Session 3

International Working Group & Country Group Review

46th Meeting of IRAC International, Brussels, Belgium

Wednesday - March 30th, 2011

Lepidoptera WG

Sybille Lamprecht

CropLife INTERNATIONAL

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Insecticide Resistance Action Committee

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Team Meetings & Calls – 2010 / 2011

- **March 2010** — **- Poster on *Tuta absoluta***
- **September 2010** — **- Resistance Monitoring DBM, Thailand / Philippines**
- DBM workshop Thailand,
- **October 2010** — **- DBM workshop Thailand**
- DBM poster
- *Lobesia botrana* poster - discussion only
- *Tuta absoluta* brochure / methods film
- **February 2011** — **- DBM workshop Thailand**
- Status IRM Educational Program Philippines (IRAC SEA / Philippines) – Info
- Posters BAW, *Lobesia*
***- Tuta absoluta* brochure**

Insecticide Resistance Action Committee

Agreed Goals for 2010

Lepidoptera WG

Goals	Objectives	Timeline
Provide information on Lepidoptera resistance issues globally	• Identification of global resistance problems associated with lepidopteran pests • Monitor resistance status • Analyze findings • Compile relevant recommendations	Ongoing ongoing
Development of educational material on IRM	• Preparation of general *Tuta absoluta* poster • Preparation of general *Plutella xylostella* poster • Preparation of 2 further posters on pests where there are resistance issues e.g. Helicoverpa spp. and *Lobesia botrana* • Principles of IRM in Lepidoptera control	Q2 2010 √ Q2 2010 √ Q4 2010 Q4 2010 ongoing
Support of other IRAC WGs and CGs	• Method evaluation (*Tuta*) • Collaboration with Diamide WG on Thailand DBM case	End Q2 2010 √ ongoing
Investigate a possible merger with the Diamide WG	• Prepare for merger with the diamide WG • Evaluate possible merger with CM WG?	Q4 2010

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Diamondback Moth Susceptibility Monitoring Locations – Co-operation with Diamides WG

Buguias, Benguet

La Trinidad, Benguet

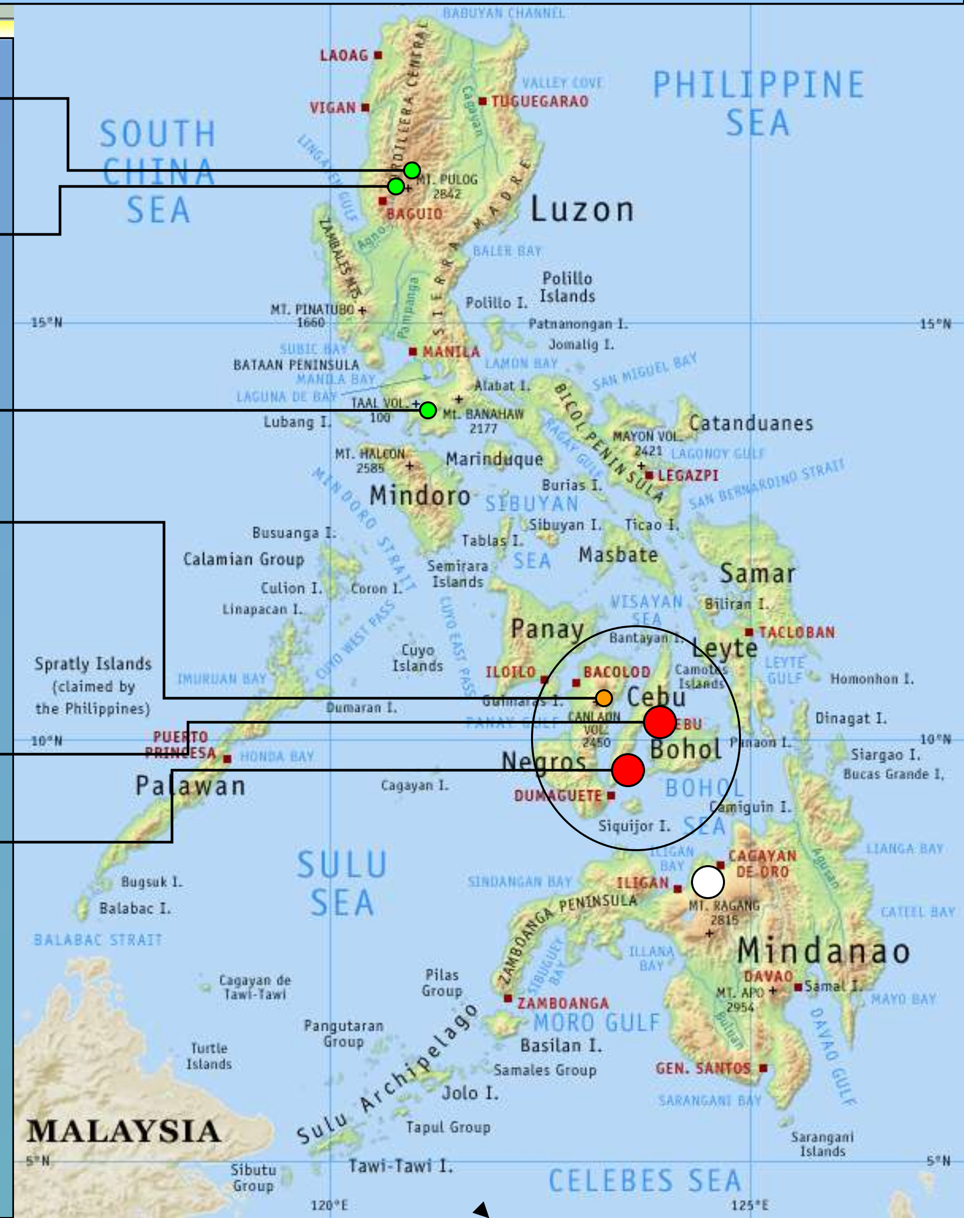
Calauan, Laguna

***Canlaon City, Negros Oriental**

*** 2009 Field Failures with Flubendiamide**

***Sudlon, Cebu**

***Dalaguete, Cebu**

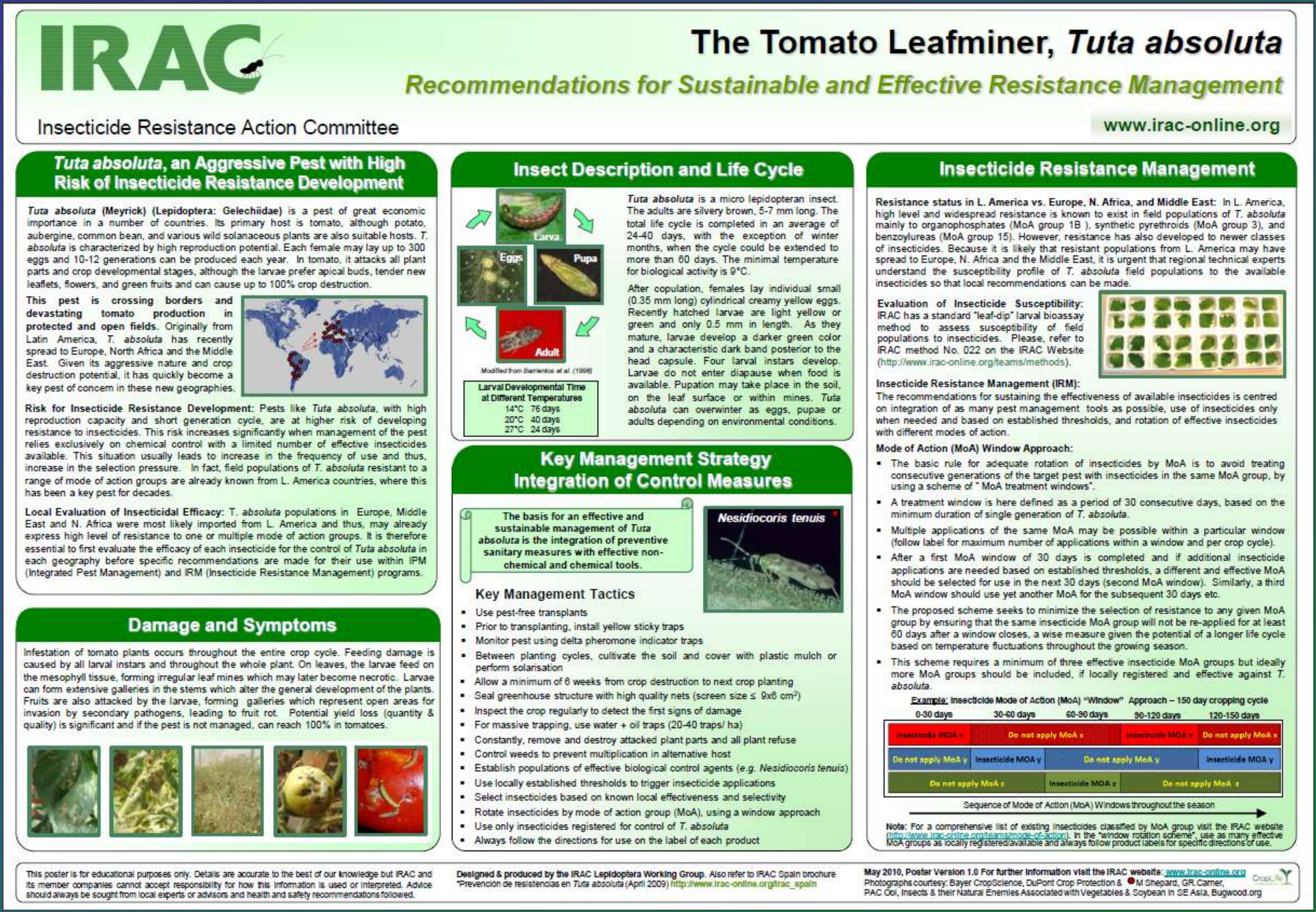


Insecticide Resistance Action Committee

Main Activities 2010

- **2011 Sixth International Workshop on Management of the Diamondback Moth - Thailand, Kasetsart University**
- **Organized** by AVRDC – The World Vegetable Center and its Regional Office for East and Southeast Asia, Thailand in association with Kasetsart University
- 200-300 researchers / multipliers
- International IRAC contributions:
  - **Booth** was available for IRAC distribution and communication of IRAC sponsored information - maintained by the Southeast Asia IRAC team
- **Seven speakers in the session**: „Preserving Chemistries for DBM Control (with emphasis on Diamides)"

C & E Resources – *Tuta absoluta* Poster



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The Tomato Leafminer, *Tuta absoluta*

Recommendations for Sustainable and Effective Resistance Management

www.irac-online.org

Tuta absoluta, an Aggressive Pest with High Risk of Insecticide Resistance Development

Tuta absoluta **(Meyrick) (Lepidoptera: Gelechiidae)** is a pest of great economic importance in a number of countries. Its primary host is tomato, although potato, aubergine, common bean, and various wild solanaceous plants are also suitable hosts. *T. absoluta* is characterized by high reproduction potential. Each female may lay up to 300 eggs and 10-12 generations can be produced each year. In tomato, it attacks all plant parts and crop developmental stages, although the larvae prefer apical buds, tender new leaflets, flowers, and green fruits and can cause up to 100% crop destruction.

This pest is crossing borders and devastating tomato production in protected and open fields. Originally from Latin America, *T. absoluta* has recently spread to Europe, North Africa and the Middle East. Given its aggressive nature and crop destruction potential, it has quickly become a key pest of concern in these new geographies.

Risk for Insecticide Resistance Development: Pests like *Tuta absoluta*, with high reproduction capacity and short generation cycle, are at higher risk of developing resistance to insecticides. This risk increases significantly when management of the pest relies exclusively on chemical control with a limited number of effective insecticides available. This situation usually leads to increase in the frequency of use and thus, increase in the selection pressure. In fact, field populations of *T. absoluta* resistant to a range of mode of action groups are already known from L. America countries, where this has been a key pest for decades.

Local Evaluation of Insecticidal Efficacy: T. *absoluta* populations in Europe, Middle East and N. Africa were most likely imported from L. America and thus, may already express high level of resistance to one or multiple mode of action groups. It is therefore essential to first evaluate the efficacy of each insecticide for the control of *Tuta absoluta* in each geography before specific recommendations are made for their use within IPM (Integrated Pest Management) and IRM (Insecticide Resistance Management) programs.

Damage and Symptoms

Infestation of tomato plants occurs throughout the entire crop cycle. Feeding damage is caused by all larval instars and throughout the whole plant. On leaves, the larvae feed on the mesophyll tissue, forming irregular leaf mines which may later become necrotic. Larvae can form extensive galleries in the stems which alter the general development of the plants. Fruits are also attacked by the larvae, forming galleries which represent open areas for invasion by secondary pathogens, leading to fruit rot. Potential yield loss (quantity & quality) is significant and if the pest is not managed, can reach 100% in tomatoes.

Insect Description and Life Cycle

Larva
Eggs
Pupa
Adult

Modified from Barrientos et al. (1998)

Larval Developmental Time at Different Temperatures
14°C 76 days
20°C 40 days
27°C 24 days

Tuta absoluta is a micro lepidopteran insect. The adults are silvery brown, 5-7 mm long. The total life cycle is completed in an average of 24-40 days, with the exception of winter months, when the cycle could be extended to more than 60 days. The minimal temperature for biological activity is 9°C.

After copulation, females lay individual small (0.35 mm long) cylindrical creamy yellow eggs. Recently hatched larvae are light yellow or green and only 0.5 mm in length. As they mature, larvae develop a darker green color and a characteristic dark band posterior to the head capsule. Four larval instars develop. Larvae do not enter diapause when food is available. Pupation may take place in the soil, on the leaf surface or within mines. *Tuta absoluta* can overwinter as eggs, pupae or adults depending on environmental conditions.

Key Management Strategy Integration of Control Measures

The basis for an effective and sustainable management of *Tuta absoluta* is the integration of preventive sanitary measures with effective non-chemical and chemical tools.

Nesidiocoris tenuis

Key Management Tactics

- Use pest-free transplants
- Prior to transplanting, install yellow sticky traps
- Monitor pest using delta pheromone indicator traps
- Between planting cycles, cultivate the soil and cover with plastic mulch or perform solarisation
- Allow a minimum of 6 weeks from crop destruction to next crop planting
- Seal greenhouse structure with high quality nets (screen size ≤ 9x6 cm²)
- Inspect the crop regularly to detect the first signs of damage
- For massive trapping, use water + oil traps (20-40 traps/ ha)
- Constantly, remove and destroy attacked plant parts and all plant refuse
- Control weeds to prevent multiplication in alternative host
- Establish populations of effective biological control agents (*e.g. Nesidiocoris tenuis*)
- Use locally established thresholds to trigger insecticide applications
- Select insecticides based on known local effectiveness and selectivity
- Rotate insecticides by mode of action group (MoA), using a window approach
- Use only insecticides registered for control of *T. absoluta*
- Always follow the directions for use on the label of each product

Insecticide Resistance Management

Resistance status in L. America vs. Europe, N. Africa, and Middle East: In L. America, high level and widespread resistance is known to exist in field populations of *T. absoluta* mainly to organophosphates (MoA group 1B), synthetic pyrethroids (MoA group 3), and benzoylureas (MoA group 15). However, resistance has also developed to newer classes of insecticides. Because it is likely that resistant populations from L. America may have spread to Europe, N. Africa and the Middle East, it is urgent that regional technical experts understand the susceptibility profile of *T. absoluta* field populations to the available insecticides so that local recommendations can be made.

Evaluation of Insecticide Susceptibility: IRAC has a standard "leaf-dip" larval bioassay method to assess susceptibility of field populations to insecticides. Please, refer to IRAC method No. 022 on the IRAC Website (http://www.irac-online.org/teams/methods).

Insecticide Resistance Management (IRM):
The recommendations for sustaining the effectiveness of available insecticides is centred on integration of as many pest management tools as possible, use of insecticides only when needed and based on established thresholds, and rotation of effective insecticides with different modes of action.

Mode of Action (MoA) Window Approach:

- The basic rule for adequate rotation of insecticides by MoA is to avoid treating consecutive generations of the target pest with insecticides in the same MoA group, by using a scheme of " MoA treatment windows".
- A treatment window is here defined as a period of 30 consecutive days, based on the minimum duration of single generation of *T. absoluta*.
- Multiple applications of the same MoA may be possible within a particular window (follow label for maximum number of applications within a window and per crop cycle).
- After a first MoA window of 30 days is completed and if additional insecticide applications are needed based on established thresholds, a different and effective MoA should be selected for use in the next 30 days (second MoA window). Similarly, a third MoA window should use yet another MoA for the subsequent 30 days etc.
- The proposed scheme seeks to minimize the selection of resistance to any given MoA group by ensuring that the same insecticide MoA group will not be re-applied for at least 60 days after a window closes, a wise measure given the potential of a longer life cycle based on temperature fluctuations throughout the growing season.
- This scheme requires a minimum of three effective insecticide MoA groups but ideally more MoA groups should be included, if locally registered and effective against *T. absoluta*.

Example: Insecticide Mode of Action (MoA) "Window" Approach – 150 day cropping cycle

0-30 days	30-60 days	60-90 days	90-120 days	120-150 days
Insecticide MOA x	Do not apply MoA x	Do not apply MoA x	Insecticide MOA x	Do not apply MoA x
Do not apply MoA y	Insecticide MOA y	Do not apply MoA y	Do not apply MoA y	Insecticide MOA y
Do not apply MoA z	Do not apply MoA z	Insecticide MOA z	Do not apply MoA z	Do not apply MoA z

Sequence of Mode of Action (MoA) Windows throughout the season

Note: For a comprehensive list of existing insecticides classified by MoA group visit the IRAC website (http://www.irac-online.org/teams/mode-of-action). In the "window rotation scheme", use as many effective MoA groups as locally registered/available and always follow product labels for specific directions of use.

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 the IRAC Lepidoptera Working Group. Also refer to IRAC Spain brochure "Prevención de resistencias en *Tuta absoluta* (April 2009) http://www.irac-online.org/irac_spain

May 2010, Poster Version 1.0 For further information visit the IRAC website: www.irac-online.org
Photographs courtesy: Bayer CropScience, DuPont Crop Protection & M Shepard, GR Carner, PAC Ooi, Insects & their Natural Enemies Associated with Vegetables & Soybean in SE Asia, Bugwood.org

C & E Resources - Support Methods WG

Insecticide Resistance Action Committee

- *Tuta absoluta* Method (IRAC No.022)
- *Tuta absoluta* Methods film

Insecticide Resistance Action Committee
www.irac-online.org

IRAC Susceptibility Test Methods Series
Version: 3

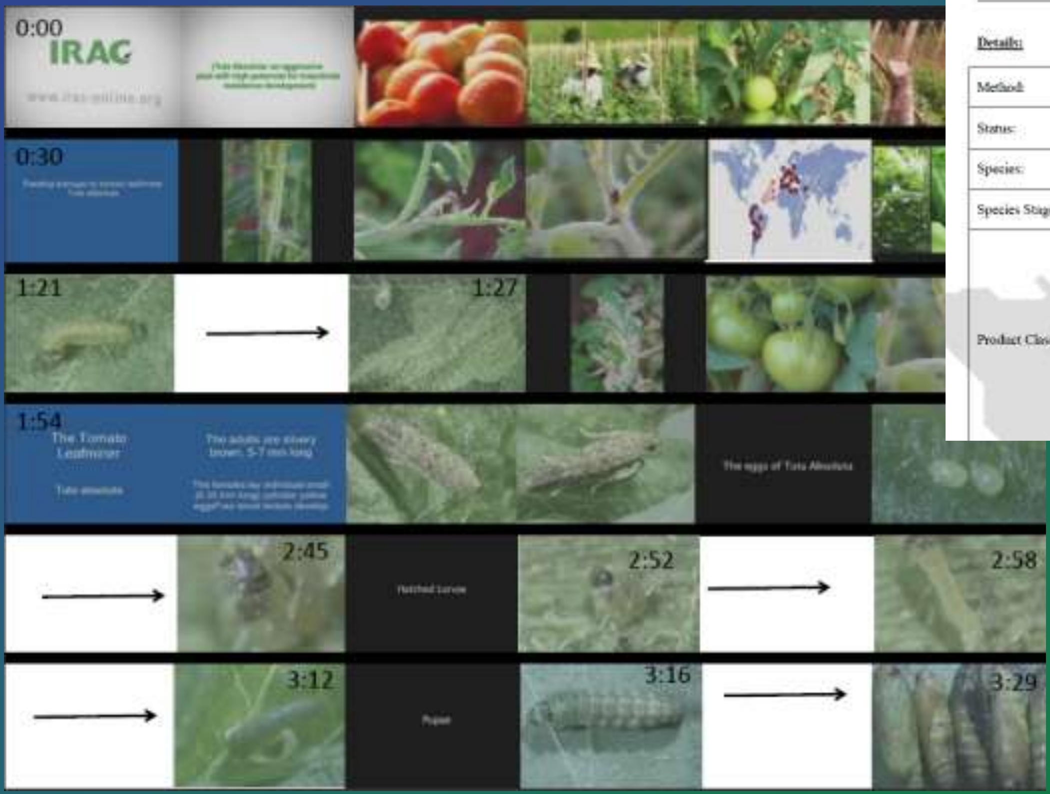
Method No: 022

DRAFT

Details:

Method:	No: IRAC No. 022
Status:	Under Review
Species:	*Tuta absoluta*
Species Stage	Larvae L2 (size: 4-5 mm)
Product Class:	Oxadiazins (IRAC MoA 22), anthranilic diamides (IRAC MoA 28), spinosyns (IRAC MoA 5)

Tuta absoluta larvae
Photograph Courtesy of DuPont Crop Protection



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C & E Resources – DBM Poster

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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, cosmopolitan species and one of the most important pest 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* are unable to overwinter and therefore annual outbreaks are attributed to migration, but in tropical and subtropical 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 and for many years continuous insecticide applications have been and continue to be the main tool.

The first cases of *P. Xylostella* resistance were reported in the 1950´s and today this species shows resistance to almost all insecticides, including recently introduced compounds with new modes of action (3).

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Plutella xylostella Damage in Brassica

Resistance Mechanisms

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

1. **Enhanced metabolic detoxification mechanisms:**
   - microsomal monooxygenases – different forms of cytochrome P450 play a major role in *P. xylostella* resistance to pyrethroids, organophosphates, abamectin and benzoylphenyl ureas (4)
   - glutathione S-transferases – for example reported to confer organophosphate resistance (3, 4)
   - carboxylesterases – involved in resistance to organophosphates and other chemical classes of insecticides (3)
2. **Insensitive acetylcholinesterase** – proven to play a role in *P.xylostella* resistance development to organophosphates and carbamates
3. **Reduced Cry1C binding to target site in midgut membrane and reduced conversion of Cry1C protoxin to toxin** – factors in resistance development to *Bacillus thuringiensis* protein Cry1C (5)
4. **Knock-down resistance** – mutation(s) in voltage-gated sodium channels providing pyrethroid resistance
5. **Other mechanisms** – include modified GABA-gated chloride channels and reduced penetration and reported to confer fiprole resistance (6)

Management Strategy

A combination of all available tools for *P. xylostella* management should be used to prevent the development of insecticide resistance:

- resistant varieties
- refuge crops
- biological control with natural enemies, e.g. *Cotesia plutellae*
- insecticide applications with mode of action rotation and windows approach
- crop hygiene

The resistance monitoring method for *Plutella xylostella* (IRAC Method No. 018) is available on the IRAC website and should be used to evaluate insecticide susceptibility.

Chemical Control of *Plutella xylostella*

- Select insecticides based on known local effectiveness and selectivity
- Rotate insecticides by mode of action group, using a window approach
- Use only insecticides registered for diamondback moth control
- Always follow the directions for use on the label of each product

MoA	Primary Site of Action	Sub-group or Exemplifying Active
1	Acetylcholinesterase inhibitors	1A:Carbamates 1B:Organophosphates
2	GABA-gated Cl channel antagonists	2B: Phenylpyrazoles (Fiproles)
3	Sodium channel modulators	3A: Pyrethroids, Pyrethrins
4	Nicotinic acetylcholine receptor agonists	4A: Neonicotinoids
5	Nicotinic acetylcholine receptor allosteric activators	Spinosyns
6	Chloride channel activators	Avermectins, Milbemycins
11	Microbial disruptors of insect midgut membranes and derived toxins	Bacillus thuringiensis var. kurstaki
13	Uncouplers of oxidative phosphorylation via disruption of the proton gradient	Pyrrols
15	Inhibitors of chitin biosynthesis, type 0	Benzoylureas
18	Ecdysone receptor agonists	Diacylhydrazines
22	Voltage-dependent Na channel blockers	22A: Indoxacarb 22B: Metaflumizone
28	Ryanodine receptor modulators	Diamides
UN	Compounds of unknown/uncertain MoA	Azadirachtin, Pyridalyl

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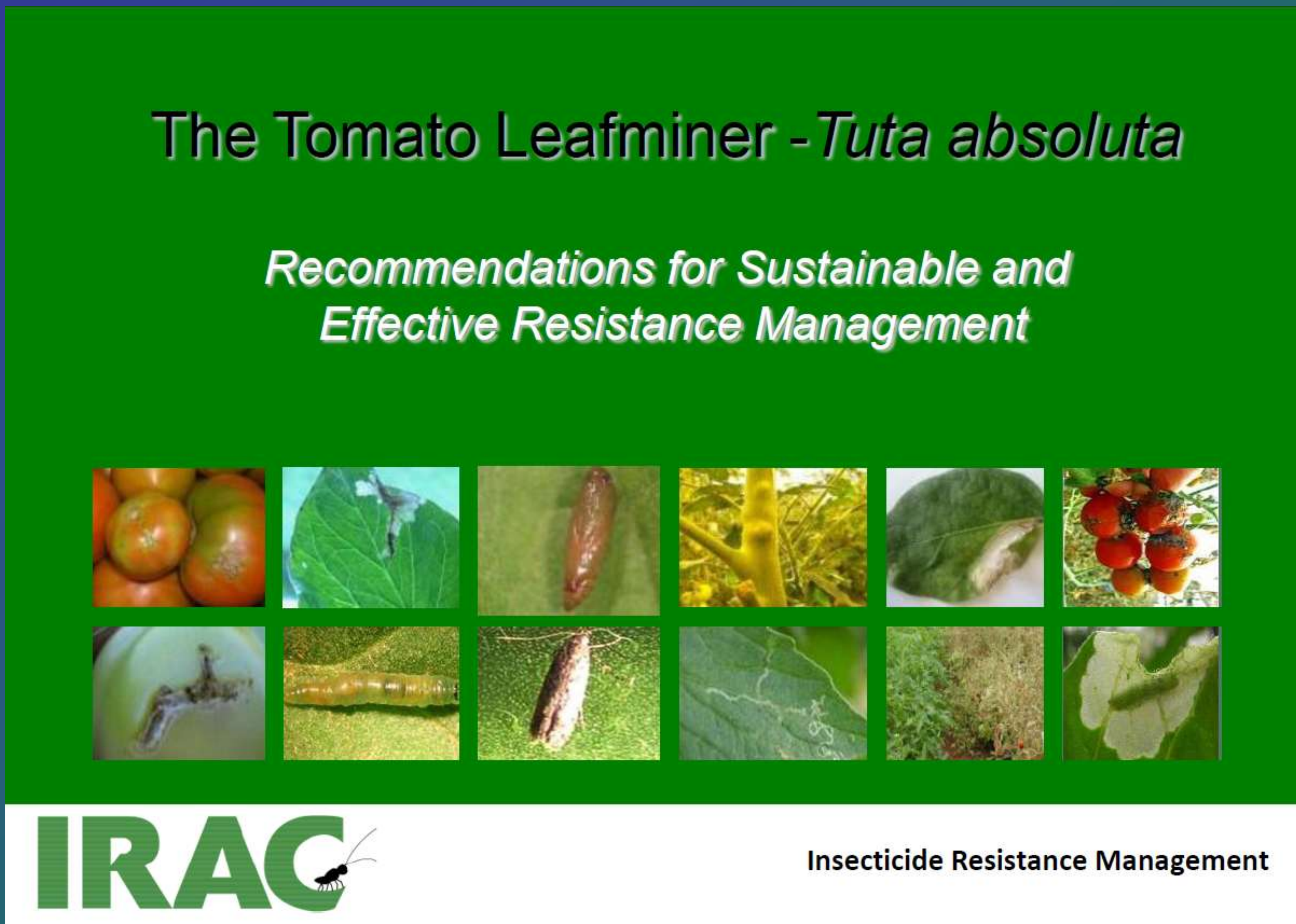
Photograhs courtesy : ● Russ Ottens, University of Georgia, ● Whitney Cranshaw, Colorado State University; Bugwood.org, ○ BayerCrop Science
CropLife

Insecticide Resistance Action Committee

Goals 2011/2012 - Finish *Tuta* broschure



Goals 2011/2012 – Finish BAW Poster

Insecticide Resistance Action Committee

Strategies for Sustainable Control of Beet Armyworm, *Spodoptera exigua*

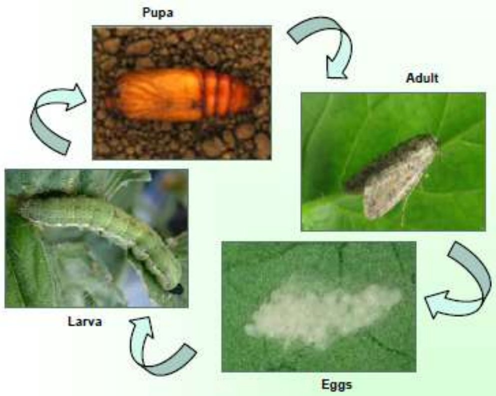
Insecticide Resistance Action Committee

www.irac-online.org

Introduction and Biological Background

Beet armyworm *Spodoptera exigua* (Hübner) (Lepidoptera: Noctuidae) is a highly dispersive, polyphagous species that can be a serious pest of vegetable, field and flower crops. Susceptible crops include asparagus cabbage, pepper, tomato, lettuce, cellery, strawberry, eggplant sugar beet, alfalfa, cotton (1)

Life cycle:



Beet armyworm is native to southeast Asia but is now found in Africa, southern Europe, Japan, Australia and north America.

It lacks a diapause mechanism and can only overwinter successfully in warm regions or in greenhouses. Nevertheless, because of its dispersal abilities, beet armyworm will regularly invade temperate areas and cause damage during the growing season.

The larvae are gregarious and may feed in large swarms, causing devastating crop losses. Larvae feed on both foliage and fruit. As they mature, the larvae become solitary. Damage includes consumption of fruit and leaf tissue and contamination of the crop. One generation can be produced in as little as 21-24 days (2).

S. exigua damage to cabbage and tomato

Resistance Mechanisms

Several biochemical mechanisms may contribute insecticide resistance in beet armyworm. These mechanisms may act separately or in concert depending on the mode of action of the insecticide.

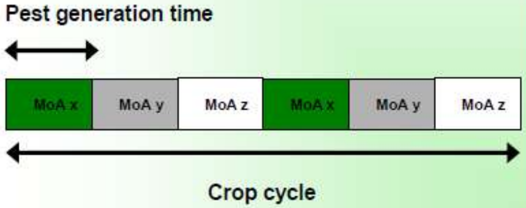
1. **Enhanced metabolic detoxification:**
   - Esterases, acetylcholinesterase and glutathione S-transferase (3)
   - Multifunctional carboxylesterase (4)
   - Mixed-function oxidases (5, 6, 7)
   - Microsomal-O-demethylase (8)
2. **Target site insensitivity** (9, 4)
3. **Sequestration by proteases or esterases, efficient cellular repair or an increase in the immune response** (10).

MoA	Primary Site of Action	Group
1	Acetylcholinesterase inhibitors	1A:Carbamates 1B:Organophosphates
2	GABA-gated Cl channel antagonists	2B: Phenylpyrazoles (Fiproles)
3	Sodium channel modulators	3A: Pyrethroids, Pyrethrins
4	Nicotinic acetylcholine receptor agonists	4A: Neonicotinoids
5	Nicotinic acetylcholine receptor allosteric activators	Spinosyns
6	Chloride channel activators	Avermectins, Milbemycins
11	Microbial disruptors of insect midgut membranes and derived toxins	Bacillus thuringiensis var. kurstaki
13	Uncouplers of oxidative phosphorylation via disruption of the proton gradient	Pyrrols
15	Inhibitors of chitin biosynthesis, type 0	Benzoylureas
18	Ecdysone receptor agonists	Diacylhydrazines
22	Voltage-dependent Na channel blockers	22A: Indoxacarb 22B: Metaflumizone
28	Ryanodine receptor modulators	Diamides
UN	Compounds of unknown/uncertain MoA	Azadirachtin, Pyridalyl

Integrated Resistance Management

Resistance occurs because of of repeated application of insecticide(s) with the same mode of action. Integrated resistance management strategies take advantage of all available pest management options to decrease insecticide selection pressure on insect populations. A combination of all available tools for *S. exigua* management should be used to prevent the development of insecticide resistance:

- Resistant crop varieties
- Biological control with natural enemies
- Application of insecticides only when needed
- Always follow the directions for use on the label of each product
- Rotate insecticide modes of action (MoA) and use a treatment window approach based on pest generation time



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Designed by IRAC Lepidoptera WG, January 2012, Poster Ver. 1.0 - For further information visit the IRAC website: www.irac-online.org
Photographs courtesy : DuPont Crop Protection

Goals 2011/2012

Goals	Objectives	Timeline
Provide information on lepidopteran resistance issues globally	■ Identification of global resistance problems associated with lepidopteran pests ■ Monitor resistance status ■ Analyze findings ■ Compile relevant recommendations	Ongoing
Development of educational material on IRM	■ Finish BAW Poster ■ Finish *Tuta absoluta* brochure ■ Preparation of film "The Resistance potential of *Tuta absoluta"* (Methods film as basis) ? http://www.youtube.com/watch?v=LihcoJPjHFU ■ Preparation of general *Lobesia botrana* poster ■ Preparation of general *Helicoverpa zea* poster ■ Preparation of general *Spodoptera frugiperda* poster ■ Principles of IRM in Lepidoptera control	Q2 2011 Q2 2011 Q2 2011 Q3 2011 Q4 2011

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Insecticide Resistance Action Committee

Goals 2011/2012

Goals	Objectives	Timeline
Represent IRAC on relevant international meetings dealing with lepidopteran pests (in co-operation with other WG / country groups)	■ Attend the Joint International Symposium on management of *Tuta absoluta* (tomato leafminer), Agadir, MA, 2011-11-16/18 (Co-operate with Diamide WG / Methods WG / IRAC Spain / ??)	Q2 - Q3
Support of IRAC WGs / CGs	■ Collaboration with Diamide WG on DBM project ■ Support IRAC Philippines and IRAC SEA on IRM Educational Program Philippines	ongoing
Merger with CM WG	■ Implement merger with CM WG	Q2 2011

Thanks for your attention !