Tuta absoluta: Insecticide Resistance Management Principles and Recommendations

IRAC Tuta IRM Task Team – 2017 (v6)
Best Management Practices to Control Tuta and Manage Insect Resistance

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8. Understand Insecticide Resistance Management PRINCIPLES
Continued Use of the Same MoA Products Throughout the Season Will Increase # of Resistant Individuals and Spray Expenses

- Number & timing of applications influence speed of resistance
- When insecticides with the same mode of action (MoA) are used repeatedly, exposing multiple consecutive pest generations, less sensitive individuals survive and resistance can evolve.
- Continued use accelerates resistance and multiplies the resistant genes in the population
- Farmers will increase rates to improve control, accelerating resistance.
- Excessive tank mixing with adjuvants and other insecticides increases
- Pest control becomes expensive
Continuous use of the same Mode of Action removes the susceptible individuals leaving a tolerant population that survives the insecticide application.
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.

Individuals in a population carry genes for resistance even before the product has ever been sprayed.

**Under DOSE**
- Kills susceptibles: most resistant insects survive

**LABEL DOSE**
- Kills susceptibles: impact some resistant insects

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

Always apply the recommended label rate that will remove susceptible, some moderately resistant, and even a portion of resistant insects.

*Understand Insec&cide Resistance Management Principles*

*Increasing dose*
- more resistant
- moderately resistant
- more susceptible

*Increasing dose*
- under dose
- label dose

*Increasing dose*
- under dose
- label dose
8. Understand Insecticide Resistance Management Principles

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

- Need to remove individuals with at least one resistant gene (RS)
- Need high level of control for an entire insect generation – prevent gene transfer
- Need back to back sprays of products with different or same mode of action if adult flights and egg laying continues
Resistance levels in pest populations can be increased through immigration of resistant insects. Therefore, the evolution of resistance in the pest population may accelerate.
Species with a higher reproductive capacity have a higher risk of developing resistance.

*Tuta absoluta* can have up to with up to 10 - 14 generations per year.

Temperature drives reproductive capacity. High temperatures increase the number of generations per year and can accelerate rate of resistance.
8. Understand Insecticide Resistance Management Principles

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

- Diversify insect control methods: Integrate cultural (sanitation), physical (mass trapping, exclusion), biological (beneficials, pheromones), and chemical control methods
- Monitor pest populations to determine the correct timing of application at the action spray threshold
- Apply the right product at the recommended life stage
- Follow labeled application rates and intervals
- Calibrate sprayer and maintain nozzles and equipment
- Use optimal spray volumes and best management technique
- Select insect control products that are compatible with natural enemies. Allow the simultaneous use of both strategies to more completely reduce a pest population.
- Avoid using products that will reduce non-target organisms
- Adjust water pH and use adjuvants if necessary
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).

Follow this rule

To prevent resistance, alternate insecticide with different mode of action numbers.

There are currently 27 insecticide modes of action identified, but not all are active against all insect pests.
Rotation of insecticides with different modes of action prevent the build up of resistant individuals in the field. This IRM strategy ensures that most resistant survivors from the MOA 1 spray(s) will be killed by the subsequent rotation of products containing different modes of actions.

After an insecticide is sprayed, the surviving insects will reproduce and the offspring will be less sensitive.

Under permanent selection pressure, the overuse of the same insecticide mode of action can select for less and less susceptibility and a resistant population will evolve.
8. Understand Insecticide Resistance Management Principles

Exposing fewer pest generations in a season to insecticides with the same MoA reduces selection pressure for resistance

Rotate MoA Products **Within Windows of Time**

Mode of Action Gap 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 of the same MoA group, by using a scheme of "MoA gap".
- A MoA gap is here defined as a period of 60 consecutive days, based on the maximum duration of a single generation of *T. absoluta*.
- A MoA sequence is here defined as one or more consecutive applications of insecticides belonging to a particular MoA group.
- After the last treatment of a MoA sequence, wait at least 60 days for new applications with insecticides of that MoA (follow label for maximum number of consecutive applications and per crop cycle).

![Diagram showing MoA sequence with a gap](image-url)

- The proposed scheme seeks to minimize the selection of resistance to any given MoA group by allowing a gap between MoA sequences, ensuring that consecutive generations of *T. absoluta* are not exposed to the same insecticide MoA group.
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 that provide poor control of the target pest increases the risk of developing Diamide resistance.

<table>
<thead>
<tr>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Gen</td>
<td>2nd Gen</td>
<td>1st Gen</td>
<td>2nd Gen</td>
</tr>
<tr>
<td>1st Gen</td>
<td>2nd Gen</td>
<td>1st Gen</td>
<td>2nd Gen</td>
</tr>
<tr>
<td>1st Gen</td>
<td>2nd Gen</td>
<td>1st Gen</td>
<td>2nd Gen</td>
</tr>
<tr>
<td>1st Gen</td>
<td>2nd Gen</td>
<td>1st Gen</td>
<td>2nd Gen</td>
</tr>
</tbody>
</table>

**No alternation/rotation**
High selection pressure
No recover of sensitive population

**Rotation within generation**
Consecutive generation exposed to same MoA. Selection pressure doesn’t change between generation. Risk of resistance development for both ai’s

**Rotation among generations**
Following generations are not exposed to same MoA. Selection pressure doesn’t increase within the generation. Recovery of susceptible population.

**Rotation within and between**
Ideal situation (very low risk) Not always applicable with good efficacy

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

- **Save money**
  - No need to increase number of insecticide applications
  - Reduces need for more expensive products or control methods
  - Helps achieve better pest control and improved yield

- **Save time**
  - Spend less time in the field making repeat applications
  - Less effort and worry trying to achieve effective pest control

- **Enhance safety of produce**
  - Better assurance of consistent crop protection
  - Minimizes residue risk on produce

- **Protect your health and your land**
  - Less active ingredient applied to ecosystem
  - Better worker safety due to fewer applications and less exposure

Source: IRAC
Mode of Action Classification: Phone/Tablet App (It's Free!!)

Search for: IRAC moa
9. Understand Insecticide Resistance Management STRATEGIES
Manage Insecticide Resistance: Follow These Recommendations

- The following IRM recommendations have been developed by the International IRAC organization, Country IRAC Groups, Country Resistance Action Groups, with leading local experts.
- This information is intended to provide the basis for developing an effective pest management program that minimizes the risk of insecticide resistance.
- These are general guidelines and will not fit all crop production systems. Adapt these recommendations and strategies to your local needs.
9. Implement Insecticide Resistance Management Strategies

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
  - Rennovate 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 modes of action.**
  - If more than one insecticide application is required during an application window then it is recommended 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 as long as combined effects (residual activity) of the applications do not exceed approximately the 30-day window.

- **Maximum Number of MoA Applications**
  - Adviseable 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.
9. Implement Insecticide Resistance Management Strategies

**IRM Recommendations for Tuta absoluta on Tomato - 2**

- 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 approximately 100 days, use the same MoA products in only 2 windows per season
- For crops less than approximately 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.

### 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.

<table>
<thead>
<tr>
<th>Gen 1</th>
<th>Gen 2</th>
<th>Gen 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>MoA A &amp; B</td>
<td>MoA C &amp; D</td>
<td>MoA A &amp; D</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Gen 1</th>
<th>Gen 2</th>
<th>Gen 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>MoA A &amp; A</td>
<td>MoA B &amp; B</td>
<td>MoA C &amp; C</td>
</tr>
</tbody>
</table>
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

Window 1
- Insecticides
  - A....A
  - or
  - A....B
  - or
  - A.....B....C

Rotation of different MoA Groups

Window 2
- Insecticide
  - D....D
  - or
  - D....E
  - or
  - D....E.....F

Window 3
- Insecticide
  - A....A
  - or
  - A....B
  - or
  - A....B....C

Window 4
- Insecticide
  - D....D
  - or
  - D.....E
  - or
  - D....E....F

Window 5
- Insecticide
  - A....A
  - or
  - A....B
  - or
  - A....B....C

Window 6
- Insecticides
  - D....D
  - or
  - D....E
  - or
  - D....E....F

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

Rotation of different MoA Groups
9. Implement Insecticide Resistance Management Strategies

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
- Sprat entomopathic nematoeds 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.
9. IRAC Poster: Implement Insecticide Resistance Management Strategies

IRAC general IRM strategy recommendations available as handout and poster
11. Examples of country IRM programs with Mode of Action rotation: Spain, Italy, Greece, Portugal
11. Examples of country MoA alternation programs:

Spain

Pest control practices (general example):
Example: planting Sep and crop removal July.
12-16 applications (as average in a long crop cycle)

Product rotation in this case (by MoA):

<table>
<thead>
<tr>
<th>3A</th>
<th>6</th>
<th>22</th>
<th>5</th>
<th>11</th>
<th>28</th>
<th>28</th>
<th>UN</th>
<th>UN</th>
<th>11</th>
<th>11</th>
<th>28</th>
<th>28</th>
<th>11</th>
<th>UN</th>
</tr>
</thead>
</table>

HYGIENE

PHYSICAL BARRIERS

USE OF TRAPS

BIOLOGICAL CONTROL (release of *N. tenuis*)

BBCH 0-10  BBCH 11-19  BBCH 21-29  BBCH 50-69  BBCH 70-81  BBCH 81-89
11. Examples of country MoA alternation programs: 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 T³ and longer day light.

Product rotation in this case (by MoA):
11. Examples of country MoA alternation programs: Portugal – Open Field

Pest control practices (general example):
Example from Portugal industry –open field-: planting Mar-Jun and crop removal Aug-Oct
3-5 applications: Diamides, Emamectine, Pirethrins (farmers try to rotate)

Product rotation example (by MoA):
11. Examples of country MoA alternation programs: Italy (Syngenta)

SPRING-SUMMER CYCLE: example of sustainable program

- **In case of persistant infestation**, make also **1 application with Spinosad**
- **Apply products with different MoA** (eg. Indoxacarb, metaflumizone)
- **2 applications with emamectine**
- **2 applications with clorantraniliprole**
- **1 application with emamectine**

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

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**DO NOT APPLY INSECTICIDES WITH SAME MoA WITHIN 60 DAY FROM THE LAST APPLICATION**
11. Examples of country MoA alternation programs: Italy (Syngenta)

Flight example  SPRING-SUMMER CYCLE: example of sustainable program

- In case of control of other Lepidopteran species, consider insecticides with different MoA (e.g. Lufenuron – IGR).

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

- 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 more persistent infestation, make 1-2 applications of metaflumizone with *Spinosad*.

- In case of more consistent infestation, make also 1 application with *Spinosad*.

- 2 applications of clorantraniliprole
- 2 applications of Indoxacarb
- 2 applications of emamectine
- 2 applications of *B. thuringensis*
- 2 applications of Indoxacarb
- 1 application of emamectine

0-30 giorni  30-60 giorni  60-90 giorni  90-120 giorni  120-150 giorni  150-180 giorni

*Fonte dati: Giacomo Purromuto*
11. Examples of country MoA alternation programs:

**Italy**  
**DuPont™ Greenhouse fall cycle**

<table>
<thead>
<tr>
<th>Descrizione stadio</th>
<th>Post-trapianto (prime foglie sviluppate)</th>
<th>Fase di preparazione palchi fiorali</th>
<th>Fase di fioritura</th>
<th>Continua fioritura e comparsa prime bacche</th>
<th>Colorazione bacche e inizio primi stacchi</th>
<th>Termine fioritura e proseguimento raccolta</th>
<th>Raccolta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Periodo indicativo per trapianto campagna autunnale</td>
<td>1 - 20 sett.</td>
<td>20 sett. - 10 ott.</td>
<td>10 - 31 ott.</td>
<td>1 - 30 nov.</td>
<td>1 dic. - 28 febb.</td>
<td>1 - 31 marzo</td>
<td>1 - 30 aprile</td>
</tr>
</tbody>
</table>

| Caratteristiche periodo | Pianta in attiva crescita, elevata pressione *Tuta* | Pianta in attiva crescita, elevata pressione *Tuta* | Immissione bombi nelle serre | Presenza bombi nelle serre e calo pressione *Tuta* | Calo temperatura e quiescenza *Tuta* | Ripresa pressione *Tuta* | Ripresa pressione Tuta |

**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 enemecinabenzato 150 g (intervallo 7-10 gg fra primo e secondo tratt.)
- Trattamenti con *Bacillus thuringiensis* (intervallo 8-10 gg fra i tratt.)
- 2 trattamenti con Steward® 12.5 g + bagnante (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

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*x2*  
*x2*  
*x2*  
*x2*  
*x2/3*  
*x2*  
*x2/3*
### 11. Examples of country MoA alternation programs:

**Italy DuPont Greenhouse spring/summer cycle**

<table>
<thead>
<tr>
<th>Product</th>
<th>Rate 1000 m²</th>
<th>IRAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steward + Codacide</td>
<td>12,5g + 150 ml</td>
<td>Group 22</td>
</tr>
<tr>
<td>Steward + Codacide</td>
<td>12,5g + 150 ml</td>
<td>Group 22</td>
</tr>
<tr>
<td>Spinosad + bagnante</td>
<td>30 ml + 0,02 V/V</td>
<td>Group 5</td>
</tr>
<tr>
<td>Spinosad + bagnante</td>
<td>30 ml + 0,02 V/V</td>
<td>Group 5</td>
</tr>
<tr>
<td>Altacor + Codacide</td>
<td>12 g + 150 ml</td>
<td>Group 28</td>
</tr>
<tr>
<td>Altacor + Codacide</td>
<td>12 g + 150 ml</td>
<td>Group 28</td>
</tr>
<tr>
<td>Emamectina Benzoato 0,95% + Bagnante</td>
<td>150 ml + 0,02 V/V</td>
<td>Group 6</td>
</tr>
<tr>
<td>Emamectina Benzoato 0,95% + Bagnante</td>
<td>150 ml + 0,02 V/V</td>
<td>Group 6</td>
</tr>
<tr>
<td>Steward + Codacide</td>
<td>12,5g + 150 ml</td>
<td>Group 22</td>
</tr>
<tr>
<td>Steward + Codacide</td>
<td>12,5g + 150 ml</td>
<td>Group 22</td>
</tr>
</tbody>
</table>

**Rules for the proper use of insecticides and the best of resistance management strategy:**

1. Respect label rates and do not use the products in drip irrigation if not provided on the label.
2. Respect intervals between treatments provided and max. number of applications per year.
3. Use only products and active ingredients registered on the crop.
4. Make the required rotations of active ingredients suggested by the label and IRAC.
5. During the crop cycle use the greatest number of active ingredients effective against *Tuta*.
6. Do not use insecticides in mixtures.
7. Do not use active ingredients with low activity in the control of *Tuta absoluta*. 
11. Examples of country MoA alternation programs:

ITALY

Tuta absoluta: pest control practice

1. Buy plants from nursery free of infestations
2. Clean the field from crop residues, use mulching, solarization, and nets for insect exclusion
3. Monitoring: use pheromone traps for monitoring the flight curve and then decide the control strategy to adopt
4. Remove the infested parts from the GH and destroy them
5. Select the product to be applied according to the label recommendation (dose, spray interval, number of applications)
6. Rotate the insecticides available, following the IRAC recommendations
7. Release favorite beneficials
11. Examples of country MoA alternation programs:

DuPontGreece Greenhouse

Tuta absoluta: Διαθέσιμα εργαλεία και διαχείριση ανθεκτικότητας
11. Examples of country MoA alternation programs:
Greece Greenhouse – Roditakis et al
11. Examples of country MoA alternation programs:
IRAC Training Tuta Poster

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

**Risk for Insecticide Resistance Development:**
*T. absoluta* (Meyrick) (Lepidoptera: Gelechiidae) is a pest of great economic importance in a number of countries. Its primary host is tomato, although potato, submerge, bean, and various wild solanaceous plants are also suitable hosts. *T. absoluta* is characterized by high reproduction potential. Each female can lay up to 300 eggs and 10-12 generations can be produced each year. In tomatoes, it attacks all plant parts and crops, developing stages from the larvae prefer apical buds, tender leaves, flowers, and green fruits and can mature up to 100% of the crop. This pest is crossing borders and devastating tomato production in protected and open fields. Originally from Latin America and the Caribbean, 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 *T. 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. Insect resistance usually leads to increases in the frequency of use and, in turn, the selection pressure. As a result, field populations of *T. absoluta* resistant to a range of active ingredients are already known from Latin 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 mostly imported from Latin America and thus may already express high levels of resistance to one or more insecticide classes. It is therefore essential to evaluate the susceptibility of *T. absoluta* in each geography before specific recommendations are made for their use within IPM (Integrated Pest Management) and IRM (Insecticide Resistance Management) programs.

**Insect Description and Life Cycle**
*T. absoluta* is a micro lepidopteran insect. The adults are alight brown, 5-7 mm long. The total life cycle is completed in an average of 21-40 days, with the exception of winter months, when the crop could be extended to more than 90 days. The minimal temperature for biological activity is 10°C.

**Management Strategy**

**Key Management Strategies**

**Use neonicotinoids**

- Prior to transplanting, apply yellow sticky traps
- Monitor pest using delta-phenone indicator traps
- Between planting cycles, cultivate the soil and cover with plastic mulch or perforated striped
- Allow a minimum of 4 weeks from crop destruction to next crop planting
- Seed greenhouse structure with high quality nets suitable for *T. absoluta* to protect the crop from the first signs of damage

**For massive trapping, use water + oil traps (20-40 traps/ha)**

- Continuously, remove and destroy attacked plant parts
- Control weeds to prevent multiplication in alternative host
- Establish populations of effective biological control agents (e.g. *Haestodectes tenellus*)
- Usually establish thresholds to trigger insecticidal applications
- Select insecticides based on known local effectiveness and selectivity
- Rotate insecticides by MoA group using a rotation approach
- Use only insecticides registered for control of *T. absoluta*
- Always follow the directions for use on the label of the product.

**Insecticide Resistance Management**

- Resistance status in L. America vs. Europe, N. Africa, and Middle East: In L. America, high levels of widespread resistance is known in field populations of *T. absoluta* resistance to organophosphates (MoA group 1B), synthetic pyridiniols (MoA group 3), and benzoylureas (MoA group 19). 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 "Luck" test laboratory method to assess susceptibility of field populations to insecticides. See IRAC Method No. 020 on the IRAC website.

**Insecticide Resistance Management (IRM):**

- The recommendations for using effective and susceptible insecticides are on the basis of integrated pest management, 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 using consecutive generations of targeted pests with insecticides in the same MoA group, by using a scheme of "MoA treatment windows."
- A treatment window is 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 MoAs may be possible within a particular window (allow 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 insecticidal applications are needed based on thresholds, different and effective MoAs should be selected for use in the next 30 days (second window). Similarly, a third MoA window should use different MoAs for the subsequent 30 days.
- 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 60-day gap ensures the potential of a full life cycle, temperature fluctuation through the growing season.

This scheme requires a minimum of three effective insecticide MoA groups but ideally 4 MoA groups should be included, ideally registered/available against *T. absoluta*.