

## **TUTA ABSOLUTA (MEYRICK) (LEPIDOPTERA: GELECHIIDAE) – BIOLOGY, ECOLOGY, PREVENTION AND CONTROL MEASURES AND MEANS IN GREENHOUSE TOMATO CROPS. A REVIEW**

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### **Abstract**

The tomato leafminer, *Tuta absoluta* (Meyrick) is a dangerous pest, difficult to control in tomato crops. In Europe, it was originally reported in eastern Spain, at the end of 2006, subsequently spreading very fast throughout the Mediterranean basin and in various countries in Europe. In Romania, was first reported in 2009, in the North West area (Satu Mare), and a year later he was identified near Bucharest, in greenhouse crops. The larvae attack both foliage and fruit during all tomato growth stages. On leaves, larvae feed only on mesophyll, leaving the epidermis intact. They also penetrate into tomato fruits where they feed and grow, leaving behind mines and galleries. The species of vegetables from Solanaceae family are the main hosts of the pest. Control of *Tuta absoluta* infestations is difficult to achieve, because the larvae are protected in the leaf mesophyll or inside the fruits. Chemical control is the primary method to manage the pest, but there are also alternative methods of control, less polluting, such as: biological control through treatments with biological products, by releasing of parasitoids and predators, insect-proof nets, pheromone traps and so on. Treatments must be applied before the pest penetrates under the epidermis of the leaves or in fruits.

Keywords: integrated control, pest, tomato leafminer

### **1. INTRODUCTION**

*Tuta absoluta* (Lepidoptera: Gelechiidae), known as the tomato leafminer, is a very important pest of tomato crops (Braham and Hajji, 2012). It was originally described as *Phthorimaea absoluta* by Meyrick in 1917, a male specimen being collected from Peru (Ferracini et al., 2019).

According to the literature, in the last 10 years, tomato crop infestation has increased from 3% to 60% worldwide (Biondi et al., 2016), so it can reduce yield by more than 90% (Batalla-Carrera et al., 2010), and in cases where effective control methods are not used, losses of 100% may be recorded (Biondi et al., 2016). It is considered a key pest of tomato crops in greenhouse and fields (Cocco et al., 2012).

The species of the Solanaceae family are the main host of the pest, tomato, potato and European black nightshade being the most suitable (Abbes et al., 2016; Desneux et al., 2010; Biondi et al., 2016), but it can also attack eggplants, peppers and tobacco (Mohamadi et al., 2017). At the same time, it can lay eggs and grow on other species of plants in the families: Amaranthaceae, Convolvulaceae, Fabaceae and Malvaceae (Biondi et al., 2016).

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The species spreads very quickly, from one area to another, by wind which favors the spread of the pest in new areas (Desneux et al., 2011; Zekeya et al., 2017). This type of spread is an advantage for the pest, its energy being available for reproduction (Gontijo et al., 2013; Cascone et al., 2015; Zekeya et al. 2017). *T. absoluta* can fly several kilometers and can be accidentally dispersed by humans in local or global crops areas through trade with infested tomatoes (Tropea et al., 2012; Bayram et al., 2015, Bettaibi et al., 2012; Zekeya et al., 2017).

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Losses caused by *T. absoluta* and its rapid spread in most areas of tomato cultivation in the world are possible due to the ability of the species to adapt to different environmental conditions (Martins et al., 2016).

## 2. BIOLOGY AND ECOLOGY

The main host of the pest is tomatoes, but it can also attack eggplants (Mohamadi et al., 2017; fig. 1, fig. 2).



Figure 1. *Tuta absoluta* attack on tomato leaves



Figure 2. *Tuta absoluta* attack on eggplant leaf

Under greenhouse conditions it can develop 10-12 generations/year (Desneux et al., 2010).

The optimal temperature for development is 30°C, and the life cycle varies between 26 and 75 days (Biondi et al., 2016), having four stages of development: egg, larva, pupa and adult (Desneux et al., 2010).

Females usually lay eggs on the leaves (Batalla-Carrera et al., 2010), being individual or, less frequently, grouped (Torres et al., 2001), on the underside of the leaves to protect them from birds or from unfavorable environmental conditions for their development (Sinclair and Hughes, 2010; Balzan and Moonen, 2015; Zekeya et al., 2017). Immediately after laying, eggs are yellowish becoming coppery-red and with two red eye-spots about one day before hatching (Torres et al., 2001). They are found on young leaves, sepals or stems (Biondi et al., 2016). The incubation period

is between 4 and 7 days at 27° C. Neonate caterpillars are pale becoming green during the second and third instars, and the abdomen is green and the thorax purple during the fourth instar. They have a body length of 7 - 10 mm at end of the later stage (Torres et al., 2001). The larvae of the fourth instar live in leaf galleries, where they feed and grow (Batalla-Carrera et al., 2010; fig. 3; fig. 4). The larvae directly affect the leaves, terminal buds, flowers and fruits (Haji et al., 1988; Lopes Filho, 1990; Castelo Branco, 1992; Souza and Reis, 1992; Torres et al., 2001; fig. 5). The mature larvae usually fall and penetrate into the soil where they produce a thin, silky cocoon that turns into prepupae and pupae (Biondi et al., 2016).

Pupae (5 - 6 mm long) have a cylindrical shape and are green (Desneux et al., 2010) and later become brownish and have a development time of 7-9 days (Torres et al., 2001). Pupae are normally found in the soil, but can also be identified on plants (Batalla-Carrera et al., 2010). In the soil, the pupae are protected from chemicals and high temperatures on days with strong sunshine (Sinclair and Hughes, 2010; Balzan and Moonen, 2015; Zekeya et al., 2017).

Adults have 6 – 7 mm in length and filiform antennae. Black spots are found on anterior wings, and females are bigger and more voluminous than the males (Desneux et al., 2010; fig. 6).



Figure 3. *Tuta absoluta* – larva



Figure 4. *Tuta absoluta* – larva and excrements



Figure 5. *Tuta absoluta* attack on tomato fruit



Figure 6. *Tuta absoluta* – adult

Females live 10 to 22 days and can lay between 60 and 120 eggs. The species needs 29-38 days to complete cycle, depending on the temperature (Batalla-Carrera et al., 2010).

The pest is active at night and adults usually remain hidden during the day, having an intense activity in the morning (Desneux et al., 2010).

The length of the development cycle depends very much on the climatic conditions, the average development time being 76.3 days at 14°C, 39.8 days at 19.7°C and 23.8 days at 27.1°C (Barrientos et al., 1998). These data were obtained based on the determination of the temperature thresholds and the thermal constant for *T. absoluta*. Temperature thresholds for eggs, larvae and pupae were estimated at  $6.9 \pm 0.5^\circ\text{C}$ ;  $7.6 \pm 0.1^\circ\text{C}$  and  $9.2 \pm 1.0^\circ\text{C}$ , respectively. The threshold for eggs-larvae-adults is  $8.1 \pm 0.2^\circ\text{C}$  (Desneux et al., 2010). The life cycle was reduced from 75 to 26 days when the temperature ranged from 17 to 33°C (Martins et al., 2016).

At the temperature of 7°C there was no egg which hatched, but at 10°C, 17% of them successfully hatched. Eggs kept at 13°C had the highest hatching percentage (92%), and it was significantly higher only at 19°C. At temperatures between 13°C and 23°C a hatching percentage of more than 80% was obtained, under fluctuating temperatures, with a daily average of 21°C. There was a significant decline in egg hatching above 23°C (Cuthbertson et al., 2013).

### 3. PREVENTION AND CONTROL MEASURES AND MEANS

The use of „insect-proof” nets and the removal of the organs of the attacked plants (leaves, fruits) from tomato crops are two important measures to prevent the spread of the pest attack. These measures are usually combined with other cultural practices: solarization to destroy pupae from the soil, covering the ground with a plastic wrap to prevent the emergence of adults from the pupae from the soil, destroying secondary host plants inside and around protected areas (Abbes et al., 2012).

There are also alternative and less polluting control methods, such as: use of light traps, synthetic pheromone traps for male annihilation or mating disturbance (with these synthetic pheromone traps, the ability of males to identify females is disturbed, thus reducing population density), microbiological control and biological control with parasites and predators (Cocco et al., 2012).

Light traps attract both males and females. Seasonal catches showed that in crops, males appear about a week earlier than females. These traps are more effective for catching males (Altermatt et al., 2009; Aksoy and Kovanci, 2016).

Pheromone traps can be used for early detection of the tomato leafminer in recently infested areas (Machekano et al., 2018, Mansour et al., 2018). When the pest settles in an area, the same traps can be used to monitor the population. This involves monitoring the flight activity during the growing season, in order to establish the optimal time for the application of insecticide treatments or, alternatively, biological control (Caparros Megido et al., 2013; Mansour et al., 2018).

The most commonly used type of pheromone trap is the Delta trap (fig. 7, fig. 8) which consist of triangular-shaped body open at ends. Inside is a removable tray with adhesives and in the middle of it is positioned the bait with pheromones (Caparros Megido et al., 2013).

Biological control can be achieved with the following products: Laser 240 SC (spinosad 240 g/l) 0.05%, BactoSpeine DF (*Bacillus thuringiensis* subsp. *kurstaki* 54%) 0.06%, Oleorgan (*Neem* oil 40%) 0.3%, Quamar (*Quassia amara* extract 75%) 0.3%, Konflic (*Quassia amara* 50% + potassium salt 50%) 0.3% (Costache et al., 2018).

In European countries where the attack of this pest occurs with high frequency, predatory species have been reported, especially from the order Hemiptera (10 species), belonging to the families Miridae, Anthocoridae and Nabidae (Zappalà et al., 2013; Ferracini et al., 2019).

Several predatory species, such as *Dicyphus errans*, *Dichypus bolivari*, *Macrolophus pygmaeus*, *Nesidiocoris tenuis* and *Nabis pseudoferus*, have been evaluated as natural enemies of the tomato leafminer (Ferracini et al., 2019).





Figure 7. Delta trap placed in the tomato crop



Figure 8. Delta trap with *Tuta absoluta* captured adults

In laboratory, *Macrolophus pygmaeus* showed a lower individual predation capacity than *Dicyphus bolivari* and *Dicyphus errans*, although in greenhouse trials, it was more effective in controlling *T. absoluta* because of its stronger numerical response (Ferracini et al., 2019; Ingegno et al., 2019).

*Macrolophus pygmaeus* and *Nesidiocoris tenuis* demonstrated similar predation characteristics. However, *Nesidiocoris tenuis* has been shown to be more effective against tomato leafminer as it can consume more eggs at higher pest densities (Ferracini et al., 2019). However, the simultaneous use of the two predatory species can lead to a more effective control at high *T. absoluta* population densities (Michaelides et al., 2018; Ferracini et al., 2019).

In Europe, almost 50 species of Hymenoptera parasitoids have been reported. They belong to the families Eulophidae, Braconidae, Ichneumonidae, Trichogrammatidae, Pteromalidae and Chalcididae in decreasing order of species abundance (Zappalà et al., 2013). Some of these have been tested for their biocontrol potential: *Bracon nigricans* (Hymenoptera: Braconidae; Biondi et al., 2013), *Necremnus tutae* (previously mentioned as *Necremnus* sp. nr. *artyne*s; Bodino et al., 2016; Calvo et al., 2013; Ferracini et al., 2012; Gebiola et al., 2015; Ferracini et al., 2019) and *Stenomesus* sp. nr. *japonicus* (Hymenoptera: Eulophidae; Chailleux et al., 2014; Ferracini et al., 2019), as well as the egg parasitoid *Trichogramma achaeae* (Hymenoptera: Trichogrammatidae; Cabello et al., 2009; Cascone et al., 2015; Ferracini et al., 2019).

*Trichogramma achaeae* which parasitizes eggs, is commercially available in Europe and North Africa, may achieve high parasitism rates (>90%) under greenhouse conditions, both alone and in combination with the predator *Nesidiocoris tenuis* (Cabello et al., 2009, 2015; Oliveira et al., 2017; Ferracini et al., 2019).

Among the larval parasitoids, *Bracon nigricans* was tested in laboratory conditions. The wasp showed a good behavioral plasticity in parasitizing the hosts (Ferracini et al., 2019). Females fed either directly on the paralyzed host or inside the leaf mines after building feeding tubes that had been made to reach the tomato leafminer larva (Biondi et al., 2013).

Particular attention has been given to eulophid parasitoids, especially to the genus *Necremnus*. The efficacy of *Necremnus tutae* was studied in combination with *Nesidiocoris tenuis* by Calvo et al. (2013) who observed that predator application prior to planting is sufficient for control (Calvo et al., 2016; Ferracini et al., 2019). In laboratory, *Necremnus tutae* determined a high mortality of *T.*

*absoluta* larvae (Bodino et al., 2018; Ferracini et al., 2012; Ferracini et al., 2019). A good growth rate was obtained at high temperatures (30°C), suggesting a high potential to reduce the pest in Mediterranean greenhouses with this parasitoids (Calvo et al., 2013; Ferracini et al., 2019). This larval parasitoids was the only one recovered from greenhouses where foliar treatments were made (Zappala et al., 2012c; Ferracini et al., 2019).

In a comparative study, females of *Stenomiesius* sp. nr. *japonicus* lived longer than those of *Necremnus tuta* and, as a result, were more effective in terms of the number of parasitized and destroyed larvae. The highest number of offspring was recorded when the wasp developed on 3rd-instar larvae, resulting in larger adults and a higher proportion of females (Chailleux et al., 2014; Ferracini et al., 2019).

Control of *T. absoluta* infestation is difficult to achieve because the larvae are protected inside the leaf mesophyll or inside the fruit (Cocco et al., 2012).

The main method of controlling this pest is the use of chemicals. However, this method has some disadvantages, such as: destruction of natural predator and parasitoids populations, accumulation of insecticide residues on tomato fruits, rapid development of resistance to insecticides (Braham and Hajji, 2012). The pest has become resistant to most insecticides used, when control products are not alternated. Resistance to abamectin, cartap, metamidophos and permethrin has been demonstrated in Brazil (Siqueira et al., 2000; Abbes et al., 2012). Similarly, *T. absoluta* showed resistance to abamectin, deltamethrin, and metamidophos in Argentina (Lietti et al., 2005; Abbes et al., 2012) and to organophosphorus insecticides in Bolivia (Moore, 1983; Abbes et al., 2012).

Low efficacy of spinosad has been reported in Chile (Reyes et al., 2012; Abbes, 2012), but Bratu et al. (2015) found that the active substance spinosad (Laser 240 SC) has a high efficacy and a long-lasting effect against the tomato leafminer.

The chemical insecticides, approved in Romania to control this pest are Voliam Targo (abamectin 18 g/l + chlorantraniliprole 45 g/l) 0.08%, Affirm (emamectin benzoate 0.95%) 0.15%, Alverde (metaflumizone 240 g/l) 0.1% (Costache et al., 2018). It is necessary to respect the preharvest interval.

It is very important to avoid repeated treatments with the same product, by alternating insecticides with different active substances, to preventing the appearance of resistance of the pest to them (Oztemiz, 2014).

An integrated pest control program, based on prophylactic measures (use of "insect-proof" nets, removal of attacked organs, etc.), pheromone traps and the use of chemical treatments, is sufficient to keep the *T. absoluta* population under effective control. However, an adequate resistance management strategy must be adopted to minimize the risk of dispersal / introduction of resistant populations into new areas of expansion. Moreover, the use of insecticides such as spinosad should be carefully monitored to prevent the emergence and rapid spread of resistance in the new area (Campos et al. 2014; Roditakis et al. 2016; Cherif et al., 2017).

#### 4. CONCLUSIONS

*Tuta absoluta* is an important pest present in tomato crops where can reduce yield by more than 90%, in the absence of adequate control measures. Use of methods to prevent the appearance and spread, such as: use of insect-proof nets, solarization, covering the ground with plastic wrap, destruction of host plants inside and around greenhouses and removal of attacked organs (leaves, fruits), is a first step to avoid the spread of the pest.

Monitoring the occurrence of the pest attack and the numerical decrease of the populations can be done with pheromone traps.

There are also non-polluting methods such as: treatments with biological products (Laser 240 SC 0.05%, BactoSpeine DF 0.06%, Oleorgan 0.3%, Quamar 0.3%, Konflic 0.3%) and releasing parasitoids and predators.

The main control method remains the chemical one through treatments with insecticides, as selective as possible against the useful entomofauna (Affirm 0.15% and Voliam Targo 0.08%), by alternation, to prevent the appearance of resistant populations.

Treatments must be applied before the pest penetrates the organs. Chemicals will be used at a medium to high attack intensity, taking into account the preharvest interval. If the attack is incipient, biological products and release of parasitoids and predators can be used.

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