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www.irac-online.org

About This Issue

In this issue we report on the latest companies joining the IRAC Executive as well as feedback on various meetings organized or attended by members of IRAC International during the last few months. This includes the IRAC Public Health Team meeting with the Liverpool School of Tropical Medicine, attendance at the 3rd European Whitefly Symposium where a poster on Whitefly Resistance Guidelines with the Neonicotinoids was presented and highlights from the IRAC-US sponsored symposium at the 56th Annual Meeting of the Entomological Society of America. There is a report on various meetings attended by the IRAC Codling Moth Working Group with screenshots showing the new Neonicotinoid whitefly poster and Codling Moth poster. Finally there is brief update on the current position regarding the revision of Directive 91/414.

IRAC Membership News

Vestergaard Frandsen is the latest company to join the IRAC Executive which means that we now have a total of 14 member companies supporting the activities of IRAC International. Vestergaard Frandsen was founded in Denmark in 1957 and specializes in disease control textiles with a focus on water-borne and vector-borne diseases. They come to IRAC through the Public Health Team but are also participating in the MOA, Methods and Resistance Database WGs. We welcome Vestergaard Frandsen to the IRAC Network and look forward to their contributions to global IRM.



IRAC Public Health Team Meets Up With The Liverpool School of Tropical Medicine

In late November, the IRAC Public Health team held a two day meeting at the Liverpool School of Tropical Medicine. The Public Health team has grown in recent months, with representatives of Vestergaard Frandsen and Chemtura joining us. Unfortunately our new colleagues were unable to meet with us in person; however, we look forward to working with them during 2009.

The first day saw a lively meeting where it was agreed that a greater emphasis should be placed on educational material. The first edition of the "Vector Manual" was seen as a success with approximately 3000 hard copies distributed. It was agreed that during 2009, we should work on an updated edition to include developments in vector control. It was also highlighted that there would be great value in translating the document into Spanish, French and Portuguese. Among other items, the concept of Resistance Risk Assessments, RRAs, was raised. This is a fairly novel approach in vector control and it was agreed it could be a valuable tool for the introduction of new vector control measures. The day was rounded off with a tour of the highly impressive new wing of the LSTM.



From left to right: Mark Hoppé, Janet Hemingway, Bob Wirtz, Mark Rowland, John Invest, Karin Horn, Ralf Nauen.

The second day was a workshop designed to look at the issue of Discriminating Doses used to identify "resistant" mosquitoes. The WHO undertook a large exercise during the 1990s, culminating in published recommended DDs. However, it has been felt for a while that the chosen doses do not provide sufficient information on which to base a resistance management strategy. To help the team grapple with these issues, Prof. Janet Hemingway from the LSTM and Mark Rowland from the LSTHM kindly agreed to add their considerable experience and expertise to our discussions. Again, a very lively discussion ensued, looking at all aspects of the generation and interpretation of DDs in the laboratory, and field. This will be an ongoing discussion, however, the Liverpool meeting was an excellent start.

3rd European Whitefly Symposium

In March 1999 the European Whitefly Study Network (EWSN) was established as an EU funded concerted action project due to increasing whitefly problems in many agricultural and horticultural cropping systems and in particular because of an increased tendency of virus spread many European experts gathered to exchange information and follow a concerted approach on communication and education.

In October (20-24) 2008 the 3rd European Whitefly Symposium was held in Aguadulce, Spain – a region known to be one of the Mediterranean hotspots for whitefly infestations. The meeting was attended by more than 100 participants from the public and private sector, including university scientists, advisors, researchers from the agrochemical industry and biological control companies.



The Organizing Committee led by Dirk Jansen (Crop Protection Area, IFAPA) did an excellent job and five different sessions were offered to the participants, covering “Faunistics, Systematics & Ecology”, “Whitefly Transmitted Viruses”, “Genomics, Proteomics & Metabolics”, “Host Plant Interactions” and “Natural Enemies, Control and IPM”. Each session was started with a keynote lecture and in total more than 45 oral presentations were given and ca. 60 posters displayed. The IRAC Neonicotinoid Team displayed its brand-new poster on whitefly neonicotinoid resistance management (see the screenshot later in the newsletter). A few presentations were given on whitefly resistance to insecticides, for example covering the age-specific expression of neonicotinoid resistance in *Bemisia tabaci* (see also *Pest Management Science* 64 (2008) 1106) or the status of insecticide resistance of *B. tabaci* Q-biotypes in Spain and Crete. Many presentations in the “Control Session” dealt with biological control of whiteflies and it was interesting that in Almeria pepper production, chemical control was to a greater or lesser extent replaced by biological control, particularly due to the introduction of a new predatory mite, *Amblyseius swirskii*. Further information is available at www.ews3.org.

IRAC Codling Moth Working Group

The Codling Moth WG was very busy during the last couple of months attending and presenting posters at the IOBC International Conference on Integrated Fruit Production in Avignon, the International Symposium on Codling Moth Control in Neustadt, and at the Western Orchard Pest & Disease Management Conference in Portland, Oregon. The opportunity was taken to distribute a questionnaire to experts so that an up to-date survey of codling moth resistance could be assessed. Results from the survey will follow in future issues of the eConnection. A screenshot of the codling moth poster is included at the end of the newsletter and the file can be downloaded from the IRAC website.

IRAC's 25th Birthday & The Next IRAC Intl. Meeting

The next major meeting of IRAC International will be in Barcelona March 31st to April 3rd, 2009. This will be an opportunity for the IRAC Executive, IRAC International Working Groups and the IRAC Country Groups to get together and review progress on global resistance management strategies and develop plans for the coming year. There will also be a joint session with IRAC Spain with presentations from guest speakers outlining some of the particular resistance problems in Spain. 2009 is also the 25th Anniversary of the formation of IRAC so an opportunity for celebration and all IRAC members are invited.

Highlights of the IRAC-US sponsored symposium "Entomology without Borders - The Next Stage in Resistance Management"

The IRAC-US sponsored symposium "Entomology without Borders - The Next Stage in Resistance Management" was held at the 56th Annual Meeting of the Entomological Society of America in Reno, Nevada, U.S.A. As a global community with free trade around the world, there are more opportunities for invasive insects to be transported across borders. One of the challenges is to find ways to manage insects that are either non-native or have developed insecticide resistance prior to border crossing. The objective of this symposium was to discuss how to manage resistance of invasive insect species.

Ron Stinner and Karl Suiter, NSF Center for Integrated Pest Management gave the first talk of the symposium which was titled "Information Systems and Intelligence Analysis Critical to APHIS Agricultural Safeguarding. APHIS (Animal and Plant Health Inspection Service) is concerned about pests that will enter the U.S. There are many databases with lots of information about pests that have entered the U.S. and the challenge is to find ways to share this information in a timely manner. A good resource is www.safeguarding.org.

Tony Shelton, Cornell University gave a talk titled "The Resistance - A Never Ending Story". There are many potential opportunities for *Plutella xylostella* outbreaks in the U.S. and the question is how does the grower or consultant learn about these outbreaks and act upon this information. Local newsletters and monitoring at the point of introduction are two good ways to disperse information. It is also important that the grower is spraying the population when it has reached an economic threshold level rather than on a calendar approach.

Shelby Fleischer, Penn State University and Bill Hutchison, University of Minnesota gave a talk titled "*Helicoverpa zea*: tracking movement and addressing resistance of an annually re-invasive migrant". A number of cooperators across the U.S. track the movement and susceptibility to pyrethroids of *H.zea*. Penn State gives this information via Pest Watch which allows the growers and consultants to know the movement over a large area. This can be accessed via www.pestwatch.psu.edu

Scott Ludwig, Texas A&M University spoke about "Ornamental pest management on a global perspective". One of the biggest challenges in working with ornamental growers is to have them admit they have a problem that needs to be addressed. With the concern of inspection and shipping their plants around the world, the growers do not want to bring negative attention to them. This is challenging when it comes to invasive species such as the Chilli thrips and the Q variant of *Bemisia tabaci*.

Peter Ellsworth, John Palumbo, Al Fournier and Yves Carrière, University of Arizona gave a talk titled "Beyond Field Borders: Cross-commodity Resistance Management of *Bemisia tabaci* - Spatial Evaluation of Group Adoption of Neonicotinoid Guidelines". A survey was conducted that measured how well the resistance management programs in Arizona were followed by growers for *Bemisia tabaci*. In many instances, the growers did an excellent job in adopting the program. There have been fewer problems with *Bemisia* since the guidelines were initiated.

Revision of Directive 91/414

As part of a wider lobbying activity, IRAC along with the other RACs produced a consultative document stressing the importance of maintaining a sufficient toolbox of actives for good resistance management and highlighting the potential implications resulting from the proposed introduction of cut-off criteria under the revision of Directive 91/414.

The directive revision process continues but the recent Parliament Plenary vote in 2nd reading resulted in an improvement on the Commission's initial proposal and the Parliament's first reading. While cut-off criteria remains a key concern there now appears to be some scope that the process will be based on risk assessment with very few substances likely to be removed directly from the market. Clear definitions will need to be put in place, in particular for endocrine disruption but a number of initiatives are ongoing particularly through ECPA and the situation continues to be monitored.

PROPOSAL ON THE REVISION OF EU DIRECTIVE

PROPOSAL ON THE REVISION OF EU DIRECTIVE 91/414

The impact on Resistance Management and Sustainable Crop Production in Europe

The views expressed here and the accompanying recommendations are endorsed by the following bodies:

Fungicide Resistance Action Committee (FRAC)

Insecticide Resistance Action Committee (IRAC)

European Herbicide Resistance Workgroup (HRAC)



The Resistance Action Committees (RACs) are specialist technical groups of CropLife International, the plant science industry global federation. The role of the RACs is to provide a coordinated industry response to prevent or delay the development of resistance through improved communication and education on resistance issues and the development of resistance management guidelines and strategies.

Resistance management strategies

It is for this reason that resistance management strategies using a broad range of diverse modes of action are commonplace; they avoid the possibility of target site cross-resistance, reduce the commercial impact should resistance to a major mode of action arise and they are part of effective product stewardship and sustainability. Moreover, effective resistance management using chemical diversity is recognized by the EU Parliament and the Commission in its regulatory framework as indicated below.

Recent IRAC Posters (pdf files of the posters are available for download from the IRAC website)



Insecticide Resistance Action Committee

The IRAC Codling Moth Working Group: Aims & Scope

www.irac-online.org

Introduction to IRAC

IRAC formed in 1984 to provide a coordinated industry response to the development of resistance in insect and mite pests. The IRAC Mission is to:

- Facilitate communication and education on insecticide and acaricide resistance
- Promote the development of Insect Resistance Management (IRM) strategies in crop protection and vector control to maintain efficacy and support sustainable agriculture and improved public health.

IRAC International today operates in three major sectors (Crop Protection, Public Health, Plant Biotechnology). It comprises 13 International Working Groups and 7 Country/Regional Groups (India, S.E. Asia, Brazil, S. Africa, US, Spain, Australia). IRAC sees IRM as an integral part of IPM.

Codling Moth Resistance Mechanisms & IRM

Mechanisms

Resistance to a specific insecticide can be due to different resistance mechanisms

- Metabolic resistance (modified enzymatic activity: MFO, GST, EST)
- Target-site resistance (KDR, MACE)
- Reduced penetration and behavioural changes.

When the mechanism(s) of resistance is not determined, it is more prudent to prevent the onset of resistance by using different insecticides to prevent the onset of resistance. Initiating use of MoA alternation (i.e. between consecutive Codling Moth generations) and other semi-chemical, bio-technical and cultural tools remains best IRM practice, since such practice will always minimize selection pressure.

Metabolic cross-resistance and its diversity: a major threat

- Metabolic resistance is the most relevant type of resistance in Codling Moth
- Different metabolic profile (enzymatic activity) can impact different MoA products
- It can concern insecticides across different MoA, but differential response between products within the same MoA can be observed
- There can be diverse patterns of metabolic resistance (different enzymatic activity)
- The diversity of the metabolic resistance found in Codling Moth can be significant across the different geographical areas.

Scenario Changes & Trends

	2000	2010	2015
No. of MoA available for codling moth control***	8	10	n.a.
No. of individual insecticides available**	High	Decreasing	Fewer
Use of semiochemicals (Mating Disruption)	Minor	Moderate	Major
Microbial insecticides	Minor	Moderate	Moderate
Biological control	Minor	Minor	Minor
Regulatory pressure	Low	High	Decreasing
Food-chain pressure	Low	High	Decreasing
Field resistance issues****	Moderate	Decreasing	Low
Resistance knowledge and investigation tools	Moderate	Increasing	High

* four introduced in 1997-2000, two in 2007-10
** according to IRAC MoA classification (version 6.1)
*** in terms of chemical classes and molecules, the criteria introduced in the revision of IRAC MoA classification 2014/14 major concern is the number of the available insecticides, with an impact on sustainable control options
**** It'll depend on the implementation of the other factors. Assumption is that sustainable insecticide use will continue to be possible and implemented. In this respect, increased use of non-chemical tools will play a key role
Major factors affecting the current scenario vs year 2000
• Increased adoption of semi-chemicals for Mating Disruption
• Reduction of chemical toolbox due to regulatory & food-chain pressure
• Improved investigation tools for resistance detection and confirmatory assays

IRAC Codling Moth Working Group

The Codling Moth Working Group was established in 2000 to deal with increased occurrence of C. Moth resistance in the 90's. Since then its scope has significantly changed. IRAC has reactivated the Codling Moth Working Group to tackle the issues and opportunities for improved IRM (Insect Resistance Management) as a result of the new scenario.

Insect resistance is 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.

Insect Resistance is an example of "evolution in action", showing how selective forces can produce changes in the gene frequency of a population.

First documented case of C. Moth resistance was in 1928 in the US, to arsenite. Since then the situation has evolved in relation to the control tools available.

Bioassay and Monitoring for Resistance

Diagnosing metabolic resistance

- The analysis of the enzymatic activity (MFO, GST, EST) in a Codling Moth population is a key element for resistance evaluation
- There is a different enzymatic activity between life-stages within the same population
- In resistant strains, the enzymatic activity may not only differ in quantitative terms, but also qualitatively (e.g. esterase isozymes)
- By itself, knowing the enzymatic profile of a given population does not allow to predict the field resistance nor the effectiveness of insecticide *
- Cross-resistance does not always concern all the insecticides with the same MoA. Azinphos-resistant C. Moth may be susceptible to Chlorypyrifos and vice-versa.

Routine vs confirmatory assays

- In the last decade, large scale monitoring for field resistance mostly relied on topical application to daupassing Codling Moth larvae
- Recent authoritative studies have confirmed their validity for IGRs, but questioned their reliability for the prediction of field resistance with some neurotoxic insecticides
- By itself, a significantly higher response in a routine monitoring conducted on non-target insect stage, does not allow to predict field resistance, unless validated with additional target-specific assays
- Validatory tests should include multiple insecticide concentrations.

Bioassaying the target-stage

- Resistance monitoring should be preferentially done on the target instar
- For larval products, ingestion bioassays on neonate larvae (P¹ or the feral population) normally provide a more reliable indication of the field situation than topical application to daupassing larvae.

 This poster is for educational purposes only. Details are accurate to the best of our knowledge but IRAC and its member companies cannot accept responsibility for how this information is used or interpreted. Advice should always be sought from local experts or advisors and health and safety recommendations followed.

Designed & produced by IRAC Codling Moth WG, September 2008, Poster Ver. 1.0
For further information visit the IRAC website: www.irac-online.org 

Scope of the Codling Moth Working Group

- Gather and share updated feedback on Codling Moth resistance (industry, expert panel, fruit growers)
- Facilitate networking between the industry and the scientific/advisory community
- Support research work aimed to standardize bioassay methods & improve their reliability
- Foster adoption of confirmatory assays on target insect stage
- Ensure a longer effective life for the available toolbox
- Provide IRM guidance and contribute to local IRM strategies, including the new chemical classes recently introduced (resistance avoidance).




Insecticides & MoA for Codling Moth

MOA GROUP	PRIMARY TARGET SITE	CHEMICAL CLASS	COMMON NAME
1A	Acyloheximide antibiotics	Carmamest	Carmate, Methoprene
1B	Acyloheximide antibiotics	Etephenophate	Etephenate, Etephenate, Acetopropalin, Phenothiazine-alkyl
2A	Sodium channel modulators	Purimex	Acetyl-Quaternary, Acetyl-Cyclodextrin, Acetyl-Quaternary, Acetyl-Quaternary, etc
2B	Cholin esterase inhibitors, type II	Resourcex	Malathion, Phenthoxine, Lufenuron, Malathion, Malathion, Malathion, etc
3A	nicotinic acetylcholine receptor agonists	Neonicotinoids	Imidacloprid, Thiamethoxam
3B	Voltage dependent K ⁺ channel blockers	Quazidex	Quazidex
4	nicotinic acetylcholine receptor effector activators	Ipomepept	Ipomepept, Ipomepept
5	Botulinum receptor agonists	Botulox	Tezepelizumab, Botulinum-toxin
6	Acetocholinesterase mimics	Phenothiazep	Parathion, Parathion-methyl
7	Cholinesterase modulators	Acetoxam	Acetoxam-thiophane
8	Nicotinic receptor modulators	Diazides	Diazides, Diazides

* The toolbox is not empty. Ten different modes of action are currently available for control of Codling Moth, whose two are novel. Although efficacy level may vary, all of them are relevant to ensure the MoA diversity needed for sustainable control

• The available toolbox should be locally qualified with the no. of authorized MoA-products. Provide a year of consistent introduction for C. Moth control and the relative efficacy level provided.

IRAC

Insecticide Resistance Action Committee

Neonicotinoids - IRM Guidelines for Sustainable Whitefly Control

www.irac-online.org

Introduction and background

The use of neonicotinoid insecticides has grown considerably since the forerunner of this group - imidacloprid was first introduced in 1991. Today seven insecticides belonging to this chemical class are available to farmers all over the world and classified as Group 4A in the IRAC Mode of Action Classification Scheme. All neonicotinoids are a subset of insecticides acting on nicotinic receptors.¹ Both *Bemisia tabaci* (sweet potato whitefly) and *Trialeurodes vaporariorum* (greenhouse whitefly) have been shown to possess a high potential for resistance development and represent one of the principal targets for which IRAC specific guidelines have been developed.²⁻⁴ Global Resistance Management Guidelines were designed by the Neonicotinoid Working Group of the Insecticide Resistance Action Committee and are based on guidelines published and updated earlier.⁵




In modern protected vegetable production sites often an integrated whitefly control approach is chosen and includes chemical and biological control measures.

Bemisia tabaci resistance around the globe



Mode of Action Classification

Group 4 Insecticide Class taken from Version 6.1 of the IRAC Mode of Action Classification Scheme

Group 4: Nicotinic acetylcholine receptor agonists	4A: Neonicotinoids	4B: Nicotine
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More information on IRAC and the Mode of Action Classification is available from: www.irac-online.org or enquiries@irac-online.org

IRAC Guidelines for Neonicotinoid Resistance Management

1. Always use products at the recommended label rates and spray intervals with the appropriate application equipment.
2. Rotation of insecticide chemistries sets against rapid selection of resistant populations.
3. Use suitable rotation partners for neonicotinoids.

An extensive range of insecticides with different modes of action which can be used as rotation partners for neonicotinoids, are available to the farmer. Advice on suitable rotation partners can be obtained from IRAC's mode of action classification available from the website (<http://www.irac-online.org>). The table on the bottom lists common whitefly MoA's in whiteflies, there is also cross-resistance to Group 9B (pyrethroids). The cross-resistance is not found in other pests.

4. The use of neonicotinoids against different pests in the same crop.
5. Multiple use of different neonicotinoids against more than one pest species in the same crop is feasible but needs at the local level, to take into account the pest populations dynamics, overlapping of the various species, their relative importance and each species potential risk for developing resistance.
6. Do not control a multi-generation pest exclusively with neonicotinoids.
7. Never use neonicotinoids for follow up treatments where resistance has already reduced their effectiveness.
8. The use of non-specific products helps to prevent the development of resistance.
9. Plan the use of neonicotinoid insecticides in such a way that they complement the efficacy of the prevalent beneficial organisms.
10. Good agricultural practices should be applied alongside physical and biological pest control methods.
11. Monitor problematic pest populations in order to detect first shifts in sensitivity.

The full IRAC Neonicotinoid RM Guidelines are included in a five page document and can be downloaded from the website 

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Designed & produced by IRAC Neonicotinoid WG, October 2008, Poster Ver. 1.0
For further information visit the IRAC website: www.irac-online.org 

Conferences & Symposia

- 3rd Intl. Symposium on Biological Control of Arthropods, Christchurch, NZ, February 8-13, 2009
- Crop Protection in Southern Britain, Peterborough, UK, February 10-11, 2009
- 5th European Mosquito Control Association Workshop, Turin, Italy March 9-13, 2009
- 2nd IOBC WG, Integrated Control of Plant Feeding Mites, Firenze, Italy, March 9-12, 2009
- German Entomological Society, Göttingen, Germany, March 16-19, 2009
- The Future of Crop Protection China, Shanghai, China, March 20-21, 2009
- 6th Intl. IPM Symposium, "Transcending Boundaries," Portland, OR, March 24-26, 2009
- 61st Intl. Symposium on Crop Protection, Gent, Belgium, May 19, 2009
- 8th International Symposium on Aphids, Catania, Italy, June 8-12, 2009
- NPMA, PestWorld, Las Vegas, USA, October 26-29th, 2009
- 5th International Bemisia Workshop, Guangzhou, China, November 9-12, 2009
- Entomological Society of America, Indianapolis, USA, December 13-17, 2009

Links to the conference websites can be found on the Events Page of the IRAC website www.irac-online.org/Events.asp

The eConnection is prepared and supported by the 14 member companies of the IRAC Executive

**Disclaimer:**

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