IRAC

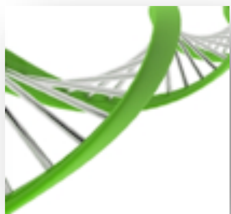
Insecticide Resistance Action Committee

IRAC, the Insecticide Resistance Action Committee: a valuable resource for resistance management.

Lakshmipathi Srigiriraju, PhD

representing IRAC International




30 years of IRAC

First IRAC Meeting – Brussels, Belgium
13 March 1984
Attendees: **6**

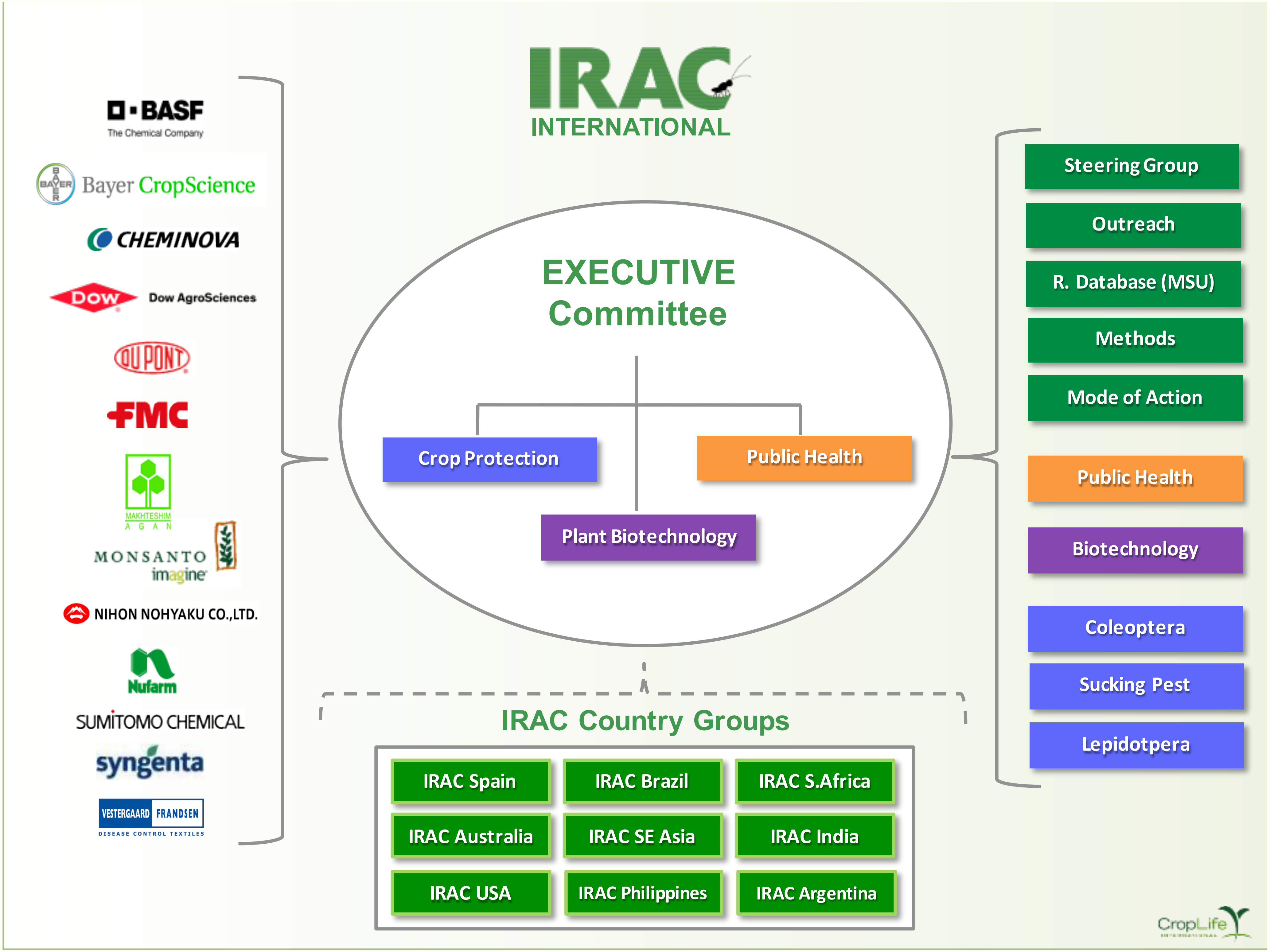
6 company members:
Voss / Ciba Geigy (Chair)
Lindley / Cyanamide
Cronin / FMC
Davies / ICI
Knauf / Hoechst
Zoebelein / Bayer

September 1992 Meeting – London, UK
6 company members; **13** attendees

March 2014 Meeting – RTP North Carolina, USA
13 company members; **50** attendees

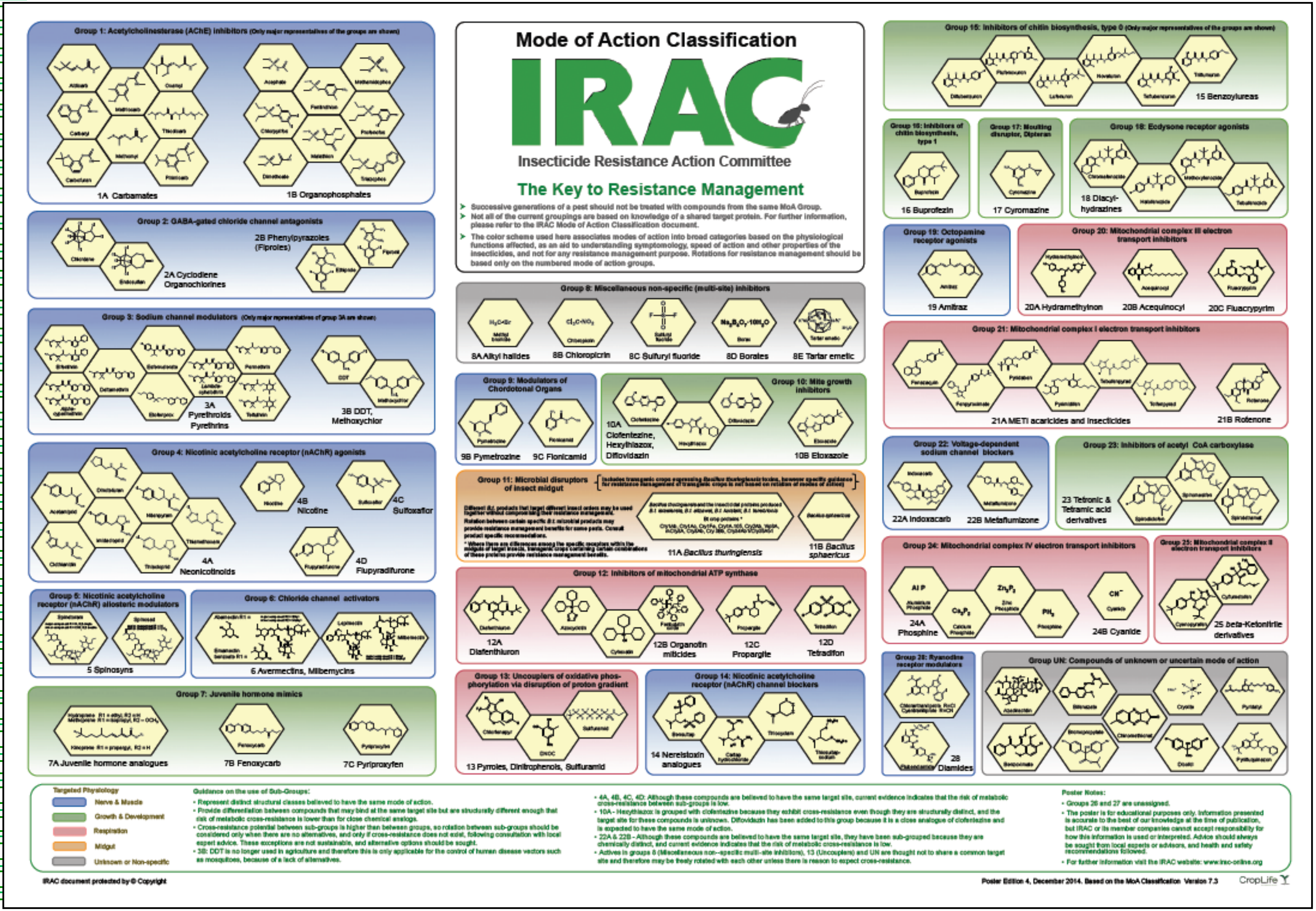
IRAC Mission

- Facilitate communication and education on resistance to insecticides and insect-resistant traits.
- Promote and facilitate development and implementation of resistance management strategies to maintain efficacy and support sustainable agriculture and improved public health.

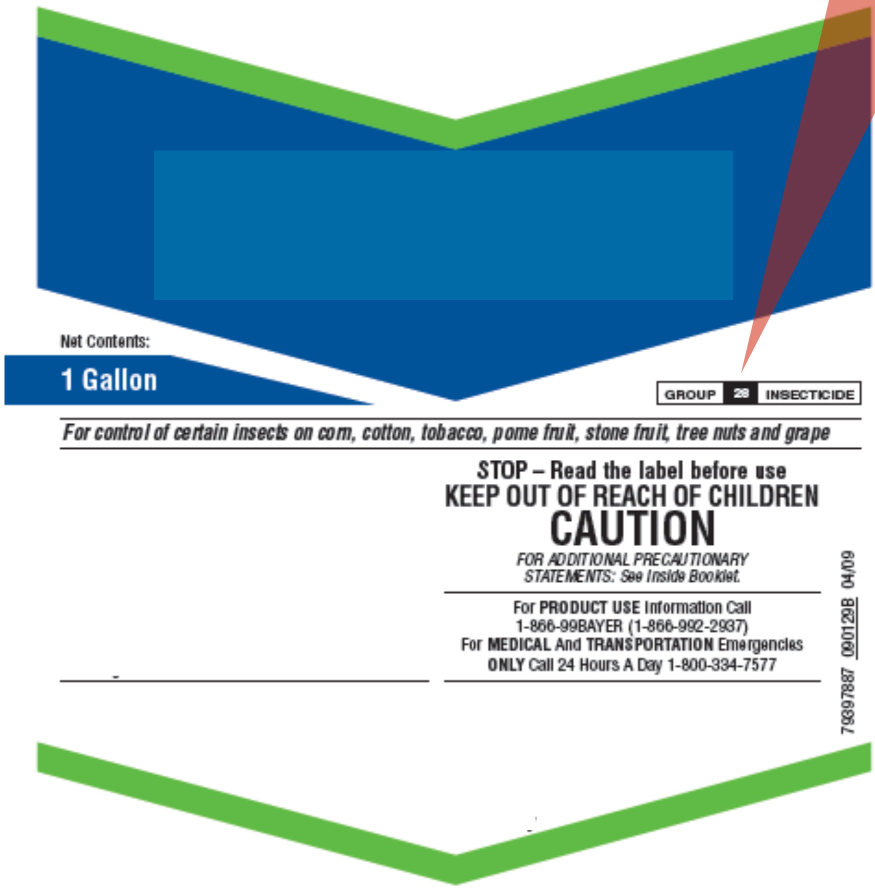

IRAC
INTERNATIONAL
BASF
The Chemical Company
Bayer CropScience
CHEMINOVA
DOW
Dow AgroSciences
DUPONT
FMC
MAKHTESHIM
AGAN
MONSANTO
imagine
NIHON NOHYAKU CO.,LTD.
Nufarm
SUMITOMO CHEMICAL
syngenta
VESTERGAARD FRANDSEN
DISEASE CONTROL TEXTILES
EXECUTIVE
Committee
Crop Protection
Public Health
Plant Biotechnology
Steering Group
Outreach
R. Database (MSU)
Methods
Mode of Action
Public Health
Biotechnology
Coleoptera
Sucking Pest
Lepidotpera
IRAC Country Groups
IRAC Spain
IRAC Brazil
IRAC S.Africa
IRAC Australia
IRAC SE Asia
IRAC India
IRAC USA
IRAC Philippines
IRAC Argentina
CropLife

IRAC Mode of Action Classification System

- The IRAC Mode Of Action (MoA) Classification is the definitive global authority on the target site of insecticides.
- It is the basis of MoA labeling of insecticides worldwide and is an essential tool for the development of insecticide resistance management (IRM) strategies.


Mode of Action Classification
IRAC
Insecticide Resistance Action Committee
The Key to Resistance Management
Group 1: Acetylcholinesterase (AChE) inhibitors
1A Carbamates
1B Organophosphates
Group 2: GABA-gated chloride channel antagonists
2A Cyclodiene Organochlorines
2B Phenylpyrazoles (Fiproles)
Group 3: Sodium channel modulators
3A Pyrethroids Pyrethrins
3B DDT, Methoxychlor
Group 4: Nicotinic acetylcholine receptor (nAChR) agonists
4A Neonicotinoids
4B Nicotine
4C Sulfoxaflor
4D Flupyradifurone
Group 5: Nicotinic acetylcholine receptor (nAChR) allosteric modulators
5 Spinosyns
Group 6: Chloride channel activators
6 Avermectins, Milbemycins
Group 7: Juvenile hormone mimics
7A Juvenile hormone analogues
7B Fenoxycarb
7C Pyriproxyfen
Group 8: Miscellaneous non-specific (multi-site) inhibitors
8A Alkyl halides
8B Chloropicrin
8C Sulfuryl fluoride
8D Borates
8E Tartar emetic
Group 9: Modulators of Chordotonal Organs
9B Pymetrozine
9C Flonicamid
Group 10: Mite growth inhibitors
10A Clofentezine, Hexythiazox, Diflovidazin
10B Etoxazole
Group 11: Microbial disruptors of insect midgut
11A Bacillus thuringiensis
11B Bacillus sphaericus
Group 12: Inhibitors of mitochondrial ATP synthase
12A Diafenthiuron
12B Organotin miticides
12C Propargite
12D Tetradifon
Group 13: Uncouplers of oxidative phosphorylation via disruption of proton gradient
13 Pyrroles, Dinitrophenols, Sulfluramid
Group 14: Nicotinic acetylcholine receptor (nAChR) channel blockers
14 Nereistoxin analogues
Group 15: Inhibitors of chitin biosynthesis, type 0
15 Benzoylureas
Group 16: Inhibitors of chitin biosynthesis, type 1
16 Buprofezin
Group 17: Moulting disruptor, Dipteran
17 Cyromazine
Group 18: Ecdysone receptor agonists
18 Diacyl-hydrazines
Group 19: Octopamine receptor agonists
19 Amitraz
Group 20: Mitochondrial complex III electron transport inhibitors
20A Hydramethylnon
20B Acequinocyl
20C Fluacrypyrim
Group 21: Mitochondrial complex I electron transport inhibitors
21A METI acaricides and insecticides
21B Rotenone
Group 22: Voltage-dependent sodium channel blockers
22A Indoxacarb
22B Metaflumizone
Group 23: Inhibitors of acetyl CoA carboxylase
23 Tetronic & Tetramic acid derivatives
Group 24: Mitochondrial complex IV electron transport inhibitors
24A Phosphine
24B Cyanide
Group 25: Mitochondrial complex II electron transport inhibitors
25 beta-Ketonitrile derivatives
Group 28: Ryanodine receptor modulators
28 Diamides
Group UN: Compounds of unknown or uncertain mode of action
Targeted Physiology
Nerve & Muscle
Growth & Development
Respiration
Midgut
Unknown or Non-specific
Guidance on the use of Sub-Groups:
Poster Notes:
IRAC document protected by © Copyright
Poster Edition 4, December 2014. Based on the MoA Classification Version 7.3
CropLife

Company agreement on mode of action labelling and 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.

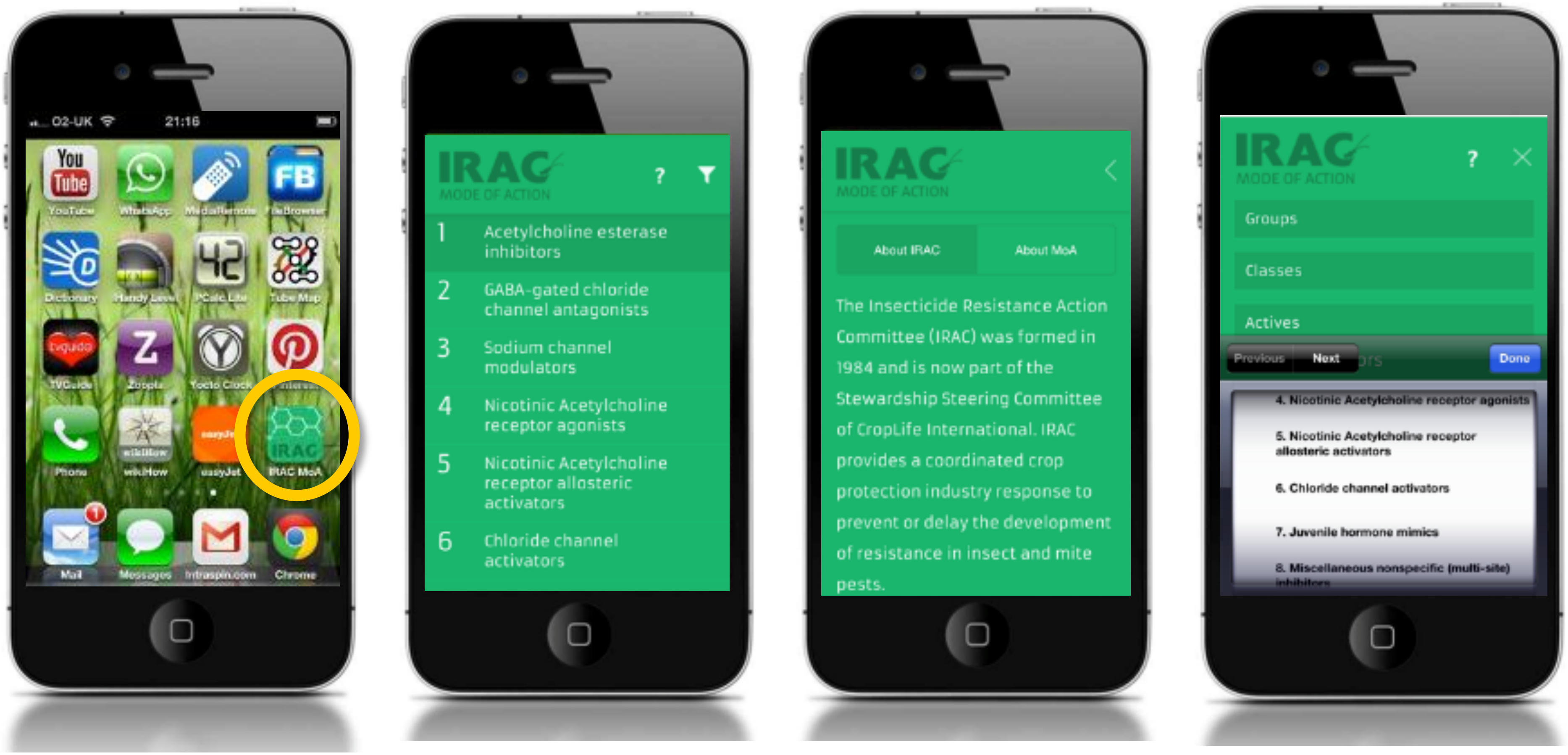
Example 3: Shortest Version – Minimal Text Required on Label

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.

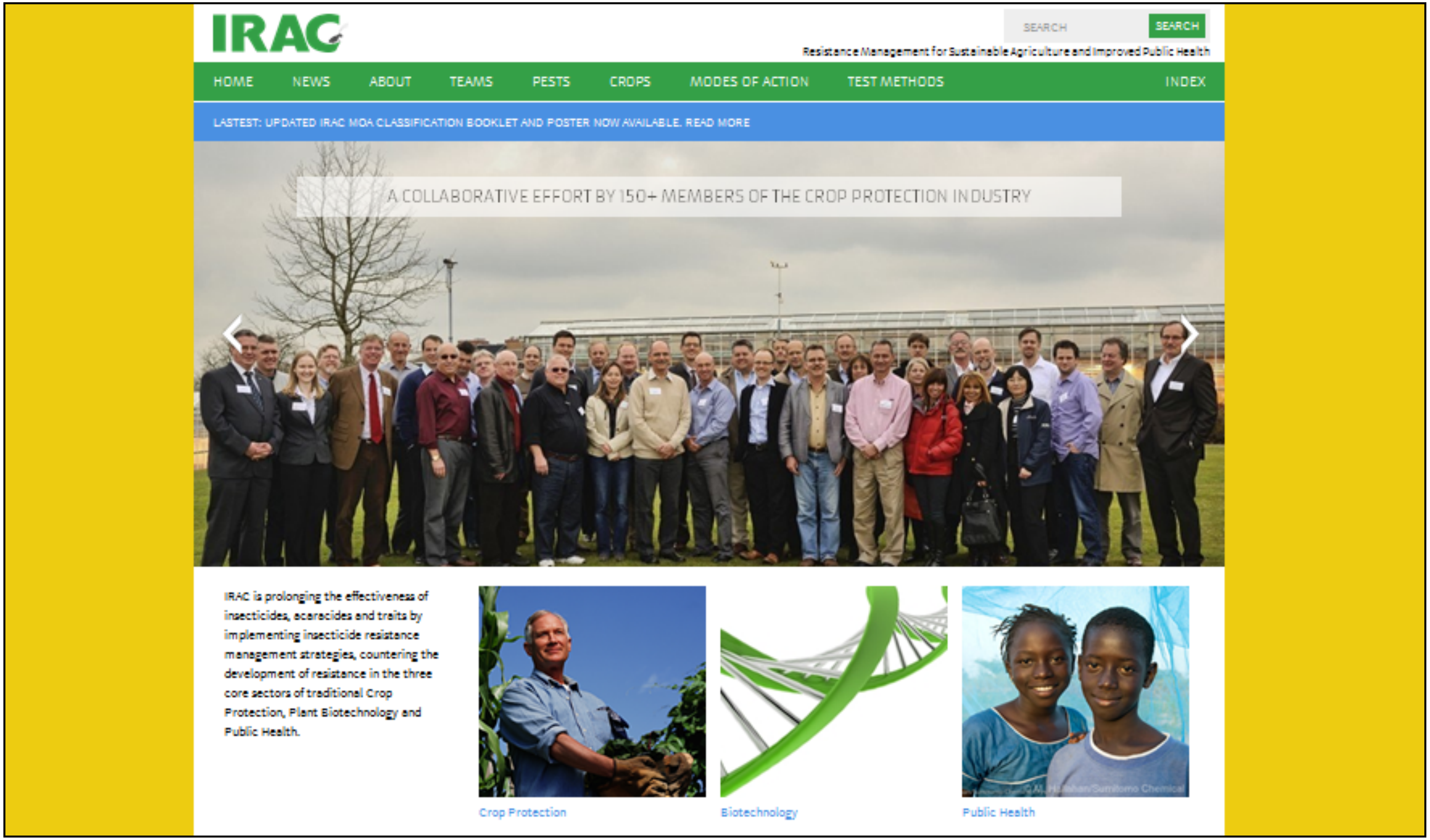
Mode of Action classification: Phone/Tablet App



IRAC

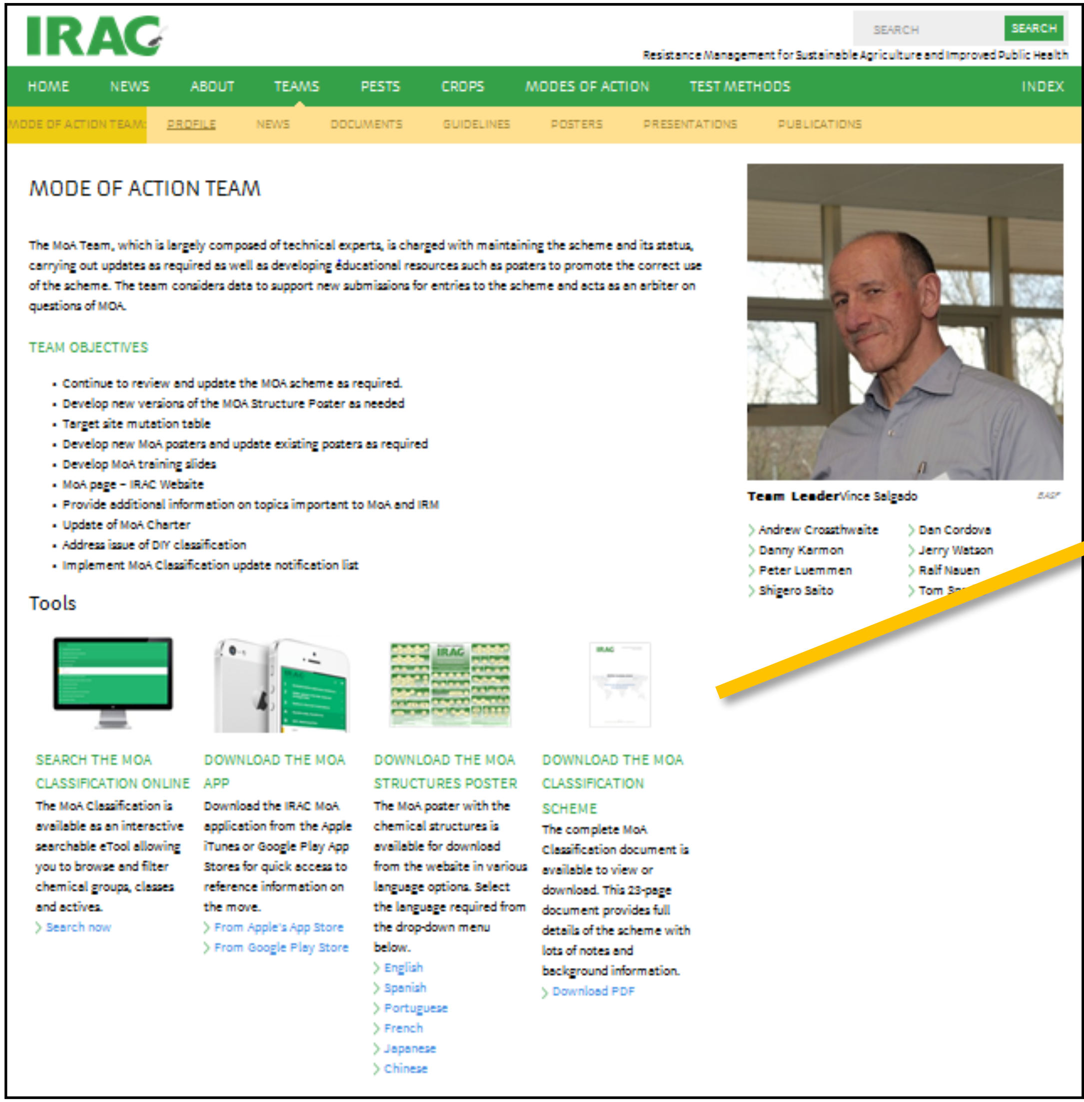
IRAC website: Communication and education

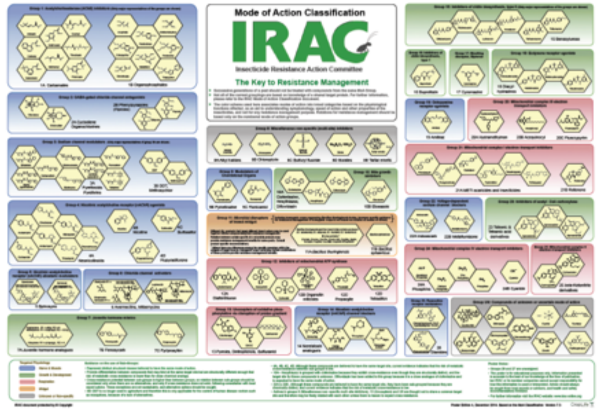
www.irac-online.org



IRAC

IRAC website: Mode of Action classification tools



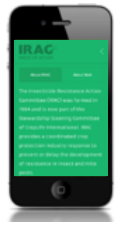


IRAC MoA poster:

- *English*
- *Spanish*
- *Portuguese*
- *French*
- *Japanese*
- *Chinese*

IRAC MoA booklet

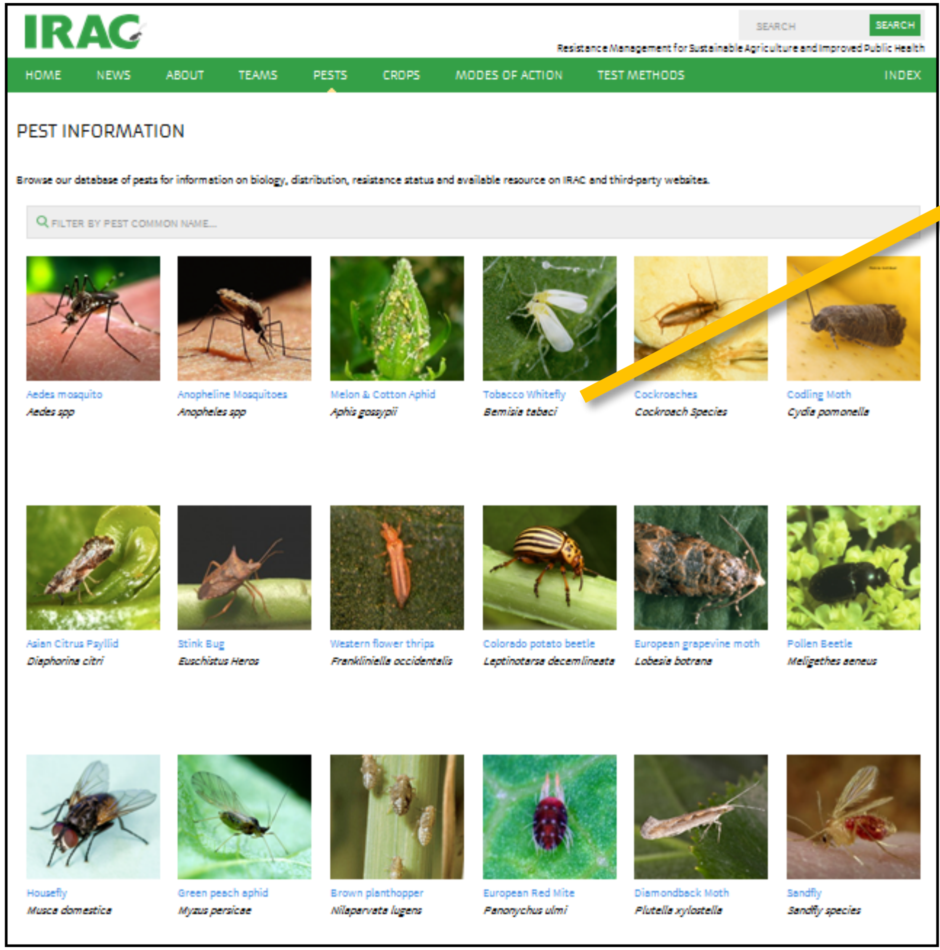
IRAC MoA website tool



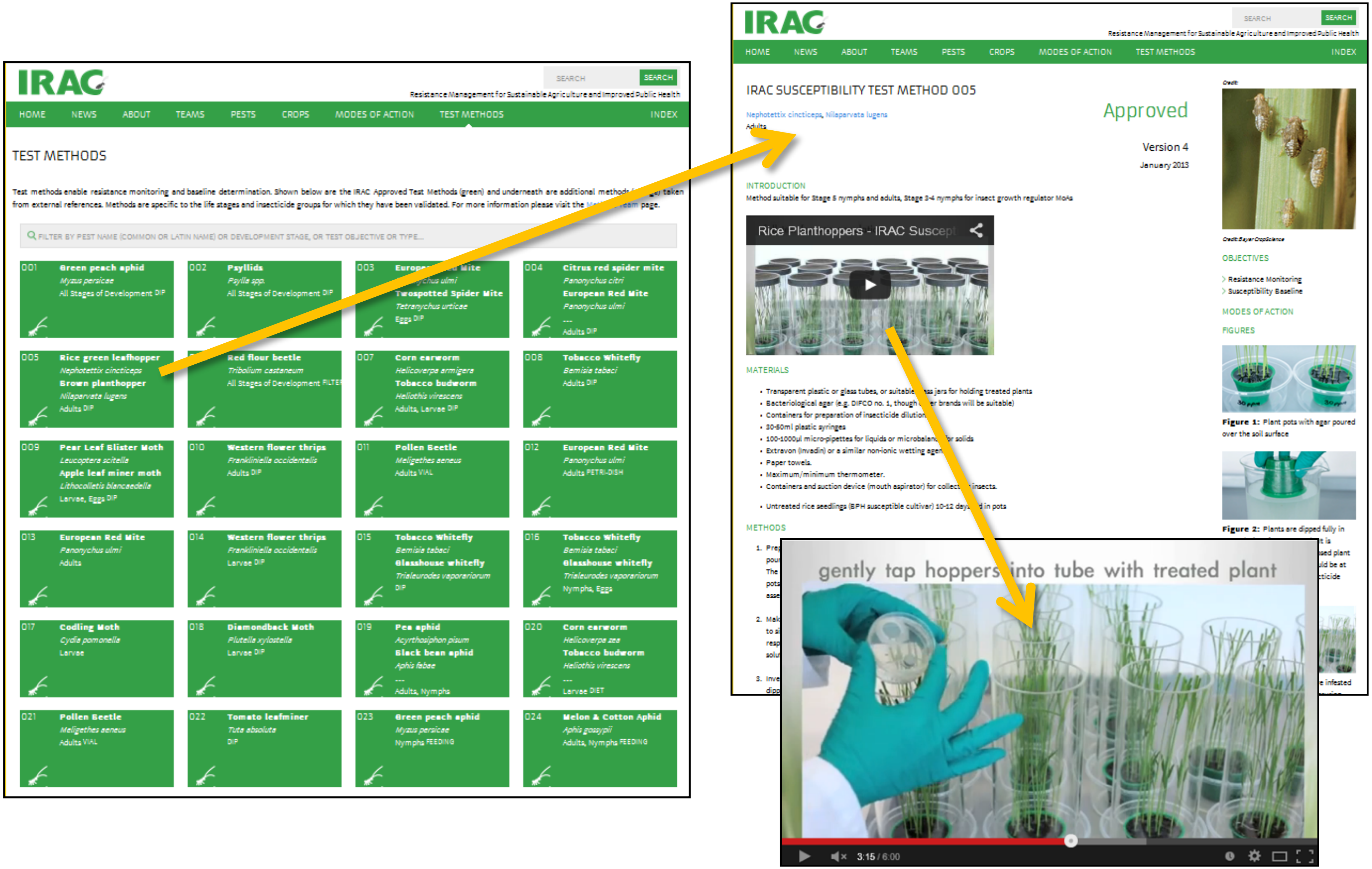
IRAC MoA phone app

IRAC

IRAC website: Pest pages



IRAC website: Methods and method videos



IRAC test method for Diamondback moth

IRAC

SEARCH SEARCH

Resistance Management for Sustainable Agriculture and Improved Public Health

HOME NEWS ABOUT TEAMS PESTS CROPS MODES OF ACTION TEST METHODS INDEX

IRAC SUSCEPTIBILITY TEST METHOD 018

Plutella xylostella
Larvae

Approved

Version 3.4
March 2010

Credit: Olaf Leillinger

INTRODUCTION

This method is suitable for use on L2 and L3 larvae

MATERIALS

Insect-proof containers, scissors, forceps, fine pointed brush, beakers for test liquids, syringes/pipettes for liquids or weighing balance for solids, syringes/pipettes for making dilutions, binocular microscope or hand lens (optional), untreated leaves of a host plant, paper towels, maximum/minimum thermometer, filter papers, seeking pin or fine forceps.

METHODS

1. Collect a representative sample of insects from a field. These may be larvae suitable for immediate testing, or eggs/L1 larvae for rearing to the appropriate stage or material from which an F1 population for testing can be reared. The insects should not be subjected to temperature, humidity or starvation stress after collection.
2. Collect sufficient non-infested, untreated host plant leaves. Whole leaves are preferred or, for some crops, the distal portions. Do not allow leaves to wilt by keeping them in a humid environment (plastic bag). *Brassica oleracea* (cabbages, cauliflowers & collards) are the recommended choice of host plant; however *Brassica rapa* (chinese cabbage, turnip) is also suitable. Choice of host plant should be recorded for future reference.
3. Prepare accurate dilutions of the test compound from the identified commercial product. For initial studies, six widely spaced rates are recommended. The use of additional wetter is only recommended for highly waxed leaf material, in which case this wetter solution is used for the "untreated" (control) solution in place of water alone. As the addition of a wetting agent can significantly affect the performance of an insecticide product in a bioassay, it is essential that details of the wetting agent are recorded with any summary data and that only data generated with the same agent and concentration are compared for susceptibility measurements.
4. Dip leaves individually in the test liquid for 10 seconds with gentle agitation and place to surface-dry on paper toweling (abaxial surface facing skywards). Ensure the entire leaf surface is emerged equally and do not allow the leaves to wilt. Dip the same number of leaves per treatment (a minimum of four replicate leaves per concentration is recommended), and treat sufficient leaf material to avoid starvation stress in the "untreated" during the test. Commence dipping the "untreated" first and work up through the test dilutions (lowest to highest).
5. Place the treated surface-dry leaves in the labeled test containers, which must be suitable for holding enough leaf material in good condition for up to 96 hours.

   Optional: A filter paper can be placed inside the base of the container to absorb any excess condensation.
6. Add equal numbers of L2 larvae to each container, so that a minimum total of 40 larvae are used per treatment, divided between at least four replicate containers. Seal the containers with the container lid.
7. Store the containers in an area where they are not exposed to direct sunlight or extremes of temperature. Record maximum and minimum temperatures. If possible a mean temperature of 25°C, 60% RH and 16:8 light/dark regime is preferred.

MODES OF ACTION

- Avermectins-Milbemycins (6)
- Benzoylureas (15)
- Carbamates (1A)
- Compounds of Unknown or Uncertain MoA (UN)
- Cyclodiene organochlorines (2A)
- Diacylhydrazines (18)
- Indoxacarb (22A)
- metaflumizone (22B)
- Organophosphates (1B)
- Phenylpyrazoles (Fiproles) (2B)
- Pyrethroids-Pyrethrins (3A)
- Spinosyns (5)

DOWNLOAD

IRAC Susceptibility Test Method 018

CONTACT INFORMATION

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IRAC International Coordinator
aporter.apa@gmail.com

web page

IRAC

Insecticide Resistance Action Committee
www.irac-online.org

IRAC Susceptibility Test Methods Series

Version: 3.4

Method No: 018

Details:

Method:	IRAC No. 018	 *Plutella xylostella larvae Courtesy of BASF*
Status:	Approved	
Species:	Diamondback Moth (*Plutella xylostella*)	
Species Stage	Larvae (L2/L3)	
Product Class:	This method is specifically recommended by the IRAC Diamide Working Group for evaluating the susceptibility status of **diamide insecticides (IRAC MoA 28)**** This method is also suitable for the following insecticide classes (IRAC MoA class): Carbamate (1A)* Organophosphate (1B)* Organochlorine (2A)* Fiprole (2B)* Pyrethroid (3A)* Spinosyn (5)* Avermectin (6)* Benzyl urea (15)** Diacylhydrazine (18)*** Indoxacarb (22A)* Metaflumizone (22B)* Pyridalyl (un)*	

Comments:

Mortality assessment period may vary depending on insecticide mode of action

The following guidelines may be used:

*72 hours assessment period
**96 hour assessment period
***120 hour assessment period (addition of fresh plant material may be necessary to avoid starvation).
Larvae should go through full molt before mortality assessment.

Description:

Materials:
Insect-proof containers, scissors, forceps, fine pointed brush, beakers for test liquids, syringes/pipettes for liquids or weighing balance for solids, syringes/pipettes for making dilutions, binocular microscope or hand lens (optional), untreated leaves of a host plant, paper towels, maximum/minimum thermometer, filter papers, seeking pin or fine forceps.

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PDF document

IRAC

eConnection: IRAC newsletter

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

IRAC Plant Biotechnology Team White Papers (Contd.)

Industry Perspectives on Insect Resistance Monitoring for Transgenic Insect-Protected Crops

Resistance monitoring is a fundamental component of insect resistance management (IRM) programs, the goal of which is to maintain product value to customers. This paper provides a consensus of IRAC member views regarding monitoring for insect resistance to transgenic crops. Resistance monitoring provides a means of detecting reductions in susceptibility of target insect pests to insecticides or *Bt* proteins that could reduce the economic value of the product; the primary goal being to detect resistance early enough to effectively deploy resistance mitigation measures and modify the IRM strategy.

Top left picture: Plant assay containers incubating in grower chamber
Bottom left picture: Burlese funnels used to extract larvae from root mats
Right picture: Larval corn rootworm samples extracted from different treatments
Photographs courtesy of Steve Thompson, DuPont Pioneer

Topics in the paper include an overview of properties of a successful resistance monitoring program, what pest species to monitor, where to focus monitoring, laboratory field-based monitoring approaches, appropriate characterization of field collections, and interpretation of bioassay data. The paper closes with a summary of IRAC members' commitment to sustainability and transparency pertaining to resistance monitoring. The full paper can be found at: http://www.irac-online.org/documents/industry-perspectives-on-ir-monitoring/?ext=pdf

Seed Blends for Resistance Management of Insect-Protected Transgenic Crops

The benefits and disadvantages of providing "refuge in the bag" are complex and the balance depends on a range of system-specific biological, agricultural, and operational considerations. While blended refuge products assure that growers plant appropriate refuges for their insect-protected biotech crops, movement of larvae between refuge and traited plants can reduce the effective refuge size and increase survival of insects that are heterozygous for resistance alleles. IRAC recognizes that for a blended refuge strategy to be successful for a given pest/crop system, it must be widely adopted among the biotech trait providers. The IRAC Position Paper describes the technical and practical issues that must be considered when evaluating blended refuge and provides guidance on decision making. In general, if a planted refuge is biologically warranted to promote product durability, larval movement between traited and refuge plants is not expected to seriously compromise durability, and grower implementation of a separate refuge is known or expected to be low, seed blends can be a valuable option for refuge deployment. The full paper can be found at: http://www.irac-online.org/documents/seed-blends-for-irm/?ext=pdf

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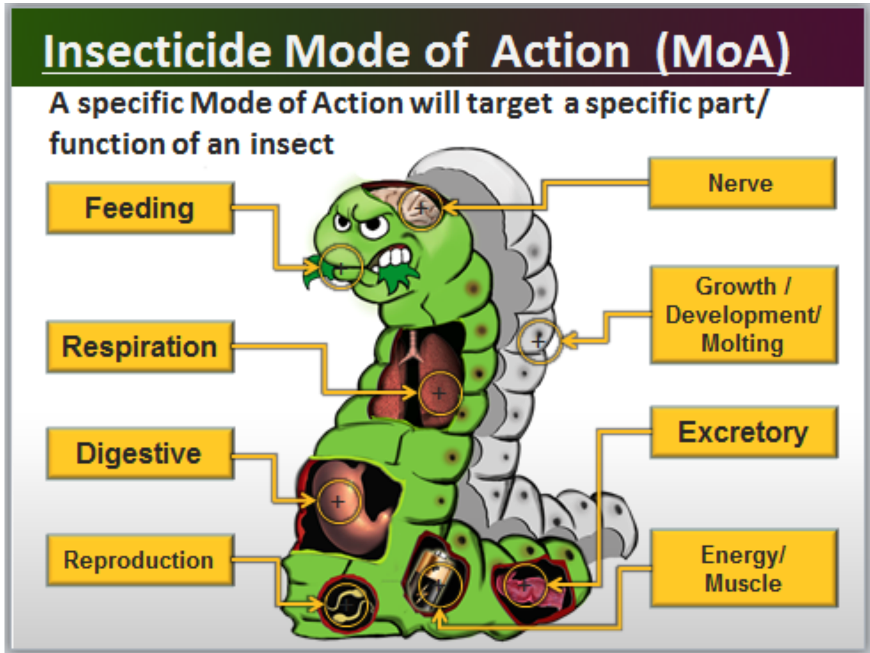
IRAC Educational resources

- Posters
- Presentations
- Booklets
- Guidelines
- Publications

Example: Farmer-focused graphic in Chinese explaining how resistance develops.


Insecticide Mode of Action (MoA)
A specific Mode of Action will target a specific part/ function of an insect
Feeding
Respiration
Digestive
Reproduction
Nerve
Growth / Development/ Molting
Excretory
Energy/ Muscle

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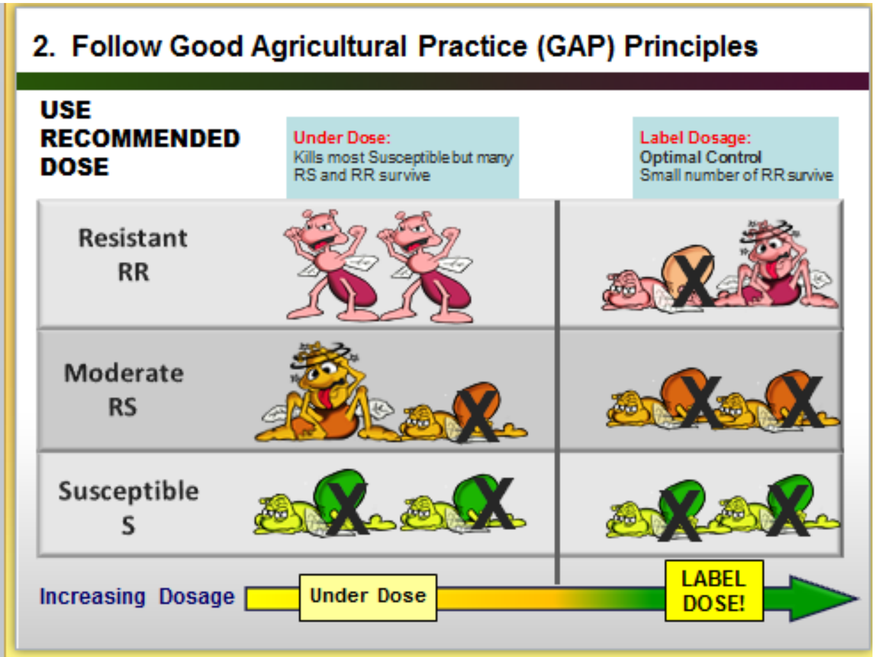
2. Follow Good Agricultural Practice (GAP) Principles
USE RECOMMENDED DOSE
Under Dose:
Kills most Susceptible but many RS and RR survive
Label Dosage:
Optimal Control
Small number of RR survive
Resistant RR
Moderate RS
Susceptible S
Increasing Dosage
Under Dose
LABEL DOSE!

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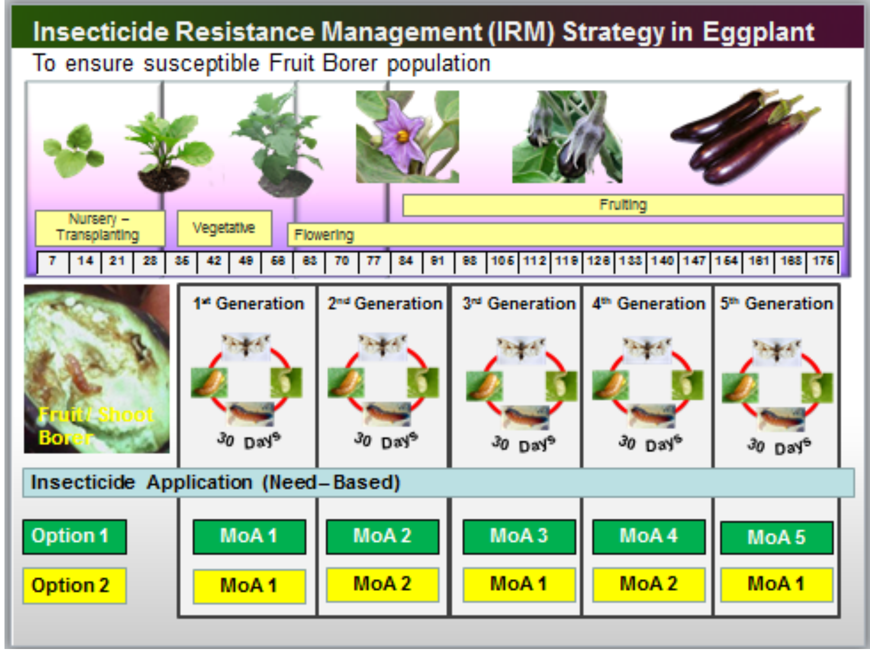
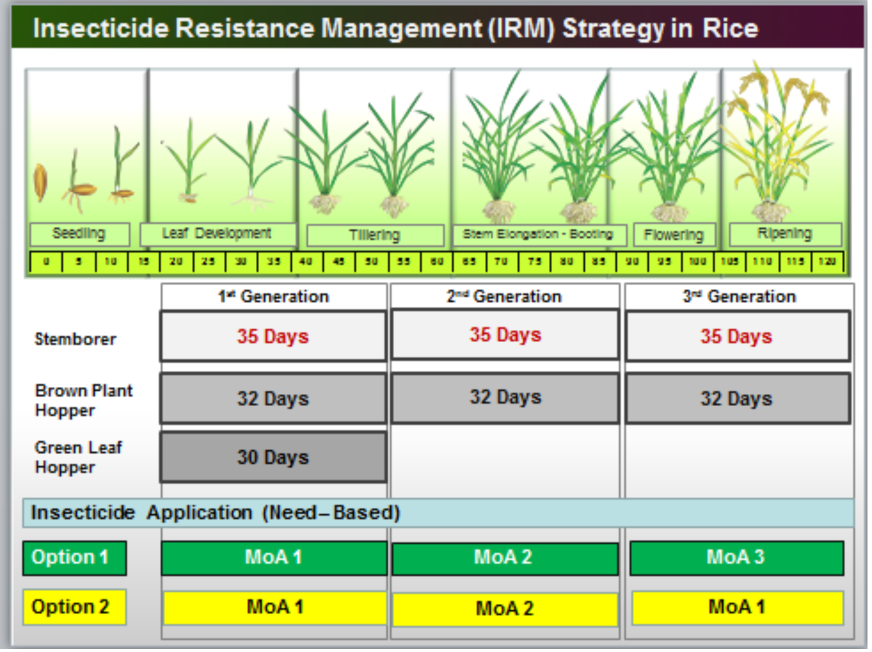

Insecticide Resistance Management (IRM) Strategy in Eggplant
To ensure susceptible Fruit Borer population
Nursery – Transplanting
Vegetative
Flowering
Fruiting
7 14 21 28 35 42 49 56 63 70 77 84 91 98 105 112 119 126 133 140 147 154 161 168 175
Fruit/ Shoot Borer
1st Generation
2nd Generation
3rd Generation
4th Generation
5th Generation
30 Days
30 Days
30 Days
30 Days
30 Days
Insecticide Application (Need – Based)
Option 1
MoA 1
MoA 2
MoA 3
MoA 4
MoA 5
Option 2
MoA 1
MoA 2
MoA 1
MoA 2
MoA 1


Insecticide Resistance Management (IRM) Strategy in Rice
Seedling
Leaf Development
Tillering
Stem Elongation - Booting
Flowering
Ripening
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
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

IRAC

Insecticide Resistance Action Committee

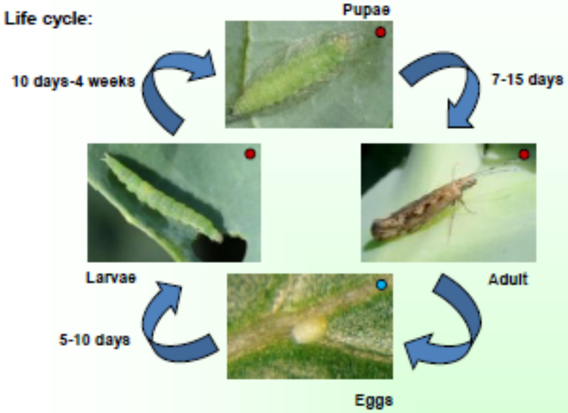
The Diamondback Moth, *Plutella xylostella*: Resistance Management is Key for Sustainable Control

www.irac-online.org

Introduction and Biological Background

Diamondback moth (*Plutella xylostella* L.) is a highly migratory and cosmopolitan species, and is one of the most important insect pests of cruciferous crops worldwide. Globally, direct losses and control costs are estimated to be US$ 1 billion (1).

Life cycle:



In temperate regions, *P. xylostella* is unable to overwinter and therefore annual outbreaks are attributed to migration, but in tropical and sub-tropical regions there can be a large number of continuous generations per year (e.g. up to 21 in Taiwan) (2) .

P. xylostella is considered to be one of the most difficult pests to control. Continuous insecticide applications have been, and in many regions still are, the main tool employed for crop protection.

Cases of *P. xylostella* resistance to insecticides were reported in the 1950's. Today this species shows resistance to most insecticide classes, including recently introduced compounds with new modes of action (3).

References

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Plutella xylostella Damage in Cabbage

Treated with insecticide — Not treated with insecticide

Resistance Mechanisms

Several biochemical mechanisms are described as conferring resistance to insecticides in diamondback moth populations. Many of these mechanisms listed below act in concert and can provide resistance factors of 1000-fold or greater.

1. **Enhanced metabolic detoxification mechanisms** (3,4)
2. **Insensitive acetylcholinesterase**
3. **Reduced Cry1C binding to target site in midgut membrane and reduced conversion of Cry1C protoxin to toxin** (5)
4. **Reduced penetration** (6,7)
5. **Target-site resistance** (7-10)

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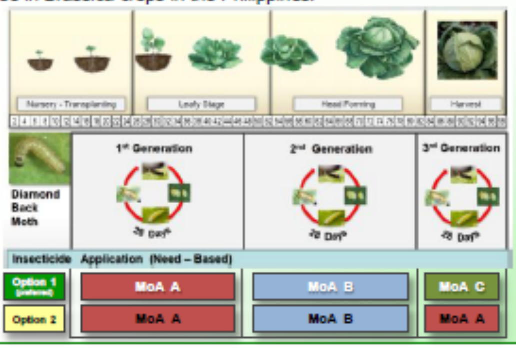

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Photograhs courtesy : Russ Ottens, University of Georgia, Whitney Cranshaw, Colorado State University; Bugwood.org BayerCrop Science CropLife

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IRAC

Insecticide Resistance Action Committee

The Diamondback Moth, *Plutella xylostella*: Resistance Management is Key for Sustainable Control

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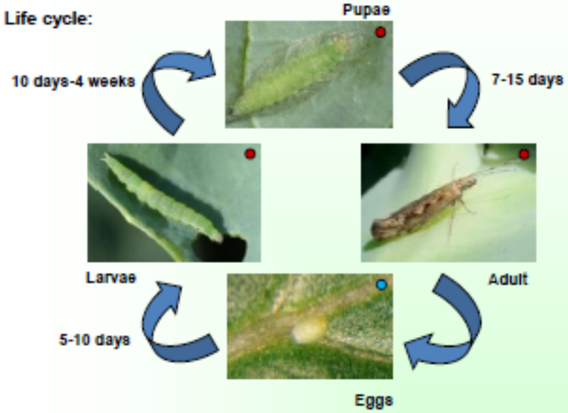

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Plutella xylostella Damage in Cabbage

Treated with insecticide | Not treated with insecticide

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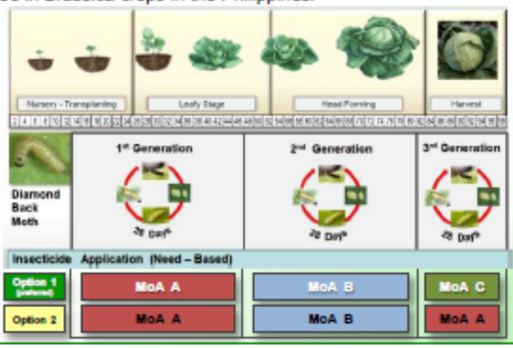

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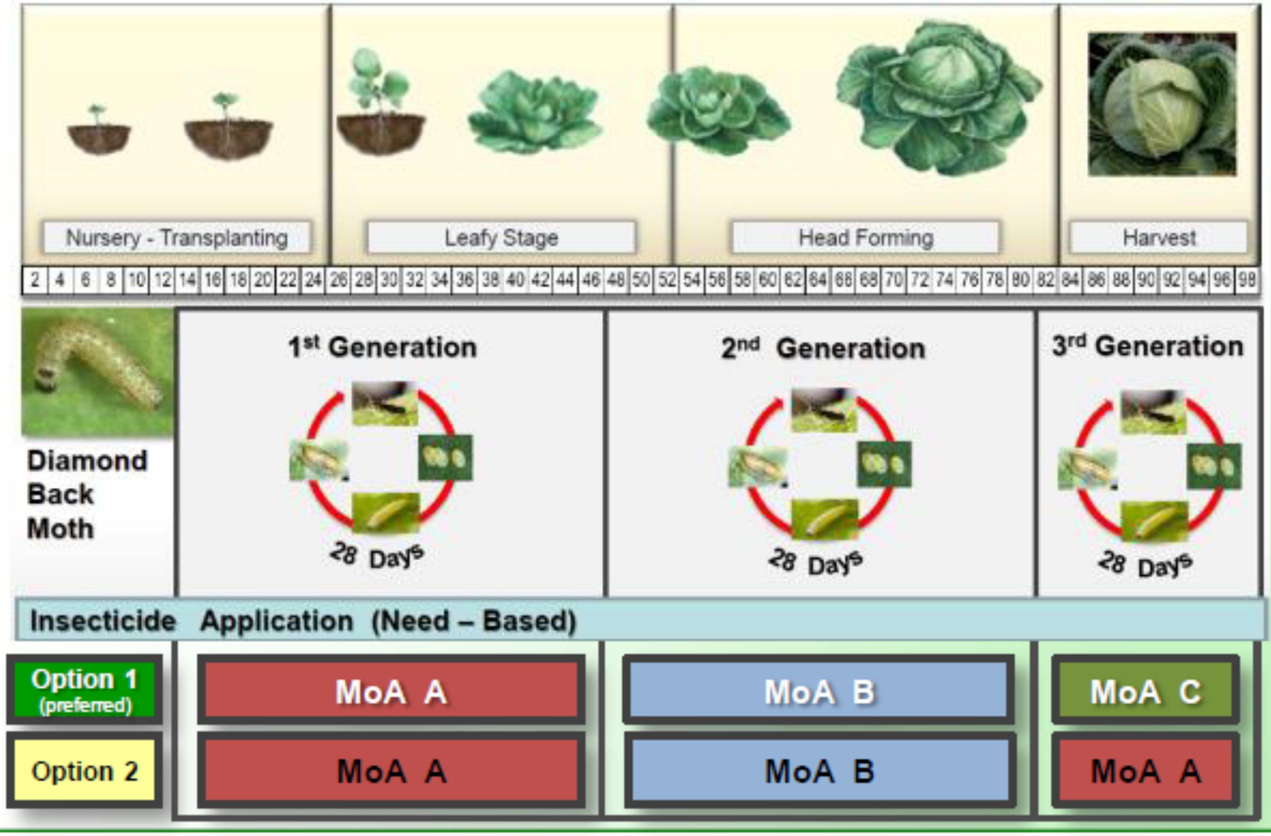

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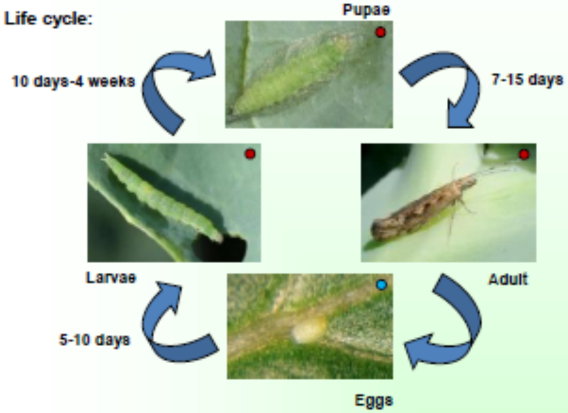

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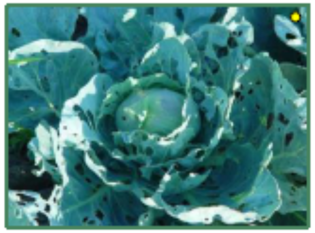

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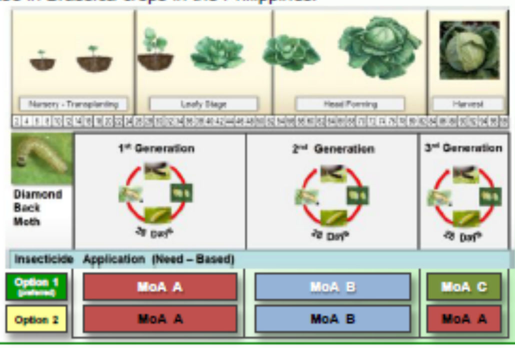

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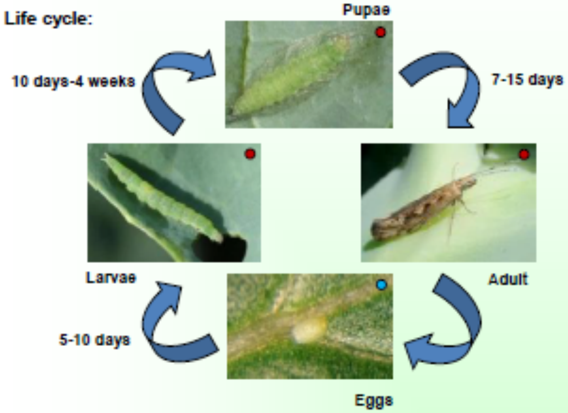

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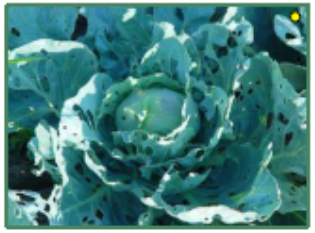
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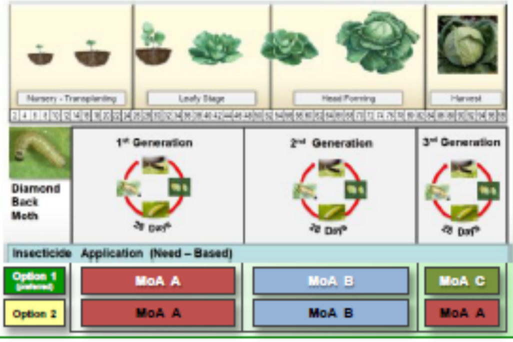

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Summary

- **IRAC is comprised primarily of representatives from agrochemical, seed, and public health companies affiliated with CropLife, and it provides coordinated industry efforts to prevent or delay resistance in insect and mite pests.**
- **IRAC International consists of several global teams that work with a number of IRAC Country Groups.**
- **A key resistance management tool is the IRAC Mode of Action Classification system.**
  - IRAC's numbered MoA groups are a simple way to communicate MoA information on product labels, which promotes more effective product rotation.
- **You can access IRAC's resources at the IRAC website (www.irac-online.org).**
  - Mode of action classification tools (webpage, posters, booklet, phone/tablet app).
  - Pest pages with details on pest biology and resistance.
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  - Michigan State University Arthropod Pesticide Resistance Database.
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  - Posters, publications, and presentations covering many aspects of resistance management for insecticides and insect-resistant traits.

Thank you

Questions?

www.irac-online.org