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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 environnement. 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 moltivoltine species. It parasitizes several cultivated and non-cultivated host plants belonging to Solanaceae, Amaranthaceae, Euphorbiaceae, Cucurbitaceae, Geraniaceae, Fabaceae, Asteraceae and Malvaceae [2]. Its presence relies on environnmental 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]. Larvaes feed and devolop 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: benzoylurea, 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 environnement 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 fungy 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 *Phthorimaea absoluta* (Meyrick, 1917) in Peruvian Andes. The genus was changed to *Gnorimoschema* then to *Scrobipalpula* and *Scrobipalpuloides*. This insect was named *Tuta absoluta* by Povolny in 1994 [11]. However, in a recent study based on parcimony analysis, *T. absoluta* was classified in a monophyletic clade that included *Phthorimaea operculella* (Zeller, 1873), and *Phthorimaea robusta* and proposed the reinstated combination *Phthorimaea absoluta* (Meyrick, 1917) and a new combination *Phthorimaea 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 distinguishable 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 diamter), 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.

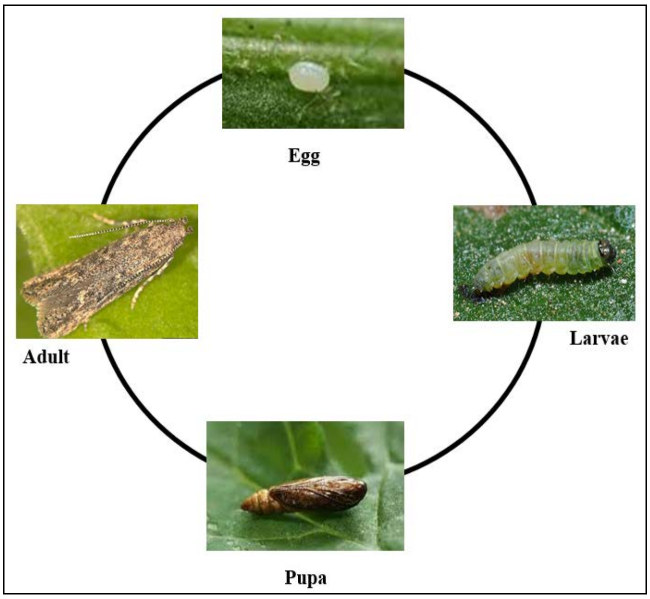

Fig 1: Life cycle of *T. absoluta*

Damages and losses caused by *T. absoluta*

The preferred host plant for *T. absoluta* feeding, oviopsition 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 effeciency of this method remains low because of the protection of the larvae in leaf mesolphyll 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 potentiel 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], lenghy 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), *Macrolophus pygmaeus* (Rambur), *Podisus nigrispinus* (Dallas), *Dicyphus errans* (Wolff) and *Brachygastra 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, *Dineulophus phthorimaeae* de Santis, *Goniozus nigrifemur* Ashmead, *Trichogramma achaeae* Nagaraja & Nagaratti and *Necremnus artynes* (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. Furthemore, the cost of consevration, 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 applicate and have low costs [28]. Also, plant extracts have low effects on human health and the environnment. Several species are used in *T. absoluta* management. The most studied belong to Lilliaceae, 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.

Alkamides found in *Acmella oleracea* have a pungent effect and seem to affect the nervous system inducing uncoordinated muscular activity. Their toxic effect is due to the disturbition 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].

Simmondsin, the major component of *Simmondsia chinensis*, exert its lethal effect by penetrating the intertugument 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 kilimandscharicum* 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	Biomassy method and pest developmental stage (in bold)	Major compenent	Results	Reference
Acmella oleracea (Asteracea)	Aerial parts	Hexane and ethanol extracts	0.5 µL of a solution of the extract are applicated on second-instar larvae placed in a Petri dish. After the application, the insects were kept in individual petri dishes containing tomato leaflets.	Alkamides: * Spilanthol, * (*E*)-*N*-isobutylundeca-2-en-8,10-diynamide * (*R*, *E*)-*N*-(2-methylbutyl)undeca-2-en-8,10-diynamide.	* 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).	[33]
Allium cepa L. (Lilliaceae)		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 80.2%. In greenhouse, after 8 days and at oncentration of 6%, extract induces a mortality of 89.7% of larvae.	[56]
Allium sativum L. (Lilliaceae)		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 oncentration of 6%, extract induces a mortality of 82.7% of larvae.	[56]
Allium sativum (Lilliaceae)	Bulbs	Aquous 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 (Lilliaceae)	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]

			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).		hours In glasshouse, its mean efficacy at 10% is 59.92% after 7 days.	
Azadirachta indica (Meliaceae)	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 62.5mg/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 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.	[59]
Azadirachta indica (Meliaceae)	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.	[58]
Carum copticum (Apiaceae)	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 ɤ-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, g-terpinene, and p-cymene	*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), *ɤ-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 ɤterpinene þ 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 + ɤ-terpinene, thymol, ɤterpinene and p-cymene, respectively.	[60]
Citrus aurantium (Rutaceae)	Peels	Essential oil	Filter papers were impregnated with oil at fumigant concentrations of 5 to 50 µl/l air and 25 to 200 µl/l air for *T. absoluta.* Each impregnated filter paper was attached to the screwcap of a Plexiglas bottle. Larvae were added to each bottle and caps were screwed on tightly.	Limonene (88.57%)	LC50 was 14.68 µl/l air LC90 was 30.18 µl/l air	[61]
Citrus limon (Rutaceae)	Peels	Essential oil	Filter papers were impregnated with oil at fumigant concentrations of 5 to 50 µl/l air and 25 to 200 µl/l air for *T. absoluta.* Each impregnated filter paper was attached to the screwcap of a Plexiglas bottle. Larvae were added to each bottle and caps were screwed on tightly.	Limonene (70.46%)	LC50 was 24.33 µl/l air LC90 was 39.2 µl/l air	[61]
Citrus limon (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 islated tomato shoots.	Limonene 52.80%	After 72h, at concentration 40mg/ml, essential oil and essential oil associated with nanoparticules induce a mortality of • 12% of eggs. • 66% and 52% of	[62]

			*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. *Inegestion 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.		larvae respectively for translaminar toxicity • 30% and 40% of larvae respectively for ingestion toxicity 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.	
Citrus reticulata (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. *Inegestion 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.	Limonene 59.19%	After 72h, at concentration 40mg/ml, essential oil and essential oil associated with nanoparticles induce a mortality of • 22% and 12% of eggs respectively. • 78% and 62% of larvae respectively for translaminar toxicity • 74% and 86% of larvae respectively for ingestion toxicity 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 nanoparticle equals 3.79 and 0.99 mg/ml respectively.	[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. *Inegestion 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.	Limonene 88.75%	After 72h, at concentration 40mg/ml, essential oil and essential oil associated with nanoparticles induce a mortality of • 92% and 40% of eggs respectively. • 80% and 62% of larvae respectively 78% and 62% of larvae respectively for translaminar toxicity • 50% and 74% of larvae respectively for ingestion toxicity For translaminar toxicity, LC50 for essential oil and essential oil associated with nanoparticles equals 5.77 and 14.68 mg/ml respectively For ingestion toxicity, LC50 for essential oil and essential oil associated with nanoparticle equals 8.9 and 1.53 mg/ml respectively.	[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		Lemongrass (*C. citratus*) at 10% induce a mortality of 96.67% in 120 hours In glasshouse, its mean efficacy at 10% is 57.94% after 7 days.	[58] Shiberu & Getu (2017)

			sprayed with plant insecticides at different concentrations (50, 75, and 100 ml/L).			
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.	[57]
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.	[58]
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.	[59]
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 green house 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 oncentration of 6%, *leaves extract induces a mortality of 74.0% *fruits extract induces a mortality of 60.7%	[56]
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.	[58]
Ocimum basilicum L. (Lamiaceae)	Leaves and flowrs	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%, *leaves extract induces a mortality of 53.8% * flowers extract induces a mortality of 73.6% In greenhouse, after 8 days and at oncentration of 6%, *leaves extract induces a mortality of 84.7% * flowers extract induces a mortality of 87.0%	[56]
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.	[58]
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%	[54]

(Lamiaceae)			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). *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	
Ocimum kilimandscharicum Gürke (Lamiaceae)	Aerial parts	Essential oil	*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). *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.	Camphor (47.0%), 1,8-Cineole (19.3%)	The repellence index at 50% was RI50 = 0.5% LC50 = 0.43 and LC90 = 1.83	[54]
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%.		In laboratory, after 5 days and at concentration of 6%, extract induces a mortality of 86.8%. In greenhouse, after 8 days and at oncentration of 6%, extract induces a mortality of 53.0%.	[56]
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 glasshouse, tomato plants were sprayed with plant insecticides at different 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.	[58]
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). In glasshouse, tomato plants were sprayed with plant insecticides at different 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.	[58]
Piper. amalago var. *medium*, *Piper. glabratum*, *Piper. mikanianum* (Piperaceae)	Leaves	Ethanolic 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.	Amides, lignans, alkaloids, and neolignans	*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.	[36]
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		The extract nduces at concentration of 77500mg/l a rate of mortality of 58% after 72 hours.	[63]

			dish containing agar.			
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 conentration 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 46667mg/l a rate of mortality of 95% after 72 hours LD90= 89383mg/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 managment remains an eco-friendly alternative for controlling of this pest. It relies on using bacteria, entomopathogenic fungi, animals and plants. Plant extracts are easy to applicate 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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