

*Review*

# **Role of aromatic plants in the integrated pest management (IPM) of *Thrips tabaci* Lindeman (Thysanoptera: Thripidae)**

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**Onion thrips, *Thrips tabaci* Lindeman is a cosmopolitan and polyphagous insect pest. Onion thrips cause direct and indirect damage to onion by feeding and ovipositing on leaves of several horticultural crops. Besides causing direct damage to its host plants, *T. tabaci* has been known as an asymptomatic transmitter of plant pathogens such as tomato spotted wilt virus (TSWV), iris yellow spot virus (IYSV) and tomato yellow ring virus (TYRV). These cause reduction of yield and decrease the market value of the crop. Several synthetic insecticides are used to control the population of onion thrips. However, these insecticides cause pesticide resistance, elimination of non-target species and environmental pollution. To solve the side effects of insecticides, it should be replaced by environmentally friendly pest management alternatives and for this, the use of plant-based pesticides is the best alternative because they do not have residue problems, negative effects on beneficial insects and do not cause air and water quality problems in the environment. Several plants have been investigated which contain bioactive compounds with a variety of biological modes of actions against onion thrips such as repellent, feeding deterrent, anti-ovipositional, fecundity deterrent and metamorphosis inhibition.**

**Key words:** Botanical plants, integrated pest management (IPM), onion thrips, secondary metabolites, modes of action.

## **INTRODUCTION**

Among the 6000 currently identified thrips species only about one percent is recorded as economically useful pests (Morse and Hoddle, 2006). This figure has implied that majority of the recorded thrips species are a major problem in agriculture. *T. tabaci* is among the major polyphagous thrips species since it has been recorded on more than 300 plant species (McKinlay, 1992). Onion

thrips is a key pest of onion and several crops and its control is important to the production and profitability of crops (Gill et al., 2015). The genetic variability of onion thrips has confirmed that *T. tabaci* is not a single pest species but rather a cryptic species complex. This concept is based on significant differences between the lineages regarding reproductive mode, host plant

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preferences and that there is considerable genetic variability within the three main lineages. The currently recognized lineages are arrhenotokous leek- (L1), thelytokous leek- (L2) and arrhenotokous tobacco-associated (T) lineages (Diaz-Montano et al., 2011; Kendall and Capinera, 1990).

Adult and larvae of onion thrips cause damage to their host by piercing and sucking sap out of the plant cells (Lewis, 1973). This damage interferes with the physiological activity of plants and such damage leads to low yield and quality in many crops. The damage to crops might be even more serious when *T. tabaci* transmits three devastating tospovirus species, such as tomato spotted wilt virus (TSWV), iris yellow spot virus (IYSV) and tomato yellow ring virus (TYRV) (Cortês et al., 1998; Hsu et al., 2010; Macharia et al., 2015; Rotenberg et al., 2015; Wijkamp et al., 1995).

Synthetic pesticides have been extensively used to control onion thrips (Din et al., 2016). However, due to their cryptic nature, high reproductive capacity, multi-generations per year, hidden lifestyle and polyphagous nature make them hard to control by synthetic insecticides. Repeated application of chemical insecticides in the field and green house often causes pesticide resistance, elimination of non-target species and secondary pest outbreaks. On the other hand, synthetic chemicals issued into the surrounding cause a chronic and acute side effect on human wellness. Due to those reasons, the use of chemical insecticide fails to fulfil the requirements of integrated pest management.

To solve all the above drawbacks of insecticides, use of integrated pest management is the most recommended. In this context, botanical plants could offer a better alternative to synthetic pesticides and effective to control many pests. For centuries, humans have been using plant-based insecticides against herbivores. In the nineteenth century, these natural pesticides became scientifically documented and widely applied in the early twentieth century (Morgan, 2004). Among the numerous botanical plant species, aromatic plants and their essential oils are appreciated in integrated pest management (Harrewijn et al., 1994). Plant-based insecticide have received more attention because (1) they do not have residue problem, (2) are target specific and (3) the target pests are not resistant to their effects, (4) do not have negative effect on beneficial insects and (5) do not cause air and water quality problems in the environment. Aromatic plants developed manifold mode of actions against pests, for example metamorphosis interfere, feeding deterrent, oviposition deterrent, repellent and adulticidal effect (Regnault-Roger, 1997). Thus, plant based pesticides effectively control pests without causing any environmental effects.

The aim of this work is to highlight the most effective botanical plants used to control onion thrips and their approaches in the field of integrated pest management. The approaches used in this work were based on

scientific and practical point of views.

## CURRENT KNOWLEDGE OF AROMATIC PLANTS ON THE CONTROL ASPECTS OF HERBIVORES

The growth in world population and increased demand for food lead to the use of modernized agricultural operations in order to increase productivity (Alam et al., 2016). In field of crop protection this has been applied by intense use of commercial pesticides against insects. Due to this several synthetic chemicals have been widely introduced as pesticides to combat insect pests. However, the toxic action of this pesticide is not specific to pest species only but it also eliminates non-targeted species like pollinators and natural enemies, pest resurgence, secondary pest's outbreaks (Aizawa et al., 2016; Foster et al., 2010; Lebedev et al., 2013; MacIntyre et al., 2005).

The evolution of plants and insects is closely associated, as they have co-existed on the earth for over 400 million years. This allows them to develop offensive and defensive strategies (Labandeira, 2007). Plant defensive strategies are grouped in to two categories: (1) constitutive defences in which plants develop specialized morphological structures to protect them from herbivores. These are cell wall, epidermal cuticle, callus deposition, lignification and stomatal closure (Sánchez and Morquecho, 2017; Saxena, 2004). Plant constitutive defensive strategies are: glandular trichomes, latex, leaves hair, thorns, spines, and thicker leaves (Hanley et al., 2007; Howe and Jander, 2008; Traw and Dawson, 2002; Yamane et al., 2010). (2) Inducible defences in which it is produced or mobilized to the damage site while a plant is injured by herbivores. This requires a specific detection of the presence of herbivores and alters gene expression. Herbivore-induced plant response formed by several phytohormones such as jasmonic acid, ethylene, salicyc acid, abscisic acid, auxin, cytokinins, brassinosteroids and gibberellins (Abe et al., 2008; Erb et al., 2012). These phytohormones involve initiating the production of secondary metabolites and proteins which are toxic to insects' biochemistry, repellent and anti-nutritional effect on the herbivores (Dicke et al., 1990; Nisha et al., 2012).

### Alkaloids

The alkaloids are widely distributed in plants and used as a means of plant defence against insects. Amaryllidaceae, Compositae, Lauraceae, Leguminosae, Liliaceae, Papaveraceae, Rutaceae, and Solanaceae plant families are rich in alkaloids (Fürstenberg-Hägg et al., 2013). Alkaloids are synthesized from plant leaves, seeds, roots and fruits. Caffeine, nicotine, morphine, strychnine, cocaine, cytosine and sparteine are alkaloid compounds and used as feeding deterrent against

herbivore (Howe and Jander, 2008).

### Phenolics

Phenolics compounds are synthesized from higher plants and able to repel herbivores, inhibit enzymes, attract pollinators and fruit dispersers, absorb UV radiation, and decrease competition between plant neighbors. Phenolics compounds bind covalently to herbivore's digestive enzymes and inactivate them from feeding which stop the growth and development of larvae (Sambangi and Rani, 2016).

### Terpenoids

It is the most diverse group of natural compounds in plants species and serves as chemical defense for plants. Terpenoid compounds are involved in plant defenses with repellent and toxic mode of actions (Shrivastava et al., 2015).

### Sulfur

Sulfur is an essential element for plants; it determines plant development, maintenance, and resistance to environmental stress. It is taken up by plants as an inorganic sulfate and incorporated in different sulfated metabolites such as glucosinolates, flavonoids, phytosulfokines, and hormones such as gibberellins. The sulfated metabolites are used as a plant defensive against herbivores by developing feeding deterrent mode of actions (Heidel-Fischer and Vogel, 2015).

### Salicylic acid

It is small phenolic phytohormone, which plays a vital role in mediating defense. Plant responses are regulated by salicylic acid when herbivores bite the phloem. Plant secondary metabolites mediated by salicylic acid affect the interaction between plants herbivores (Shi et al., 2016). When a plant faces many herbivore attacks, induced defense is mediated through interconnection of the jasmonic acid, salicylic acid, and ethylene signal transduction pathways.

## THE SYNERGIC RELATIONSHIP BETWEEN ONION THRIPS AND PLANTS

Onion thrips is a polyphagous thrips insect species as it has been recorded on more than 300 plant species (McKinlay, 1992). Both adults and larvae of onion thrips cause damage to their hosts by piercing the surface tissues and sucking the contents of plant cells. This damage decreases the photosynthetic capacity, growth, and reproduction of the plants, producing silvery white

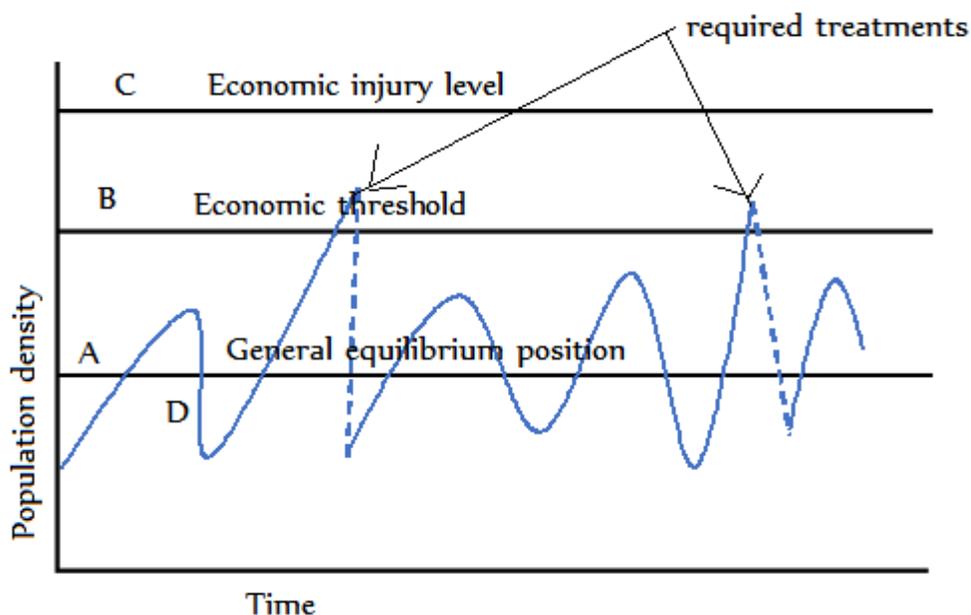
spots, twisting and curling damage symptoms (Lewis, 1973). Besides causing direct damage to the crops *T. tabaci* is a vector of three devastating tospovirus species such as tomato spotted wilt virus (TSWV), iris yellow spot virus (IYSV) and tomato yellow ring virus (TYRV) (Cortés et al., 1998; Hsu et al., 2010; Macharia et al., 2015; Rotenberg et al., 2015; Wijkamp et al., 1995). These tospovirus species cause mottling and speckling of leaf, necrotic lesions, sunken and ring spot damage symptoms. Onion thrips cause total yield reduction from 4 to 27% and bulb size reduction from 28 to 73% (Fournier et al., 1995; Lewis 1973). Occasionally, the yield loss may reach 90% when the crop is attacked in its early growth stage (Anonymous, 1984).

In order to decide on the effective control strategy the growers would need to establish the economic threshold level of this pest species (Figure 1). Action threshold of a pest is one of the most important decision-making elements in integrated pest management. However, the reliable treatment threshold level for *T. tabaci* is designed based on season (dry or rainy), resistance level of crop varieties (Gill et al., 2015). In California, there is a threshold of thirty thrips per plant at mid-season. In New York State a threshold of three thrips per leaf has been suggested, and one thrips per leaf for Spanish and green bunching onions (Gill et al., 2015). The other entomologist suggests an initial treatment threshold of one thrips per plant and then waiting until they reach five thrips per plant for a second treatment (Hatfield, 2003). In Ethiopia, the economic threshold level of onion thrips is five to ten per plant (Shiberu and Mahammed, 2014).

Figure 1 show a general schematic graph of the fluctuations in population density and threshold level to determine the effective managements (Stern et al., 1959). (A) general equilibrium position indicated the average density of a population over a period of time. On this position the number of pests does not cause economic loss; (B) economic threshold indicated the density at which control measures should be applied to control pests from reaching the economic-injury level. The economic threshold is slightly lower than the economic-injury level to allow enough time for the introduction of control measures and for these measures to take effect before the population reaches the economic-injury level; (C) economic-injury level refers to the lowest population density that will cause economic damage; (D) the fluctuations in population density before and after control measurements. At the time of applying a control management, the pest population decreases before their populations reach the economic injury level and the densities remain above or below the general equilibrium position.

## EFFICACY OF BOTANICAL PLANT DERIVATIVES AGAINST ONION THRIPS

To solve the negative effect of insecticides in the



**Figure 1.** A general schematic graph of the fluctuations in population density and threshold level to determine the effective managements (Stern et al., 1959).

ecosystem, secondary compounds from plants are an alternative ways against insect pests. Plant secondary metabolites and essential oils are considered as part of the chemically based defensive system against onion thrips (Table 1). Currently, the secondary metabolites of plants are recognized as potent alternatives for controlling the population of onion thrips. These secondary compounds are produced naturally from plant root, leaf, flower, seed and stem against many insect species. Several plants have been investigated to control the different biological mode of actions including repellent, antifeedant, anti-ovipositional, toxic, fecundity and egg sterility, and metamorphosis inhibition (Koschier and Sedy, 2003; Stella et al., 2010).

#### **METHODS TO APPLY THE AROMATIC PLANTS AND THEIR DERIVATIVES AND MECHANISMS OF ACTIONS**

As other insects, onion thrips use vision and olfaction to orient towards host plants. While insects select the host plants, aromatic plants produce secondary metabolites against this pest. These secondary metabolites appear to be quite specific for a given target and serve the host plants as defence compounds against herbivores by developing different mode of actions such as repellent, antifeedant, anti-ovipositional, toxic, fecundity and egg sterility, and metamorphosis inhibition.

#### **Attractants activity**

Onion thrips are small insects and live in hidden space

such as under the curled leaf and leave them easily during management. To make reliable management for such condition colored sticky board is an optional. Color sticky board is effective for small insect species such as dipteran, hymenopteran, thysanopteran and other insect species. Like other thrips species, white, yellow and blue traps visually attract onion thrips (Vernon and Gillespie, 1990). Sticky boards are effective. Sticky traps are mostly used in monitoring plants to detect pests before infestations, or to check out if the plants are free of any flying pest species. The sticky boards record and show the infestation level of pests; they are used to decide the future direction of pest management.

Trap effectiveness increases by combining an attractive color cue with an attractive odour cue because attractive odour derived from aromatic plants are a complex mixture of different groups of secondary metabolites. Combining two or more attractive secondary metabolites seems to be a common practice towards trap efficiency improvement. However, the mixing of p -Anisaldehyde and methyl isonicotinate has less efficiency for onion thrips compared to applying them separately (Teulon et al., 2007). This implies that onion thrips would have only one odour receptor and the other implication might be blended compounds could be masking each other (Koschier, 2008). The masking effect between the secondary compound has been reported also for aphids (Nottingham et al., 1991). The secondary metabolites such as monoterpenes, sesquiterpenes and phenylpropanoid should be applied on the sticky boards to attract the pest and stick them on the sticky board. Sticky boards can be installed near the entrances to detect any pest migration and drawn to the wind

**Table 1.** List of plants that have been practically used to control population of onion thrips.

Plants list	Main active compounds	References
<i>Artemisia arborescens</i>	Sabinene, terpinene, linalool, thujone	Militello et al. (2012); Van Tol et al. (2007)
<i>Azadirachta indica L.</i>	Triterpenes, salannin, nimbin, azadirone, amoorastaitin, vepinin, vilasinin, gedunin, nimbolin, salannol, salannolacetate tetranortriterpenoid or limonoid	Dayan et al. (2009); Saxena (2004); Shiberu and Negeri (2014)
<i>Chrysanthemum cinerariaefolium</i>	Terpinolene,	Ikolova and Eorgieva (2014)
<i>Datura stramonium</i>	Tropane alkaloid (hyoscyamine, hyoscine)	Fitiwy et al. (2015)
<i>Dianthus caryophyllus</i>	Benzaldehyde	Teulon et al. (1993); Teulon and Ramakers (1990)
<i>Dodonae angustifolia L.</i>	Terpenoids, Flavanone, Santin, Kaempferol, Rhamnocitrin	Omosa et al. (2016); Shiberu and Negeri (2014)
<i>Melaleuca alternifolia</i>	$\alpha$ -Thujene, Sabinene, 1,8-Cineole, Terpeneol, Bicyclogermacrene, Terpinene	Yang et al. (2013); Van Tol et al. (2007)
<i>Nicotiana glauca</i>	Triterpenes, tetraterpenes, isoprenoids, cembranoids, labdanoids, alkaloids, flavonoids, anthocyanins, nicotinoids, benzaldehyde	Nugroho and Verpoorte (2002); Teulon and Ramakers (1990)
<i>Ocimum gratissimum</i>	Alkaloids, tannins, flavonoids and oligosaccharides	
<i>Origanum majorana</i>	Ursolic acid, oleanolic acid, $\beta$ -sitosterol, triacontanol and tyrosinase	Prabhu et al. (2009)
<i>Rosmarinus officinalis</i>	Wogonin (flavonoid), Carnolic acid, rosmarinic acid, camphor, caffeic acid, ursolic acid, betulinic acid, and carnosol	Rao et al. (2011)
<i>Tagetes minuta</i>	Linalool, Limonene, Palmitic acid, Alloocimene, Trans-tagetone	Ferella et al. (2018); Vallverdú-Queral et al. (2014)

direction. Sticky boards are not used as a holistic pest management system; they are used to detect early infestation of pests. It may be effective for a small greenhouse/growing bed whilst larger areas can be divided into small sections to provide easier monitoring.

### Repellent activity

Botanical plant families, genera or species have characteristic odors and such chemical traits usually are repellents to numerous species of insects (Deletre et al. 2016). In a strict sense, the host selection process of thrips is followed by testing various plant cues such as color, shape and size of the plants (Lewis, 1973). Repellents are products of secondary metabolites and used as olfactory messengers to insects. These plant cues have the potential to interfere with the host selection. Repellent is a major constituent in the natural defence systems of plants. The repellent mode of action is provided by plants that have emitted secondary compounds and discourages insects from landing or moving on plant surface. It helps to prevent and control the outbreak of insects. Onion thrips are repelled by Rosemary (*Rosmarinus officinalis* L.) essential oil and deterred by the essential oils of marjoram (*Origanum majorana* L.), lavender (*Lavandula angustifolia* L.) and mint (*Mentha arvensis* L.) (Koschier and Sedy, 2003).

### Oviposition deterrent

Plant and insect interactions are not just influenced by interactions between plants and feeding but also by the close relationships between plants and egg deposition. Plant nutritional quality particularly nitrogen content, architecture, morphology and anatomy and secondary compounds is reported as detrimental factors for ovipositional choice of females (Koschier and Sedy, 2003). Similarly, these secondary metabolites affect the settling and feeding ability of onion thrips and finally stop feeding, and starvation to death (Singh and Saratchandra, 2005). Field examination with *Azadirachta indica* extracts showed that the effect against onion thrips correlated with ovipositional deterrence, feeding deterrence, toxicity and sterility. Physiological toxicity of azadiracht retards growth, which affects the fecundity of females and therefore decreases the density of onion thrips (Shiberu and Negeri, 2014).

### Metamorphosis deterrent

Metamorphosis is a gradual change in every developmental stage of insects. Insects have two developmental metamorphosis such as hemimetabolous and holometabolous. However, it is exceptional for thrips species because they follow the transition between

hemimetabolous and holometabolous postembryonic developmental stages as an immature nymph exhibit many similarities with adults. Hormones synthesized by endocrine glands control insects' growth and metamorphosis. In other words, the hormone balance determines whether the next molting is larval-larval, larval-prepupal, pre-pupal-pupal, or pupal-adult. The interference of molting steps due to the hormonal imbalance leads to mortality. The secondary metabolites derived from plants mimic as prothoracicotropic hormone (PTTH) and block ecdysone, refuse the next molting and finally lead to death (Schmutterer, 1990).

## CONCLUSION AND FUTURE PROSPECTIVE

Today the aromatic plants and their derivative essential oils have received a special attention in research regarding economic and ecological importance. Currently, onion thrips have spread worldwide and cause the destruction of agricultural production. However, there are no true selective insecticides against this pest in relation to integration into the existing integrated pest management. In the last few years, the usage of essential oils has been increased against onion thrips. Aromatic plant essential oils has been a potent alternative to control other thysanoptera thrips species such as *Frankliniella occidentalis*, *Thrips palmi*, *Limothrips cerealium*, *Thrips fuscipennis*, *Thrips imagines*, *Thrips obscuratus*. Therefore, a diversified use of essential oils by the development of their use in the pest management sector could be of both economic and ecological benefit. Benefits include the following: 1) they do not have residue problem, which is a matter of substantial concern for consumers, 2) are target specific and 3) the target pests are not resistant to their effects, 4) do not have negative effect on beneficial insects and 5) do not cause air and water quality problems in the environment.

Based on the mitochondrial DNA data, reproduction mode, and host adaptation, *Thrips tabaci* is not a single pest; rather it has three major evolutionary lineages; two of them are associated with leek, whereas the third one is associated with tobacco. The two types of leek-associated *T. tabaci* were found to coexist outdoors; the frequency of these two forms vary temporally on the same host plants but the effect of plant odour on these lineages has been rather neglected. To formulate control strategies for onion thrips, it is essential to know detailed information on all the three lineages. All the studied aromatic plants use only their general name, onion thrips and we are not sure which aromatic plants are effective in onion thrips lineages. Here it is recommended to compile information on each lineage and there is need to confirm the promising aromatic plants against onion thrips lineages. Therefore, in the future it would be grateful to check the effectiveness of aromatic plants and their

derivatives against *T. tabaci* cryptic species complex.

## CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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