sites of *Aedes aegypti* and *Aedes albopictus* is a well known strategy, although success will depend on conducting detailed surveys, identification of the breeding sites and subsequent treatment with an appropriate larvicide. Failure to locate some of the breeding sites will result in later resurgence of the mosquito population. The breeding sites may be small and numerous so the more diligent the survey the better the results.

#### Nuisance mosquitoes

The same careful surveying and treatment of breeding sites also applies to control of urban *Culex* spp. However the breeding sites differ from *Aedes* spp. as they will often breed in water of higher organic matter or in drains, ditches etc.

#### Malaria

For the control of *Anopheles* spp. in malaria control programmes the use of larvicides can be beneficial as they allow the use of IGR's (insect growth regulators) or biologicals that are not available as adulticides and therefore allow the implementation of a resistance management strategy. In addition the use of larvicides can give additive impact when integrated with LLINs or IRS treatments. Careful surveying and identification of breeding sites is essential. Larviciding may not be applicable for certain species such as forest associated species such as *An. dirus* etc. due to the difficulty in locating breeding sites or if the breeding sites are too widespread, such as *An. gambiae s.l.* in many parts of rural Africa. However in some situations, such as peri-urban environments and highlands, where larval habitats may be 'few, fixed and findable' it may be possible to develop and sustain a larval control programme that will have a good impact. Anopheline larval control will work best and be most cost-effective in where habitats are seasonal and are accessible by ground crews, and in cooler parts of Africa where larval development is prolonged.

The choice of larvicide will depend on the sensitivity of the treatment site and other user requirements, e.g. are there non-target insects, crustacea, fish etc. that may be put at risk or is a larvicide required which will give long residual performance reducing the frequency of re-treatments. In addition any pre-existing resistance must be noted and larvicides avoided which have the same MoA.



## Introduction

There are five key species of plant and leaf hoppers which are known to be important pests of rice in Asia and Australasia.

They belong to two families, the Delphacidae and Cicadellidae. Delphacidae includes the brown planthopper (*Nilaparvata lugens*), small brown planthopper (*Laodelphax striatellus*) and whitebacked planthopper (*Sogatella furcifera*) which tend to inhabit the base of the plant, whilst the green paddy leafhopper (*Nephotettix virescens*) and rice green leafhopper (*Nephotettix cincticeps*) from the Cicadellidae family tend to inhabit the upper parts of the plant.

Both families are economically important pests of rice, when favourable conditions allow them to reach high infestation levels. All the species feed by the insertion of stylet mouth parts into the plant phloem tissue and damage is caused by either direct sap loss or through the injection of toxic saliva. The distinctive browning and wilting of rice plants, which is caused by hopper infestation is commonly known as 'hopper burn'. Plant and leafhoppers are also known to transmit various plant viruses such as grassy stunt and rice-stripe cereal mosaic.

Treatment with insecticides has been the primary control option for growers, with systemic insecticides more favoured in recent years. However the selection of resistant plant varieties and use of biological control agents are also important control method for these pests.



## Insecticide Resistance

Insecticide Resistance has been recorded in rice hopper species since the early 1960's, when organophosphate, carbamate and cyclodiene organochlorine insecticides were the main methods of chemical control. Although further insecticide chemistry has been introduced to control hoppers, the importance of rice as a staple food crop and the reliance on insecticides for the control of insect pests has seen the continued evolution of insecticide resistance. The most recent developments has seen populations of *Nilaparvata lugens*, *Laodelphax striatellus* and *Sogatella furcifera* independently develop resistance to neonicotinoid and phenylpyrazole insecticides. At the time of writing there is no evidence of a common cross-resistance resistance between chemical classes of insecticide across these species, however there is evidence that individual hoppers may exhibit multiple mechanisms of resistance to one or more insecticide modes of action.

Table 1: Insecticide modes of action to which field collected rice hoppers have been reported in literature as being (1960-2010).

Insecticide Chemistry	Mode of Action	<i>Nilaparvata lugens</i>	<i>Laodelphax striatellus</i>	<i>Sogatella furcifera</i>	<i>Nephotettix virescens</i>	<i>Nephotettix cincticeps</i>
Carbamates	1A	X	X	X	X	X
Organophosphates	1B	X	X	X	X	X
Cyclodiene organochlorines	2A	X	X			
Phenylpyrazoles (Fiproles)	2B	X	X	X		
Pyrethroids	3A	X	X	X		
Neonicotinoids	4A	X	X	X		
Selective Feeding Blockers	9B & 9C					
Chitin Biosynthesis inhibitor	16	X	X	X		

The information presented in this table is based on peer-reviewed published reports of field collected populations of rice hoppers being isolated at a specific time and location before being tested for insecticide susceptibility. Insecticide resistance is a dynamic process, and therefore, the information provided does not reflect the current status of insecticide resistance in all countries or locations.

## Distribution & Migration

Table 2: Recorded regional range of different rice hoppers.

The regional range of each of the five key species of rice hoppers varies and in many cases over-lap. Many of the species are migratory in nature and therefore each species may not reach pests status in all of its range every year.

The brown planthopper (*Nilaparvata lugens*) for example is recorded as being an immigrant pest in China, Japan and Korea after migrations from tropical and sub-tropical regions of S.E. Asia. Infestation levels in these countries are often dependant on environmental conditions throughout the region.

	<i>N. lugens</i>	<i>L. striatellus</i>	<i>S. furcifera</i>	<i>N. virescens</i>	<i>N. cincticeps</i>
Japan	X	X	X	X	X
Korea	X	X	X	X	X
Taiwan	X	X	X	X	X
China	X	X	X	X	X
Philippines	X	X	X	X	
Vietnam	X	X	X	X	
Laos	X	X	X	X	
Cambodia	X	X	X	X	
Thailand	X	X	X	X	
Myanmar	X	X	X	X	
Malaysia	X	X	X	X	
Indonesia	X	X	X	X	
Australia	X	X	X	X	
India	X	X	X	X	
Pakistan	X	X	X	X	
Pacific Islands	X	X	X	X	

## Resistance Management

As there is no evidence of cross-resistance amongst the groups insecticides used for rice hopper control, it is recommended that the rotation of effective insecticides with different modes of action are used to provide insect control, whilst at the same time reducing the risk of insecticide resistance from developing. The following should be considered when designing an insect control program for rice hoppers:

- Plan ahead. Determine when in a typical season insecticides applications are likely to be needed and plan for the rotation of insecticides with different modes of action, avoiding the consecutive use of products belonging to the same mode of action group. Plan for contingencies in case extra applications are needed due to atypical pest infestations. Consider the presence of other insect pests of rice (e.g. Stemborers or leafhoppers) and required treatments.
- Determine which insecticides are most effective for controlling each rice pest during each application timing. If the presence of other rice pests over-lap with rice hoppers, consider using pest specific insecticides rather than broad spectrum insecticides, which may increase unnecessary resistance selection pressure for either or both pests.
- Evaluate the current insecticide resistance situation in the area (consult local crop advisors and experts). Avoid using insecticides already affected by resistance where possible.
- Consider the impact of the insecticides on non-target insects and natural predators, especially during early season applications, where maintaining natural predators can reduce the need for later sprays.
- Consider the use of insect-resistant rice varieties and the use of biological control agents.
- Always follow insecticide label instructions for application timings, volumes and concentrations.

## Susceptibility Monitoring

The topical application of insecticides using a syringe, as described by multiple researchers has proved to be a useful bioassay in determining the susceptibility of insecticides, which have strong contact activity against rice hoppers. Extensive monitoring programs have been conducted across the host range of these pests with neonicotinoid, carbamate, phenylpyrazole and buprofezin insecticides.

Alternatively leaf dip assays, as described in the IRAC approved method No. 005, provide a method of assessing the activity of all insecticides which are utilised for the control of planthoppers, including pymetrozine, which primarily acts by reducing feeding and egg lay. A video of this method is available via the IRAC web-site.

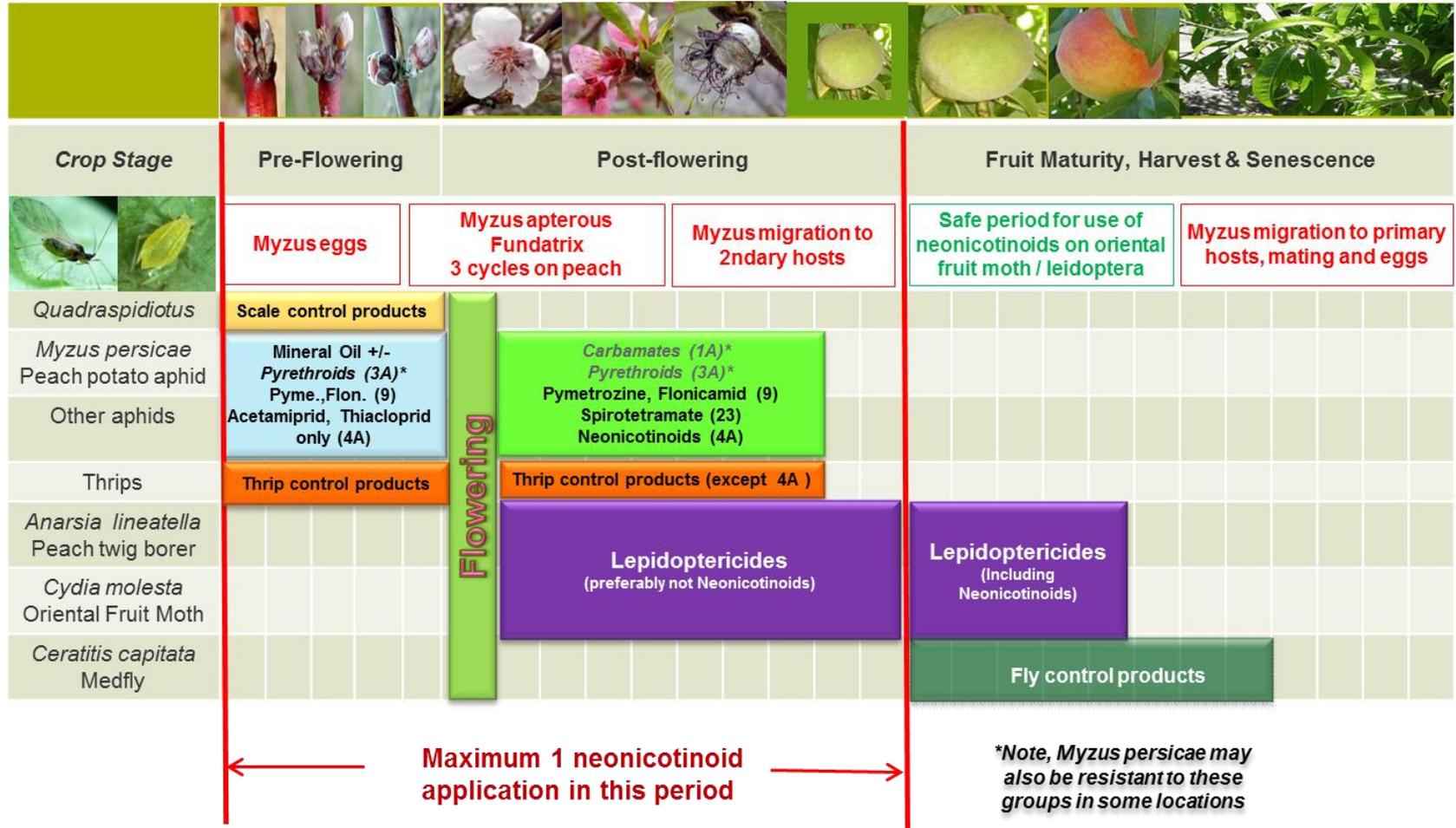


## **Working Group Activities**

IRM RECOMMENDATIONS

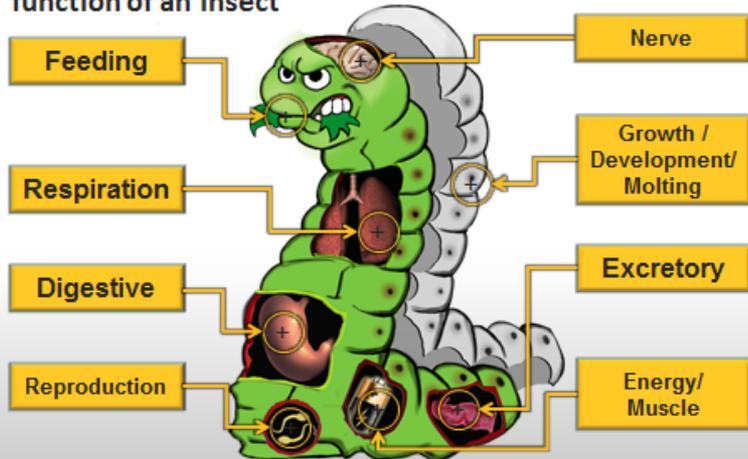
# 2013: Myzus resistance in Peaches in S. Europe

IRAC management recommendations for neonicotinoid resistant *Myzus persicae*:  
 Example 2014: **Peaches, Nectarines in Southern Europe**



# Insecticide Mode of Action (MoA)

A specific Mode of Action will target a specific part/function of an insect



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## 2. Follow Good Agricultural Practice (GAP) Principles

### USE RECOMMENDED DOSE

**Under Dose:**  
Kills most Susceptible but many RS and RR survive

**Label Dosage:**  
Optimal Control  
Small number of RR survive

Resistant RR		
Moderate RS		
Susceptible S		

Increasing Dosage **Under Dose** **LABEL DOSE!**

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## IRAC 杀虫剂的抗性管理 (IRM) 策略

田间在发生的故事.....



## Insecticide Resistance Management (IRM) Strategy in Rice

	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120					
	Seedling					Leaf Development					Tillering					Stem Elongation - Booting					Flowering					Ripening				
Stemborer						1 <sup>st</sup> Generation					2 <sup>nd</sup> Generation					3 <sup>rd</sup> Generation														
						35 Days					35 Days					35 Days														
Brown Plant Hopper						32 Days					32 Days					32 Days														
Green Leaf Hopper						30 Days																								
Insecticide Application (Need-Based)																														
Option 1						MoA 1					MoA 2					MoA 3														
Option 2						MoA 1					MoA 2					MoA 1														

# IRAC International Statements on IRM practice

IRAC International Insecticide Mixture Statement

Version: 1.0

## IRAC International Insecticide Mixture Statement

**As with applying single active ingredient products, insecticide mixture products should be used with careful consideration of the characteristics of the individual active substances, use pattern and pest complex targeted. The primary intention for the use of an insecticide mixture (tank-mix or pre-formulated mixture) is, in most cases, not resistance management, but pest<sup>1</sup> management. The following should be considered before using insecticide mixtures for insect pest control:**

- 1) Mixtures of insecticides provide technical advantages for controlling pests in a broad range of settings, typically by increasing the level of target pest control and/or broadening the range of pests controlled.
- 2) Most mixtures are not primarily used for purposes of insect resistance management (IRM).
- 3) In the majority of settings, the rotation of insecticide modes of action is considered the most effective IRM approach. Insecticide mixtures may offer benefits for IRM when appropriately incorporated into rotation strategies with additional mode(s) of action, but generally a single mixture should not be relied upon alone.
- 4) All of the following should be considered when using mixtures for IRM:
  - a) Individual insecticides selected for use in mixtures should be highly effective and be applied at the rates at which they are individually registered for use against the target species.
  - b) Mixtures with components having the same IRAC mode of action classification are not recommended for IRM.
  - c) When using mixtures, consider any known cross-resistance issues between the individual components for the targeted pest/s.
  - d) Mixtures become less effective if resistance is already developing to one or both active ingredients, but they may still provide pest management benefits.
  - e) The IRM benefits of an insecticide mixture are greatest if the two components have similar periods of residual insecticidal activity. Mixtures of insecticides with unequal periods of residual insecticide activity may offer an IRM benefit for the period where both insecticides are active.

<sup>1</sup> Pests include species relevant to both crop protection and public health

IRAC NEWSLETTER ISSUE 35

OCTOBER 2014

## IRAC International Statement: Considerations for the resistance management value of using insecticidal chemistry on transgenic crops expressing insecticidal proteins.

Chemical insecticides can be applied to conventional and transgenic crops expressing insecticidal proteins. Insecticidal chemistry may be applied to transgenic crops for a number of reasons, particularly to broaden the range of pests controlled or increase the level of target pest control. In certain circumstances, the application of chemical insecticides to transgenic crops also may be considered for insecticide resistance management (IRM) purposes.

All currently commercialized synthetic insecticidal chemistries offer an alternative mode of action to the insecticidal proteins expressed in transgenic plants and there is little evidence for cross-resistance between these chemistries and the insecticidal proteins\*. Therefore the combined use of synthetic insecticidal chemicals and proteins which target the same insect pest offers the potential for an IRM tactic that could be beneficial for preserving the susceptibility of the target insects to both components. However, negative IRM impacts may arise if chemical insecticides are applied to a non-transgenic refuge as this reduces the population of insects that are susceptible to the plant expressed protein. Therefore when selecting refuge size and structure, it is important to take into account chemical insecticide application programs.

When considering a pest management program, it is important to take into account IRM considerations for both the transgenic trait (i.e. refuge adoption) and the chemistries being employed (both foliar applied and seed treatments). The following should be considered when assessing the IRM value of applying chemical insecticides to transgenic crops expressing insecticidal proteins:

- 1) An IRM benefit of the combined use of insecticide chemistry and transgenic crops expressing insecticidal proteins will only occur while the target insect population is exposed simultaneously to lethal doses of both the insecticide chemistry and the insecticidal protein(s).
- 2) For there to be an IRM benefit, the insecticide should be applied to the transgenic crop but not the refuge. In cases where both the transgenic crop and the refuge are treated with the insecticide, the IRM benefits will be neutralized. In circumstances where only the refuge is sprayed, this will have a negative effect on IRM for the transgenic crop. Despite the neutral or negative effects on IRM, insecticide sprays applied to the refuge may offer other benefits such as improved pest control.
- 3) In most cases, a refuge-in-a-bag (RIB) strategy does not allow for the selective application of chemical insecticides only to the transgenic plants, and therefore the impact of chemical applications to both the transgenic plants and the embedded refuge is unlikely to provide an IRM benefit.
- 4) The application of insecticides to a field that contains, or is suspected to contain, a significant proportion of target pests that are resistant to the transgenic crop can provide local suppression of the pest population and slow the geographic spread of the resistant insects. This use of insecticides can therefore provide area-wide IRM benefits.
- 5) The combined effects of the chemical insecticide and the expressed insecticidal proteins will be less effective and potentially detrimental if resistance has or is already developing to either the chemical or the protein(s).

\*Not including foliar applied sprays which are based on *Bacillus thuringiensis* proteins.

# IRAC guidelines on on IRM practice

## Insecticide Resistance Management Global Guidelines for IRAC Group 28 (Diamide) Insecticides

Issued: December 2008

Version: 1.1

Prepared by: IRAC

## How to Develop an Insect Resistance Management Plan: Practical Approaches for Local Environments



## IRM for Transgenic Crops in Small-Holder Agricultural Systems

Issued, August 2013

Version 1.0

Prepared by: IRAC International

## IRAC Position on Seed Blends for IRM

Issued, August 2013

Version 1.0

Prepared by: IRAC International Plant Biotechnology Committee

# Company agreement on mode of action labelling & alignment of IRM label language.



**GROUP 28 INSECTICIDE**

## Example 2: Short Version

**Insecticide Resistance Management (IRM)**

General Recommendations:

\_\_\_ (product name) contains \_\_\_ (active ingredient name), a Group 28 Insecticide.

Unless directed otherwise in the specific crop/insect sections of the label, the following practices are recommended to prevent or delay the development of insecticide resistance to \_\_\_ (product name) and to Group 28 insecticides:

- Apply \_\_\_ (product name) or other Group 28 insecticides using a "window" approach to avoid exposure of consecutive insect pest generations to the same mode of action. Multiple successive applications of \_\_\_ (product name) are acceptable if they are used to treat a single insect generation.
- Following a "window" of \_\_\_ (product name) or other Group 28 insecticide, rotate to a "window" of applications of effective insecticides with a different mode of action.
- The total exposure period of all "Group 28-active windows" applied throughout the crop cycle (from seedling to harvest) should not exceed 50% of the crop cycle.
- Incorporate IPM techniques into the overall pest management program.
- Monitor insect populations for loss of field efficacy.

For additional information on insect resistance, modes of action and monitoring visit the Insecticide Resistance Action Committee (IRAC) on the web at <http://www.irac-online.org>.

## Example 3: Shortest Version – Minimal Text Required on Label

**Insecticide Resistance Management (IRM)**

General Recommendations:

In order to avoid fast resistance development, avoid treating consecutive generations of the target pest with the same product or products with the same mode of action. Apply \_\_\_ (product name) using a "window" approach, alternating blocks of treatments with \_\_\_ (product name) followed by blocks of treatments with other effective products with different modes of action. The total exposure period of all "Group 28 active windows" applied throughout the crop cycle cannot exceed 50% of the crop cycle.

For additional information on insect resistance, modes of action and monitoring visit the Insecticide Resistance Action Committee (IRAC) on the web at <http://www.irac-online.org>.



**Questions ?**