



Insecticide Resistance Action Committee

TUTA TASK TEAM UPDATE

International IRAC Mtg

Philadelphia, PA USA

March 2017



IRAC

Abundant, Good-Quality Technical Info Available



Criteri di lotta contro la tignola del pomodoro (*Tuta absoluta*)

Siamo andati a visitare le prime prove sperimentali su *Tuta absoluta* del pomodoro in Sicilia. I risultati su che i prodotti piu' validi in Brasile e in Spagna funzionano bene anche da noi.

Tutto "corre"

Un bravo collega due mesi fa in Spagna ci faceva notare come l'andata mondiale di diffusione di *Tuta absoluta* sul pomodoro tendeva a coincidere con quella di altri insetti nocivi. Mi ha fatto pensare di osservare con qualche attenzione questo fenomeno. Ho cominciato a disquisire questo fenomeno in un articolo pubblicato sulla rivista "Entomologica". Anche Franco ha fatto un articolo su *Tuta absoluta* in un numero di "Entomologia".

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Tuta absoluta - The Tomato Leafminer or Tomato Borer

Recommendations for Sustainable and Effective Resistance Management



Tuta absoluta

Biology Guide and Integrated Control Approaches

Edited by Luigi Sannino, Bruno Espinosa

IRAC International Diamide Working Group

Stewardship of the Ryanodine Receptor Modulators, currently including products containing chlorantraniliprole, cyantraniliprole, and flubantraniliprole.

www.irac-online.org

Tuta absoluta - a new severe tomato pest

Life cycle, behaviour and control measures with DuPont™ insecticides compatible with IRM programmes

Research Article

Determination of baseline susceptibility of European populations of *Tuta absoluta* (Meyrick) to indoxacarb and chlorantraniliprole using a novel dip bioassay method

Emmanuel Roditakis,^{a*} Christina Skarmoutsou,^a Marianna Staurakaki,^a María del Rosario Martínez-Aguirre,^b Lidia García-Vidal,^b Pablo Bielza,^b Khalid Haddi,^c Carmelo Rapisarda,^c Jean-Luc Rison,^d Andrea Bassi^e and Juiis A Teixeira^f

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(wileyonlinelibrary.com) DOI: 10.1002/ps.2404

IRAC Insecticide Resistance Action Committee

The Tomato Leafminer / Tomato Borer, *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

Insect Description and Life Cycle

Insecticide Resistance Management

Key Management Strategy: Integration of Control Measures

Damage and Symptoms

Resistance Management

Resistance Monitoring

IRAC Insecticide Resistance Action Committee

Who are we?

Identify and assess risk and crop

Example of DBM IRM Strategy - China

Resistance Management Guidelines

Diagnose resistance

Stewardship of the Ryanodine Receptor Modulators

www.irac-online.org

Early years: Focus on Spain and Italy



Sensitivity bioassays results (IRAC method 022)

Sensitivity bioassays (*T. absoluta* baseline)



- The development of a robust bioassay is essential for determination of baseline toxicity of insecticides and the design of monitoring surveys.
- **Determine the product baseline susceptible populations from Spain, Italy and Greece**

E. Roditakis *et al.*, *Pest Manag Sci* 5 Aug. 2013

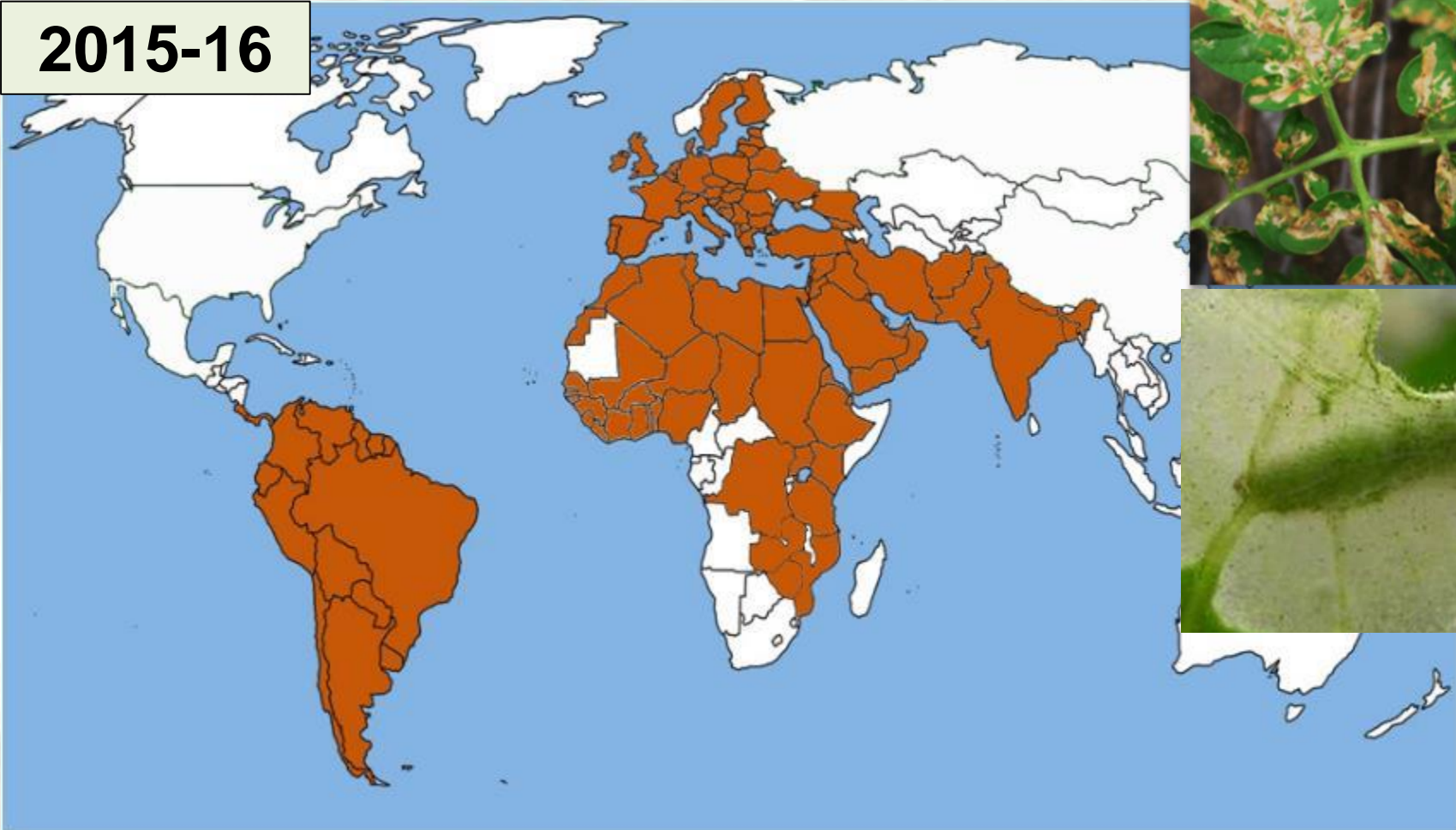
Recorded 13 February 2013
(wileyonlinelibrary.com) DOI 10.1002/ps.3404

Determination of baseline susceptibility of European populations of *Tuta absoluta* (Meyrick) to indoxacarb and chlorantraniliprole using a novel dip bioassay method

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Tuta presence and pest status globally.

2015-16



Antonio BIONDI, Lucia Zappalà, Giovanna Tropea Garzia, Gaetano Siscaro; University of Catania, ITALY antonio.biondi@unict.it

**In 10 years from 3% to 60% of tomato crops
2.8 million hectares**



First report of *Tuta absoluta* resistance to diamide insecticides

Emmanouil Roditakis · Emmanouil Vasakis ·
Maria Grispou · Marianna Stavrakaki ·
Ralf Nauen · Magali Gravouil · Andrea Bassi



2014-15



Chlorantraniliprole (season long appl.)

Untreated Check



Tuta Resistance: Tale of Two Countries

Grower Practices Determine Pest Susceptibility

- growers trained on similar IRM recommends and training materials

SPAIN	SICILY-ITALY
Dedicated technicians who scout and advise	Few advisors
Mandated release of bio control agents	Uncommon Practice
Extensive use of physical/cultural control measures: adult traps, solarization, sanitation	Mostly ignored
Attention to renovating GH's to exclude Tuta	Apathetic - Passive
Depend on multiple Modes of Action	Highly dependent on diamides
More effective different MoA products available	Fewer product available (lost to "R")



2016 Lepidoptera Working Group Company Team Members

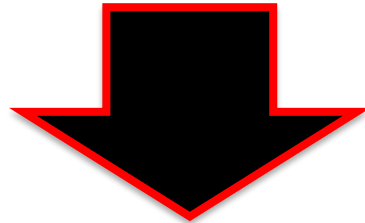
10 Crop Protection Company Members Represented:
4 Companies Volunteered – Core Team

NAMES	COMPANY
Adeline Bertrand, Sebastian Coggiol	ADAMA
Werner Heck, Lixin	BASF
Nigel Godley, Ralf Nauen	Bayer
Jim Dripps, Maria Torne	Dow
Luis Teixeira, John Andalaro, Andrea Bassi	DuPont
Eric Andersen	FMC
Nobuyuki Nonaka	Nihon Nohyaku
Brian Duggan	Nufarm
Robert Senn, Jan Elias	Syngenta
Daniel Zommick	Sumitomo



Overall Objective of the Tuta Task Team Project:

Provide cross-industry advice for best practice Tuta insect control in selected Europe, Middle East, and African countries by designing a regional Tuta pest control program that will be adapted, communicated and implemented locally to influencers, growers, and the industry supply chain.



- **Tuta Pest Management Practices**
- **Tuta IRM Recommends**



Best Management Practices to Control Tuta and Manage Insect Resistance

2016 Core and Extended Tuta Task Team

COMPANY	CORE MEMBERS	EXTENDED MEMBERS
BASF	Cesar Blanco Ruiz	
Dow	Maria Torne	Aris Chloridis Enzo Tescari
DuPont	Luis Teixeira John Andaloro Stefano Pasquini	Jean-Luc Rison Ümit Ersöz David de Scals Christos Theocharis
Syngenta	Robert Senn Stefano Ramella	Desiree van Heerden Pedro Vega Radwan Ftayeh Sinisa Jelovcan
Experts - Spain	Antonio Monserrat Pablo Bielza	



IRAC Tuta Task Team Project: Focus Countries





Local Help from CRAG Teams

Existing Country IRAC and Resistance Action Groups (former Diamide teams) in Focus Countries

Spain	IRAC/CRAG
Italy	CRAG
Turkey	CRAG
Israel	CRAG
Morocco	CRAG
Rep S. A.	IRAC/CRAG



IRAC Tuta Task Team Project

PROCESS

- ✓ Numerous teleconferences throughout 2016
- ✓ Collected, collated, and wrote Tuta pest management, IPM, and IRM recommendations
- ✓ Identified and involved team leaders for focus countries.
- ✓ Two day organizing mtg in Malaga Spain
 - visited Spain greenhouses for clarity
 - developed a plan for local implementation in 2017/18
 - finalized educational/technical documents – Jan 2017
- ✓ ***Now developing a country interaction and audit plan***



Insecticide Resistance Action Committee

Best Management Practices to Control *Tuta absoluta* and Recommendations to Manage Insect Resistance

IRAC *Tuta* IRM Task Team

2017 Version 6



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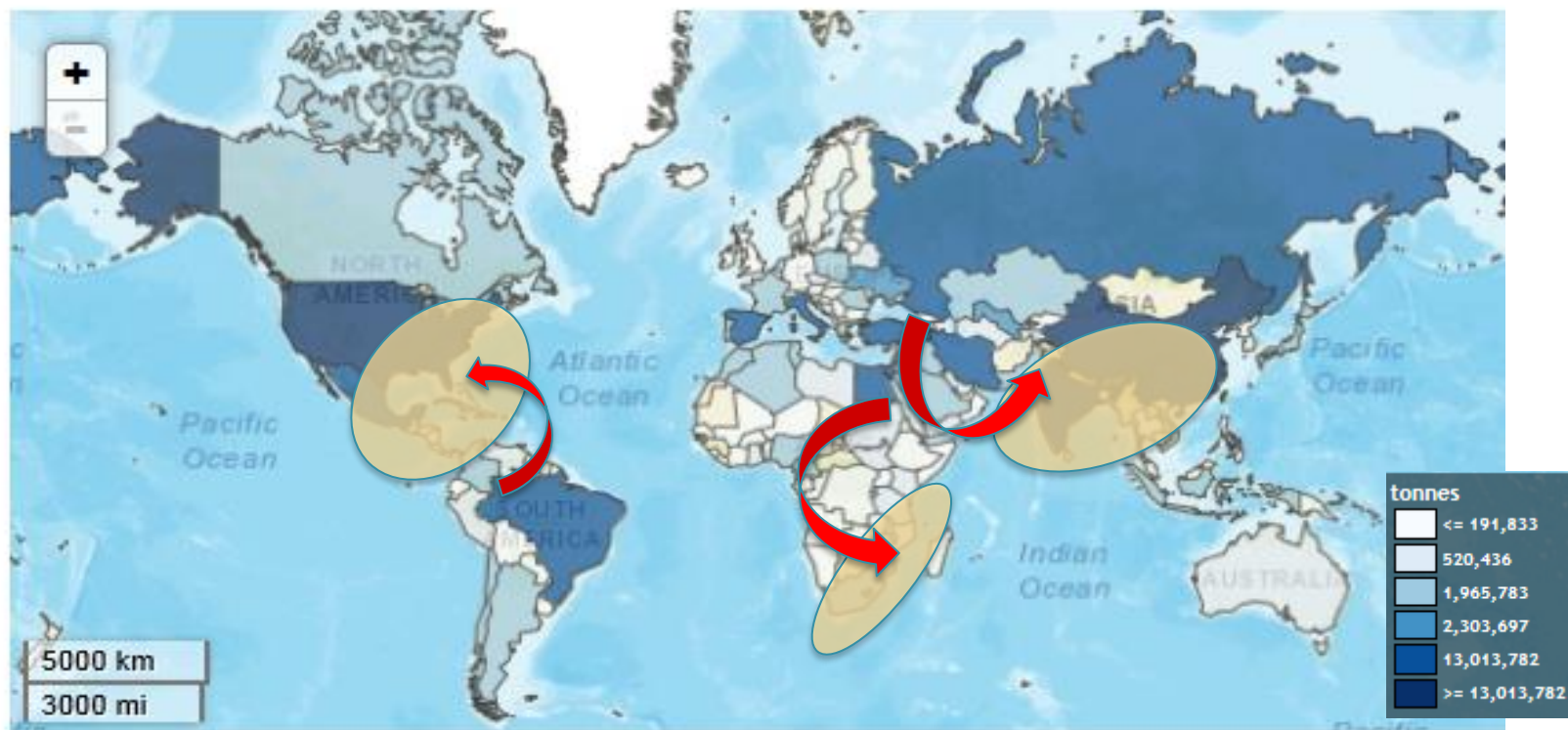
1. Update Tuta presence and pest status globally
2. Recognize Tuta life stages, life cycle, damage, and plant symptoms
3. Tuta control products, resistance publications, and method to evaluate efficacy
4. Monitor Tuta populations
5. Integrate key Tuta control strategies
6. Understand Action Thresholds for chemical and microbiological control
7. Maximize pest control using adjuvants and app tech equipment
8. Understand Insecticide Resistance Management Principles
9. Implement Insecticide Resistance Management Strategies
10. Grower adoption of Tuta IRM: Factors that influence Growers
11. Examples of country MoA alternation programs
12. Country IRM execution guidelines

1. Update *Tuta* presence and pest status globally.

Possible areas under risk of pest spread

Main world tomato production areas at risk

Production quantities by country Average 2008 - 2014



FAO stats2016

- Confirmation of presence in India and Middle east makes Afganistan, Pakistan, India, Nepal and China as risk areas (Nepal: "Sensitizing workshop on *Tuta absoluta*: An impending threat to tomato production" 2015 Sponsored by IAPPS)
- Actions at OIRSA (International Regional Organization for Agricultural Health) Including : El Salvador, Costa Rica Honduras, Guatemala, Mexico, Belice, Nicaragua and Panamá
- Presence in Kenia and Tanzania makes that Mozambique, Malawi, Zimbabwe, Zambia, Botswana as well as South Africa are at risk

2.

Tuta absoluta Life Cycle



Egg
3 - 8 d



Larva
9 - 30 d



Pupa
6 - 20 d



Adult
6 - 15 d ♂
10 - 25 d ♀

- *Egg to adult: 25 - 80 days*
- *Thermal threshold for juvenile development*
 - lower: $10 > x < 13$ °C
 - upper: $30 > x < 35$ °C

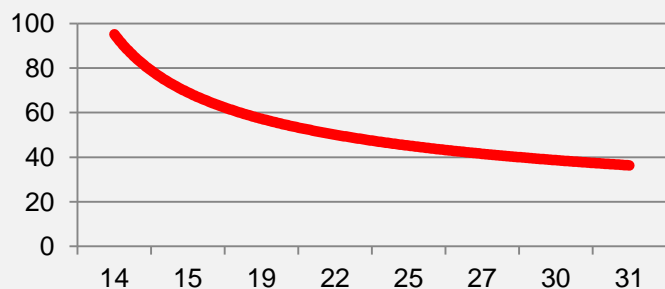
(Various authors; Cuthbertson et al. 2013)

- *Up to 13 generations per year*
- *Good cold resistance*

– supercooling points: larvae (-18.2°C), pupae (-16.7 °C), adults (-17.8°C)

– the lower lethal temps for adults at 0°C (17.9 d), 5°C (27.2 d)

(Van Damme et al. 2015)



2.

Tuta absoluta: Typical Damage

Leaf damage up to 100%)
Decrease photosynthesis and yields

Tuta absoluta

Liriomyza
spp.



***Tuta absoluta* Fruit Damage**



3. Tuta control products, resistance publications, and method to evaluate efficacy.




IRAC Susceptibility Test Methods Series

Method No: 022

Version: 3

Details:

Method:	No: IRAC No. 022	 <p><i>Tuta absoluta</i> larva Photograph Courtesy of: DuPont Crop Protection</p>
Status:	Approved	
Species:	<i>Tuta absoluta</i>	
Species Stage	Larvae L2 (size: 4-5 mm)	
Product Class:	Oxadiazins (IRAC MoA 22), anthranilic diamides (IRAC MoA 28), spinosyns (IRAC MoA 5)	
Comments: In order to obtain homogeneous <i>Tuta absoluta</i> larvae (same age, nutritional and general health condition), it is highly recommended that insects collected from the field (F ₀ generation) are brought to a laboratory and reared to the F1 generation for evaluation of insecticide susceptibility.		

5. Integrate key Tuta control strategies

Integrated Pest Management – non chemical key tactics:

1. GH cleaning and sanitation

- Prevent carry over of the pest from the previous crop; sanitation of the GH for a better start; use pest-free transplants; remove and destroy attacked part plants



2. Physical control - Insect exclusion

- GH modern structures; insect netting; double doors climate control



3. Cultural control - Mass trapping

- Water/oil based and sticky traps pheromone-baited

4. Biocontrol – Natural enemies

- Establish populations of effective biological control agents; select crop protection spray programs safe vs beneficials



5. Mating disruption

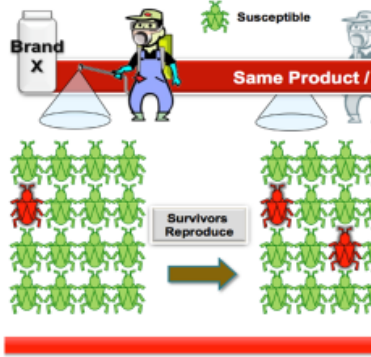
- Mating disruption contribution when low density population of *T. asboluta*

8. Understand Insecticide Resistance Management PRINCIPLES

8. Understand Insecticide Resistance Management Principles

Continuous use of the same Mode of Action removes the susceptible individuals leaving a tolerant population that survives the insecticide application

Possible Scenario for Resistance Develop



8. Understand Insecticide Resistance Management Principles

Rotate MoA Products Within Windows of Time

IRM guidelines below show least to best product rotation recommendations

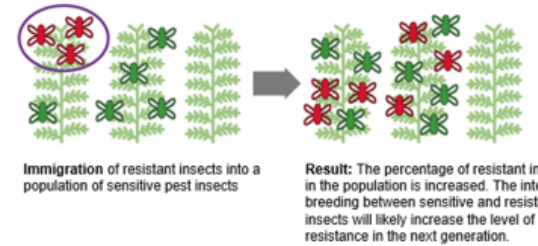
Maintaining insect susceptibility greatly depends on rotation of insecticides with effective products with a different MOA that eliminate resistant individuals. Rotation with products provide poor control of the target pest increases the risk of developing Diamide resistance

Year 1		Year 2		Year 3		Year 4		
1st Gen	2nd Gen	1st Gen	2nd Gen	1st Gen	2nd Gen	1st Gen	2nd Gen	
↑	↑	↑	↑	↑	↑	↑	↑	No alternation/rotation High selection pressure No recover of sensitive population
↑	↑	↑	↑	↑	↑	↑	↑	Rotation within a group Consecutive generations exposed to same MoA. Selection doesn't change before next generation. Risk of development for both
↑	↑	↑	↑	↑	↑	↑	↑	Rotation among groups Following generation exposed to same MoA. Selection pressure doesn't increase in the generation. Recovers susceptible population
↑	↑	↑	↑	↑	↑	↑	↑	Rotation within a group Ideal situation (very rarely achieved) with good efficacy

8. Understand Insecticide Resistance Management Principles

Insect Migration (exchange of Resistant insects) Influences the Speed of Resistance.

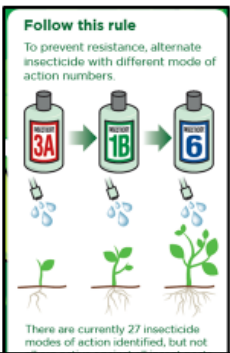
- Resistance levels in pest populations can be INCREASED through immigration of resistant insects. Therefore, the evolution of resistance in the pest population may accelerate.



8. Understand Insecticide Resistance Management Principles

Rotating insecticides with Different Modes of Action Reduces Selection Pressure for Resistance

- Repeated exposure of pest populations to insecticides with the same Mode of Action will select for resistant insects.
- Two successive insect generations shouldn't be treated with insecticides that have the same Mode of Action number (examples 3, 1, 6). Products in Mode of Action subgroups (example 3A) should not be rotated among products within the same MoA group (example 3).



IRAC A Tool to Help You Find Different Product Classes

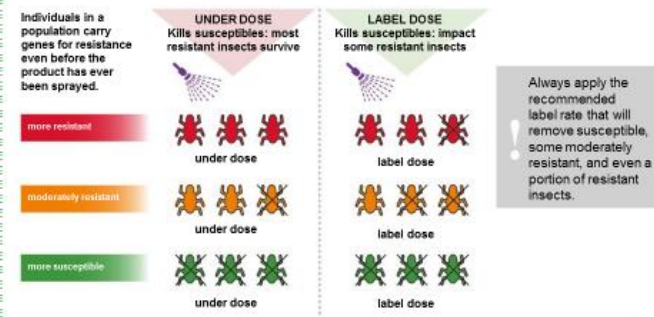
Mode of Action Classification: Phone/Tablet App

Search for: IRAC moa

8. Understand Insecticide Resistance Management Principles

Under-dosing Speeds the Rate of Resistance: Maximize Insect Kill With Every Spray

An under-dosed insecticide application may not remove moderately resistant insects from a pest population. This can accelerate the evolution of resistance



Implementing IPM Removes Resistant Individuals from the Population and Improves Level of Pest Control

Reproductive Capacity Influences the Speed of Resistance

Acquiring the highest level of pest control within a generation removes Resistant genes.



IRM Recommendations for *Tuta absoluta* on Tomato - 1

• Practice Integrated Pest Management

- Remove and destroy infested cull tomatoes and plant material
- Remove all wild Solanaceous and other host plants near greenhouse
- Renovate greenhouse to exclude *Tuta* adults
- Use pheromones and sticky traps to monitor and mass trap adults
- Augment and conserve natural enemy populations
- Apply entomopathic nematodes (*Steinernema feltiae*) in a foliar spray
- Use optimal spray volume, maintain and calibrate spray equipment
- Treat large areas to same MoA
- CALIBRATE/ MAINTAIN sprayers. Clean/replace nozzles.

• 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 insect pest species to the same insecticide modes of action.
- Each window should be approximately 30 days.

• Rotate insecticides with different MoA.

- If more than one insecticide application is required during an application window then it is recommended to use an insecticide with a different MoA.
- Multiple applications of insecticides with the same mode of action within a single window are acceptable as long as combined effects (residual activity) of the applications do not exceed approximately the 30-day window.

• Maximum Number of MoA Applications

- It is preferred to use the same MOA products in only 2 windows per season
- Avoid using the same Mode of Action products in more than 3 windows.

• Insecticide mixtures

Tank mixing products:

- Do not tank-mix insecticide products with the SAME MoA.
- When tank-mixing insecticide products with DIFFERENT MoA's, follow label rates for each insecticide.
- Respect maximum number of applications, PHI and REI stated in the label of each product.
- Product(s) applied on subsequent window/pest generation should have an MoA that is different from both tank-mix partners.

• Avoid insecticides with *Tuta* resistance

Consult with local experts to determine which insecticides are affected by resistance in your locality. A preference to insecticides which are not affected by resistance should be given.

• Preserve non-target & beneficial organisms

The use of selective insecticides with reduced impact on non-target and beneficial organisms is recommended whenever possible.

• Manage the removal of in-season infested stems and fruit

In addition to practicing clean sanitation pre and post season it is critical to remove and destroy plant stems pruned during the season and all cull/waste tomato after each harvest.

• Rotate crops and Incorporate a Host Free Period

- Subsequent crop plantings should be of a different crop type, which is not a host to the insects which are pests of *Tuta*.
- Institute an area-wide fallow period where only non-host crops to *Tuta* can be planted disrupting the life cycle of *Tuta*.



IRM Recommendations for Tuta absoluta on Tomato - 2

MULTIPLE MoA PRODUCTS AVAILABLE
 Different MoA products can be used in the same window but they must be rotated to different MoA products in the next window.

Gen 1	Gen 2	Gen 3
MoA <u>A & B</u>	MoA <u>C & D</u>	MoA <u>A & D</u>

FEW MoA PRODUCTS AVAILABLE
 Apply products with the same MoA in the same window.

Gen 1	Gen 2	Gen 3
MoA <u>A & A</u>	MoA <u>B & B</u>	MoA <u>C & C</u>

- Rotating products with different Modes of Action delays resistance. Don't apply the same Mode of Action continuously:
 - Rotate insecticides with different modes of action using the window approach to minimize exposure of sequential generations of a pest species to the same insecticide MoA.
 - Each "treatment window" should be approximately 30 days.
 - Multiple applications can be made in a window:
 - If more than one insecticide application is required then attempt to use an insecticide with a different mode of action.
 - Multiple applications of insecticides with the same mode of action within a single window are acceptable if their combined residual activity does not exceed approximately the 30-day window.
 - After a "treatment window" of approximately 30 days rotate to a window with different MoA products for approx 30 days.. Allow at 30-60 days before applying the same mode of action again.
- For crops longer than approx. 100 days, use the same MoA products in only 2 windows per season
- For crops less than approx 100 days then use same MoA products in only one window within the crop cycle.
 A short cycle crop (< 50 days) is a "treatment window". Rotate products with different MoA in the next planting.
- Don't treat the crop for more than approximately 50% of the cropping season or 50% of the total number of applications with same MoA

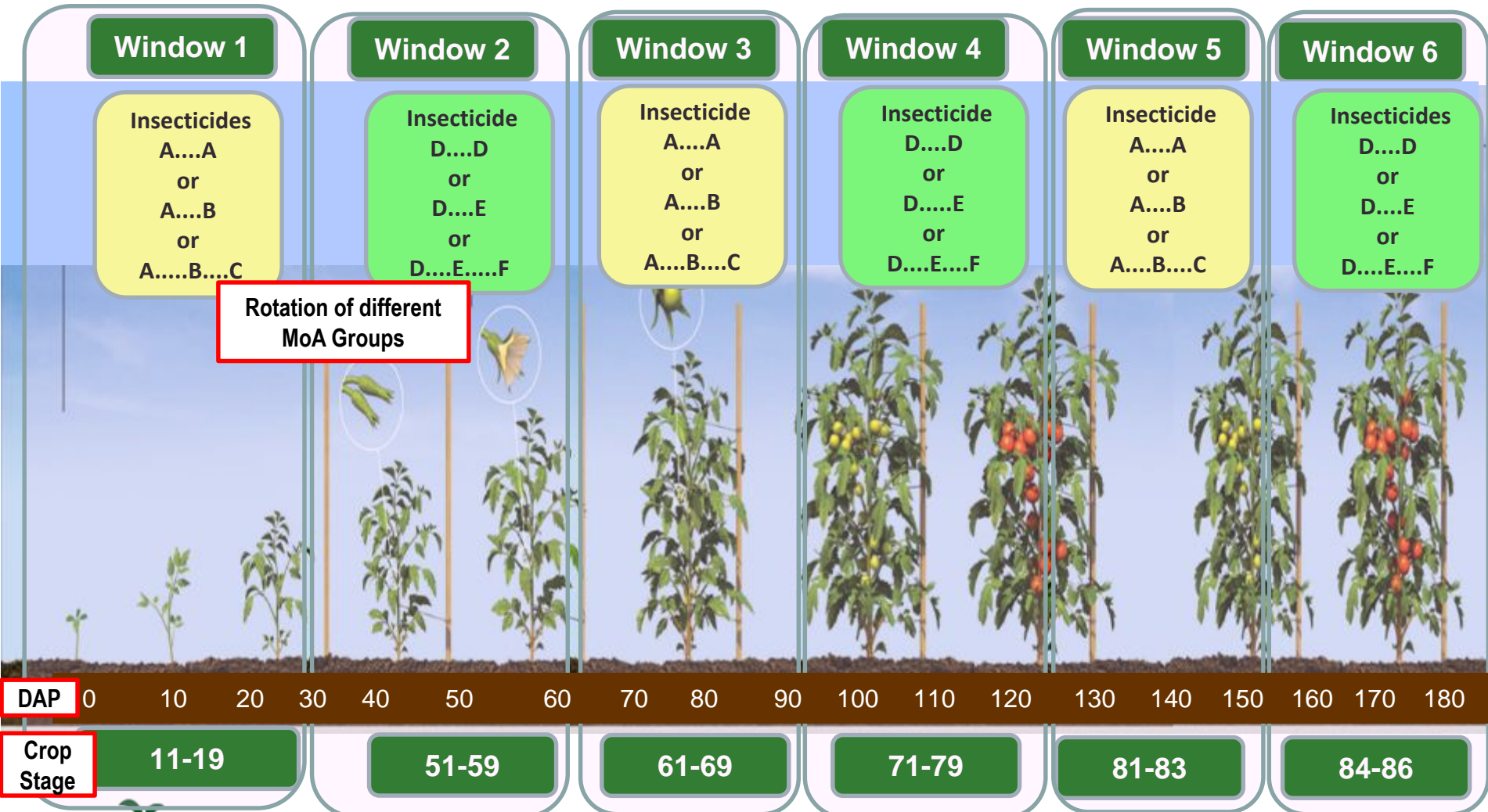


IRM Recommendations for *Tuta absoluta* on Tomato - 3

- **Select insecticides based on known local effectiveness and selectivity to beneficials.**
 - Know the attributes of your pest control products (adulticide, ovicide, larvicide, safety to beneficials, residual, spectrum)
 - Use larvicides to treat young larvae
 - Do not underdose. Follow label rates and intervals
 - Use surfactants (wetting agents) to assure better coverage or methylated seed oil to acquire leaf cuticle penetration. Surfactants may be important to improve the activity of some insecticides.
 - In high populations combine larvicide with adulticide or ovicidal product
- **Use sufficient spray volume.**
 - Maximize coverage to maximize pest kill
- **Whenever possible, use products and mixes that are selective and conserve natural enemies and pollinators**
 - Conserve natural enemies early season so they can assist in pest control season-long.
 - Use B.t.'s and non-chemical products against low *Tuta* populations.
- **Stop using products that are not providing good efficacy. Try that product again next season.**
- **Ideal to treat large areas with the same mode of action product and follow the same window rotation strategy**
- **Tank mix insecticides to control different life stages and manage pest populations.**
- **Rotate solanaceous crops with crops that are not a host to *Tuta*.**

9. Implement Insecticide Resistance Management Strategies

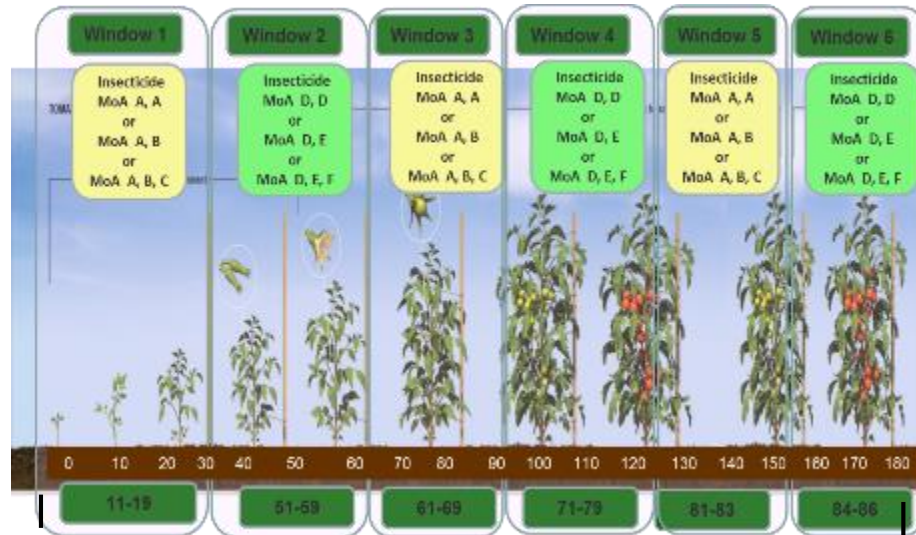
Example: Application Windows for *Tuta absoluta* on Tomato
Do not to use the same insecticide MoA used in a previous window



DAP 0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180

Crop Stage 11-19 51-59 61-69 71-79 81-83 84-86

Pest Population Control and IPM Activities



Pre-Season

- Remove cull piles
- Kill weed hosts
- Renovate GH
- Moth-proof GH (fix screens)
- Monitor adults-Ph Traps
- Choose tolerant varieties
- Use pest free transplants

During-Season

- Manage the removal of in-season infested pruned stems and fruit
- Use pheromones and sticky traps to monitor and mass trap adults.
- Use pheromone dispensers for Mating Disruption
- Spray entomopathic nematodes and nonchemical products that will not select for insecticide resistance.
- Augment and conserve natural enemy populations
- Use optimal spray volume, maintain and calibrate spray equipment

Post-Season

- Remove cull piles
- Kill weed hosts
- Renovate GH
- Moth-proof GH
- Solarize soil
- Rotate to non-host crop & Incorporate a host free period:
 - subsequent crop plantings should be of a different crop type, which is not a host to the insects which are pests of Tuta.
 - Institute an area-wide fallow period where only non-host crops to Tuta can be planted disrupting the life cycle of Tuta

11. Examples of country MoA alternation programs:

IRAC Spain

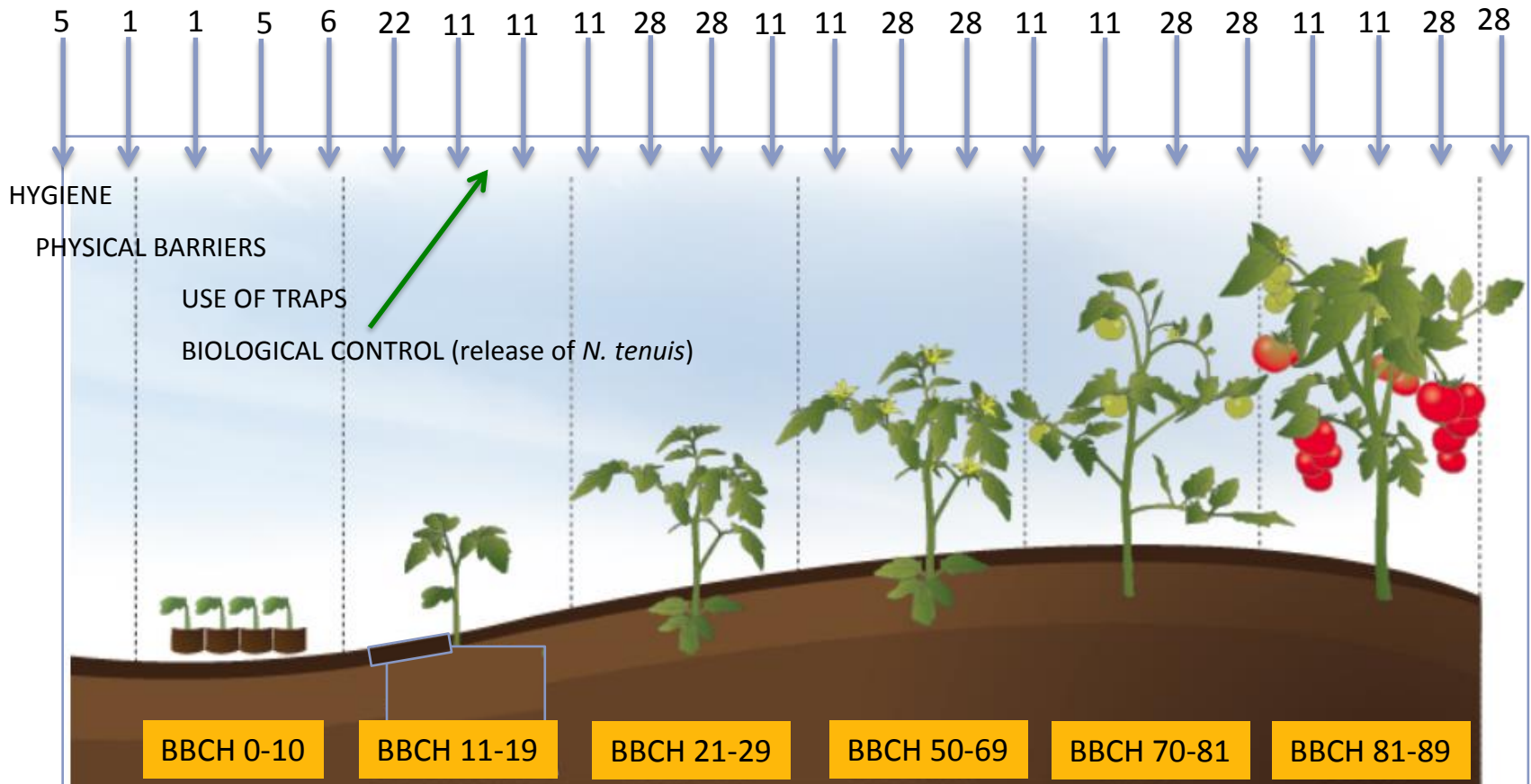
Pest control practices (worse case scenario example):

Example from Murcia: planting 3rd Sep 14 and crop removal 10th July 15

23 applications: 9 BT; 8 Diamides, 2 Spinosad, 1 Emamectine, 1 Indoxacarb and 2 Methomyl.

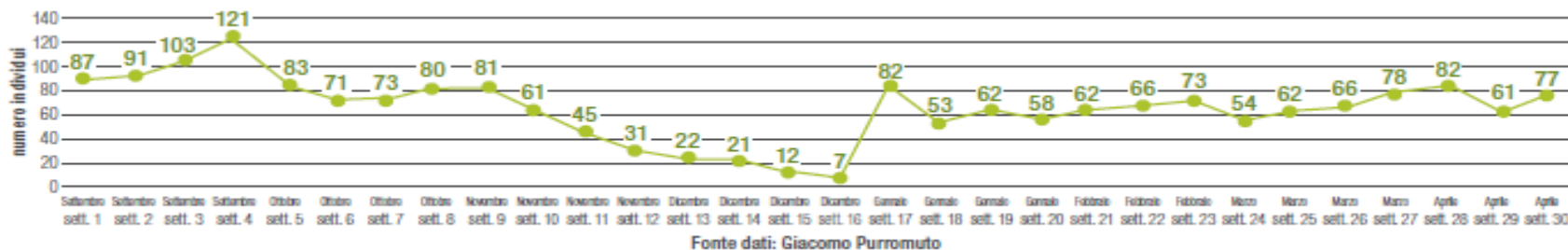
Up to 11 generations/crop cycle => shorter intervals with warm T^a and longer day light.







Product rotation in this case (by MoA):



11. Examples of country MoA alternation programs: Italy (Syngenta)

Flight example **SPRING-SUMMER CYCLE: example of sustainable program**










					
0-30 giorni	30-60 giorni	60-90 giorni	90-120 giorni	120-150	150-180
2 applications of clorantraniliprole	2 applications of Indoxacarb	2 applications of emamectine	2 applications of <i>B. thuringensis</i>	2 applications of Indoxacarb	1 application of emamectine
			In case of more consistent infestation, make 1-2 applications of <i>metaflumizone</i>		In case of persistent infestation, make also 1 application with <i>Spinosad</i>

- In case of high Tuta pressure, and with applications made with short spray interval (7-10 days), integrate the spray calendar with *B. thuringensis*)
- In case of control of other Lepidopteran species, consider insecticides with different Moz (e.g. Lufenuron – IGR)

DO NOT APPLY INSECTICIDES WITH SAME MoA WITHIN 60 DAY FROM THE LAST APPLICATION

11. Examples of country MoA alternation programs:

Italy DuPont™ Greenhouse fall cycle

Descrizione stadio	Post-trapianto (prime foglie sviluppate)	Fase di preparazione palchi fiorali	Fase di fioritura	Continua fioritura e comparsa prime bacche	Colorazione bacche e inizio primi stacchi	Termine fioritura e proseguimento raccolta	Raccolta
Periodo indicativo per trapianti campagna autunnale	1 - 20 sett.	20 sett. - 10 ott.	10 - 31 ott.	1 - 30 nov.	1 dic. - 28 febb.	1 - 31 marzo	1 - 30 aprile
Caratteristiche periodo	Pianta in attiva crescita, elevata pressione <i>Tuta</i>	Pianta in attiva crescita, elevata pressione <i>Tuta</i>	Immissione bombi nelle serre	Presenza bombi nelle serre e calo pressione <i>Tuta</i>	Calo temperatura e quiescenza <i>Tuta</i>	Ripresa pressione <i>Tuta</i>	Ripresa pressione <i>Tuta</i>
							
Stadio BBCH	11 - 19	51 - 59	61 - 69	71 - 79	81 - 83	84 - 86	87 - 89
Prodotti e dosi per ettolitro	2 trattamenti con Steward® 12.5 g + bagnante (intervallo 10-12 gg fra primo e secondo tratt.)	2 trattamenti con Spinosad 25 ml (intervallo 10 gg fra primo e secondo tratt.)	2 trattamenti con Altacor® 12 g + Codacide® (intervallo 7-10 gg fra primo e secondo tratt.)	2 trattamenti con emectinabenzoato® 150 g (intervallo 7-10 gg fra primo e secondo tratt.)	Trattamenti con <i>Bacillus thuringiensis</i> (intervallo 8-10 gg fra i tratt.)	2 trattamenti con Steward® 12.5 g + bagnante (intervallo 10-12 gg fra primo e secondo tratt.)	Trattamenti con <i>Bacillus thuringiensis</i> (intervallo 8-10 gg fra i tratt.) o con Spinosad in caso di infestazioni perduranti



Group 22A
Oxadiazine



Group 5
Spinosins



Group 28
Diamides



Group 6
Avermectines



Group 11
Bacillus



Group 22A
Oxadiazine



Group 11
Bacillus

11. Examples of country MoA alternation programs: IRAC Training Tuta Poster



Insecticide Resistance Action Committee

The Tomato Leafminer / Tomato Borer, *Tuta absoluta* Recommendations for Sustainable and Effective Resistance Management

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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 increases 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



Source: from Hernandez et al. (2008)

Larval Developmental Time at Different Temperatures	Days
14°C	35 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 80 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 effective and sustainable management of *Tuta absoluta* is the integration of cultural, behavioural, biological and chemical control.



Key Management Tactics

- Use pest-free transplants
- Prior to transplanting, install yellow sticky traps
- Monitor pest using delta phenomex 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 new substrate for *T. absoluta*
- 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
- Control weeds to prevent multiplication in alternative host
- Establish populations of effective biological control agents (e.g. *Neelidoborus renalis*)
- Use locally established thresholds to trigger insecticide applications
- Select insecticides based on known local effectiveness and selectivity
- Rotate insecticides by MoA group using a gap/sequence 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. See IRAC Method No. 022 on the IRAC Website.



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 Window Approach:

- The basic rule for adequate rotation of insecticides by mode of action (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 or different MoA's 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, different and effective MoA's should be selected for use in the next 30 days (second MoA window). Similarly, a third MoA window should use different MoA's 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 90 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/effective against *T. absoluta*.

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



Notes:

- Within a "window" (MoA 1, 2 or 3 in the diagram above) more than one application of the same MoA or different MoA's can be applied if necessary and depending on label advice, as long as these MoA's are not re-applied for 90 days as indicated above.
- Following the "window rotation scheme", example above, use as many effective MoA groups as locally registered/effective and always follow product labels for specific directions of use.
- For a comprehensive list of existing insecticides classified by MoA group visit the IRAC website (www.irc-online.org/terms-of-action).

12. Guidance for Locally Adapting and Implementing IRM Strategies

Checklist for country implementation teams to initiate and maintain IRM plan

- Step I Organize-Meet-Align: A team of industry, university, local experts, and consultants
- Step II Understand the common objectives and expectations of the team – Pick a Leader
- Step III Review IRAC's Code of Conduct & Antitrust Rules
- Step IV Select target locations/growers/areas of common farming practices to focus effort
- Step V Adapt regional Tuta IRM BMP guidelines to local area
- Step VI Develop a plan to implement the IRM BMP strategies to focus areas
- Step VII Develop plan to best communicate MOA to growers and Tuta industry
- Step VIII Develop plan to educate growers & the ag community
- Step IX Communicate advantages of IRM & grower's responsibility to practice IRM
- Step X Implement MoA communication, IRM strategies, grower/influencers education plans
- Step XI Plan to take a leadership role once resistance occurs