Session 3

47th Meeting of IRAC International, Indianapolis, USA

March 27-30th 2012

Lepidoptera WG

IRAC

Insecticide Resistance Action Committee

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Team Meetings & Calls – 2011 / 2012

- **February 2011**
  - ***Tuta absoluta brochure***
  - **Drafts for posters on *Spodoptera exigua* and *Lobesia botrana***
  - **DBM workshop Thailand**
  - **Status IRM Educational Program Philippines (IRAC SEA / Philippines) – Info**
- **March 2011 / Spring Meeting**
  - **Posters on *Spodoptera exigua* and *Lobesia botrana***
  - ***Tuta video* in co-operation with Methods WG**
  - **Preparation of EPPO Workshop on *Tuta***
- **May 2011**
  - **Merger with Codling Moth WG**
  - ***Tuta* brochure**
  - ***Tuta video* in co-operation with Methods WG**

Team Meetings & Calls – 2011 / 2012

- **October 2011**
  - **Posters on *Spodoptera exigua* and *Lobesia botrana***
  - **Decision: no *Tuta*-Video**
  - **Preparation EPPO Workshop / IRAC Presentation, Tuta C&E Material, Diamides Kick-off Meeting Country Group**
  - **Summary on EPPO Symposium for E-connection**

- **February 2012**
  - **Preparation of Spring Meeting (Goals & Objectives)**

Agreed Goals for 2011

Lepidoptera WG

Goals	Objectives	Timeline
Provide information on Lepidoptera resistance issues globally	• Identification of global resistance problems associated with lepidopteran pests • Monitor resistance status • Analyse findings • Compile relevant recommendations	On-going
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	Q3 2011 **ongoing** Q2 2011 **done** Q3 2011 Q3 2011 Q4 2011 Q4 2011 **ongoing** Q4 2011
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)	Q4 2011 **done**
Support of other IRAC WGs and CGs	• Co-operate with IRAC-Spain in regard to *Tuta absoluta* topics • Collaboration with Diamide WG on DBM project • Support IRAC Philippines and IRAC SEA on IRM Educational Program Philippines	On-going
Investigate a possible merger with the Codling Moth WG	• Implement merger with the Codling Moth WG	Q1 2011 **done**

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Main Activities 2011
Focus on *Tuta absoluta*

16-18 Nov. 2011
Organized by EPPO/IOBC/FAO/NEPPO – Agadir /Morocco

- 200 participants from more than 30 European and Mediterranean Countries as well as from the Middle East. Researchers, regulatory authorities, experts from extension services and crop protection industry

- **Presentation (S.Lamprecht)**: „General Introduction on the Insecticide Resistant Action Committee“.

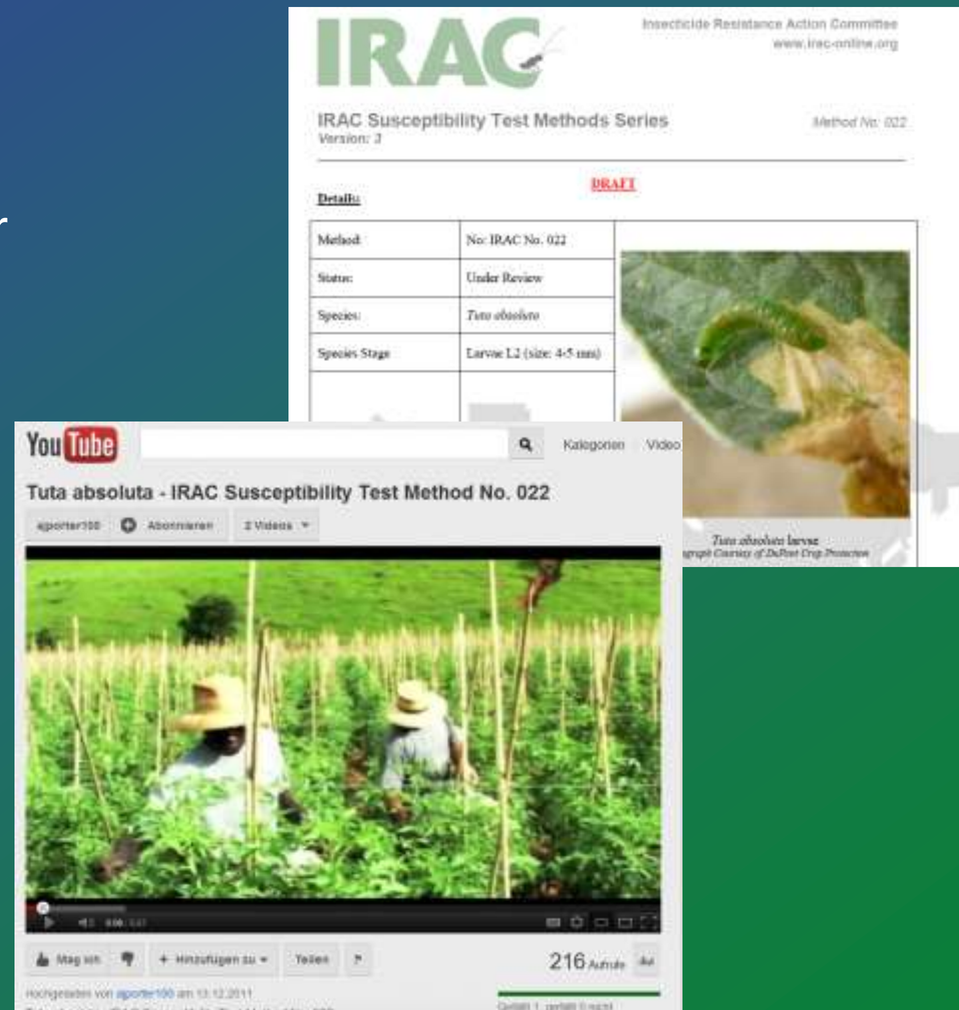
- **Booth** was available for IRAC distribution and communication of IRAC sponsored information – General information on IRAC, MoA brochure, *Tuta absoluta* brochure, *Tuta* poster, *Tuta* methods video

Collaboration with other IRAC WG´s

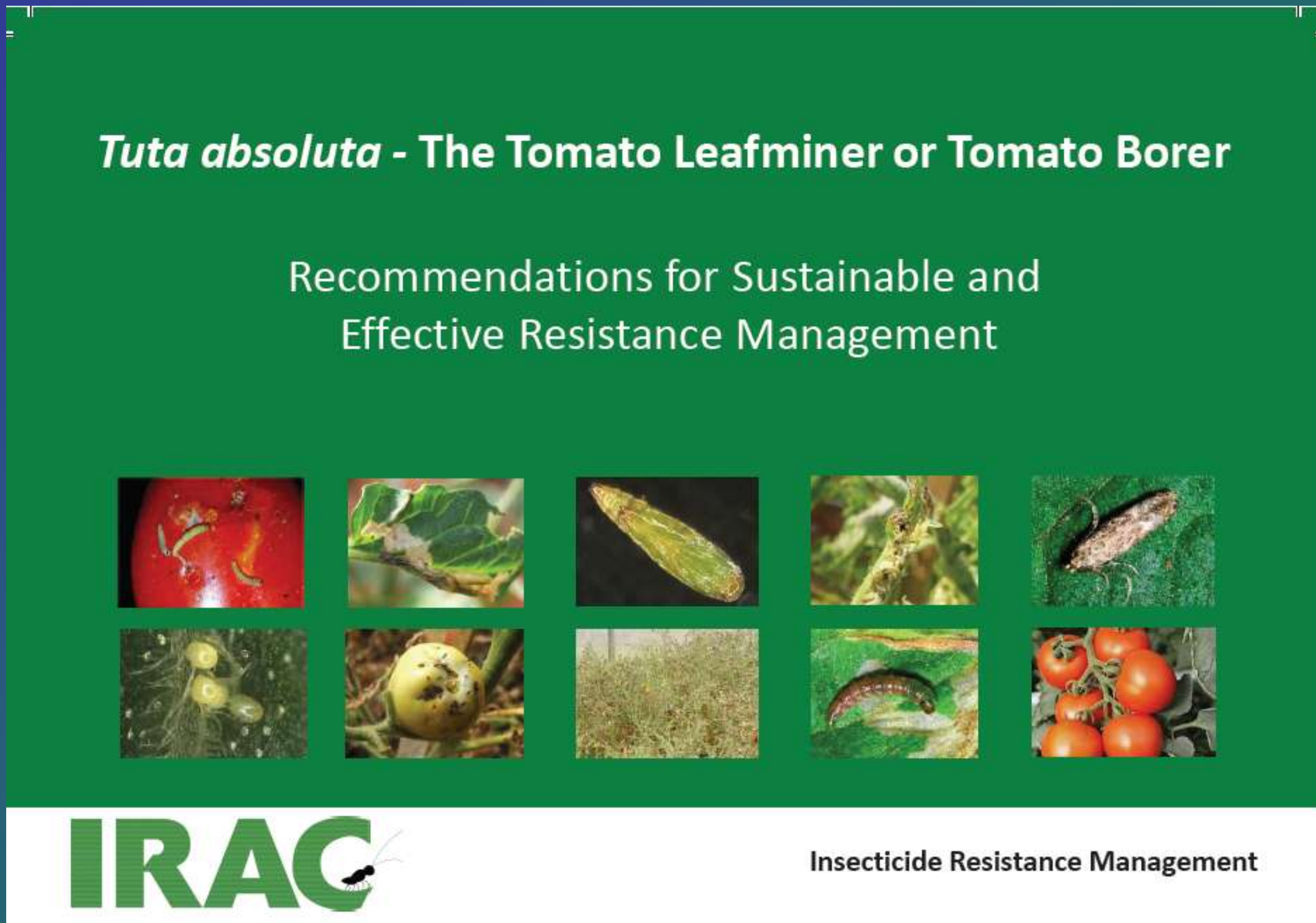
- **Kick-Off Meeting of a <u>Diamide Country Group</u>,**
  at the Tuta-Workshop in Agadir

- **<u>Support Methods Group</u>**
  establishing *Tuta absoluta* Method

- **<u>Support Methods Group</u>**
  in compiling a *Tuta absoluta* methods video



C & E Resources
Tuta absoluta brochure



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Goals 2012 – Finish BAW Poster

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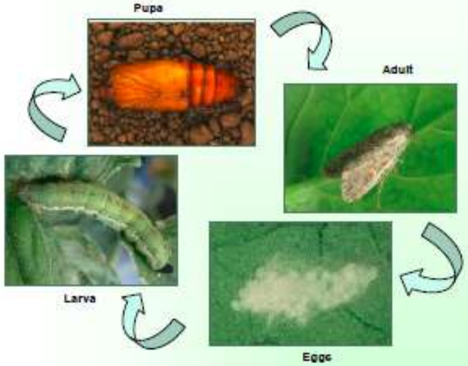
Strategies for Sustainable Control of Beet Armyworm, *Spodoptera exigua*

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, celery, strawberry, eggplant, sugar beet, alfalfa, cotton.

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.

S. exigua damage to cabbage and tomato

Resistance Mechanisms

Several biochemical mechanisms may contribute to the evolution of insecticide resistance in beet armyworm. These mechanisms may act separately or in concert.

1. Enhanced metabolic detoxification, including increased activity of esterases, mixed-function oxidases, and microsomal-O-demethylase.
2. Target site insensitivity.
3. Sequestration by proteases or esterases, efficient cellular repair or an increase in the immune response.

Benefits of Maintaining Insect Susceptibility:

- **For growers:**
  - More choice of control options.
  - Consistent pest control allows higher and more predictable crop yields.
  - Stable crop protection costs.
  - No need to increase the number of applications or amount of control product used.
- **To the environment:**
  - Lower risks to the ecosystem because less pest control product is applied to crops.
- **To the industry:**
  - Increased product longevity with better return on investments.
  - Correct use of insecticides is a critical product stewardship goal.

Integrated Resistance Management

Resistance occurs because of repeated exposure of multiple pest generations to 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:

- **Chemical control**
- Always follow the directions for use on the label of each product.
- Consult product label or IRAC's website (www.irac-online.org) to determine the mode of action of each product.

IRAC MoA Class	Primary Site of Action
1	Acetylcholinesterase inhibitors
2	GABA-gated Cl channel antagonists
3	Sodium channel modulators
4	Nicotinic acetylcholine receptor agonists
5	Nicotinic acetylcholine receptor allosteric activators
6	Chloride channel activators
11	Microbial disruptors of insect midgut membranes
13	Uncouplers of oxidative phosphorylation
15	Inhibitors of chitin biosynthesis, type 0
18	Ecdysone receptor agonists
22	Voltage-dependent Na channel blockers
28	Ryanodine receptor modulators
UN	Compounds of unknown/uncertain MoA

- **Integrated Pest Management**
- Apply insecticides only when needed by following insect pest pressure and using thresholds.
- Choose crop varieties less susceptible to beet armyworm and consider crop rotation.
- Safeguard predators and parasitoids and/or release natural enemies.
- **Integrated Resistance Management**
- Don't treat successive generations with products of the same mode of action.
- Use an approximately 30 day window to conduct sprays of insecticides of the same mode of action.
- Only reuse a mode of action if 30 days have passed since the previous treatment window.
- Do not apply products of the same mode of action over more than 50% of the crop cycle.
- To avoid treating subsequent plantings of short cycle crops (<50 days) with products of the same mode of action, consider using the duration of the crop cycle as the treatment window.

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 2012 - Finish *Lobesia botrana* poster

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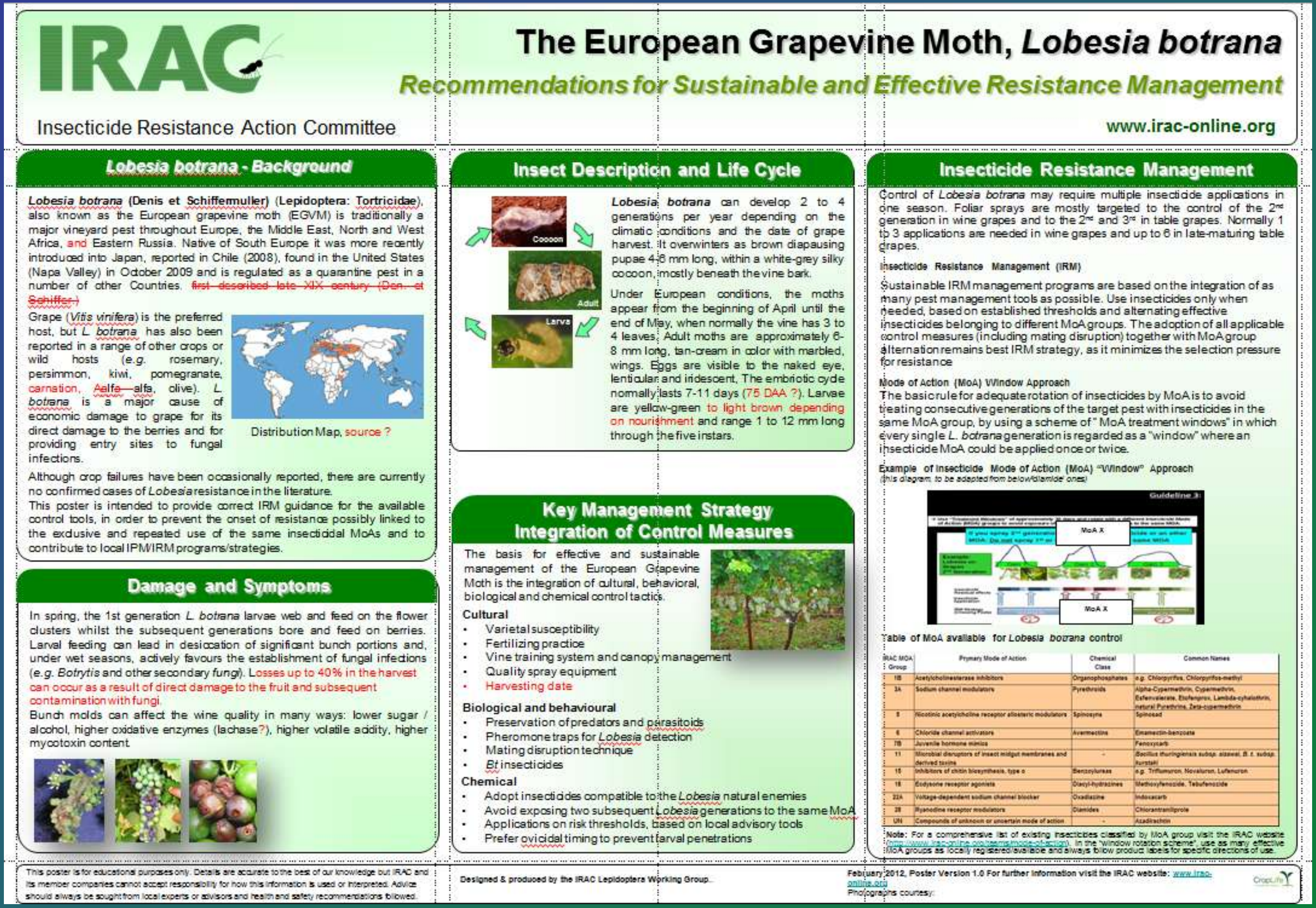

The European Grapevine Moth, *Lobesia botrana*

Recommendations for Sustainable and Effective Resistance Management

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www.irac-online.org

Lobesia botrana - Background

Lobesia botrana (Denis et Schiffermuller) (Lepidoptera: Tortricidae), also known as the European grapevine moth (EGVM) is traditionally a major vineyard pest throughout Europe, the Middle East, North and West Africa, and Eastern Russia. Native of South Europe it was more recently introduced into Japan, reported in Chile (2008), found in the United States (Napa Valley) in October 2009 and is regulated as a quarantine pest in a number of other Countries. ~~first described late XIX century (Den. et Schiffer.)~~

Grape (*Vitis vinifera*) is the preferred host, but *L. botrana* has also been reported in a range of other crops or wild hosts (e.g. rosemary, persimmon, kiwi, pomegranate, carnation, ~~Aalfa~~ alfa, olive). *L. botrana* is a major cause of economic damage to grape for its direct damage to the berries and for providing entry sites to fungal infections.

Distribution Map, source ?

Although crop failures have been occasionally reported, there are currently no confirmed cases of *Lobesia* resistance in the literature.

This poster is intended to provide correct IRM guidance for the available control tools, in order to prevent the onset of resistance possibly linked to the exclusive and repeated use of the same insecticidal MoAs and to contribute to local IPM/IRM programs/strategies.

Damage and Symptoms

In spring, the 1st generation *L. botrana* larvae web and feed on the flower clusters whilst the subsequent generations bore and feed on berries. Larval feeding can lead in desiccation of significant bunch portions and, under wet seasons, actively favours the establishment of fungal infections (e.g. *Botrytis* and other secondary fungi). Losses up to 40% in the harvest can occur as a result of direct damage to the fruit and subsequent contamination with fungi.

Bunch molds can affect the wine quality in many ways: lower sugar / alcohol, higher oxidative enzymes (lachase?), higher volatile acidity, higher mycotoxin content.

Insect Description and Life Cycle

Cocoon

Adult

Larva

Lobesia botrana can develop 2 to 4 generations per year depending on the climatic conditions and the date of grape harvest. It overwinters as brown diapausing pupae 4-6 mm long, within a white-grey silky cocoon, mostly beneath the vine bark.

Under European conditions, the moths appear from the beginning of April until the end of May, when normally the vine has 3 to 4 leaves. Adult moths are approximately 6-8 mm long, tan-cream in color with marbled, wings. Eggs are visible to the naked eye, lenticular and iridescent. The embriotic cycle normally lasts 7-11 days (75 DAA ?). Larvae are yellow-green to light brown depending on nourishment and range 1 to 12 mm long through the five instars.

Key Management Strategy Integration of Control Measures

The basis for effective and sustainable management of the European Grapevine Moth is the integration of cultural, behavioral, biological and chemical control tactics.

Cultural

- Varietal susceptibility
- Fertilizing practice
- Vine training system and canopy management
- Quality spray equipment
- Harvesting date

Biological and behavioural

- Preservation of predators and parasitoids
- Pheromone traps for *Lobesia* detection
- Mating disruption technique
- *Bt* insecticides

Chemical

- Adopt insecticides compatible to the *Lobesia* natural enemies
- Avoid exposing two subsequent *Lobesia* generations to the same MoA
- Applications on risk thresholds, based on local advisory tools
- Prefer ovicidal timing to prevent larval penetrations

Insecticide Resistance Management

Control of *Lobesia botrana* may require multiple insecticide applications in one season. Foliar sprays are mostly targeted to the control of the 2nd generation in wine grapes and to the 2nd and 3rd in table grapes. Normally 1 to 3 applications are needed in wine grapes and up to 6 in late-maturing table grapes.

Insecticide Resistance Management (IRM)

Sustainable IRM management programs are based on the integration of as many pest management tools as possible. Use insecticides only when needed, based on established thresholds and alternating effective insecticides belonging to different MoA groups. The adoption of all applicable control measures (including mating disruption) together with MoA group alternation remains best IRM strategy, as it minimizes the selection pressure for resistance

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" in which every single *L. botrana* generation is regarded as a "window" where an insecticide MoA could be applied once or twice.

Example of Insecticide Mode of Action (MoA) "Window" Approach

(this diagram to be adapted from below/diamide ones)

Guideline 3:

MoA X

MoA X

Table of MoA available for *Lobesia botrana* control

IRAC MOA Group	Primary Mode of Action	Chemical Class	Common Names
1B	Acetylcholinesterase inhibitors	Organophosphates	e.g. Chlorpyrifos, Chlorpyrifos-methyl
3A	Sodium channel modulators	Pyrethroids	Alpha-Cypermethrin, Cypermethrin, Esfenvalerate, Etofenprox, Lambda-cyhalothrin, natural Pyrethrins, Zeta-cypermethrin
5	Nicotinic acetylcholine receptor allosteric modulators	Spinosyns	Spinosad
6	Chloride channel activators	Avermectins	Emamectin-benzoate
7B	Juvenile hormone mimics		Fenoxycarb
11	Microbial disruptors of insect midgut membranes and derived toxins	-	*Bacillus thuringiensis* subsp. aizawai, *B. t.* subsp. kurstaki
15	Inhibitors of chitin biosynthesis, type 0	Benzoylureas	e.g. Triflumuron, Novaluron, Lufenuron
18	Ecdysone receptor agonists	Diacyl-hydrazines	Methoxyfenozide, Tebufenozide
22A	Voltage-dependent sodium channel blocker	Oxadiazine	Indoxacarb
28	Ryanodine receptor modulators	Diamides	Chlorantraniliprole
UN	Compounds of unknown or uncertain mode of action	-	Azadirachtin

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.

Designed & produced by the IRAC Lepidoptera Working Group.

February 2012, Poster Version 1.0 For further information visit the IRAC website: www.irac-online.org

Photographs courtesy:

CropLife

Goals 2012 – Update Codling Moth Poster

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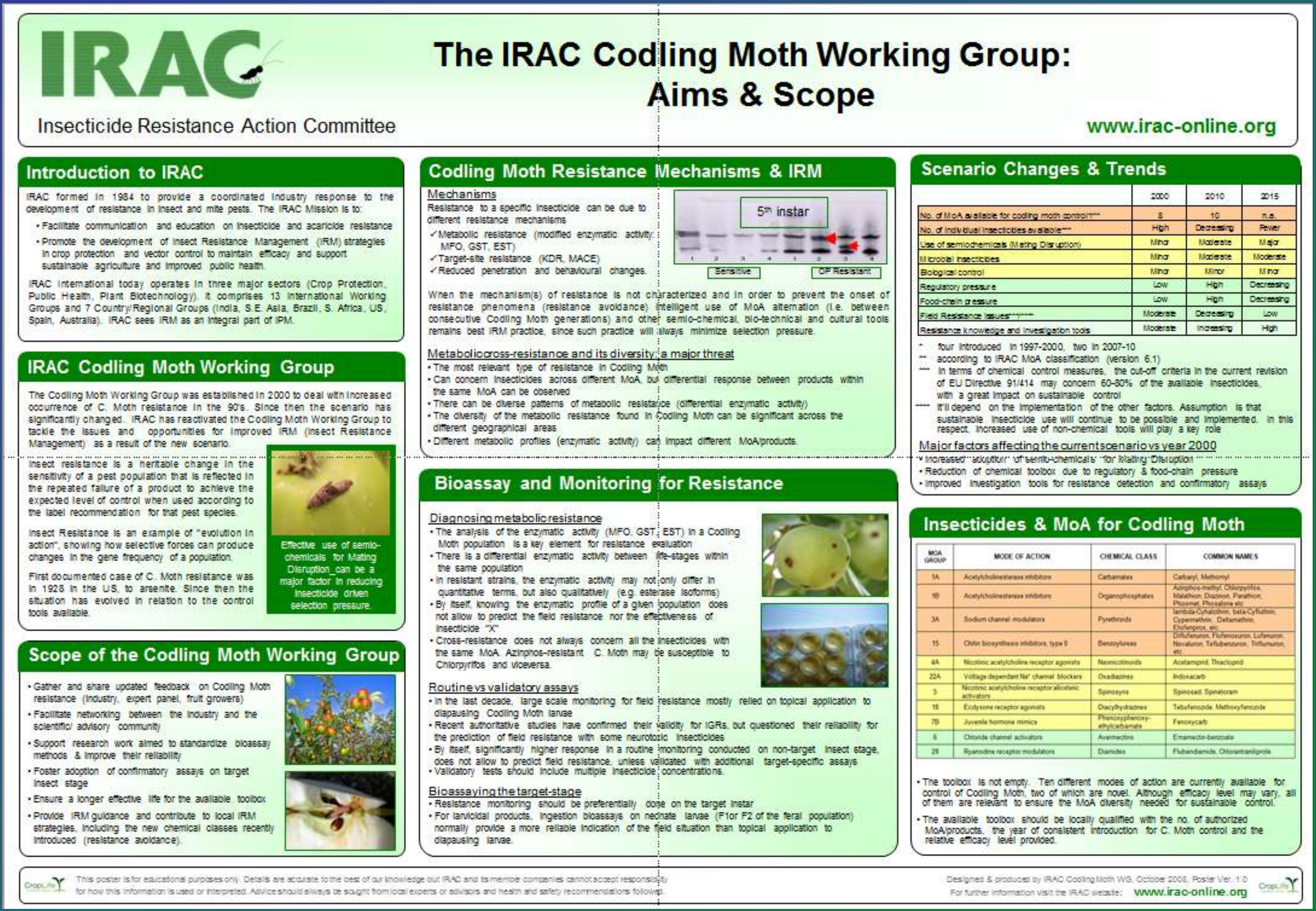

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The IRAC Codling Moth Working Group: Aims & Scope

www.irac-online.org

Introduction to IRAC

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

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

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

IRAC Codling Moth Working Group

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

Insect resistance is a heritable change in the sensitivity of a pest population that is reflected in the repeated failure of a product to achieve the expected level of control when used according to the label recommendation for that pest species.

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

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

Effective use of semio-chemicals for Mating Disruption can be a major factor in reducing insecticide driven selection pressure.

Scope of the Codling Moth Working Group

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

Codling Moth Resistance Mechanisms & IRM

Mechanisms

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

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

When the mechanism(s) of resistance is not characterized and in order to prevent the onset of resistance phenomena (resistance avoidance) intelligent use of MoA alternation (i.e. between consecutive Codling Moth generations) and other semio-chemical, bio-technical and cultural tools remains best IRM practice, since such practice will always minimize selection pressure.

Metabolic cross-resistance and its diversity: a major threat

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

Bioassay and Monitoring for Resistance

Diagnosing metabolic resistance

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

Routine vs validatory assays

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

Bioassaying the target-stage

- Resistance monitoring should be preferentially done on the target instar
- For larvicidal products, ingestion bioassays on neonate larvae (F1or F2 of the feral population) normally provide a more reliable indication of the field situation than topical application to diapausing larvae.

Scenario Changes & Trends

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

* four introduced in 1997-2000, two in 2007-10
** according to IRAC MoA classification (version 6.1)
*** In terms of chemical control measures, the cut-off criteria in the current revision of EU Directive 91/414 may concern 60-80% of the available insecticides, with a great impact on sustainable control
**** It'll depend on the implementation of the other factors. Assumption is that sustainable insecticide use will continue to be possible and implemented. In this respect, increased use of non-chemical tools will play a key role

Major factors affecting the current scenario vs year 2000

- Increased adoption of semio-chemicals for Mating Disruption
- Reduction of chemical toolbox due to regulatory & food-chain pressure
- Improved investigation tools for resistance detection and confirmatory assays

Insecticides & MoA for Codling Moth

MOA GROUP	MODE OF ACTION	CHEMICAL CLASS	COMMON NAMES
1A	Acetylcholinesterase inhibitors	Carbamates	Carbaryl, Methomyl
1B	Acetylcholinesterase inhibitors	Organophosphates	Azinphos-methyl, Chlorpyrifos, Malathion, Diazinon, Parathion, Phosmet, Phosalone etc
3A	Sodium channel modulators	Pyrethroids	lambda-Cyhalothrin, beta-Cyfluthrin, Cypermethrin, Deltamethrin, Etofenprox, etc
15	Chitin biosynthesis inhibitors, type 0	Benzoylureas	Diflubenzuron, Flufenoxuron, Lufenuron, Novaluron, Teflubenzuron, Triflumuron, etc
4A	Nicotinic acetylcholine receptor agonists	Neonicotinoids	Acetamiprid, Thiacloprid
22A	Voltage dependent Na^+ channel blockers	Oxadiazines	Indoxacarb
5	Nicotinic acetylcholine receptor allosteric activators	Spinosyns	Spinosad, Spinetoram
18	Ecdysone receptor agonists	Diacylhydrazines	Tebufenozide, Methoxyfenozide
7B	Juvenile hormone mimics	Phenoxyphenoxy-ethylcarbamate	Fenoxycarb
6	Chloride channel activators	Avermectins	Emamectin-benzoate
28	Ryanodine receptor modulators	Diamides	Flubendiamide, Chlorantraniliprole

- The toolbox is not empty. Ten different modes of action are currently available for control of Codling Moth, two of which are novel. Although efficacy level may vary, all of them are relevant to ensure the MoA diversity needed for sustainable control.
- The available toolbox should be locally qualified with the no. of authorized MoA/products, the year of consistent introduction for C. Moth control and the relative efficacy level provided.

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

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Insecticide Resistance Action Committee

Goals 2012 (not yet agreed)

Goals	Objectives	Timeline
Provide information on Lepidoptera pest resistance issues globally	Identify IRM needs for *Plutella xylostella, Spodoptera frugiperda,* and *Spodoptera exigua*: • Monitor resistance status • Analyse findings • Compile relevant recommendations • Share information with relevant Working Groups and Country Groups.	Draft Q2 2012 / Finish Q4 2012
Develop educational materials on Lepidoptera pest IRM	• Prepare "Principles of IRM in Lepidoptera control" materials (eg. Poster, Booklet, Slides) • Finish *Spodoptera exigua* and *Lobesia botrana* posters • Prepare *Spodoptera frugiperda* and *Helicoverpa zea* posters	Outline Q2 2012 / Finish Q4 2012 Q1 2012 Draft Q3 2012 / Finish Q4 2012

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Insecticide Resistance Action Committee

Goals 2012 (not yet agreed)

Goals	Objectives	Timeline
Develop a plan for increased outreach activities of the Lepidopteran WG	Identify specific international and national and meetings related to lepidoptera pest management where the Lep WG and IRAC should be represented.	Q2 2012 (??)
	Represent IRAC on relevant international meetings dealing with lepidopteran pests (in co-operation with other WGs/CGs)	On-going
Support other IRAC WGs and CGs	Work to ensure consistency of IRM messages across Working Groups and Country Groups	On-going
	Increase exchange of information and joint review of documents with Diamides WG and other Working Groups and Country Groups	On-going