# The IRAC Codling Moth Working Group: Aims & Scope

Insecticide Resistance Action Committee

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.

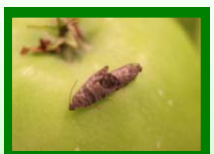
## IRAC Codling Moth Working Group

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

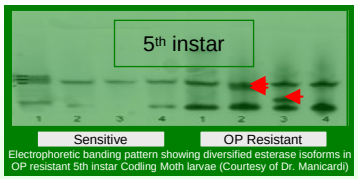
- Gather and share updated feedback on Codling Moth resistance (industry, expert panel, fruit growers)
- Facilitate networking between the industry and the scientific/ advisory community
- Support research work aimed to standardize bioassay methods & improve their reliability
- Foster adoption of confirmatory 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.




Electrophoretic banding pattern showing diversified esterase isoforms in OP resistant 5th instar Codling Moth larvae (Courtesy of Dr. Manicardi)

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

- Metabolic resistance is the most relevant type of resistance in Codling Moth
- Different metabolic profiles (enzymatic activity) can impact different MoA/products
- It 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.

## 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 criteria introduced in the revision of EU Directive 91/414 may concern a significant number of the available insecticides, with an impact on sustainable control options

**** 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 | PRIMARY TARGET SITE | 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 | Diflufenuron, Flufenoxuron, Lufenuron, Novaluron, Teflubenzuron, Triflumuron, etc |
| 4A | Nicotinic acetylcholine receptor agonists | Neonicotinoids | Acetamiprid, Thiacloprid |
| 22A | Voltage dependant $Na^+$ channel blockers | Oxadiazines | Indoxacarb |
| 5 | Nicotinic acetylcholine receptor allosteric activators | Spinosyns | Spinosad, Spinetoram |
| 18 | Ecdysone receptor agonists | Diacylhydrazines | Tebufenozide, Methoxyfenozide |
| 7B | Juvenile hormone mimic | 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, whose two 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.



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For further information visit the IRAC website: www.irac-online.org

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