# Integrated Pest Management Manual for Tomato leaf miner (*Tuta absoluta*)

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*Tuta absoluta* moth

# About SCLAMP-EA project

Scaling-up Climate-Smart Pest Management Approaches for Enhanced Maize and Tomato Systems Productivity in Eastern Africa (SCLAMP-EA) is a project funded by German Corporation for International Cooperation (GIZ). It is a 3-year project running from 2020 to 2022.

The purpose of the project is to facilitate the large-scale adoption of proven and piloted Climate Smart Pest Management (CSPM) technologies and practices by smallholder farmers to improve their food and nutrition security through mitigating yield losses due to key insect pests in maize and tomato.

The projects' target areas are:

Ethiopia (Southern/SNNPR in Dawuro, Angacha and Shebedino; Northern/Amhara in South Wollo and Western Oromia Region in Sasiga and Diga); and

Uganda (Central Uganda in Rakai and Kyotera; Eastern Uganda in Kamuli, Namutumba, Mbale and Kween; and Northern Uganda in Amuru, Nwoya, Adjumani and Pakwach/ Southern West Nile).

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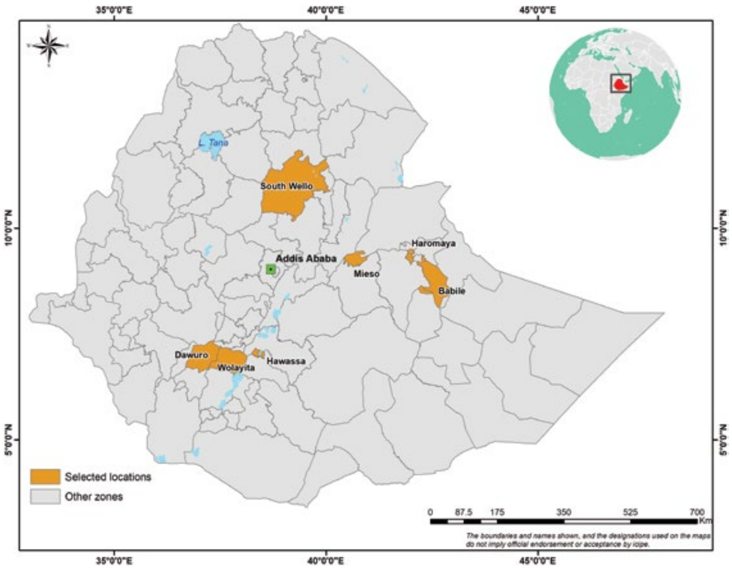
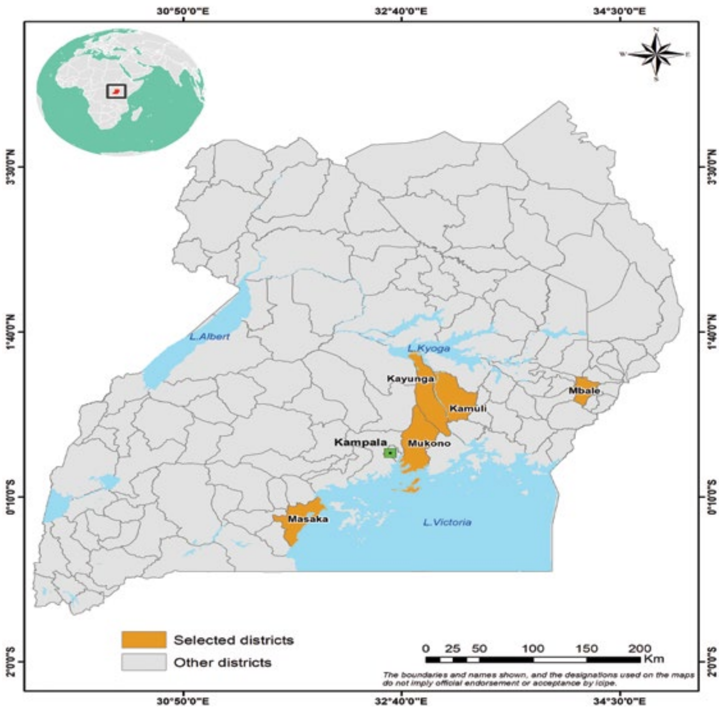
## Map showing SCLAMP-EA project areas in Ethiopia (top) & Uganda (bottom).



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## Purpose of the manual

The purpose of this manual is to present Integrated Pest Management (IPM) practices that are recommended to be implemented by tomato growers. These IPM practices will reduce damage caused by Tomato leaf miner (*Tuta absoluta*), increase yield and quality of tomato, protect the environment and safeguard human health – through reduced use of synthetic chemicals.

This manual provides description of *T. absoluta*, symptoms of damage and available management options.

## Objective of the manual

The fundamental objective of this manual is to strengthen the practice of IPM for *T. absoluta* in Uganda and Ethiopia. The challenge currently being faced by smallholder farmers and extension officers is the lack of adequate information on available IPM practices. Consequently, there is low adoption rate of IPM practices and overreliance on synthetic chemicals for pest and disease control.

## Abbreviations

| | |
|---|---|
| CABI | Centre for Agriculture and Bioscience International |
| cm | Centimetre |
| CSPM | Climate Smart Pest Management |
| EIL | Economic Injury Level |
| FAO | Food and Agriculture Organization |
| GAP | Good Agricultural Practices |
| GIZ | German Corporation for International Cooperation |
| ha | Hectare |
| *icipe* | International Centre of Insect Physiology and Ecology |
| IPM | Integrated Pest Management |
| m | metre |
| RH | Relative Humidity |
| SCLAMP -EA | Scaling-up Climate-Smart Pest Management Approaches for Enhanced Maize and Tomato Systems Productivity in Eastern Africa |
| USD | United States Dollar |

# Introduction

Tomato (*Solanum lycopersicum*) is one of the most widely cultivated vegetable crops in Africa. Tomatoes are highly nutritious, containing substantial amounts of Vitamin A and Vitamin C, and therefore play an important role in food security and nutrition. They are often consumed raw, as an essential ingredient in many dishes, sauces, salads and drinks. Tomato is an important cash crop for farmers, providing employment opportunities in the value chain.

In the 2018 cropping calendar, tomato production in Ethiopia was 43,816 tons from a harvested area of 7,089 ha, and in Uganda, 39,462 tons from a harvested area of 7,200 ha. The average yields of tomato in Ethiopia and Uganda are 6 ton ha-1 and 5 ton ha-1 respectively, which is very low compared with world average yields of 38 ton ha-1 (FAOSTAT, 2018).

The crop is grown throughout the year in open fields and in greenhouses; however, production is constrained by biotic (pests and diseases) and abiotic (low moisture stress and low soil fertility) factors. The common tomato pests are whiteflies, American bollworm, aphids, leaf miners, red spider mites, thrips and nematodes (CABI, 2015). Diseases affecting tomato production are wilts, blights, leafspots and mildew. Recently, tomato has been highly affected by an invasive insect pest, *Tuta absoluta*, which is commonly known as tomato leafminer.

*Tuta absoluta* is a small yet highly destructive pest that affects mainly tomatoes, as well as other Solanaceous plants. The pest is currently the major limiting factor for tomato production, worldwide. Without adequate control, *T. absoluta* infestation can result in tomato yield losses of up to 100%. *Tuta absoluta* causes widespread damage to tomato crops by mining the leaves. These mines are formed by the larvae (caterpillars). Leaf mines are wide, silvery, and gradually become brown and necrotic. Leaf necrosis may result in leaf death or premature leaf drop. Mines in the fruit can also lead to fruit rot.

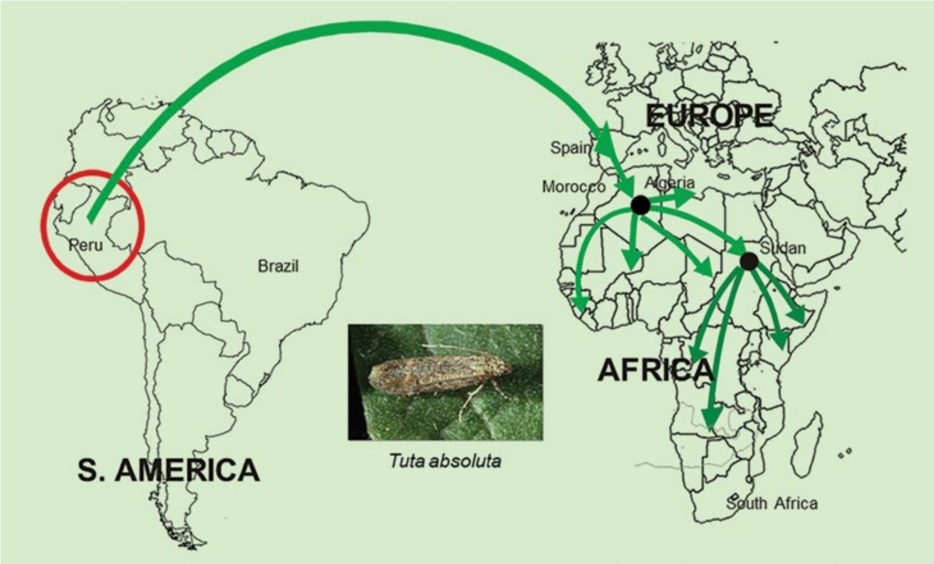


**Figure 1: *T. absoluta* invasion pathway**

*Tuta absoluta* originated from South America and from 2006, it invaded several countries in Europe, Africa and Asia, causing extensive economic damage (Figure 1). *T. absoluta* was first detected in North Africa (Tunisia and Morocco) in 2008 and has since spread to 41 of the 54 African countries. The pest was reported in Ethiopia in 2012 and in Uganda in 2015.

The impacts of the pest include:

- severe yield loss
- reduction of crop quality
- increasing tomato prices
- regional bans on the trade of tomato including seedlings.

More importantly, the widespread dispersion of the pest has led to a massive increase in synthetic insecticide applications, the disruption of integrated management programmes for other tomato pests, and an increase in the cost of crop protection. The use of synthetic insecticide has also posed a health risk for growers, consumers and the environment.

Farmers in Africa currently depend solely on the use of synthetic chemicals for the control of *T. absoluta*. However, such practices are unsustainable due to the above-mentioned reasons.

Good Agricultural Practices (GAP) and Integrated Pest Management (IPM) are essential components of sustainable agriculture (Table 1).

Integrated Pest Management is an ecosystem-based approach to crop production and protection that combines different management practices to grow healthy crops and minimize the use of pesticides. Integrated Pest Management emphasizes the growth of a healthy crop, with the least possible disruption to the ecosystems.

The best way to control both pests and diseases is to keep plants healthy.

**Table 1: Good agricultural practices**

| |
|---|
| **Build healthy soil** that provides a home to friendly insects and provide crops with adequate nutrients. |
| **Ensure that soil moisture is adequate** to prevent moisture stress. |
| **Use resistant varieties**. Plant seeds which are resistant to common pests and diseases. |
| Use **recommended spacing** for each crop. Planting crops too close together limits the sunshine and air that reaches the leaves, and allows diseases to thrive. But planting crops farther apart leaves room for weeds, dries the soil, and may reduce the harvest. |
| **Plant at the right time**. Pests and diseases often respond to the weather, such as the first rains. Planting with the first rains can make crops benefit from nitrogen rush, and the crops will be mature enough to resist pests or diseases that come at a certain time. |
| Ensure **crop diversity** through intercropping, and practise agro-forestry. Large areas with only one kind of plant attract pests. |

# Biology and lifecycle of *T. absoluta*

The female moth lays up to 260 eggs, mostly singly, on leaves, stems and young fruit. The larvae bore between the epidermal layers of the leaf, creating mines and, when older (at the $3^{rd}$ to $4^{th}$ instar), they leave these mines and travel to new locations to mine again.

Young larvae usually attack the leaves, but can be found in growing points and in the flower. Later-stage larvae tend to attack the fruit. Pupation happens in the mine, outside the mine, or in the soil.

At 20 ˚C, the average developmental period from egg to adult is 40 days.

Knowing the life cycle of *T. absoluta* (Figure 2) can help with selecting and understanding pest management methods.

Adult moths are active during night and hide between leaves during the day. Females live for two weeks, whereas the males live for one week. *Tuta absoluta* has a high reproductive potential, capable of up to 12 generations per year.

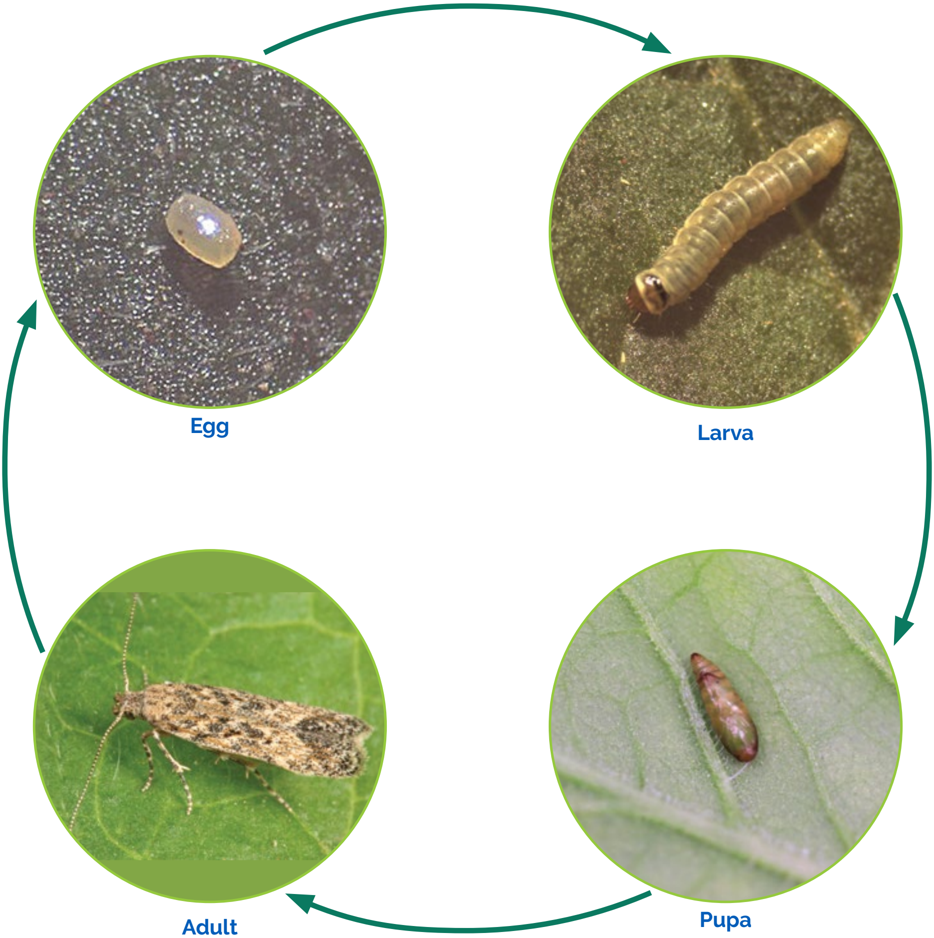


**Figure 2: Lifecycle of *T. absoluta***

# Host plants

Tomatoes are the main host plants of *Tuta absoluta*. It can also feed, develop and reproduce on other cultivated Solanaceous plants, namely eggplant (***Solanum melongena*** L.), potato (***Solanum tuberosum*** L.), sweet pepper (*Solanum muricatum* L.) and tobacco (*Nicotiana tabacum* L). It infests wild Solanaceae such as Black nightshade (*Solanum nigrum* L.), Common Thorn-apple (*Datura stramonium* L.) and Glaucous tobacco (*Nicotiana glauca*).

## Symptoms and nature of damage

Tomato plants can be infested by *T. absoluta* at all growth stages, from seedlings to mature plants. The larvae attack leaves, stems, flowers and fruits. In leaves, the larvae feeds in between leaf tissues, making irregular-shaped mines (Figure 3). The mines increase in length and width as the larvae develop. When the population levels are high, leaf mines merge, causing entire leaves and stems to turn brown and die (Figure 4). This reduces photosynthetic ability, therefore reducing crop yield. As the larvae feed, they excrete copious amounts of frass. In shoots, larvae of *T. absoluta* usually gain entry through the apical end or at the angle formed between the petioles and the leaves. The larva usually enters the fruit under the calyx and tunnels the flesh, leaving galleries clogged with frass. *Tuta absoluta* causes cosmetic damage to tomato fruits (Figure 5) and entry holes act as pathways for pathogens that cause fruit rot (Figure 6).

**Figure 3: *T. absoluta* caterpillar eating away the green part of the leaf. Note the black frass**

**Figure 4: Tomato leaves drying up due to damage by *T. absoluta***

**Figure 5: Blemishes on tomatoes as a result of *T. absoluta* damage lead to loss in market value.**

**Figure 6: Tomatoes rotting as a result of secondary infection following initial attack by *T. absoluta* larvae**

## Means of Dispersal

Movement of the different life stages of *T. absoluta* occurs through:

- Transportation by humans, carried on infested seedlings, infested tomato fruits and along with packing materials, farm equipment and transportation vehicles.
- Larvae spin silken threads to move from plant to plant. Mature larvae exit the plant and move to the soil to pupate.
- Adult moths fly from infested fields to colonize new plants or new areas, and they also drift with wind currents.

## Integrated pest management

Integrated Pest Management (IPM) is an approach designed to manage pests and diseases with as little damage as possible to people and the environment. IPM focuses on long-term prevention or suppression of pest problems. Different techniques are used within IPM, including scouting and monitoring, as well as preventive cultural, mechanical and biological control in a compatible manner. Corrective chemical control measures are used as a last resort.

The emphasis of IPM is on control, not eradication. Wiping out a whole pest population is often impossible, be expensive and environmentally unsafe.

IPM programmes work to create acceptable pest levels. Economic Injury Level (EIL) is the point where a pest begins to cause enough damage to justify the time and expense of control measures. Below the EIL, it is not cost-effective to control the pest population because the cost of treatment exceeds the amount of losses inflicted by the pest damage. Above the EIL, the benefit of treatment is greater than the cost of treatment. The EIL for *T. absoluta* is 3 larvae per plant.

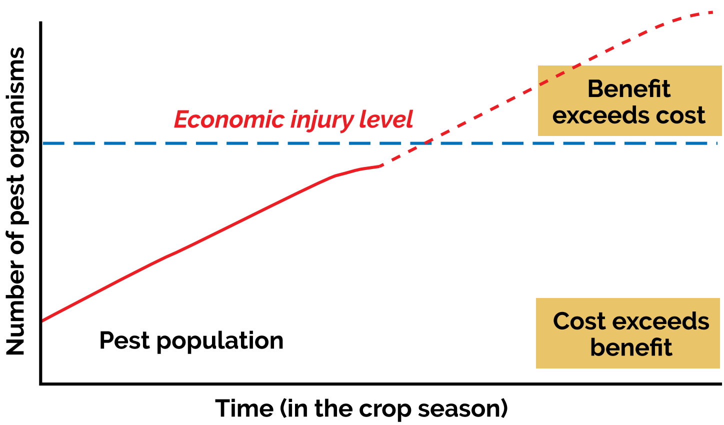


**Figure 7: Economic Threshold**

## Integrated pest management methods for *T. absoluta*

Integrated Pest Management is a knowledge-intensive system that has a continuous improvement cycle. With each crop cycle, more emphasis is placed on preventive strategies and gaining knowledge not only about *T. absoluta* and its behaviour, but also about what conditions are favourable or unfavourable to its development. This is illustrated by Figure 8.


**Figure 8: Five components of IPM**

## Scouting

Scouting is an important tool in IPM. It entails field observation made on regular basis during the crop production cycle for pests, diseases, weeds and crop health (nutrition and water needs) (Figure 9).

When scouting your crop for *T. absoluta*, check for the following signs and symptoms:

- presence of eggs, larvae, pupae or moths
- silvery tunnels on the leaves
- premature falling off of leaves
- tiny holes on stems
- larvae and mines inside fruits
- exit holes on fruits surrounded by frass
- fruit rot due to secondary infection

**Figure 9: A farmer inspecting her tomato fruits**

## Monitoring

Pest levels are monitored through use of insect traps (e.g. light traps, coloured sticky traps, pheromone traps). Pheromone traps can give early warning of infestation and will capture *T. absoluta* moths in low- to medium-level infestations. Only males are captured in pheromone traps, when they are looking for females to mate with. Moth captures show the presence of the pest.

### Types of traps used for monitoring and mass trapping of *T. absoluta*:

There are three types of pheromone traps used for the monitoring and mass trapping of *T. absoluta*

**1 – Delta trap***:* It consists of 3 parts - a triangular-shaped body, a removable sticky liner, and a metal hanger (Figure 10). A pheromone lure rubber dispenser (Figure 11) is placed on the sticky liner that is housed in the triangular-shaped body. The lure emits a pheromone (sex hormone) that attracts male moths. The moths are trapped by glue on the sticky liners.

**Figure 10: *T. absoluta* moths caught by sticky insert of a Delta trap.**

**Figure 11: Lures**

**2 – Water trap:** A plastic basin is filled with water and a pheromone lure is fixed in the middle of the basin using a wire (Figure 12). Ordinary detergent or oil is mixed with the water to break the surface tension. Water can be replaced any time when necessary.

**Figure 12: Homemade water trap**

**3 – Light trap (Ferolite):** This is similar to water trap but contains 2 cells to load pheromone and a light unit powered by solar energy cell (Figure 13). The Ferolite utilizes a specific wavelength of light in combination with sex pheromones to lure *T. absoluta* moths into the water-based trap. The plastic base is filled with water, to which a few drops of liquid soap are added. Ferolite traps both male and female moths.

**Figure 13: Ferolite trap**

**4 – Multi-lure trap:** This contains more than one type of lure to attract different types of insects. It consists of a two-piece plastic, cylinder-shaped invaginated container (Figure 14).

**Figure 14: Multi-lure trap**

Lures are replaced after every 4 to 6 weeks, as their effectiveness decreases with exposure period in the field.

**Figure 15: Delta trap in greenhouse, trap height is adapted according to the height of the plant**

### Procedure for monitoring *T. absoluta* using traps

1. Place two Delta traps with lures in your field to monitor the number of *T. absoluta* moths 2 weeks before setting up nursery.
2. Place the Delta trap at a height of 20 cm before planting and change with increase of canopy to 60 cm (Figure 14). Moths are found in the upper parts of the canopy but never beyond 1 m high.
3. Count and record number of moths per trap on a daily basis.
4. Trap density for monitoring:
    - In open-field crops, 2 – 3 traps per hectare
    - 1 trap per 400m$^2$ in greenhouses
5. When catches in monitoring traps exceed 3 moths per trap per week, mass-trapping should be started (Table 2).

**Table 2: Risk of infestation according to capture of *T. absoluta* moths**

| Infestation level | Number of moths captured/trap/week |
|---|---|
| Low | 1-3 |
| Moderate | 4-30 |
| High | > 30 |

## Mechanical control

Mechanical control is the management of pests by use of physical means, such as mass trapping and use of screen houses.

## Mass trapping

Mass trapping makes use of traps to catch a large proportion of the pest population and reduce pest pressure. Traps used for monitoring *T. absoluta* can also be used as a control method when pest densities are low (<30 males per trapper week). A huge number of pheromone-baited traps are placed in strategic sites within a crop to reduce the number of males and reduce mating incidences, thus reducing the number of viable eggs produced. Mass trapping can result in reduction in *T. absoluta* populations when started early and used consistently with other management measures.

The recommended trap density for mass trapping is:

- 40 to 50 traps per hectare in open fields
- 20 to 25 traps per hectare in greenhouses

Change the traps when full or after 6 to 8 weeks.

Install water traps for male mass trapping with pheromone lures (20 to 40 water traps per hectare) some weeks before planting. Continue using water traps after planting, especially at the beginning of the season.

## Use of *T. absoluta* proof screenhouse

Tomatoes can be grown under a greenhouse or a net house to exclude pest from the crop. Greenhouses should be fitted with insect exclusion nets and double-doors that can be tightly sealed (Figure 16). To prevent the entry of the pest, nets with a minimum density of 9 x 6 threads per $cm^2$ can be used. Any openings or gaps in the structure should be repaired. Human movement from infested to non-infested greenhouses should be avoided and growers should make sure that they are not carrying live adult moths on their body or clothing when entering greenhouses.

**Figure 16: Tomatoes grown in a net house**

## Cultural control

Cultural control is the modification of the crop environment in order (i) to avoid the meeting of crop susceptible stage with pest highest density, or (ii) to improve the crop growing condition, or (iii) to make the environment unfavorable for the pest. Cultural control methods include:

- **Creation of proper conditions for growing healthy crops** that can better withstand pests. For example, ensuring healthy soils; good nursery management to start the crop with healthy, vigorous seedlings; adequate spacing; proper irrigation; and adequate fertilization. Proper fertilization provides the required nutrients to the plant and this gives the plant a competitive ability to tolerate pest damage. Studies have shown that *T. absoluta* takes longer to develop in fertilized soils. Irrigation not only provides an optimum environment for plant growth but also drowns the pest, which is useful in bringing down its population.

- **Crop rotation with non-solanaceous crops**: Rotate tomato with crops such as beans, cabbage, maize, onions and fodder grasses. If you are not practising crop rotation, allow a minimum of 6 weeks from crop destruction to planting the next tomato crop to prevent carry-over of the pest.

- **Maintain crop diversity** comprising suitable wild plants that are hosts of the predators, to allow the natural enemy to persist in the environment when the presence of prey is low. Such plants provide refuge, food and alternative prey throughout the year.

- **Intercrop** tomatoes with other crops, e.g. sesame, to increase the population of natural enemies.

- **Sanitation:**

  - **Remove and destroy sources of infestation** such as crop residues (stem, leaves, fruits, etc), symptomatic leaves and fruits, and bury them at least 1-metre deep to break the life cycle of *T. absoluta*.

  - **Destroy alternative hosts** of *T. absoluta,* e.g. volunteer potato, sweet pepper, Black nightshade, eggplant or tobacco, in the vicinity of the tomato field/ screen house. Also, destroy wild host plant such as datura or common thorn apple (before and during the cropping cycle).

  - **Destroy crop residue after harvest** of tomato, potatoes, eggplants or peppers as soon as possible. They can be destroyed by burning, burying or covering with transparent plastic film to ferment them.

  - **Clean all equipment used in the transportation** of tomatoes, such as boxes, crates and trucks, by using soap and water.

- **Deep ploughing** – Cultivate the soil to a depth of 10 cm after harvest to expose and kill pupae. This will help to reduce pest carryover between crops.

- **Solarization:** After ploughing and irrigating the soil, it is covered with a clear or translucent polyethylene sheet for 2–3 months, depending on the intensity of sunshine. Successful solarization results from adequate sunshine, good land preparation and land availability for rotation and fallowing for up to 6 weeks. Solarization is more suitable for nursery beds and small plots but can also be used in the field.

- **Pest avoidance:** avoid growing tomatoes during the late dry season. Plant short-duration varieties that can escape the pest.

## Biological control

Biological control is the use of living organisms to suppress the population density or impact of a specific pest organism, making it less abundant or less damaging than it would otherwise be. These organisms are also known as natural enemies. Examples of biological control agents are parasitoids, predators, nematodes, fungi, bacteria, protozoa and viruses.

Biological control is implemented through three methods:

a) **Classical biological control** (importation of natural enemies), where the natural enemy is introduced in a new environment to achieve control;
b) **Augmentative biological control** (mass-production of natural enemies), in which a large population of natural enemies already present is regularly released to increase their numbers for control;
c) **Conservation biological control** (maintenance of natural enemies), in which measures are taken to maintain natural enemies through adaptation of specific cultural practices.

### Parasitoids

Parasitoids are a group of insects that parasitize other insects or arthropods at any host stage. Insects that parasitize eggs are called eggs parasitoids, insects that parasitize larvae are called larval parasitoids and insects that parasitize pupae are called pupal parasitoids. A parasitoid is only parasitic in its immature stage. The free-living adult parasitoids lay their eggs inside the host or attach them outside the host.

Parasitoids are the most widely used natural enemies of *T. absoluta* in South America, where the pest originates. *Dolichogenidea gelechiidivoris* is a parasitoid wasp that controls *T. absoluta* by laying its eggs inside the pests' larvae (Figure 17). The parasitoid eggs develop inside *T. absoluta* larvae, and eventually emerge as adult wasps thereby killing *T. absoluta* larvae. When released in large numbers, parasitoid wasps spread rapidly, looking for *T. absoluta* infested plant material. The releases can be done repeatedly. Under laboratory conditions, *Dolichogenidea gelechiidivoris* has an average parasitism rate of over 70%. For parasitoids to be effective farmers need to conserve them by applying a *T. absoluta* IPM approach and avoiding the use of synthetic insecticide. Famers also need to practise appropriate habitat management to provide refugia and food (e.g. nectar) for adult parasitoids.

**Figure 17: *Dolichogenidea gelechiidivoris* wasp**

## Predatory mirid bugs

Two mirid bugs, ***Nesidiocoris tenuis*** and ***Macrolophus pygmaeus,*** feed on *T. absoluta* eggs and larvae when encountered outside mines. Farmers should adopt cultural practices that conserve natural enemies, e.g. maintaining crop diversity comprising suitable wild plants that are hosts of the predators and intercropping tomato with sesame to enhance mirid activity.

## Nematodes

Entomopathogenic nematodes (EPNs) (***Steinernema*** sp). ***Steinernema feltiae*** has been tested for the management of *T. absoluta*, and laboratory and field trials revealed high larval mortality (78 –100%).

## Biopesticide

Biopesticides are naturally occurring beneficial microbes, such as fungi and bacteria, which have been isolated, tested and mass-produced as a crop protection agent (Figure 18). Entomopathogenic fungi ***Metarhizium anisopliae*** (a beneficial soil fungus), infects and kills *T. absoluta* $4^{th}$ instar larvae and adults, consequently it reduces pupation and adult emergence. Different isolates of ***M. anisophliae*** have been evaluated under semi field conditions. Three potent isolates: ICIPE 18, ICIPE 20 and ICIPE 665 caused *T. absoluta* adult mortality of 95%, 87% and 86%, respectively. These isolates can be developed as effective biopesticides and used in combination with Tuta pheromone (TUA-Optima®) for mass trapping and autodissemination.


**Figure 18: Biopesticide containing spores of *M. anisopliae***

## Botanical extracts

Botanicals are plant extracts used in the management of pests and may be contact or systemic in action. Neem oil (Azadirachtin), an extract from neem (*Azadirachta indica*) seeds, is used as a contact insecticide against *T. absoluta*.

## Chemical control

The use of synthetic pesticides should be considered as a last resort. Chemical control is not very effective in the management of *T. absoluta* because the larvae are hidden inside leaves, fruits and stems, making it hard for the pesticide to reach the pest. In addition, since the pest has a high reproductive capacity and very short generations, there is an increased risk of the pest developing resistance to chemicals. It is essential to use selective pesticides to protect mirid predators. IPM advocates the use of synthetic pesticides only when it is absolutely necessary and on the basis of scouting information.

# Summary of *Tuta absoluta* IPM technologies

## Monitoring

**Description:** Place pheromone traps and sticky traps at strategic locations in nurseries and fields at least 2 weeks before planting tomato crop (Figure 19).

**Impact:** Monitoring establishes early pest presence of the pest and gives an indication of the pest population.

**Where it has been proven:** Brazil, Italy, Kenya

**How it works:** Males moths are captured in pheromone traps, when they are looking for females to mate with. Pheromone traps give an early warning of *T. absoluta* infestation, which is important for decision making.

**Cost:** USD 6.5 per trap

**References:** Rwomushana et al., 2019; Witzgall et al., 2010

**Figure 19: Delta trap in greenhouse, trap height is adapted according to the height of the plant**

## Mass trapping

**Description:** Place pheromone traps at densities of 20 to 25 traps in a greenhouse. Keep on trapping for 3 weeks after harvest.

**Impact:** Long term reduction in *T. absoluta* population. .

**Where it has been proven:** Brazil, Egypt, Italy, Kenya

**How it works:** Pheromone traps attract and kill moths (Figure 20). The removal of a high proportion of male moths reduces mating incidences and, consequently, the number of viable eggs. With less or no hatching of *T. absoluta* eggs, the population is significantly reduced. Light traps utilize a specific wavelength of light in combination with sex pheromones to lure both male and female moths into a water-based trap.

**Cost:** USD 260 per hectare

**References:** Rwomushana et al., 2019; Witzgall et al., 2010

**Figure 20: *Tuta absoluta* moths caught by sticky insert of a Delta trap.**

## Screenhouse

**Description:** Grow tomatoes under net-houses or in greenhouses.

**Impact:** The use of nets can cause a 70% decrease in chemical sprays by farmers and a 35 - 70% increase in marketable yields of tomato (Figure 21).

**Where it has been proven:** Kenya, Tanzania

**How it works:** Nets provide a physical barrier that prevents *T. absoluta* adult from accessing the crop. In addition, nets retain beneficial biocontrol agents; improve seedling germination, survival and transplant quality; and result in microclimate modifications (temperature, relative humidity, soil moisture, light), which is important for the tomato crop.

**Cost:** USD 1,640 to construct a greenhouse (8 m X 15 m) and USD 2 per metre of netting material

**References:** Rwomushana et al., 2019

**Figure 21: Tomatoes grown in a net house**

## Biological control

**Description:** Use of natural enemies to control *T. absoluta* (Figure 22). Examples are larval parasitoid (*Dolichogenidea gelechiidivoris*), egg parasitoids (*Trichogramma cacoeciae*, *Trichogramma bourarachae*) and predatory mirid bugs (*Nesidiocoris tenuis*).

**Impact:** Reduction in leaf damage in greenhouse tomato after releasing adult parasitoids. Reductions of 87% and 78% in leaf damage, in greenhouse tomato, after releasing 25,000 adults of parasitoid *Trichogramma cacoeciae* or *Trichogramma bourarachae* respectively. Predatory mirid *Nesidiocoris tenuis* reduced the density of *T. absoluta* eggs in greenhouses. *Dolichogenidea gelechiidivoris* has an average parasitism rate of over 60%.

**Where it has been proven:** Kenya, South America, Tunisia

**How it works:** Parasitoid eggs develop inside *T. absoluta* larvae, and eventually emerge as adult wasps, thereby killing *T. absoluta* larvae. Mirid bugs feed on *T. absoluta* eggs and larvae.

**Cost**: Rearing cost

**References**: Rwomushana et al., 2019; Mansour et al.,2018; Zouba et al., 2013

**Figure 22: Field release of parasitoid wasp *D. gelechiidivoris* by *icipe* staff**

## Biopesticide

**Description**: Use of pesticide formulations that consist of a microorganism (e.g. a bacterium, fungus, virus or protozoan) as the active ingredient (Figure 23).

**Impact**: Entomopathogenic fungi *Metarhizium anisopliae* and *Beauveria bassiana* caused female moth mortality of 37% and 68%, respectively. *Bacillus thuringiensis* var. kurstaki is effective against *T. absoluta* larvae.

**Where it has been proven:** Egypt, Ethiopia, Ghana, Kenya, South Africa

**How it works:** *Metarhizium anisopliae* infects the 4$^{th}$ instar larvae and adults of *T. absoluta*, causes death and consequently reduces pupation and adult emergence. Three potent *M. anisopliae* isolates are compatible with *T. absoluta* pheromone lure (TUA-Optima®), with potential to be used for autodissemination through "attract and infect" approach. *Bacillus thuringiensis* is able to infect all the larval instars of *T. absoluta*. **Cost:** *M. anisophliae* ICIPE 18, ICIPE 20 and ICIPE 655 isolates have not been commercialized.

**References:** Akutse et al., 2020; Rwomushana et al., 2019; Moussa et al., 2018; Abd El-Ghany et al., 2016; Giustolin et al., 2001.


**Figure 23: Biopesticide containing spores of *M. anisopliae***

## Botanicals

**Description:** Use of plant extracts to control *T. absoluta* e.g. use of extracts from neem seed (Figure 24), garlic, basil, thyme, castor bean, eucalyptus and onion.

**Impact:** Neem seeds extracts has reduced the percentage of infestation of tomato fruits and yield loss under greenhouse conditions.

**Where it has been proven:** Kenya

**How it works:** Acts as a contact and systemic insecticide against low infestations of *T. absoluta* larva

**Cost:** Neem-based products cost USD 12–15 for 1 litre.

**References:** Rwomushana et al., 2019; Abd El-Ghany et al., 2016; Birhan, 2018; Kona et al., 2014.

Figure 24: Neem seeds

## Field Sanitation

**Description:** Destroy infected plants (Figure 25). Collect and destroy debris after harvest. Leave a minimum of 6 weeks after harvest and destruction of the tomato crop until planting the next one. Check transplants for presence of tomato leafminer damage before field planting. Remove alternative hosts, e.g. *Solanum*, *Datura* and *Nicotiana* species.

**Impact:** Reduced infestation.

**Where it has been proven:** Kenya, Zambia

**How it works:** Destroying infested plants and plant parts helps to limit the possibility for the pest at a particular life-stage to develop to the next, and thus controlling the pest population. Inspecting transplants ensures there are no eggs, larvae or pupae that might develop and spread. Removal of wild relatives from the vicinity of tomato will eliminate alternative hosts, limiting the chances of the pest developing and moving to the next generation.

**Cost:** Labour

**References:** Rwomushana et al., 2019

**Figure 25: Healthy tomato crop in greenhouse.**

## Crop rotation

**Description:** Plant non-solanaceous crops after a tomato crop (Figure 26). Avoid overlapping tomato crops.

**Impact:** Prevents pest build up

**Where it has been proven:** Africa

**How it works:** Lack of a host plant breaks life cycle of *Tuta absoluta*

**References:** Rwomushana et al., 2019

**Cost:** Opportunity cost

**Figure 26: Cowpea plant**

## Fertilization

**Description:** Application of organic fertilizer to tomato crops (Figure 27).

**Impact:** Reduction in number of infestation plants. *Tuta absoluta* takes longer to develop in fertilized soils.

**Where it has been proven:** Iran

**How it works:** Provides required nutrients to the plant and this gives the plant a competitive ability to tolerate pest damage. Organic manure supplies balanced source of nutrition for plant growth, since the organic matter gradually is degraded by microorganisms and the available nutrients of these materials are released slowly.

**Cost:** Fertilizer cost and labour

**References:** Mohamadi et al., 2017

**Figure 27: Farmer examining a compost heap**

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# Glossary

**Augmentation**: periodically increasing either the number of parasites or predators or the supply of their food resources to assure that adequate numbers of parasites and predators are present to provide the desired level of pest control.

**Biopesticide:** a type of pesticide derived from natural materials such as fungi, bacteria, viruses, nematodes and plant-derived chemical compounds.

**Climate Smart Pest Management:** a cross-sectoral approach that aims to reduce pest-induced crop losses, enhance ecosystem services, reduce greenhouse gas emissions, and strengthen the resilience of agricultural systems under climate change.

**Frass:** droppings or waste left by feeding insects.

**Instars:** Insect form between successive moults.

**Larva (plural larvae):** immature stages of an insect, often worm-like in appearance.

**Natural enemies:** living organisms that feed on a crop pest.

**Necrosis:** death of a plant part.

**Parasitoid:** an organism that gains nutrients and resources from a host and ends up killing or sterilizing the host in the process.

**Pathogens:** disease-causing organisms, including viruses, bacteria, and fungi that kill or debilitate their hosts.

**Pheromones:** chemicals secreted by an organism to attract individuals of the opposite sex of the same species for mating.

**Predators**: insects that attack and feed on another insect (prey). Predators feed on all stages of the host (pest) i.e. eggs, larvae, pupae and adults. Each predator requires a number of prey individuals to enable it to reach maturity e.g. predatory mites, predatory bugs, ladybird beetles, hoverflies and lacewings.

**Pupa (plural pupae):** the stage of development between larva and adult in the life cycle of some insects (for example moths and flies). Pupae usually have a hard skin and do not move or feed.

**Pupation:** process that occurs when a larva develops to a pupa.

**Refugia:** any local environment that has escaped regional ecological change and therefore provides a habitat for endangered species

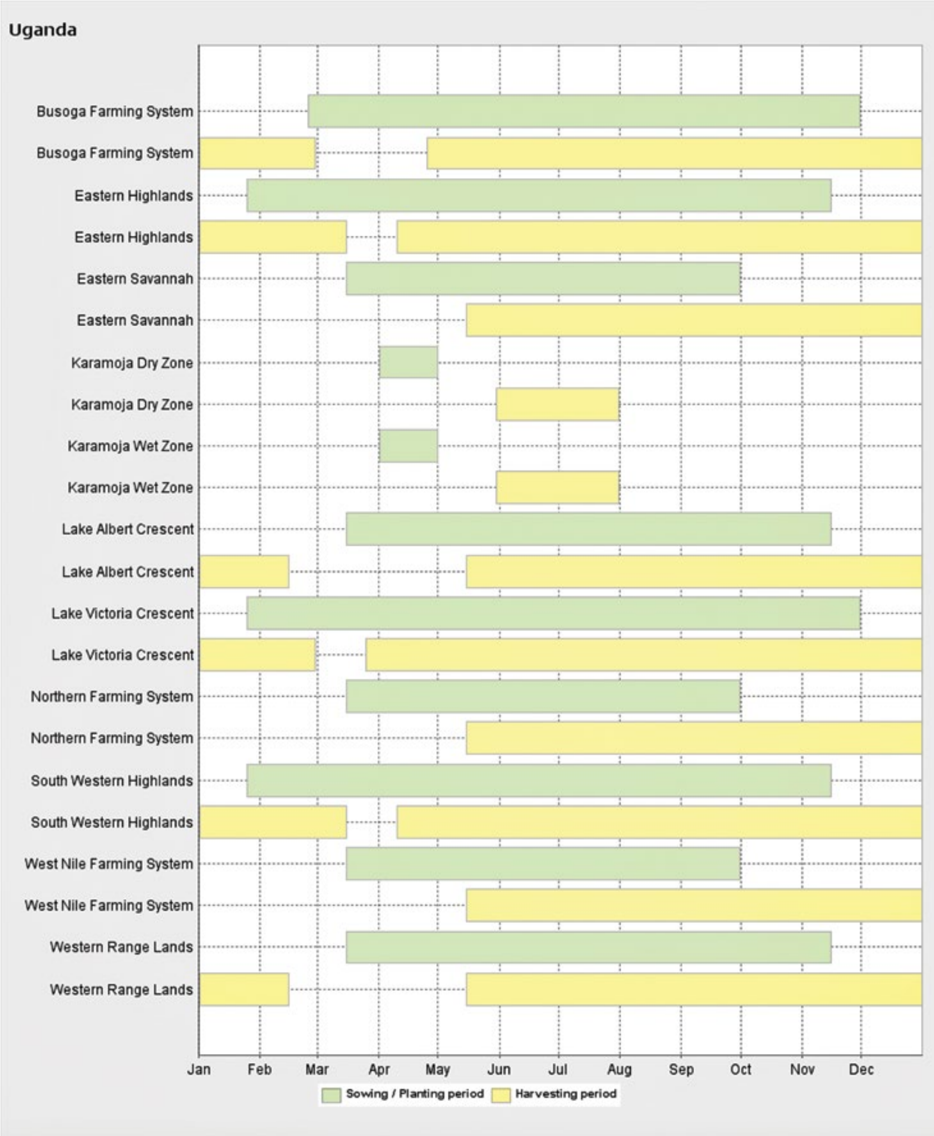
**Solanaceae:** plant family containing tomatoes and other crops such as eggplants, potatoes and peppers.

**Solarize:** to cover the soil with clear or transparent polyethylene sheets, with the aim of heating the soil with the hot sunshine to kill pests and disease organisms.

# Annex 1: IPM Technology profile for *Tuta absoluta*

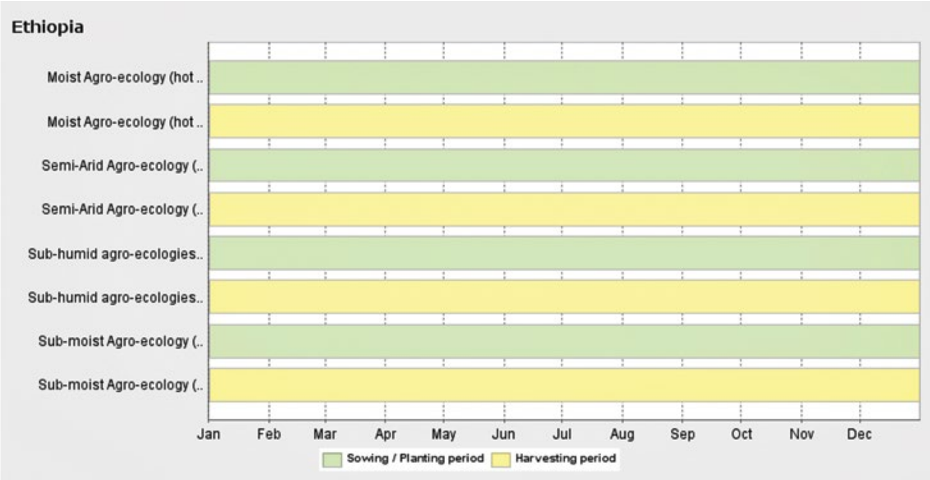
| Technology and brief description | Owner of Technology | Location proven | Success factors obtained | Cost of the technology (USD) | Recommendations | Value chains suited for technology application |
|---|---|---|---|---|---|---|
| **Monitoring**<br>Use of pheromone traps to monitor pest. | *icipe* and partners | Brazil, Kenya, Italy, Uganda, | Early detection of pest | USD 6.5 for one Delta trap and USD 45 for one Ferolite trap. | Monitor twice a week<br>Replace lures every 4-6 weeks | Cereals, legumes, vegetable, fruits and flowers |
| **Mechanical control**<br>Use of pheromones traps to attract and kill moths (mass trapping).<br>Use of nets or greenhouses to exclude pests from tomato crop. | *icipe* and partners | Brazil, Kenya, Italy, Uganda, Tanzania | Long-term reduction in *T. absoluta* population.<br>Increased tomato yield.<br>Decreased use of pesticides. | USD 260 per hectare for mass trapping<br>USD 1,640 for a greenhouse.<br>USD 2 for a metre of netting material. | Practicse mass trapping over large areas. | Cereals, legumes, vegetable, fruits and flowers |
| **Parasitoids**<br>Use of natural enemies such as parasitoids (*Dolichogenidea gelechiidivoris*) | *icipe* and partners | Europe<br>Kenya, Rwanda<br>South America, Tunisia | Reduced *T. absoluta* population | Rearing cost of parasitoids | Use cultural practices that conserve parasitoids.<br>Avoid use of synthetic insecticide. | Cereals, legumes, vegetable, fruits and flowers |
| **Biopesticides**<br>Use of pesticide which consist of a fungus (*Metarzhizium anisophliae*) as its active ingredient. | *icipe* and partners | Egypt, Ethiopia, Ghana, Kenya, South Africa | Reduced pest population | *M. anisophliae* ICIPE 18, ICIPE 20 and ICIPE 655 isolates have not been commercialized. | Needs repeat applications to control the vulnerable pest stages. | Cereals, legumes, vegetable, fruits and flowers |
| **Botanical extracts**<br>Use of plant extracts *e.g.* Neem oil (Azadirachtin) | *icipe* and partners | Kenya, Rwanda | Increased marketable fruit yield<br>Reduced leaf damage | USD 12 to 15 per litre | Needs repeated applications. | Cereals, legumes, vegetable, fruits and flowers |
| **Cultural control**<br>Field sanitation, use of organic manure and crop rotation | | Africa, America | Increased yield<br>Reduced pest population | Labour | Used in combination with other control measures | Cereals, legumes, vegetable, fruits and flowers |

# Annex 2: Tomato crop calendar for Uganda




*Source: FAO*

# Annex 3: Tomato crop calendar for Ethiopia




*Source: FAO*

# Annex 4: Protocol for rearing *Tuta absoluta* and *Dolichogenidea gelechiidivoris*

## Rearing of *Tuta absoluta*

### Field Sampling:

- Infested tomato leaves are sampled from tomato open fields or greenhouses.
- GPS reading for the sampling points are recorded.
- The collected leaves samples are kept in ventilated paper bags or cool boxes and transported to the Insectary.

### Sample processing and laboratories maintenance

- Samples collected from the field are placed and incubated in ventilated Perspex cages (65 x 45 x 45 cm) in the laboratory.
- Field infested leaves are maintained at 25 ±2 ˚C; 65 ± 5 RH; and 12L: 12D regime, with fresh or uninfested tomato leaves till adult emergence.
- Emerged moths are aspirated to a clean ventilated Perspex cages (50 x 50 x 60 cm); and provided with 100% honey put as droplets on inner-top side of the cages and water in form of moistened cotton wool. The moistened cotton wool is a source of nourishment and maintains humidity within the rearing cage.
- 6 -8 weeks old potted tomato plants (1 Plant:100 Moths) are introduced into the insect rearing cages for oviposition (infestation by *T. absoluta* moths).
- After every two days, the infested plants are removed from the rearing cages and replaced with fresh uninfested potted tomato plants as described above.
- The infested plants are maintained on a bench awaiting hatching of the eggs and larval development (from 1st to 3rd Instar larvae).
- Plants infested with *T. absoluta* Larvae instar 3 (L3) are cut and introduced into incubation Perspex cages (65 x 45 x 45 cm) and maintained with fresh uninfested tomato leaves till adult emergence.
- Sheets of paper towel are neatly spread on the bottom inner-side of the incubation cage to absorb moisture from the decomposing leaves and to provide a dry surface for pupation.
- The procedure for collection of adults and maintenance of newly emerged moths is applied similar with Sample processing and laboratories maintenance.

## Nurseries/Greenhouse maintenance and growing of tomato (host plant):

- Tomato seeds (e.g variety Simlaw Rio Grande) are sown in plastic germination trays
- Seedlings, 2-weeks old, are transplanted into 2-liter plastic pots
- The plants are maintained under standard agronomic practices.

## Rearing of the parasitoid, *Dolichogenidea gelechiidivoris*

- Parasitoid cocoons received from *icipe*
- The emerging parasitoids wasps are aspirated into ventilated Perspex cages (40 x 40 x 50 cm) and provided with 100% honey droplets put on top underside of the cage and water in form of moistened cotton (also maintains humidity within the rearing cage).
- Infested tomato plant parts (leaves and stems) are cut, and introduced to mated wasps (2 days old; 1 Parasitoid:20 Larvae instar 2) in a clean Perspex cage (20 x 20 x 20 cm) for 24 hours.
- The parasitized larvae are removed (replaced with infested plant parts) and maintained with uninfested leaves in a clean Perspex cage (65 x 45 x 45 cm) until *T. absoluta* or D. gelechiidivoris emergence.
- Newly emerged parasitoids are transferred (using semi-automated insect aspirators) to the wasps rearing cages (40 x 40 x 50 cm) and maintained as described above.
- Any dead parasitoid wasps are preserved in 95% ethanol.

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# Partners

## *icipe* – Working in Africa for Africa...

International Centre of Insect Physiology and Ecology (*icipe*) – was established in 1970 in direct response to the need for alternative and environmentally-friendly pest and vector management strategies. Headquartered in Nairobi, Kenya, *icipe* is mandated to conduct research and develop methods that are effective, selective, non-polluting, non- resistance inducing, and which are affordable to resource-limited rural and urban communities. *icipe*'s mandate further extends to the conservation and utilisation of the rich insect biodiversity found in Africa.

*icipe* contributes to sustainable food security in Africa through the development of integrated pest management systems for major agricultural and horticultural crops. Such strategies include biological control and use of behaviour- modifying and arthropod-active botanicals. *icipe* puts emphasis on control approaches that have no detrimental impact on the environment. These options are always designed to fit the needs of the farmers and are developed on-farm and with farmers' participation. In addition to fruit flies, other key areas of *icipe*'s research include pests of tomato, brassicas, beans, and staple food crops such as maize and sorghum.

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*Dolichogenidea gelechiidivoris*

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