A review of the management of Tuta absoluta (Meyrick) (Lepidoptera: Gelechiidae) with special reference to biological control using plant extracts

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Abstract

The tomato leaf miner Tuta absoluta is one of the most destructive pests of tomato plant Solanum lycopersicum L worldwide. Synthetic chemical insecticides are mainly used to manage T. absoluta. However, their excessive use has led to serious problems concerning human health, non-target organisms and environment. Biological control, using bacteria, entomopathogenic fungi, animals and plants remain an eco-friendly alternative for controlling the tomato leaf miner. Here we review the use of biological management of T. absoluta with special reference to control using plant extracts.

Keywords: Tuta absoluta, tomato, biological control, plant extracts.

Introduction

The tomato leaf miner or tomato borer or the South American tomato pinworm Tuta absoluta (Meyrick) (Lepidoptera: Gelechiidae) is one of the most damaging pests in many countries in America, Europe, Africa, and Asia [1]. In the last decade, this insect infested 60% of the tomato crops in many areas of the world. T. absoluta is a multivoltine species. It parasitizes several cultivated and non-cultivated host plants belonging to Solanaceae, Amaryllidaceae, Euphorbiaceae, Cucurbitaceae, Geraniaceae, Fabaceae, Asteraceae and Malvaceae [2]. Its presence relies on environmental conditions. Its development time is shorter at 28°C and 52 or 72 % relative humidity [3]. Eggs are laid on leaves, stems and fruits [4]. Larvae feed and develop on leaves, fruits, flowers, buds and young shoots creating mines and galleries [5].

The primary method to manage the pest is chemical control using synthetic insecticides [6, 7, 8]. These insecticides belong to several chemical groups: benzoyleurea, spinosyn, pyrethroid, oxadiazine, diacylhydrazine, avermectin, ryanoid. Insecticides have many effects such as neurotoxicity, growth inhibition [9]. However, this method has multiple drawbacks like destruction of non-target organisms [10], effects on human health and environment contamination, insecticide resistance, reduced profit due to high synthetic pesticides costs [7]. In recent years, an increasing interest in using biological control including animals, entomopathogenic fungi and bioinsecticides has been noted. The aim of this paper is to list biological methods used to control T. absoluta with special reference to plant extracts.

Taxonomy, origin and distribution of T. absoluta

Tuta absoluta was first reported as Phthorimaeoa absoluta (Meyrick, 1917) in Peruvian Andes. The genus was changed to Gnrorimoscherna then to Scrobipalpula and Scrobipalpuloides. This insect was named Tuta absoluta by Povolny in 1994 [11]. However, in a recent study based on parsimony analysis, T. absoluta was classified in a monophyletic clade that included Phthorimaeoa operculella (Zeller, 1873), and Phthorimaeoa robusta and proposed the reinstated combination Phthorimaeoa absoluta (Meyrick, 1917) and a new combination Phthorimaeoa chiquitella (Busck, 1910) [12].

Originated in South America, the tomato leaf miner was first introduced accidentally in Spain 2006 from where it spread to other countries in Europe, Africa and Asia [13].
**Biology of T. absoluta**

*T. absoluta* has a life cycle of four stages: the egg, the larvae, the pupa and adult (Fig 1). A sexual dimorphism is noted in *T. absoluta* from pupae stage. Indeed, female pupae can be distinguished by two small tubercles present on the eighth abdominal segment. Also, female pupae and adults are heavier and bigger than males [4].

Temperature, relative humidity and hostplant are the most important factors that affect the tomato leaf miner life cycle [3]. Adults are nocturnal. During the day, they hide between host leaves [11] or on the tarpaulin of the greenhouse. A couple a days after emergence, female release sex pheromones; a mix of tetradecatrienyl acetate (90%) and tetradecadienyl acetate (10%) to attract male for mating [14, 15]. In *T. absoluta*, the mechanism of reproduction involves either sexual reproduction and deuterotoky parthenogenetic process in which males and females are produced [16]. Fecundity was highest at 28 °C and 52% relative humidity [3]. The life cycle of the tomato leaf miner is characterized by the following traits [17]:
- Oviposition can take place on leaves, veins, stems, sepals and fruits. A female can lay around 260 eggs during its life cycle. Eggs deposited are oval-cylindrical (0.4mm length; 0.2mm diameter), hatch in about 7 days,
- Larvae stage lasts 8 days and there are four instars
- Pupa stage lasts 10 days: pupa are brown (4.3 mm in length and 1.1 mm in width).
- Adult stage: female lives 10-15 days and male lives 6-7 days.

![Life cycle of T. absoluta](image)

**Fig 1:** Life cycle of *T. absoluta*

**Damages and losses caused by T. absoluta**

The preferred host plant for *T. absoluta* feeding, oviposition and growth is tomato. Larvae consumes leaf mesophyll and can induce two types of damages. Direct damages are related to the reduction of plants photosynthetic capacity and their production levels in consequence. Indirect damages are related to secondary infections due to pathogens developing on the injured plant and fruit tissues [13]. The tomato leaf miner can reduce the totality of tomato yield if no control is taken [6]. Damages caused by *T. absoluta* are summed up in reduced production, additional management costs and decreased and/or restricted trade [18].

**Control and management of T. absoluta**

Some cultural control measures have been taken (crop rotation, selective removal, destruction of parasitised plants) [19]. However, the main strategy used to manage *T. absoluta* is chemical insecticides. Nevertheless, the efficiency of this method remains low because of the protection of the larvae in leaf mesophyll or in fruit [20] and its resistance to several chemical pesticides [9, 21]. In order to decrease synthetic chemical insecticides, many strategies are used including pheromones and biological control.

**Pheromones based control**

Pheromones based strategies include pest detection, population monitoring, mass annihilation and mating disruption techniques [22]. A quantity of both *T. absoluta* pheromones on pheromone lures coupled with traps are used for the pest monitoring. Traps with dark colors seem to be more effective in catching males [23]. The placement of a trap is related to its height, its position with respect to vegetation and its density [24].

Mass annihilation consists in mass trapping or lure and kill techniques. This approach relies on the attraction of adults to a lure (semichemicals or a light source) combined to a large-capacity trap or a pesticide impregnated target (adhesive surface or water trap) [25]. For the management of the tomato borer, a matrix formulated with 0.3% sex pheromone and 3% cypermethrin is available [26].

The mating disruption is a technique that aims to reduce the pest population by introducing synthetic female pheromone that confuses individuals and disrupts mating [20]. The same reference showed that tomato leaf miner can be managed by means of mating disruption if the treatments are carried out in greenhouses well isolated that prevent new adults from entering.

Traps with pheromones is an effective technique to catch adults of *T. absoluta* [27]. Nevertheless, parthenogenetic potential of the pest reduces the success of these strategies [16]. Also, using pheromone mediated management have some demerits such as its high costs and limited availability [28].

**Bacteria and entomopathogenic fungi**

The most bacterial control agents used to manage *T. absoluta* is *Bacillus thuringiensis*, [29, 30, 31, 32] and *Saccharopolyspora spinosa* [33]. Also, several entomopathogenic fungi are used in the control of tomato leaf miner: *Metarhizium anisopliae* [34, 35], *Beauveria bassiana* [36, 37, 38], *Aspergillus oryzae* [39], *Saria farinosa* [40], *Clonostachys sp* [38] and *Purpureocillium lilacinum* [40]. Nutrient exhaustion and toxicosis induced by fungi penetration leads to death of the insect [41].

Despite merits of using bacteria and entomopathogenic fungi in the control of pests, they have some inconveniences like side effects on non-target organisms caused by *Bacillus thuringiensis* [42], lengthy duration of fungi effect [41] and the possibility of resistance of pests against microorganisms used [16].

**Animals**

71 species belonging to 24 families and 8 orders are identified as predators of *T. absoluta* [43]. The most studied are *Nesidiocoris tenuis* (Reuter), *Macropholus pygmaeus* (Rambur), *Podisus nigrispinus* (Dallas), *Dicyphus errans* (Wolff) and *Brachygaster lecheguana* (Latreille). According to the same reference, the list of enemies of tomato leaf miner hold 102 parasitoids belonging to 11 families and 2 orders.
The most studied are Trichogramma pretiosum Riley, Pseudapanteles (=Apanteles) dignus (Muesebeck), Neochrysocharis formosa (Westwood), Trichogramma sp. Westwood, Apanteles sp. Förster, Earinus sp. Wesmael, Dineuphus phthorimaeae de Santis, Goniozus nigrifemur Ashmead, Trichogramma achaeae Nagaraja & Nagaratti and Necremmus arynus (Walker). 75% parasitizes larvae. Also, some entomopathogenic nematodes are used in the control of T. absoluta [28]. The most used are Steinernema feltiae, Steinernema carpocapsae and Heterorhabditis bacteriophora [44, 45, 46].

Using animals to control T. absoluta is a promising strategy. Although, it may have some drawbacks. Indeed, predators or parasitoids can be polyphagus and can attack non-target organisms. Also, introducing exotic species can induce a disorder of the environment. Furthermore, the cost of conservation, transport and release of animals may be high. Some studies using IPM combine the use of predators with biopesticides [47].

**Biological control of T. absoluta using plant extracts**

Using plant-extracts remains a more eco-friendly approach than synthetic insecticides. Botanicals remain a viable option for sustainable T. absoluta control. Indeed, they are widely available, easy to apply and have low costs [28]. Also, plant extracts have low effects on human health and the environment. Several species are used in T. absoluta management. The most studied belong to Liliaceae, Meliaceae, Rutaceae and Lamiaceae. Several parts of the plant are used, in particular leaves, seeds and peels. Aqueous extracts, ethanolic extracts and essential oils are the most forms used. Larvae is the most stage targeted because it’s the stage that causes the most important damages. Major components are probably responsible for the biological effects. Some examples are presented here.

Alkaloids found in Acemella oleracea have a pungent effect and seem to affect the nervous system inducing uncoordinated muscular activity. Their toxic effect is due to the disturbance of the ongoing processes of hostolysis of pest tissues [48]. Piperamides, often found in the genus Piper, have dual biological activity on insects, including neurotoxic effect inducing in larvae symptoms of lethargy and low mobility and lipid metabolism effects [49, 50, 51]. Simmonsin, the major component of Simmondsia chinensis, exert its lethal effect by penetrating the integument of the insect and affecting nervous or respiratory system [52]. It may induce a degree of desiccation and impair some vital physiological functions [53]. Some components like methyl eugenol present in Ocimum gratissimum and Ocimum klimandscharicum inhibit the enzyme acetylcholinesterase which can eventually lead to paralysis in the pest [54]. Botanicals effectiveness can be improved by nanoparticles that solve problems related to essential oil volatility, low water solubility and the tendency [55].

### Table 1: List of plants used to make botanicals used against Tuta absoluta.

| Species                  | Extracted organ | Form of extract | Biomass method and pest developmental stage (in bold) | Major component                                                                 | Results                                                                                     | Reference |
|--------------------------|-----------------|-----------------|-------------------------------------------------------|-----------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|-----------|
| Acemella oleracea        | Aerial parts    | Hexane and ethanol extracts | In laboratory, second-instar larvae were transferred on uninfested tomato leaves in a Petri-dish. Tomato leaves were soaked in extract solution then left to dry before introducing to larvae. A tomato green house plot was treated with the extract at concentration of 6%. | Alkaloids: * Spilanthol, * (E)-N-isobutylundec-2-en-8,10-dynamide * (R, E)-N-(2-methylbutyl)undeca-2-en-8,10-dynamide. | In laboratory, after 5 days and at concentration of 6%, extract induces a mortality of 80.2%. In greenhouse, after 8 days and at concentration of 6%, extract induces a mortality of 89.7% of larvae. | [33]      |
| Allium cepa L.           | Aqueous extract | Aqueous extract | In laboratory, second-instar larvae were transferred on uninfested tomato leaves in a Petri-dish. Tomato leaves were soaked in extract solution then left to dry before introducing to larvae. A tomato green house plot was treated with the extract at concentration of 6%. | * The hexane extract causes 100.0% (N = 60) mortality in T. absoluta at a concentration of 10 µg of extract per mg of insect after 6 h of exposure. * The ethanol extract showed high activity (88.3% mortality). * Spilnathol is the most active (LD50 = 0.13 µg mg-1). | In laboratory, after 5 days and at concentration of 6%, extract induces a mortality of 82.6%. In greenhouse, after 8 days and at concentration of 6%, extract induces a mortality of 84.6%. In greenhouse, after 8 days and at concentration of 6%, extract induces a mortality of 82.7% of larvae. | [56]      |
| Allium sativum L.        | Aqueous extract | Aqueous extract | In laboratory, second-instar larvae were transferred on uninfested tomato leaves in a Petri-dish. Tomato leaves were soaked in extract solution then left to dry before introducing to larvae. A tomato green house plot was treated with the extract at concentration of 6%. | | In laboratory, after 5 days and at concentration of 6%, extract induces a mortality of 84.6%. In greenhouse, after 8 days and at concentration of 6%, extract induces a mortality of 82.7% of larvae. | [56]      |
| Allium sativum L.        | Bulbs           | Aqueous extract | Tomato plants were sprayed with the extract at 5ml/L three times at two week intervals. Reduction of total number of mines induced by larvae is calculated. | | Extract induces a reduction of 69.32% (in 2011) and 78.33% (in 2012) after the 3rd spray and increased the yield of tomato. | [57]      |
| Allium sativum L.        | Cloves          | Aqueous extracts | In laboratory, plant crude extracts were sprayed on larvae in the Petri | | In laboratory, extract induces at 10% a mortality of 95% in 120 | [58]      |
| Study                  | Plant Part          | Extract Type     | Methods                                                                 | Results                                                                 |
|-----------------------|---------------------|------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|
| Azadirachta indica    | Seeds               | Ethanolic extract| Eggs were prepared in Petri-dishes and were topically treated with the different concentrations of the extract (1000, 500, 250, 125 and 62.5 mg/L). Recently hatched larvae were placed in Petri-dishes with tomato leaf, previously immersed in the extract at different concentrations (8000, 6000, 4000 and 2000 mg/L). | *After 4 days, around 25% of egg mortalities were obtained with the different concentrations *Larval mortalities ranging between 33- 46.7% were obtained after 24 hours *Higher larval mortalities, up to 100%, were obtained after 4 days of treatments. |
| Azadirachta indica    | Seeds               | Aqueous extract   | In laboratory, plant crude extracts were sprayed on larvae in the Petri dish at several concentrations (50, 75, and 100 mL/L). In glasshouse, tomato plants were sprayed with plant insecticides at different concentrations (50, 75, and 100 mL/L). Neem seed (A. indica) at 10% induce a mortality of 98.33% in 120 hours. In glasshouse, its mean efficacy at 10% is 66.54% after 7 days. | *Essential oil: (LC30 ¼ 3.05, LC50 ¼ 6.14 and LC90 ¼ 33.83 mL/mL) *Thymol (LC30 ¼ 3.57, LC50 ¼ 7.72 and LC90 ¼ 50.90 mL/mL), *γ-terpinene (LC30 ¼ 4.52, LC50 ¼ 9.67 and LC90 ¼ 62.27 mL/mL) *p-cymene (LC30 ¼ 4.97, LC50 ¼ 11.74 and LC90 ¼ 96.03 mL/mL) * A significant inhibition of AChE activity in the treated larvae by all treatments except for γterpinene + p-cymene * In vitro experiments representing AChE inhibition with IC50 values were recorded 0.370, 0.457, 0.528, 1.094 and 1.323 mL/mL for thymol + p-cymene, thymol, γ-terpinene and p-cymene, respectively. |
| Carum copticum        | Seeds               | Essential oil     | Bioassay was done with early fourth instar larvae. Initially, preliminary tests determined the effective dose ranges; of 2, 4, 8, 16, and 32 mL/mL of extract and thymol, and 3, 6, 12, 24, and 48 mL/mL of γ-terpinene and p-cymene; were used against the larvae. The fresh tomato leaf discs were prepared and immersed in aforementioned concentrations of essential oil and its constituents. Fourth instar larvae were transferred into each disc. To determine extract and their constituents effects on the detoxifying enzymes and acetylcholine esterase, samples were prepared by homogenizing fourth-instar larvae, in 500 mL phosphate buffer. Then, the samples were centrifuged and the supernatants were used as the enzyme source. Thymol, γ-terpinene, and p-cymene | *Contact toxicity on eggs: tomato plants were sprayed with the formulations at concentrations (2.5, 5, 10, 20 and 40mg×mL−1). After drying 10 treated eggs were transferred on the untreated and isolated tomato shoots. Limonene (88.57%) After 72h, at concentration 40mg/ml, essential oil and essential oil associated with nanoparticles induce a mortality of 12% of eggs. Limonene (70.46%) After 72h, at concentration 40mg/ml, essential oil and essential oil associated with nanoparticles induce a mortality of 66% and 52% of |
| Plant Name | Part | Extract/Compound | In Laboratory | Glasshouse | Concentration | Mortality | LC50 (mg/ml) | Reference |
|------------|------|------------------|--------------|------------|---------------|-----------|--------------|-----------|
| Citrus reticulata (Rutaceae) | Peels | Essential oil | *Translaminar toxicity on larvae: second instar larvae were transferred to untreated shoots and left to settle until they entered the leaves. Then, they were sprayed, dried and isolated. *Ingestion toxicity on larvae: tomato plants were sprayed and left to dry. shoots were collected and individually isolated. Second instar larvae were transferred to each treated shoot. | | | | | [62] |
| Citrus sinensis L (Rutaceae) | Peels | Essential oil | *Contact toxicity on eggs: tomato plants were sprayed with the formulations at concentrations (2.5, 5, 10, 20 and 40mg×mL−1). After drying 10 treated eggs were transferred on the untreated and isolated tomato shoots. *Translaminar toxicity on larvae: second instar larvae were transferred to untreated shoots and left to settle until they entered the leaves. Then, they were sprayed, dried and isolated. *Ingestion toxicity on larvae: tomato plants were sprayed and left to dry. shoots were collected and individually isolated. Second instar larvae were transferred to each treated shoot. | | | | | [62] |
| Cymbopogon citratus (Poaceae) | Leaves | Aqueous extract | In laboratory, plant crude extracts were sprayed on larvae in the Petri dish at several concentrations (50, 75, and 100 ml/L). In glasshouse, tomato plants were sprayed with the formulations at 2.5, 5, 10, 20 and 40mg×mL−1. After drying 10 treated eggs were transferred on the untreated and isolated tomato shoots. | | | | | [58] |

For translaminar toxicity, LC50 for essential oil and essential oil associated with nanoparticle equals 7.58 and 11.06 mg/ml respectively.

For ingestion toxicity, LC50 for essential oil and essential oil associated with nanoparticle equals 111.04 and 47.4 mg/ml respectively.

For translaminar toxicity, LC50 for essential oil and essential oil associated with nanoparticles equals 6.45 and 23.09 mg/ml respectively.

For ingestion toxicity, LC50 for essential oil and essential oil associated with nanoparticles equals 3.79 and 0.99 mg/ml respectively.
| Plant Family | Type | Extract | Methodology | Result |
|-------------|------|---------|-------------|--------|
| Cymbopogon citratus (Poaceae) | Leaves | Aqueous extract | Tomato plants were sprayed with the extract at 5ml/L, three times at two week intervals. Reduction of total number of mines induced by larvae is calculated. | Extract induces a reduction of 65.43% (2011) and 78.33% (2012) after the 3rd spray. |
| Eucalyptus spp (Myrtaceae) | Oil | | In laboratory, plant crude extracts were sprayed on larvae in the Petri dish at several concentrations (50, 75, and 100 ml/L). In glasshouse, tomato plants were sprayed with plant insecticides at different concentrations (50, 75, and 100 ml/L). | Oil induces a reduction of 57.11% (2011) and 61.39% (2012) after the 3rd spray and increased the yield of tomato. |
| Jatropha curcus (Euphorbiaceae) | Seeds | Petroleum ether extract | Eggs were prepared in Petri-dishes and were topically treated with the different concentrations of the extract (1000, 500, 250, 125 and 62.5mg/L). Recently hatched larvae were placed in Petri-dishes with tomato leaf, previously immersed in the extract at different concentrations (8000, 6000, 4000 and 2000 mg/L). | *After 4 days, around 18% of egg mortalities were obtained with the different concentrations *Larval mortalities ranging between 23.5 - 48.5% were obtained after 24 hours. *Higher larval mortalities, up to 100%, were obtained after 4 days of treatments. |
| Melia azedarach L. (Meliaceae) | Leaves and fruits | Aqueous extract | In laboratory, second-instar larvae were transferred on uninfested tomato leaves in a Petri-dish. Tomato leaves were soaked in extract solution then left to dry before introducing to larvae. A tomato greenhouse plot was treated with the extract at concentration of 6%. | In laboratory, after 5 days and at concentration of 6%, leaves and fruits extract induce a mortality of 91.2%. In greenhouse, after 8 days and at concentration of 6%, *leaves extract induces a mortality of 74.0% *fruits extract induces a mortality of 60.7%. |
| Nicotiana species (Solanaceae) | Leaves and stalks | Aqueous extract | In laboratory, plant crude extracts were sprayed on larvae in the Petri dish at several concentrations (50, 75, and 100 ml/L). In glasshouse, tomato plants were sprayed with plant insecticides at different concentrations (50, 75, and 100 ml/L). | Tobacco (Nicotiana species) at 10% induces a mortality of 80% in 120 hours. In glasshouse, its mean efficacy at 10% is 62.10% after 7 days. |
| Ocimum basilicum L. (Lamiaceae) | Leaves and flowers | Aqueous extract | In laboratory, second-instar larvae were transferred on uninfested tomato leaves in a Petri-dish. Tomato leaves were soaked in extract solution then left to dry before introducing to larvae. A tomato greenhouse plot was treated with the extract at concentration of 6%. | In laboratory, after 5 days and at concentration of 6%, *leaves extract induces a mortality of 53.8% * flowers extract induces a mortality of 73.6% In greenhouse, after 8 days and at concentration of 6%, *leaves extract induces a mortality of 84.7% * flowers extract induces a mortality of 87.0%. |
| Ocimum basilicum (Lamiaceae) | Oil | | In laboratory, plant crude extracts were sprayed on larvae in the Petri dish at several concentrations (50, 75, and 100 ml/L). In glasshouse, tomato plants were sprayed with plant insecticides at different concentrations (50, 75, and 100 ml/L). | Oil induces a reduction of 67.97% (2011) and 72.78% (2012) after the 3rd spray. |
| Ocimum gratissimum L. | Aerial parts | Essential oil | *The repellent effect of the extract and some of their constituents on Methyl eugenol (39.5%) The repellence index at 50% was RI50 = 0.13% | |
| Species (Family) | Type | Extract/Constituents | Methodology | Infestation | Results |
|-----------------|------|----------------------|-------------|-------------|---------|
| *Ocimum* kilimandscharicum Gürke (Lamiaceae) | Aerial parts | Essential oil | Adults were evaluated in a two choice cuboidal plexi-glass wind tunnel at several concentrations (0.031, 0.063, 0.125, 0.25, 0.5 and 1 μl/ml). | *The toxic effect of exposing adults to extract at different concentrations (0.031, 0.063, 0.125, 0.25, 0.5 and 1 μl/ml−1) of the oil and some of their constituents is studied in small cage chambers.* | Eugenol (29.7%) | LC50 = 0.24 and LC90 = 0.66 |
| *Pelargonium* zonale (Geraniaceae) | Aqueous extract | | In laboratory, second-instar larvae were transferred on uninfested tomato leaves in a Petri-dish. Tomato leaves were soaked in extract solution then left to dry before introducing to larvae. A tomato green house plot was treated with the extract at concentration of 6%. | *The repellent effect of the extract and some of their constituents on adults was evaluated in a two choice cuboidal plexi-glass wind tunnel at several concentrations (0.031, 0.063, 0.125, 0.25, 0.5 and 1 μl/ml).* | Camphor (47.0%), 1,8-Cineole (19.3%) | The repellence index at 50% was RI50 = 0.5% LC50 = 0.43 and LC90 = 1.83 |
| *Phytolacca* dodecandra (Phytolacaceae) | Leaves and seeds | Aqueous extract | In laboratory, plant crude extracts were sprayed on larvae in the Petri dish at several concentrations (50, 75, and 100 ml/L). | In laboratory, endod seed (*P. dodecandra*) at 10% induces a mortality of 56.67% in 120 hours. In glasshouse, its mean efficacy at 10% is 36.51% after 7 days. Endod leaf (*P. dodecandra*) at 10% induces a mortality of 55% in 120 hours. In glasshouse, its mean efficacy at 10% is 36.94% after 7 days. | Amides, lignans, alkaloids, and neolignans | Piper. amalago var. medium induces a mortality of 66.66% in 24 hours LC50 (95%CI) in 24 hours=1.008 LC90 (95%CI) in 24 hours=4.464 Piper. Mikanianum induces a mortality of 50.47% in 24 hours Piper. Glabratum induces a mortality of 41.9% in 24 hours extracts caused a significant reduction in the weight of the surviving larvae by the sixth day (144 hours) of exposure. | |
| *Pimpinella* anisum (Apiaceae) | Oil | | In laboratory, plant crude extracts were sprayed on larvae in the Petri dish at several concentrations (50, 75, and 100 ml/L). | Oil induces a reduction of 67.15% (2011) and 70% (2012) after the 3rd spray and increased the yield of tomato. | | |
| *Piper* amalago var. medium, *Piper* glabratum, *Piper* mikanianum (Piperaceae) | Leaves | Ethanol extracts | The extract was sprayed on tomato leaves detached from potted plants until the excess started dripping off the leaves. After drying the waste (~30 min), the leaflets were placed separately in plastic Petri dishes and infested with five newly-hatched larvae. | *Piper. amalago var. medium induce a mortality of 66.66% in 24 hours LC50 (95%CI) in 24 hours=1.008 LC90 (95%CI) in 24 hours=4.464 Piper. Mikanianum induces a mortality of 50.47% in 24 hours Piper. Glabratum induces a mortality of 41.9% in 24 hours extracts caused a significant reduction in the weight of the surviving larvae by the sixth day (144 hours) of exposure.* | Amides, lignans, alkaloids, and neolignans | |
| *Ricinus* communis (Euphorbiaceae) | Seeds | Ethanol extract | Tomato leaves containing larvae were dipped in 5 preparations of the extract (1%, 2%, 10%, 20% and 100%) and then left to dry. The leaves were then placed in a Petri dish. | The extract induces at concentration of 77500mg/l a rate of mortality of 58% after 72 hours. | | |
| Plant Species                   | Part Used | Extract Type | Description                                                                 | Results                                                                 | Reference |
|-------------------------------|-----------|--------------|-----------------------------------------------------------------------------|-------------------------------------------------------------------------|-----------|
| *Ruta graveolens* (Rutaceae)  |          | Oil         | In laboratory, plant crude extracts were sprayed on larvae in the Petri dish at several concentrations (50, 75, and 100 mL/L). In glasshouse, tomato plants were sprayed with plant insecticides at different concentrations (50, 75, and 100 mL/L). | Oil induces a reduction of 65.36% (2011) and 70.56% (2012) after the 3rd spray. | [58]      |
| *Simmondsia chinensis* (Simmondsiaceae) | Seeds | Simmondsin extract by ammonium hydrogen peroxide, isopropanol, acetone, or water at concentrations of 25, 50, 75 or 100%. | Larvae (2nd larval instar) and tomato leaves were put in Petri-dish and were sprayed with a tested treatment (3 mL/Petri-dish). | Simmondsin after 7 days inside tomato leaf tunnel with topical application and at concentration of 100%, Simmondsin extract by *ammonium hydrogen peroxide induces a mortality of 76.66%. *isopropanol induces a mortality of 76.66%. *acetone induces a mortality of 96.66%. *water induces a mortality of 95%. | [38]      |
| *Thymus vulgaris* (Lamiaceae)  | Leaves   | Ethanol extract | Tomato leaves containing larvae were dipped in 5 preparations of the extract (1%, 2%, 10%, 20% and 100%) and then left to dry. The leaves were then placed in a Petri dish containing agar. | Induces at concentration of 4667mg/l a rate of mortality of 95% after 72 hours LD90=8938mg/l | [63]      |

**Conclusion**

*Tuta absoluta* is one of the most harmful insect pests of several cultivated and non-cultivated host plants, particularly tomato plant *Solanum lycopersicum* L. Chemical insecticides are mainly used to manage the tomato leaf miner. However, their excessive use has led to several problems. Biological management remains an eco-friendly alternative for controlling this pest. It relies on using bacteria, entomopathogenic fungi, animals and plants. Plant extracts are easy to apply and have low costs. Several species, plant parts and extracts forms are used. Biological effects of these extracts are due probably to their major components that affect vital physiological functions such as neurophysiology and and respiration.

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