

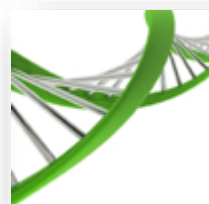


Insecticide Resistance Action Committee

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# IRAC International

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# 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.

# 13 Member Companies (8 Croplife)

ADAMA

AgBiTech

BASF  
We create chemistry

BAYER

Dow  
Dow AgroSciences

DU PONT

FMC

MONSANTO  
imagine

NIHON NOHYAKU CO.,LTD.

SUMITOMO CHEMICAL

syngenta

VESTERGAARD®  
IMPACTING PEOPLE

Nufarm

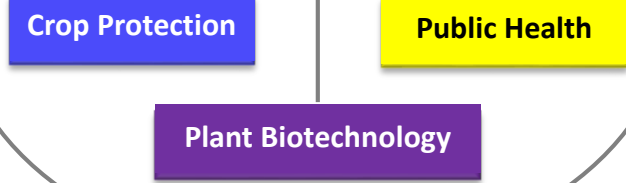
Mitsui Chemicals

April 2017

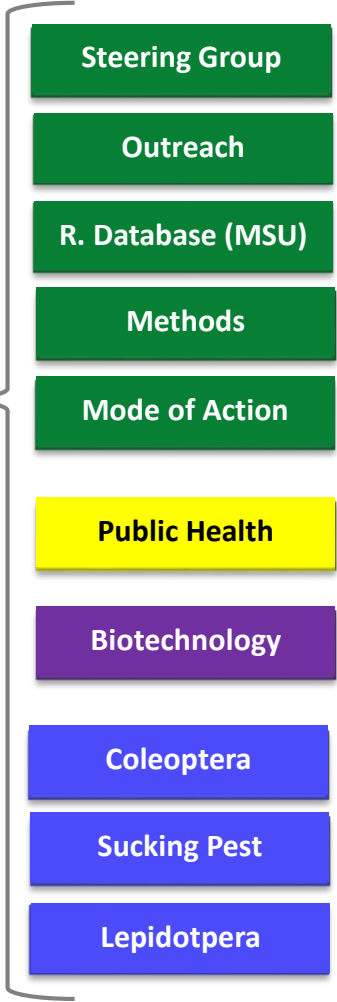
Sep 2017



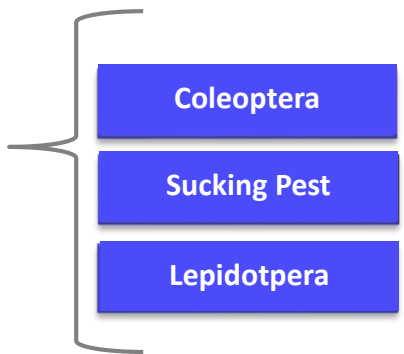
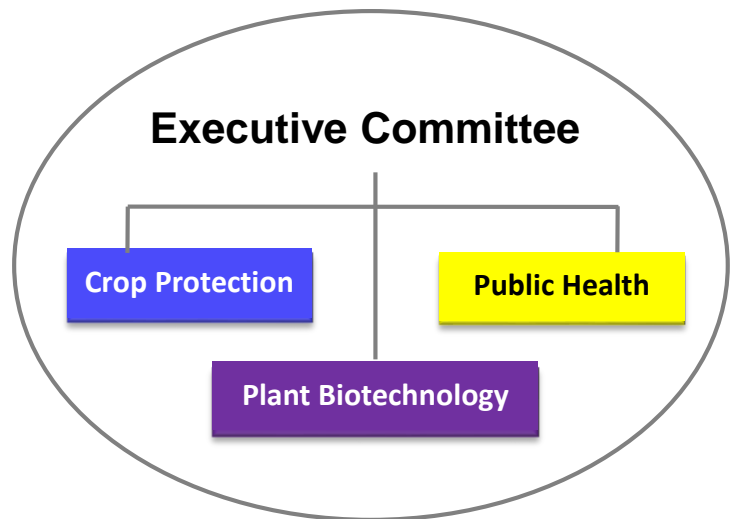
## Executive Committee



## IRAC Country Groups



# Crop Protection Country Working Groups



## IRAC Country Groups



Working groups established to develop IRM guidelines for diamide insecticides, then expanded to provide lepidopteran IRM. Final stage has been to expand to cover other pests and crops.

# IRAC Task Teams

Short lived collaborative teams with specific objectives



## Executive Committee

Crop Protection

Public Health

Plant Biotechnology

## IRAC Country Groups

IRAC Spain

IRAC Brasil

IRAC S.Africa

IRAC Australia

IRAC SE Asia

IRAC India

IRAC USA

IRAC Philippines

IRAC Argentina

## Brazil Cotton, Corn & Soybean IRM

IRAC International

IRAC Brasil

Ministry of Ag,  
Grower Representatives

Industry advisors

University experts

## Puerto Rico IRM

IRAC USA

IRAC International

PRABIA

## *Tuta absoluta* IRM

IRAC International

IRAC Spain

University experts

Industry advisors

# IRAC Executive objectives 2017-18

- Enhance available information on pest resistance on IRAC web-site.

Western flower thrips  
*Frankliniella Occidentalis*

*Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) originated in western North America and has since become a major pest of vegetables, fruit and ornamental crops across the US and around the world. *F. occidentalis* are small (1-2 mm long), slender, soft-bodied insects that are yellow to light brown in color; adults have distinctive fringed wings. It can develop quickly, going from egg to adult in two weeks or less at favorable temperatures. Adult females insert eggs into plant tissue under the epidermis. When mature, larvae drop to the soil to go through the prepupal and pupal stages, and finally return to the plants as adults. Larvae and adults feed on flowers, buds, terminals, leaves, and fruit.



*Frankliniella occidentalis* feed by rasping open plant cells and sucking up the cell contents. The damaged cells collapse, leaving bronzed or russeted areas on the leaves or fruits. Besides the direct plant damage this pest causes, *F. occidentalis* also transmits several species of destructive plant viruses in the genus Tospovirus (Bunyaviridae), including Tomato Spotted Wilt Virus (TSWV) and Impatiens Necrotic Spot Virus (INSV), of which it is the most important vector worldwide.

Adults can move long distances on air currents to find new food; adults and larvae can also be transported on transplants. Although there are some effective natural enemies of *F. occidentalis*, growers rely on chemical control to reduce damaging populations of this pest. Natural enemies such as predatory bugs (*Orius* spp.), lacewings (*Chrysopa* spp.) and predatory mites (*Amblyseius* spp., *Neoseiulus* spp.) can provide significant control of *F. occidentalis* populations. The number of effective chemical compounds that control *F. occidentalis* is very limited and insecticide resistance has been reported to several major classes of insecticides.



Western flower thrips resistance profile

Species	Distribution	Chemical class	Mechanisms
Frankliniella occidentalis	Europe, Africa, North America	Carbamates (1A)	Metabolic: Enhanced detoxification by monooxygenases
Frankliniella occidentalis	Europe, Africa, Australia, North America	Organophosphates (1B)	Metabolic: Enhanced detoxification by monooxygenases
Frankliniella occidentalis	Europe, Africa, USA	Cyclodiene organochlorines (2A)	Metabolic

Frankliniella occidentalis	Europe, Australia, USA	Pyrethroids-Pyrethrins (5A)	Metabolic: Enhanced detoxification by monooxygenases. Links to target site resistance (kdr)
Frankliniella occidentalis	China, Spain	Neonicotinoids (4A)	Cytochrome P450 detoxification
Frankliniella occidentalis	Australia, Brazil, China, Spain, USA	Spinosyns (5)	Altered target site resistance: G278E mutation in the α6 subunit of nAChR
Frankliniella occidentalis	China, USA	Avermectins (6)	
Frankliniella occidentalis	China	Pyriproxyfen (7C)	

Western flower thrips susceptibility test methods

**014**

Larvae  
*Dip*

**010**

Adults  
*Dip*

▶

Key western flower thrips resources



References

- Estensebeleczenzymes and insecticide resistance in *Frankliniella occidentalis* populations from the south-east region of Spain. López-Soler N, Cervantes A, Mooren OD, Martínez-Pardo R, Barceló MD. (2008). *Pest Management Science*, Vol. 64 (12), 1259-66. doi: 10.1002/ps.1687.
- Field-evolved resistance to insecticides in the invasive western flower thrips *Frankliniella occidentalis* (Pergande) in China Wang ZH, Gong XJ, Jin GH, Li BY, Chen JC, Kang ZJ, Zhu L, Gao YL, Reia S, Wei SJ. (2016). *Pest Management Science*, Vol. 72 (7), pp.1440-1444, DOI: 10.1002/ps.4200.

- Greater focus on providing resistance information.
- Aim to be a first destination and subsequent hub-site for resistance knowledge.

# IRAC Executive objectives 2017-18

- Enhance available information on pest resistance on IRAC web-site.
- Complete agreement with IRAC member companies on MoA icon adoption.



Use the IRAC Mode Of Action (MoA) system to identify Insecticide, Fungicide, and Herbicide products that attack the same pest target sites and properly rotate to practice ideal IRM.

Examples:

The image displays three Syngenta product labels with arrows pointing to their respective MoA icons: Herbicide (Group 1), Fungicide (Group 12), and Insecticide (Group 4A).

**Fusilade<sup>DX</sup> Herbicide**  
 Group 1 Herbicide  
 Postemergence Herbicide for Control of Perennial and Annual Grass Weeds  
 Active Ingredient:  
 Fluzifop-P-butyl Butyl (R)-2-[4-[[2-(trifluoromethyl)-2-pyridinyl]oxy]phenoxyl]propanoate\* 24.5%  
 Other Ingredients: 75.5%  
 Total: 100.0%  
 \*Fusilade DX Herbicide contains 2 pounds (-) isomer (fluzifop-P-butyl) per gallon. Contains petroleum distillate.  
 KEEP OUT OF REACH OF CHILDREN. CAUTION  
 EPA Reg. No. 100-1070 EPA Est. 11778-IA-01  
 Product of United Kingdom Formulated in the USA  
 SCP 1070A-L1D 0111 338556 1 gallon Net Contents

**Scholar<sup>®</sup> Fungicide**  
 Group 12 Fungicide  
 Active Ingredient: Fludioxonil (CAS No. 131341-86-1)... 50.0%  
 Other Ingredients: 50.0%  
 Total: 100.0%  
 Scholar is a 50% wettable powder.  
 KEEP OUT OF REACH OF CHILDREN. CAUTION  
 syngenta<sup>®</sup>

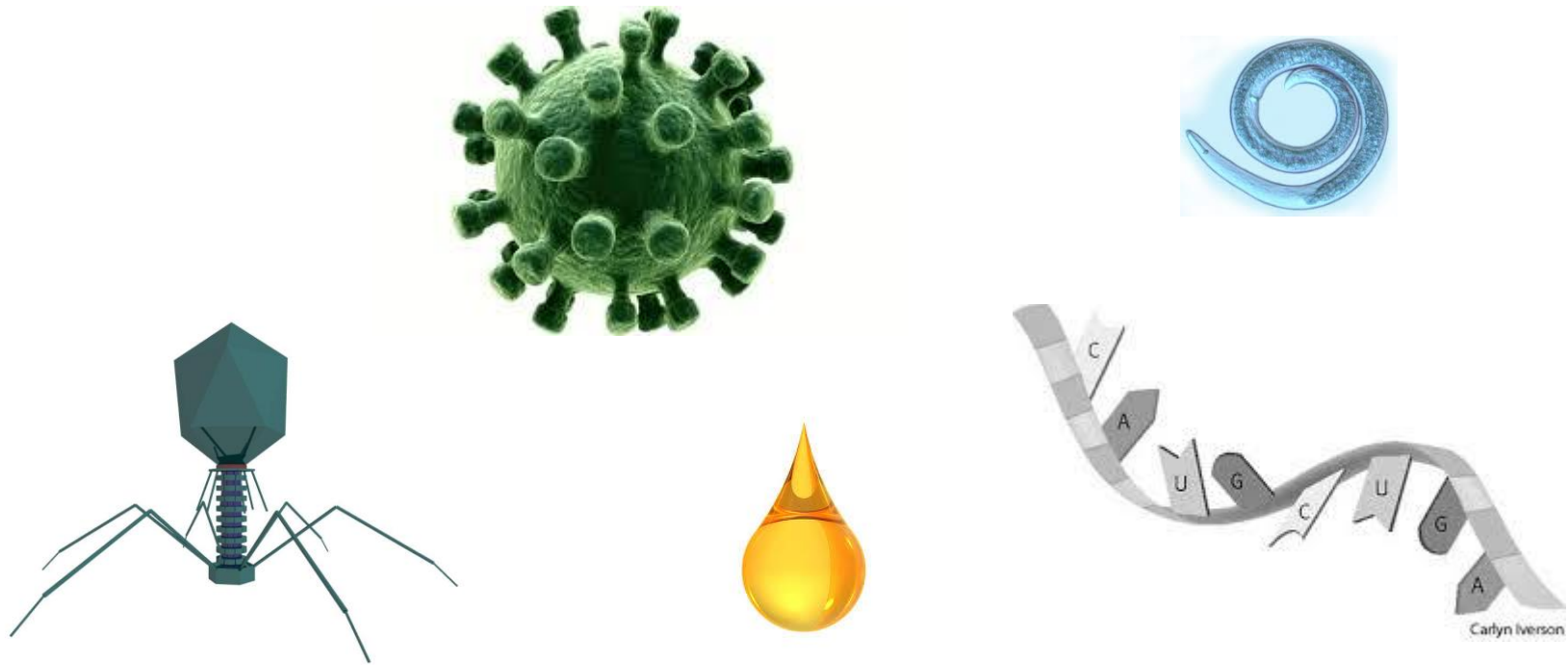
**Durivo<sup>®</sup> Insecticide**  
 Group 4A Insecticide  
 For control of listed insect pests infesting specified crops  
 Active Ingredient:  
 Thiamethoxam<sup>1</sup> 17.5%  
 Chlorantraniliprole<sup>2</sup> 8.8%  
 Other Ingredients: 73.7%  
 Total: 100.0%  
<sup>1</sup>CAS No. 150719-29-4  
<sup>2</sup>CAS No. 500008-45-7  
 Durivo is a soluble concentrate containing 1.67 lb. of thiamethoxam and 0.825 lb. chlorantraniliprole per gallon.  
 KEEP OUT OF REACH OF CHILDREN.  
 Si usted no entiende la etiqueta, busque a alguien para que se la explique a usted en detalle. (If you do not understand the label, find someone to explain it to you in detail.)  
 See additional precautionary statements and directions for use in booklet.  
 EPA Reg. No. 100-1918  
 EPA Est. 100-NE-001  
 SCP 1318A-L1D 0911 948336 1 gallon (128 fluid ounces) Net Contents

- Agreement on voluntary use of MoA icons within IRAC member companies.
- Awaiting ongoing Croplife Intl. discussions across insecticide, fungicide and herbicide labels before implementation.

# IRAC Executive objectives 2017-18

- Enhance available information on pest resistance on IRAC web-site.
- Complete agreement with IRAC member companies on MoA icon adoption.
- Develop IRM classification scheme for biological and non-chemical insecticides.

# Classification schemes for non-synthetic chemical insecticides and alternative methods of insect control



- Agreed that some form of classification for `Alternative` methods of control.
- IRAC MoA working group working on a draft proposal.

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- Find long term solution for resistance record database.

# MSU APRD database

- MSU APRD database: New version.
- IRAC funded an update to the database with increased search functionality.
- Can now search for multiple parameters.
- Functionality much improved.
- Working on including a laboratory vs. field derived resistance search function.
- Working on regional descriptors (i.e. search by geographic region (Northern Europe) not just by country).

Arthropod Pesticide Resistance Database

Welcome Search Login Sign Up Contact

Order: [Select to Add] Family: [Select to Add] Genus: [Select All] Active Ingredient: [All] MOA Abbr: [All]

Resistance Year: [All] Publication Year: [All] Country: [All]

Search | Reset

Parameters: **Selecting multiple parameters from same category is treated as OR**

Genus: [bemisia X] MOA Abbr: [9B X OR 4A X] Country: [Italy X OR Spain X]

Genus Species	Taxonomy (family - order)	Common Name(s)	# Cases	Group
bemisia tabaci	aleyrodidae homoptera	sweetpotato whitefly	30	AG

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- Still a need to find a long term solution: Changes in MSU staff & need for more accurate database
- Ongoing discussions to find a long term way of recording resistance cases.

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- Provide an IRAC guidance document on IRM Modelling.

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- Working group established and first meeting in August.
- Agreed to develop two streams of information:
  - Page on IRAC web-site explaining fundamentals of insecticide resistance modelling for visitors with no background in modelling (hands on use of model, facts & figures, what you can expect, what do you need, etc.
  - IRAC position paper for those with more advanced knowledge: Different modes, parameter use, etc

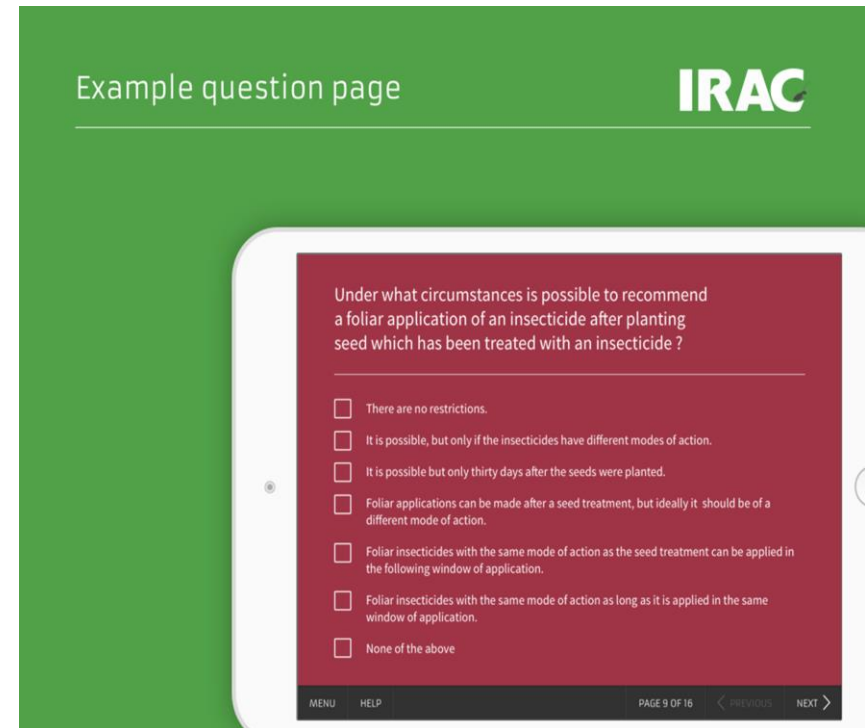
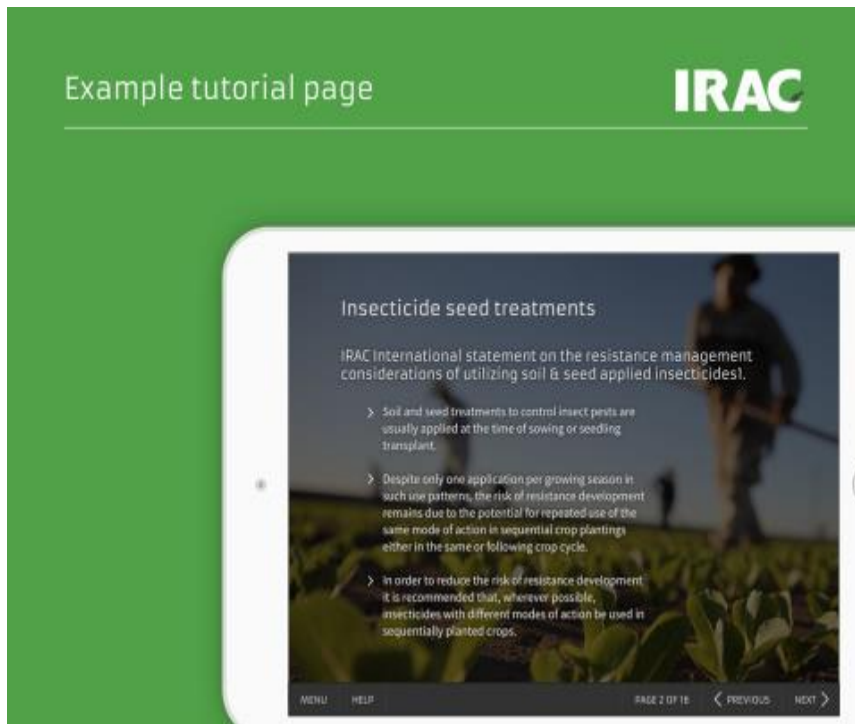
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- Provide an IRAC guidance document on IRM Modelling.
- Development of an IRM online training tool.



# Online IRM Training

- Online training in basic IRM.
- Target audience still needs to be defined:
  - Students, Farm managers, Pesticide Retailers, Company sales teams.
- Can we use existing training materials ?
- Timelines, resoruces and funding still in discussion.



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- Provide an IRAC guidance document on IRM Modelling.
- Development of an IRM online training tool.
- Develop RAC proposal for the generation of EU regulatory data and engage with pesticide regulators in Europe.

A joint FRAC, HRAC and IRAC workshop was held on the 13th September in order to discuss the process of generating resistance data in support of the registration and re-registration of pesticides in Europe. The outputs of this meeting and subsequent individual discussions within the RACs will be communicated once the recommendations are fully developed.

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- Development of an IRM online training tool.
- Develop RAC proposal for the generation of EU regulatory data and engage with pesticide regulators in Europe.
- Completion of Task Team activities (Puerto Rico & *Tuta absoluta*)
- Assess potential for New Task Team in Africa to address threat of invasive *Spodoptera frugiperda*?

Currently IRM implementation and advice is being provided by IRAC South Africa. No further input from IRAC International is currently required.

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- Develop RAC proposal for the generation of EU regulatory data and engage with pesticide regulators in Europe.
- Completion of Task Team activities (Puerto Rico & *Tuta absoluta*)
- Assess potential for New Task Team in Africa to address threat of invasive *Spodoptera frugiperda*?
- Formation of an IRAC Nematode working group

1<sup>st</sup> meeting on the 25<sup>th</sup> September

- IRAC is focused on providing practical resistance management advice to those that implement or advise on pest management.
- Growers, farm managers, independent advisors, extension services & industry representatives

IRM guidelines for conventional and transgenic corn, developed in collaboration with non-industry experts from Brazil

- NOTE: In the following, documents the word "insecticides" refers to chemical & biological insecticides which are applied as either foliar, soil or seed treatments. It does not include plant incorporated proteins (PIPs) which have insecticidal activity.
- Only apply insecticides at economic pest thresholds. Follow locally established economic pest thresholds for the application of foliar insecticides in order to optimize insecticide use. Always use labeled rates and water volumes.
  - Use Windows of Insecticide Application. Use windows of application to minimize exposure of sequential generations of a target pest species to the same insecticide mode of action. Each window should be approximately 30 days to coincide with a single generation of the target insect.
  - Rotate insecticides with different modes of action. If more than one insecticide application is required during an application window then it is recommended to use an insecticide which has a different mode of action. However, multiple applications of insecticides with the same mode of action within a window should be avoided.
  - Manage crop post-harvest stubble & volunteers. Scour the field during pre-planting burn down with a herbicide and if insects are observed in the remaining crop residue, the use of foliar applied insecticides is recommended for their control.
  - Rotate crops. Subsequent crop plantings should be of a different crop type, which is not a host to the insects which are pests of corn. A practice window is created.
- Recommendations specific to corn expressing Bt proteins
- Rotate Bt corn refuge within 400m of the Bt corn's refuge is recommended for maximum efficacy.
  - Insecticide application should be minimized on the refuge. The number of sprays on the refuge should follow the label instructions for the refuge. When to be scouted and sprayed at the same time as the Bt corn. The refuge should be either a non-host crop or a host crop.

### KNOWING YOUR INSECT MODE OF ACTION IS THE KEY TO INSECT RESISTANCE MANAGEMENT

Although insecticide products may contain different ingredients, these ingredients can often work in the same way!

The insecticide mode of action can easily be identified by the IRAC mode of action classification label.

All insecticides which share the same number have the same or similar modes of action.

There are currently 26 insecticide mode of action identified, but not all are active against all insect pests.


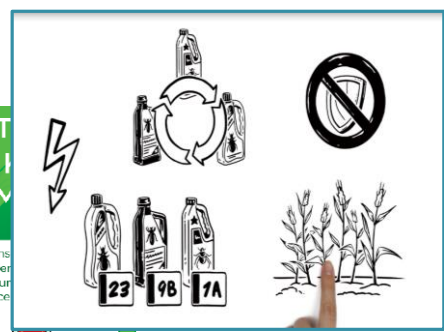
Rotate ins with differ action num resistance



ADDITIONAL KEY ADVICE TO AVOID RESISTANCE DEVELOPMENT

- Combine the use of chemicals and natural pest control methods
- Follow labels instructions on the use of each insecticide product, including rates and water volumes.
- Check and maintain spraying equipment and replace spray nozzles when needed
- Target the most susceptible life stages of the pest insect
- Try to use insecticides which have a minimal impact on natural pest enemies and water volumes.
- Avoid using insecticides with known resistance problems

MEMBERS OF IRAC

### IRAC Examples: Corn Application Windows

Condensed version

Foliar application of insecticides at locally agreed pest threshold. Do not use same Insecticide MoA used in previous window, and subsequent crop planting

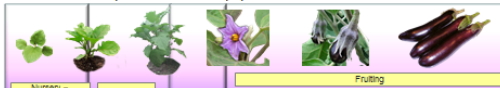
	Pre-Planting Window	Window 1 05-12	Window 2 12-18	Window 3 18-24	Window 4 24-30
Conventional Corn	Insecticide MoA 1	Insecticide MoA 2	Insecticide MoA 3	Insecticide MoA 4	Insecticide MoA 5
Bt Corn MAIN CROP	Insecticide MoA 1	Insecticide MoA 2	Bt toxin (single mode of action) MoA 11		
Bt Corn REFUGE	Insecticide MoA 1	Insecticide MoA 2	Insecticide MoA 3	Insecticide MoA 4	Insecticide MoA 5

Phenology: Pre-Planting (dessecação), Planting, Vegetative, Reproductive

IRM programs for eggplant and rice used in train the trainers programs in China & the Philippines

### Insecticide Resistance Management (IRM) Strategy in Eggplant

To ensure susceptible Fruit Borer population




1<sup>st</sup> Generation 2<sup>nd</sup> Generation 3<sup>rd</sup> Generation 4<sup>th</sup> Generation 5<sup>th</sup> Generation

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



1<sup>st</sup> Generation 2<sup>nd</sup> Generation 3<sup>rd</sup> 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

IRM Leaflet providing Basic IRM advice for small holders.