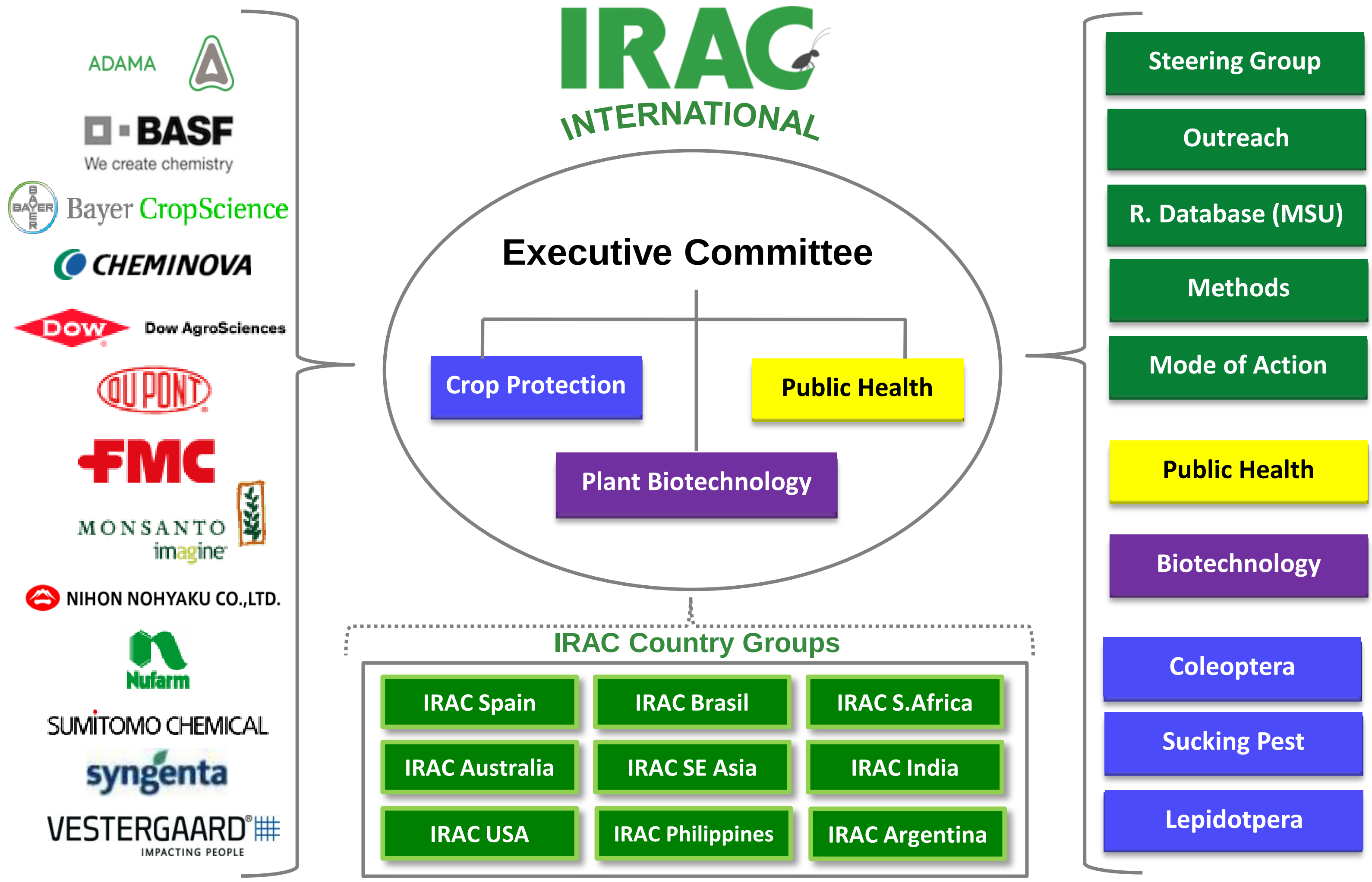
Insecticide Resistance Action Committee

IRAC overview & update on activities.

EPPO Meeting
September 2015






IRAC
INTERNATIONAL
ADAMA
BASF
We create chemistry
Bayer CropScience
CHEMINOVA
Dow
Dow AgroSciences
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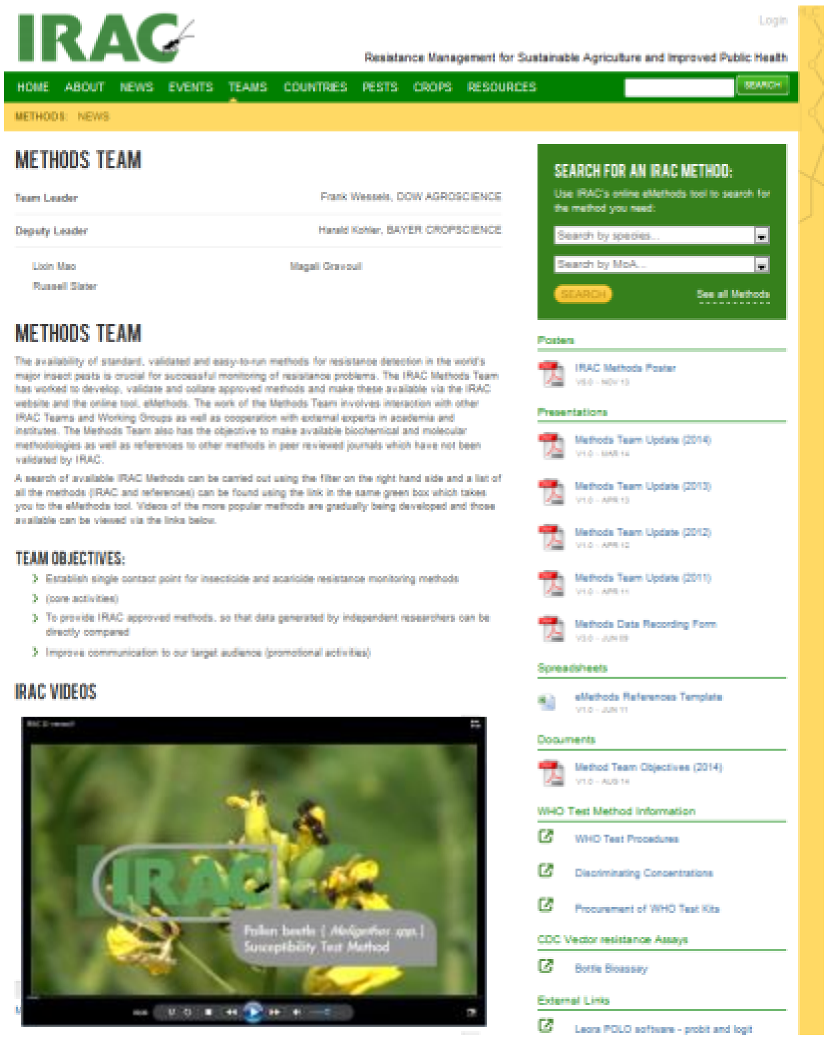
IRAC Country Groups
IRAC Spain
IRAC Brasil
IRAC S.Africa
IRAC Australia
IRAC SE Asia
IRAC India
IRAC USA
IRAC Philippines
IRAC Argentina
Steering Group
Outreach
R. Database (MSU)
Methods
Mode of Action
Public Health
Biotechnology
Coleoptera
Sucking Pest
Lepidotpera

IRAC web-site: communicating knowledge & education

IRAC web-site: Pest Pages

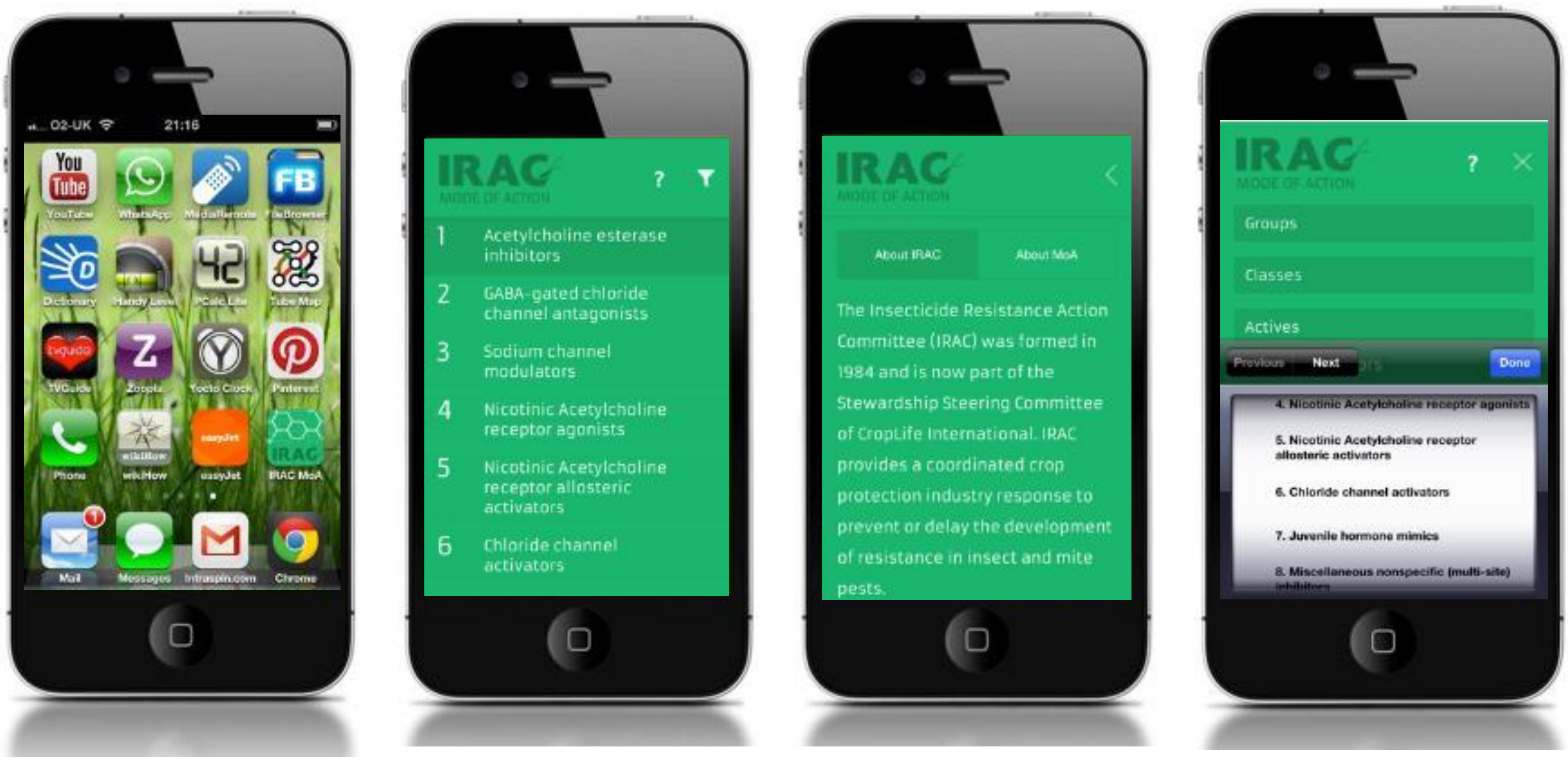
IRAC web-site: Methods & Method videos



IRAC

IRAC web-site: Mode of action classification tools

Mode of Action classification: Phone/Tablet App

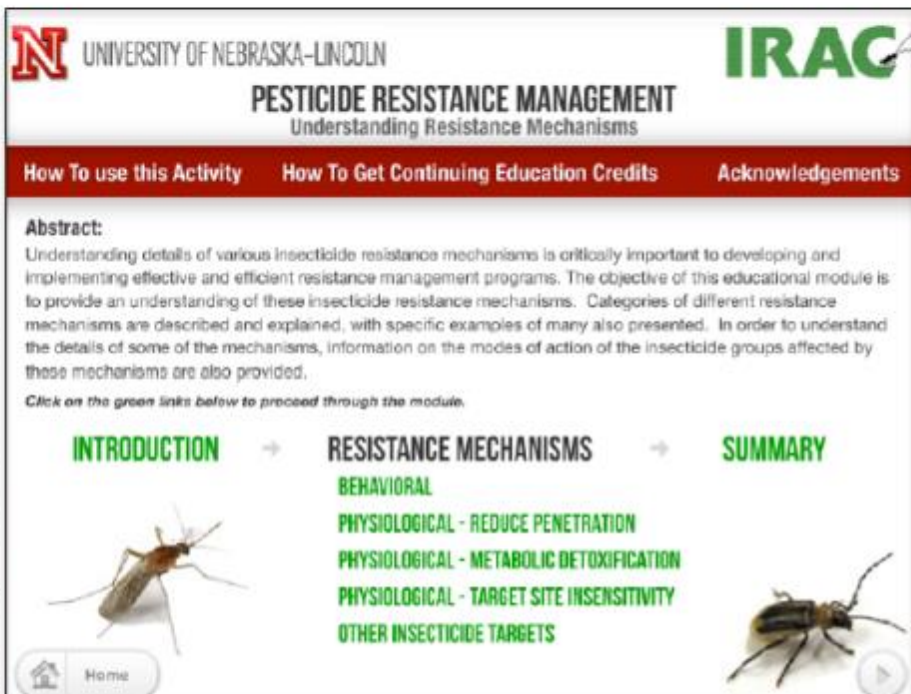


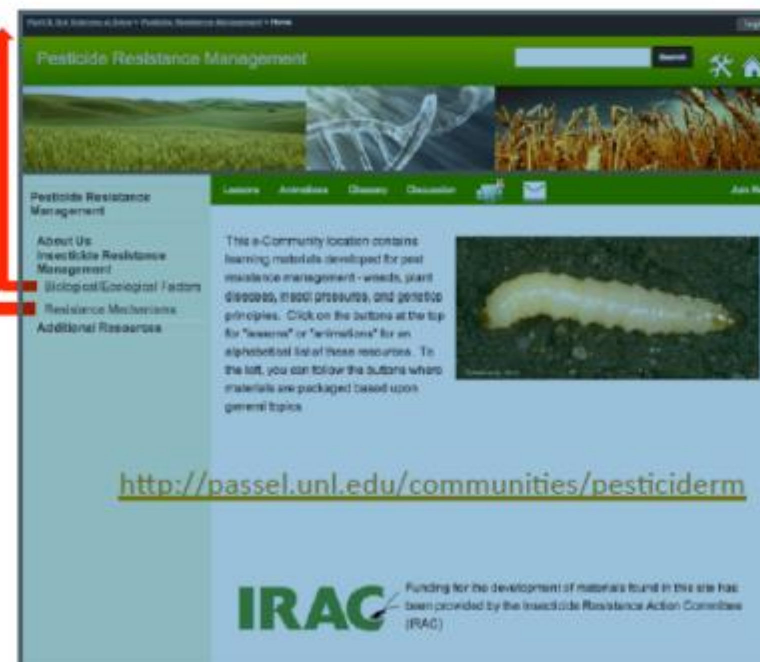
IRAC

UNL Educational Modules

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

Contents: 120 Lessons and 116 Animations





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

E-Connection: IRAC news letter

IRAC NEWSLETTER ISSUE 35 — OCTOBER 2014

IRAC eConnection

Insecticide Resistance Action Committee

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 *Diaphorina 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

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 *Diaphorina 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 us 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

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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.

Grain aphid (*Sitobion avenae*)

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, 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/

IRAC

Working Group Activities

RESISTANCE MONITORING

IRAC

Insecticide Resistance Action Committee

IRAC Coleopteran Working Group

Pollen Beetle Resistance Monitoring 2013

www.irac-online.org

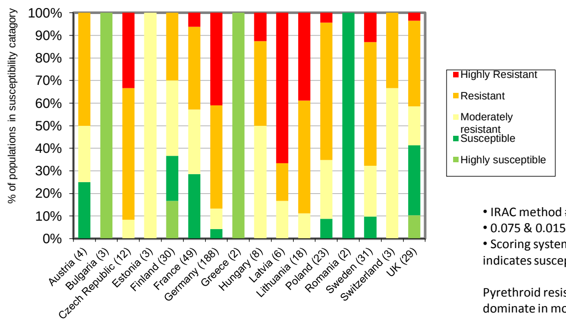
Introduction and Background

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).

2013 pyrethroid resistance monitoring: *Meligethes aeneus*

3A IRAC MoA



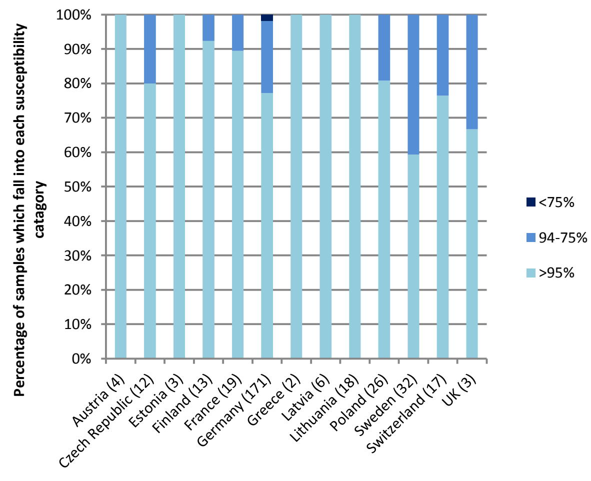
- IRAC method #11
- 0.075 & 0.015 ug/cm² lambda-cyhalothrin doses
- Scoring system based on mortality at both doses indicates susceptibility status.

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

2013 neonicotinoid susceptibility monitoring: Meligethes aeneus

4A IRAC MoA

- IRAC method # 21
- 1.44ug/cm² thiacloprid dose: > 95% mortality indicates susceptibility.



22A IRAC MoA 1B IRAC MoA

Indoxacarb & Organophosphate susceptibility

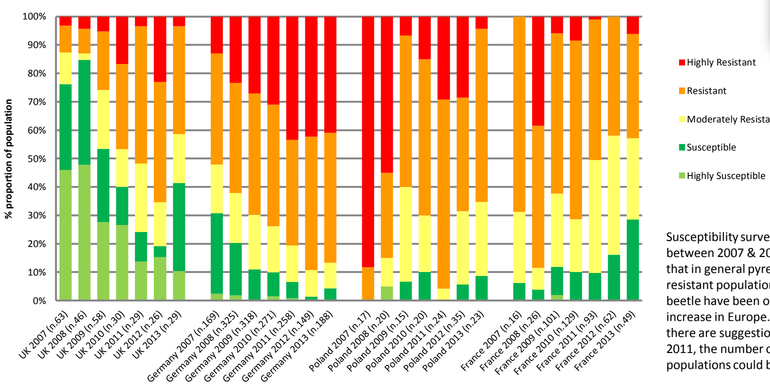
- IRAC method # 25 (Chlorpyrifos-ethyl)
- IRAC Method # 27 (Indoxacarb)

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

3A IRAC MoA



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.

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).
- 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.

Version 1.0, Designed and produced by IRAC Coleopteran Working Group, February 2014, Photographs courtesy of Syngenta Crop Protection

Visit to IRAC web-site for further details at www.irac-online.org

CropLife

Research Projects

IRAC-BR
Comitê Brasileiro de Ação a Resistência a Inseticidas

- *Spodoptera frugiperda*
- *Tuta absoluta*
- *Alabama argillacea*[1]
- *Grapholita molesta*[1]
- *Bemisia tabaci*
- *Euschistus heros*
- *Chrysodeixis includens*
- *Helicoverpa armigera*
- *Tetranychus urticae*[2]

[1] Concluded [2] Institutional

Working Group Activities

EDUCATIONAL MATERIAL

IRAC

Theory & Practice of Mosquito Larviciding

IRAC
Insecticide Resistance Action Committee

www.irac-online.org

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.irac-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.irac-online.org

WHO (2006): Pesticidesand their application WHO/CDC/NTD/WHOPES/GCDPP 6th edition, 114pp. 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 or 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.

CropLife

IRAC

Insecticide Resistance Action Committee

Rice Hoppers

www.irac-online.org

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 famillies 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 mosiac

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 organophospahte, 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* independantly 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	*Nilaparvata lugens*	*Laodelphax striatellus*	*Sogatella furcifera*	*Nephotettix virescens*	*Nephotettix cincticeps*
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.

	N.lugens	L.striatellus	S.furcifera	N.virescens	N.cincticeps
Japan	x	x	x	x	x
Korea	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		
India	x	x	x	x	
Pakistan	x		x		
Pacific Islands	x		x		

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.

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 untypical pest infestations. Consider the presence of other insect pests of rice (e.g. Stemborers or leaffolders) 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

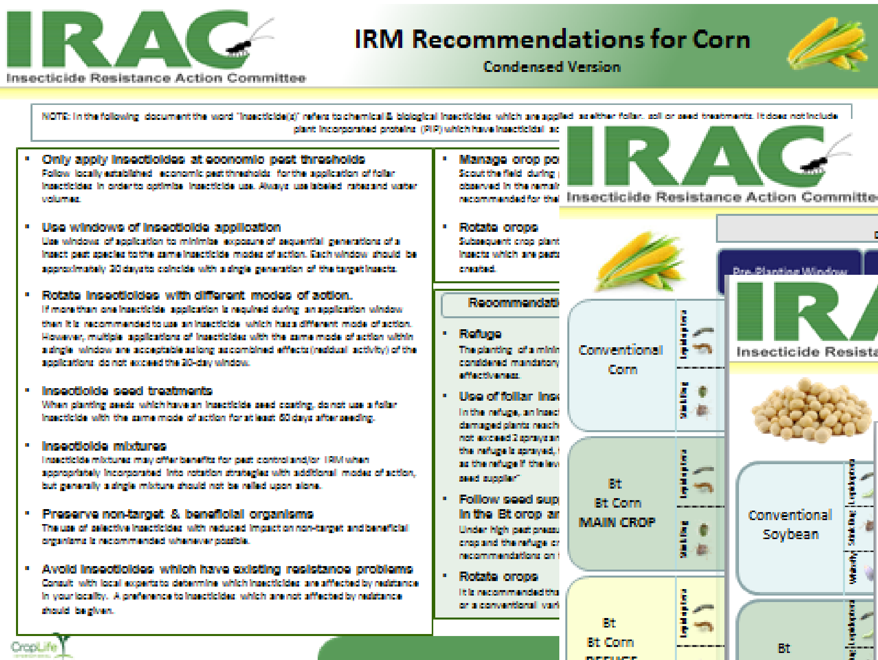
The topical application of insecticides using a syringe, as described by multiple researchers has proved to be a useful bioassay in determining the susceptibility of insecticides, which have strong contact activity against rice hoppers. Extensive monitoring programs have been conducted across the host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

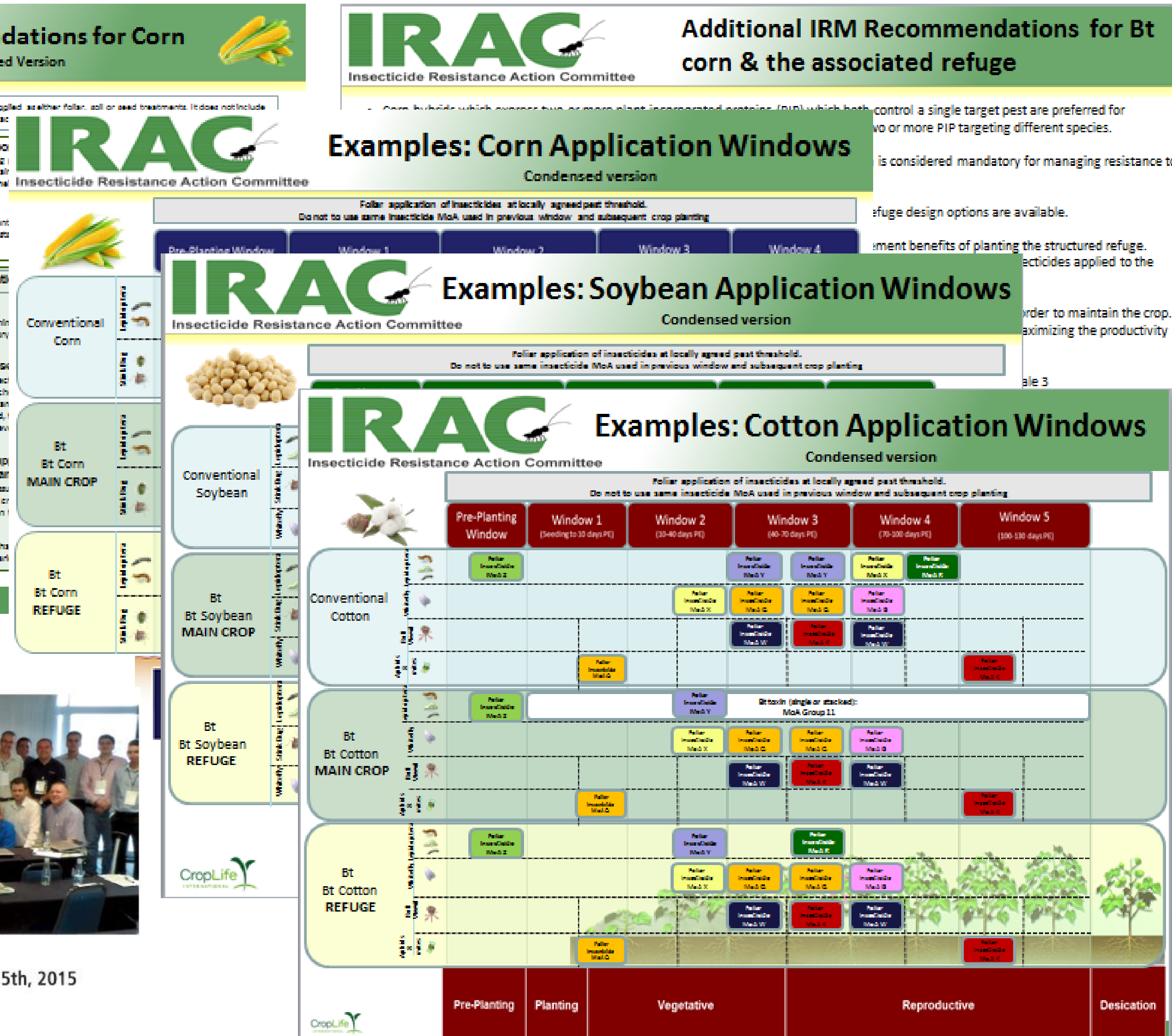
Alternativly leaf dip assays, as described in the IRAC approved method No. 005, provide a method of assessing the activity of all Insecticides wihch are utilised for the control of planthoppers, including pymetrozine, which primarily acts by reducing feeding and egg lay. A video of this method is available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

Working Group Activities

IRM RECOMMENDATIONS

- IRM ‘Task Team’ established for developing IRM recommendations in Brazil for corn, cotton & soybean.
- IRAC International, IRAC Brazil, Ministry of Agriculture, EMBRAPA, University experts, Growers associations.

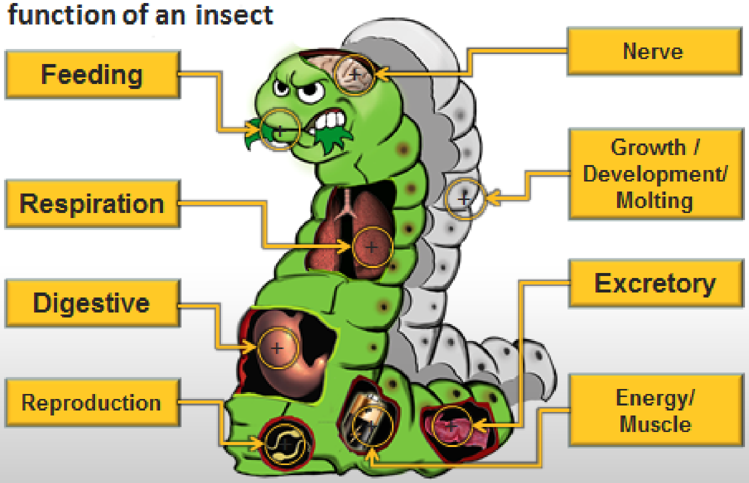




Task Team Meeting - Brasília, DF, Brazil - March 3rd - 5th, 2015

Insecticide Mode of Action (MoA)

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



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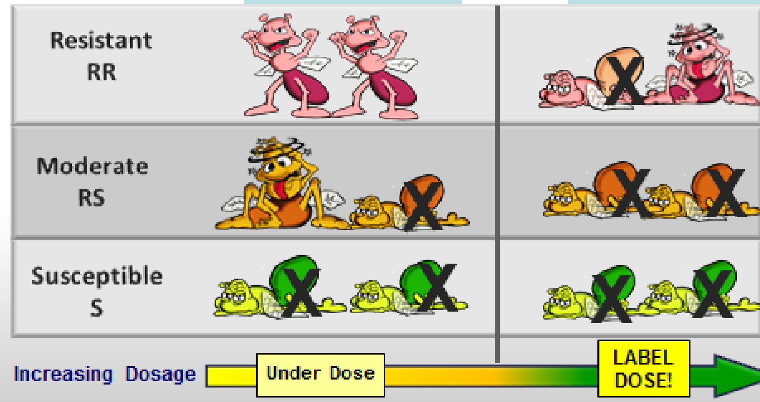
2. Follow Good Agricultural Practice (GAP) Principles

USE RECOMMENDED DOSE

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

Label Dosage: Optimal Control Small number of RR survive



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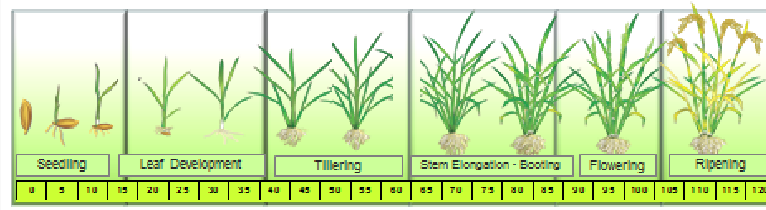
IRAC 杀虫剂的抗性管理（IRM）策略

田间在发生的故事……

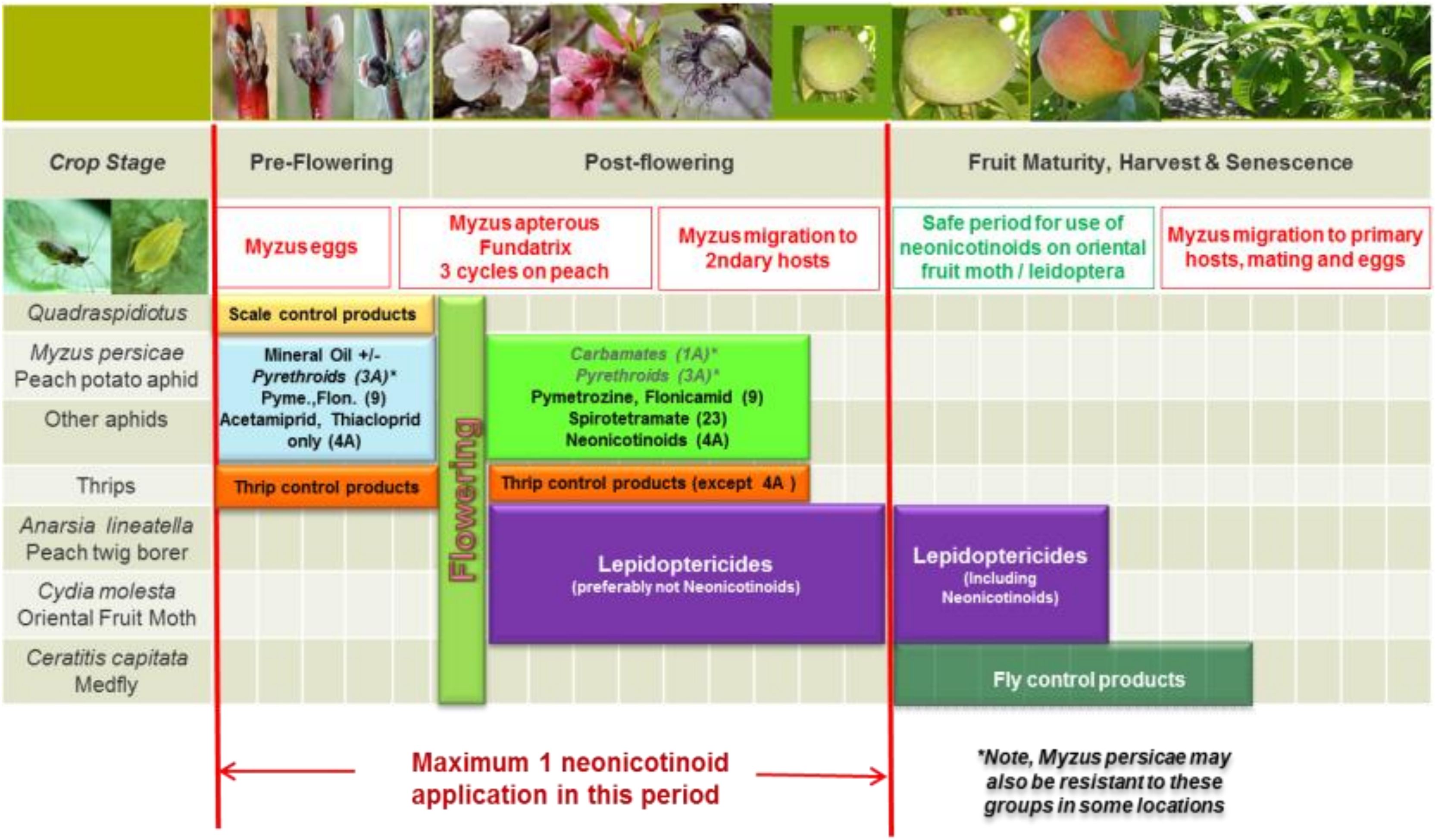
Insecticide Resistance Management (IRM) Strategy in Rice



	1st Generation	2nd Generation	3rd Generation
Stemborer	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

2013: Myzus resistance in Peaches in S. Europe

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



IRAC-Croplife – IRM recommendations targeted to grower (Draft)

IRAC

IRAC International Statements on IRM practice

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[1] 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.

[1] Pests include species relevant to both crop protection and public health

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.

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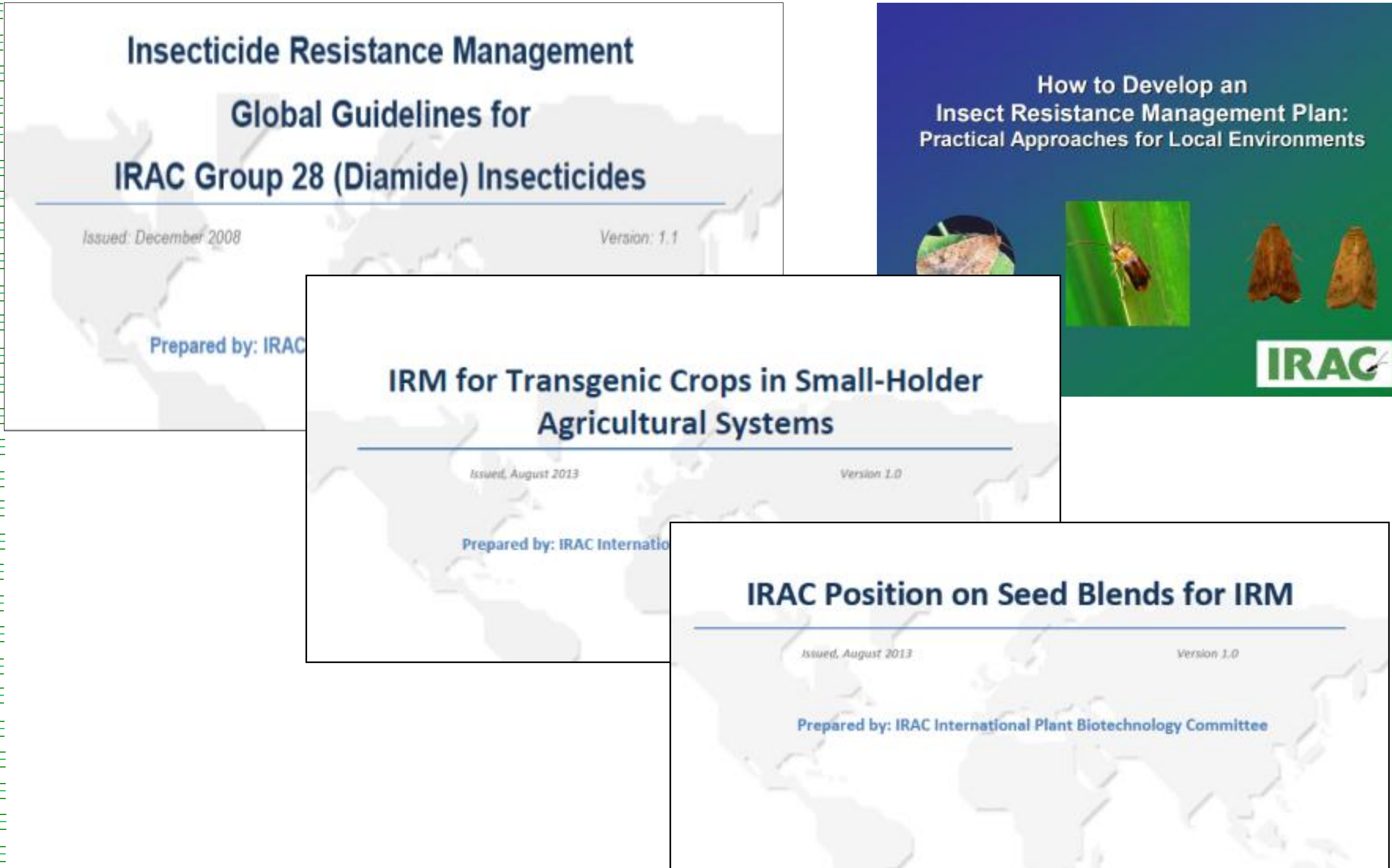
IRAC guidelines on on IRM practice



Some points of common interest for EPPO & IRAC ?

- Supermarket limitations on the number of active ingredients used for pest, disease & weed control – Increased resistance risk (ECPA, RAC's & EPPO ?)
- Resistance risk data submission in Europe. Can we more useful data by focusing on key risks and working cross-company.
- *Tuta absoluta* – Can we build on excellent work, by focusing communication on growers in resistance affected and at risk countries in a 'Task team'