

# Potential volatiles emitted from jasmine plants infested by two spotted spider mite and its attraction to predatory *Scirtothrips dorsalis*

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## Research Article

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# Abstract

Induction of plant defense in response to herbivore involves emission of synomones that attracts natural enemies of herbivores. Herbivore-Induced volatiles were extracted from fresh healthy jasmine plants (*Jasminum sambac* L) and infested jasmine plants damaged by two spotted spider mite, *Tetranychus urticae* Koch. and analysed through Gas Chromatography-Mass spectrometry (GC-MS) to determine volatile hydrocarbon profile in them. The results revealed that both the healthy and damaged leaves had emitted hydrocarbon compounds numbering 19 and 31 respectively and some compounds were detected twice or even thrice. The variation in the hydrocarbon constituents of healthy and damaged plants clearly depicts the emission of volatiles responsible for attracting beneficials witnessing tritrophic interactions in jasmine ecosystem. The healthy jasmine plants emanated natural enemy attractants, linalool, methyl salicylate and alpha-farnesene, apart from other volatile organic compounds (VOC). Linalool is a volatile chemical that is produced by herbivore damage that attracts natural enemies. The compound allyl isothiocyanate was detected in two spotted mite infested jasmine extracts at 4.307 mts in a peak area of 1664139 mm<sup>2</sup>. Allyl isothiocyanate serves the plant as a defense against herbivores; since it is harmful to the plant. Allyl iso thiocyanate detected in enormous quantity in mite infested jasmine plants is a positive cue for commercial preparation of artificial lures to attract mite natural enemies in jasmine ecosystem. In the olfactometer behavioural bioassay studies, maximum number of released mite predator, *Scirtothrips sexmaculaus*, oriented on mite infested jasmine plant volatiles (18.5 nos), followed by leaf web worm (13.0) and healthy plant volatiles (5.5 nos).

## Introduction

Jasmine (*Jasminum sambac* (L.) Aiton) known in persian as yasmin *ie.* 'Gift of God' is one of the oldest fragrant flowers of India. It is traditionally as well as commercially cultivated for its sweet-scented flowers. As the demand for high grade perfumes has greatly increased in recent times, there is tremendous scope for the production of concretes and oils from jasmine flowers (Prakash and Muniandi 2014). Also, the need for the mesmerizing jasmine flowers for diverse necessities like religious ceremonies, official and home decorations, weddings, funerals etc. is ever rising. Hence, the area and production of total flowers in India were increasing impressively over the years. There are many factors that affect jasmine production, of which pest incidence takes major lead. Among the arthropods attacking jasmine, the two-spotted spider mite, *Tetranychus urticae* Koch is one of the prime pests which devastates the productivity of the crop. It is the most widely known member of the family Tetranychidae. In jasmine, flowering commences during March-April and comes to peak in May-July. During this period, the weather is too hot and is favorable for multiplication and so the population density increases rapidly. An adult female can lay more than 100 eggs in three weeks on the undersurface of the leaves. Eggs hatch in four to five days and the entire life cycle from egg to adult is completed in one to three weeks, depending on the temperature. The life-cycle of *T. urticae* consists of five different stages such as egg, larva, protonymph, deutonymph and the adult. Mites are typically found on the underside of leaves, but may colonise entire plants during outbreaks. The mites suck sap from cells on the underside of plant

leaves, in the early stages and characteristic white speckles can be seen from the upper leaf surface. As mite number density increases in number and size, these white speckles also increase and the leaf exhibits a bleached appearance (Demirel and Cabuk 2018; Martinez-Ferrer et al. 2006). In case of severe infestation, the whole plant becomes pale in colour, and affects production and size of the flower buds. Damage to the leaves inhibits photosynthesis, and severe infestations can result in premature leaf fall, shoot dieback, and decreased plant vigor. Although the individual lesions are very small, attack by hundreds or thousands of spider mites can cause thousands of lesions and thus can significantly reduce the photosynthetic capability of plants (Zhang 2003) (Fig. 1). Such buds fetch a low market price. Silk webbing on the undersides of leaves are characteristic signs of spider mites. Under high population densities, the mites move to the tip of the leaf or top of the plant and congregate using strands of silk to form a ball-like mass, which will be blown by winds to new leaves or plants, in a process known as “ballooning.” (Fig. 1).

To manage this pest jasmine growers, rely on synthetic chemical pesticides, which causes resurgence with the population increases after few months, later disproportionately requiring repeated application with higher dosages, which finally became hazardous and uneconomical, leading to the endangerment of ecosystem by reducing the diversity of natural enemies. In addition, direct toxicity to human beings, animals and environment is of serious concern. It is pertinent that a change in the mite pest management strategy may form a meaningful solution to avoid the ill-effects caused by the synthetic chemical acaricides especially as environmental contaminants. Therefore, in search of safer alternatives, attention has been focused on exploration of semiochemical mediated approaches through host plant defense mechanisms. An approach of using semiochemicals in pest management is to exploit ways to chemically augment, conserve or enhance the efficacy of natural enemies in a crop ecosystem. Use of these biochemicals especially, the synomones released by host plants is of significance in biological control.

Plants respond to herbivory through different defensive mechanisms. The induction of volatile emission is one of the important and immediate response of plants to herbivory. Herbivore-induced plant volatiles (HIPVs) are involved in plant communication with natural enemies of the insect herbivores, neighboring plants, and different parts of the damaged plant (Hilker and Meiners 2006). Release of a wide variety of HIPVs in response to herbivore damage and their role in plant-plant, plant-carnivore and intraplant communications represents a new facet of the complex interactions among different trophic levels (Ahmad et al. 2004). Use of these biochemicals, especially the synomones released by host plants is of significance in biological control. The importance of biological control in pest management is well recognized all over the world, in the recent past. Inventory on the predatory complex is a vital component to identify the locally adapted, dominant, efficient species that can be promoted as promising candidate predator for managing these pests. In particular, synomones play a major role by guiding the natural enemies to the potential host or prey on the plant. Such clues may be utilized to stimulate foraging and host selection behavior of entomophages thereby increasing their effectiveness for IPM. The six-spotted thrips, *Scolothrips sexmaculatus* (Pergande) (Thysanoptera: Thripidae) (Fig. 2) is considered to be an

effective predator against small insects and spider mites (Gilstrap 1995). *Scolothrips sexmaculatus* is reported as an effective predator of two spotted mite, in ornamental crops (Suman et al. 2018).

In view of this, in the present study, the hexane leaf extracts of jasmine damaged by two spotted mite and healthy leaves were analyzed through GC-MS to determine the mite induced volatile profile in them. In addition, the attraction of the thrips predator, *S. sexmaculatus* to the volatiles from *T. urticae* infected leaves was determined.

## Materials And Methods

### Volatile extraction

A volatile collection unit (VCU) was used for collection of head space volatiles. The potted plant of *Jasminum sambac* with flower buds was kept inside an air-tight glass jar and 10 mites/ leaf was placed inside each bud using a camel hair brush and the maggots were allowed to feed overnight. Air was pumped into the jar through activated charcoal at the rate of 100 ml/min. Head space volatiles from the damaged jasmine plants were collected on to the adsorption tubes (Gainesville, FL (352)283 – 0133; P/N VCT-1/4-4-PQR-Q;1/4'ODx4"L VCT). Both sides of the adsorption tube were fitted with steel mesh grids to prevent the adsorbent falling apart. Head space volatiles were trapped for 2h and stopped for half an hour and again collected for another 2 h. The pumping was stopped to prevent accumulation of moisture inside the VCU and to prevent excess heat generated in the motor of the vacuum pump used for pumping air. Each time a new adsorption tube was used for collection of head space volatiles. The adsorbed volatiles were eluted immediately with 20 ml HPLC grade hexane. The eluted hexane extract was concentrated and then injected into GC-MS. The same methodology was followed again with another fresh potted jasmine plant with flowers and larva of budworm was released @1 /bud for collection of budworm induced volatiles, another fresh potted jasmine plant and maggot of blossom midge was released @1/bud for blossom midge induced volatiles, another fresh potted jasmine plant and larva of leaf webworm was released @1/leaf for leaf webworm induced volatiles. The undamaged jasmine plant was placed inside the volatile collection unit and volatiles were collected for comparison.

*Identification of volatiles using GC-MS.* Gas Chromatography combined with mass spectroscopy, a preferable methodology for routine hydrocarbon analysis of compounds was taken up. Volatile hydrocarbon analysis was carried out on a GC MS-QP 2010 Plus (Shimadzu Kyoto, Japan) mass selective detector (70 eV) equipped with a 10:1 split injector. The gas chromatograph was armed with a 30 m fused silica capillary column having 0.25 mm ID and 0.25  $\mu$ m film thickness run in constant flow mode (1.0 ml/min helium). Oven temperature programmed at 60°C (1 min hold), then to 220°C at 10°C/min rate (5 min hold) and then to 240°C at 50°C/min rate (8 min hold). Injector temperature was set at 275°C. One microlitre of the volatiles were injected using auto sampler into the GC-MS system for analysis. Injections were done in split 10:1 mode. Shimadzu GC-MS Lab solution software was used for the analysis of compounds in the volatile. Injected samples were separated into various constituents with different retention time and detected by mass spectrophotometer. The compounds of interest were

identified using standard NIST mass spectral (NIST MS 2) library. The chromatogram, a plot of intensity against retention time was recorded by the software attached to it. From the chromatogram the compounds were identified by comparing the data with the existing software libraries.

### **Behavioral bioassay of *S. sexmaculatus* for volatiles using olfactometer**

The orientation behavior of the *Chrysoperla zastrowi sillemi* was studied using an eight arm olfactometer according to Ranjith (2007) and Hao et al. (2012). The olfactometer had a release chamber at the center and was connected by a pure air inlet tube. For creating pure air current the air inlet tube was connected to a blower through an air inlet chamber fitted with a charcoal filter and an air-flow meter. The blower unit had a battery- operated mini-fan fitted in a glass tube to generate an air current at the rate of 2 m/s.

The orientation behavior of the predator/parasitoid, towards the volatile fractions was studied using six arm olfactometer under laboratory condition at  $26 \pm 2^{\circ}\text{C}$  and  $65 \pm 5\%$  RH and 150 lux light density. The four saturated test fractions from four pests of jasmine @ 50  $\mu\text{l}$  each and a positive control with water and a negative control with hexane were placed on filter paper strips of 30 mm x 10 mm (odour source) separately at the six arms. After permitting the solvent to evaporate for 2 min, the filter paper strip was inserted in to the connector tubes from which insects were physically excluded to avoid contamination. Fifty *S. sexmaculatus* adults were released from the top of the olfactometer through the circular entrance and the number of thrips opting for each volatile fraction was recorded. Observations were taken at 2h and 4h after release. An air delivery system, passed humidified and purified air through Teflon tubes into the olfactometer arms. Air flow for working of olfactometer was maintained @ 7.15 ml/min using a blower fitted to the four arms of the olfactometer. Vacuum cleaning was done before and after completion. Three replicates were maintained.

### **Statistical Analysis**

The analysis of variance was carried out by completely randomized design (CRD) using AGRES software. The data on the efficacy of synomones from the mite induced volatiles on the attraction of *Scirtothrips dorsalis* was transformed to  $\sqrt{x} + 0.5$  and analyzed by completely randomized design (CRD). The treatment mean values of the experiment were compared using Latin Square Distribution (LSD) ( $p \leq 0.05$ ) using AGRES software.

## **Results**

### **GC-MS analysis of volatiles emanated from healthy jasmine plants**

The volatile profile emitted from healthy jasmine plants were furnished in Table 41. The healthy jasmine plants emitted 19 volatile compounds *viz.*, cyclohexanol, cyclohexanone, 2-pentanol, 3-hexanol, 3-heptanol, 2-pentene, benzaldehyde, cyclopentanol, benzyl alcohol, heneicosane, linalool, phenyl methyl alcohol, methyl salicylate, alpha-farnesene, di-octyl acetate, octadecane, tricosane, octacosane and

octadecane, with linalool in maximum quantity of 4942096 mm<sup>2</sup>. Methyl salicylate and alpha-farnesene were detected in a peak area of 263826 and 215542 mm<sup>2</sup> respectively (Fig. 3).

### **GC-MS analysis of volatiles emanated from mite infested jasmine plants**

The volatile profile emitted from mite infested jasmine plants were furnished in Table 1. The mite infested plants consists of 31 volatile compounds *viz.*, cyclohexane, allyl isothiocyanate, styrene, nonane, 3-pentanol, 3-hexanol, cyclopentanol, 3-methyl-, cyclohexanol, naphthalene, azulene, dodecane, benzothiazole, tridecane, heneicosane, hexadecane, heptadecane, xanthene, octadecane, nonadecane, eicosane, tetracosane, heneicosane, pyrene, fluoranthene, tricosane, tetracosane, heneicosane hentriacontane, bis (2-ethylhexyl) phthalate, hexacosane, heneicosane and quinolone. The compound tetracosane was detected twice and heneicosane was detected thrice. The compounds with probability to attract natural enemies, styrene, naphthalene and azulene were detected in leafwebworm induced volatile compounds along with bis (2-ethylhexyl) phthalate, recorded a peak area of 4112779391 mm<sup>2</sup> representing a maximum quantity of 93.44 per cent (Fig. 4).

Table 1

Volatile profile of the healthy and two spotted mite, *Tetranychus urticae* damaged plants of jasmine, *Jasminum sambac* L.

| Healthy plant |                            |                         | Mite damaged plant |                            |                          |
|---------------|----------------------------|-------------------------|--------------------|----------------------------|--------------------------|
| RT<br>(min)   | Area<br>(mm <sup>2</sup> ) | Name of the<br>compound | RT<br>(min)        | Area<br>(mm <sup>2</sup> ) | Name of the compound     |
| 4.309         | 1448100                    | Cyclohexanol            | 4.264              | 624584                     | Cyclohexane              |
| 4.519         | 12211                      | Cyclohexanone           | 4.304              | 1664139                    | Allyl isothiocyanate     |
| 4.690         | 15383                      | 2- Pentanol             | 4.451              | 2976175                    | Styrene                  |
| 4.690         | 15383                      | 3- Hexanol              | 4.558              | 1824419                    | Nonane                   |
| 5.033         | 964571                     | 2-Pentene               | 5.016              | 23030924                   | 3-Pentanol               |
| 5.856         | 175210                     | Benzaldehyde            | 5.451              | 12362254                   | 3-Hexanol                |
| 5.965         | 1274302                    | Cyclopentanol           | 5.951              | 38307424                   | Cyclopentanol,           |
| 7.558         | 838689                     | Benzyl alcohol          | 6.529              | 4709653                    | Cyclopentanol, 3-methyl- |
| 8.300         | 116978                     | Heneicosane             | 7.770              | 2315105                    | Cyclohexanol             |
| 9.278         | 4942096                    | Linalool                | 11.643             | 2196523                    | Naphthalene              |
| 9.676         | 693649                     | Phenyl methyl alcohol   | 11.643             | 2196523                    | Azulene                  |
| 11.926        | 263826                     | Methyl salicylate       | 11.996             | 2179198                    | Dodecane                 |
| 17.305        | 215542                     | Alpha-Farnesene         | 12.547             | 791670                     | Benxathiazole            |
| 27.552        | 4684360                    | Octadecane              | 14.051             | 1387549                    | Tridecane                |
| 27.552        | 4684360                    | Tricosane               | 17.553             | 1074991                    | Heneicosane              |
| 27.552        | 4684360                    | Octacosane              | 18.435             | 685665                     | Hexadecane               |
| 27.552        | 4684360                    | Octadecane              | 19.616             | 1191960                    | Heptadecane              |
|               |                            |                         | 19.707             | 2910547                    | Xanthene                 |
|               |                            |                         | 20.721             | 1846424                    | Octadecane               |
|               |                            |                         | 21.763             | 1356824                    | Nonadecane               |
|               |                            |                         | 22.817             | 3080582                    | Eicosane                 |
|               |                            |                         | 22.817             | 3080582                    | Tetracosane              |
|               |                            |                         | 24.045             | 1197206                    | Heneicosane              |
|               |                            |                         | 24.663             | 2098199                    | Pyrene                   |

| Healthy plant | Mite damaged plant |            |                             |
|---------------|--------------------|------------|-----------------------------|
|               | 24.663             | 2098199    | Fluoranthene                |
|               | 27.538             | 2620713    | Tricosane                   |
|               | 29.025             | 5717506    | Tetracosane                 |
|               | 30.839             | 7931928    | Heneicosane                 |
|               | 30.839             | 7931928    | Hentriacontane              |
|               | 30.972             | 20400249   | Diisooctyl phthalate        |
|               | 32.230             | 4112779391 | Bis(2-ethylhexyl) phthalate |
|               | 33.130             | 15218660   | Hexacosane                  |
|               | 33.130             | 15218660   | Heneicosane                 |
|               | 35.199             | 2563687    | Quinoline                   |

#### **Orientational response of *S. sexmaculatus* to synomonal extracts of saturated hydrocarbons**

The attraction of the mite predator, *S. sexmaculatus* to the two spotted mite, *T. urticae*, reveals that 17 and 20 nos of predatory thrips oriented to volatile extracts from jasmine plants infested by two spotted mite, followed by the leaf webworm infested jasmine leaves oriented 9 and 17 predatory thrips 2 and 4 HAT. Healthy jasmine plant, bud or m infested plant and blossom midge infested plant volatiles were on par in attraction, luring 5.50, 6.00 and 5.00 thrips in an average. In the negative control of hexane and positive control of water, 3 and 2 thrips were oriented 2 HAT and none at 4 HAT (Table 2).

Table 2

Oriental response of *S. sexmaculatus* to potential synomones from jasmine leaves infested by mites

| T. No.         | Treatments                           | No. of predators attracted (HAT) |                           |                           |
|----------------|--------------------------------------|----------------------------------|---------------------------|---------------------------|
|                |                                      | 2                                | 4                         | Mean*                     |
| T <sub>1</sub> | Healthy jasmine plants               | 8.00<br>(2.82) <sup>b</sup>      | 3.00 (1.66) <sup>b</sup>  | 5.50 (2.34) <sup>d</sup>  |
| T <sub>2</sub> | Budworm infested jasmine buds        | 7.00<br>(2.64) <sup>b</sup>      | 5.00 (2.23) <sup>b</sup>  | 6.00 (2.44) <sup>c</sup>  |
| T <sub>3</sub> | Midge infested jasmine buds          | 6.00<br>(2.45) <sup>b</sup>      | 4.00 (2.00 ) <sup>b</sup> | 5.00 (2.23) <sup>d</sup>  |
| T <sub>4</sub> | Leaf webworm infested jasmine leaves | 9.00<br>(2.99) <sup>b</sup>      | 17.00 (4.00) <sup>a</sup> | 13.00 (3.60) <sup>b</sup> |
| T <sub>5</sub> | Mite infested jasmine leaves         | 17.00<br>(4.12) <sup>a</sup>     | 20.00 (4.66) <sup>a</sup> | 18.50 (4.30) <sup>a</sup> |
| T <sub>6</sub> | Negative control (Hexane)            | 3.00<br>(1.73) <sup>c</sup>      | 0.00 (0.00) <sup>c</sup>  | 1.50 (1.22) <sup>e</sup>  |
| T <sub>7</sub> | Positive control (Water)             | 0<br>(0.00) <sup>d</sup>         | 1.00 (1.00) <sup>c</sup>  | 0.50 (0.71) <sup>e</sup>  |
| SE             | CD(0.05)                             | 00.1230<br>0.2608                | 0.1187 0.2516             | 0.1209<br>0.2563          |

## Discussion

The healthy jasmine plants had emitted 19 compounds including the natural enemy attractants, linalool, methyl salicylate and alpha-farnesene, apart from other volatile organic compounds (VOC). Linalool is a volatile chemical that is produced by plant leaves in a wide variety of plant species, when they are damaged by insect herbivores. The effect of linalool on Western Flower Thrips (WFT) (*Frankliniella occidentalis*), a common insect pest in greenhouses, in transgenic chrysanthemum plant lines that had a higher linalool production, showed initial attraction and then repellence to the pest, which was correlated to the attraction of natural enemies (Yang et al., 2013). Linalool is likely to mediate the interaction between herbivores and their natural enemies, attracted by terpenes. Experimentally, a study of *Arabidopsis thaliana* engineered to overexpress a terpene synthase leading to the emission of large amounts of linalool, which is normally produced only in trace levels, which significantly repelled *Myzus persicae* aphids, due to attraction of natural enemies that naturally check the aphids (Aharoni *et al.*, 2003). Methyl salicylate and alpha farnesene, were also found to be emitted from healthy jasmine plants, whose ability to attract natural enemies was substantiated by (Mallinger *et al.* 2011; Pare and Tumilson

1997). Alpha-farnesene caused a 2-to-3-fold elevation in egg parasitism of *Lygus lineolaris* in a cotton field (Williams *et al.* 2008).

The mite infested plants constitute 31 volatile compounds, with bis (2-ethylhexyl) phthalate emanated in maximum quantity. Bis (2-ethylhexyl) phthalate, a six-carbon compound was detected due to herbivory of mite infested leaves in a peak area of 4112779391 mm<sup>2</sup> constituting 85.828 percent of the total compound present implying its maximum presence. In general, green leaf volatiles are six carbon compounds which are very quickly produced and/or emitted upon herbivory which play an important role in plant defenses and as bis (2-ethylhexyl) phthalate is also six carbon compound, produced due to leaf herbivory in jasmine ecosystem, there are chances for its potential role in natural enemy attraction. Liu *et al.* (2007) reported the presence of volatile, bis (2-ethylhexyl) phthalate in honeydew from both *B. tabaci* on cabbage and *T. vaporariorum* on cucumber and its role as kairomone in host-searching of parasitoids. Dicacodyl phthalate another compound was detected along with Bis (2-ethylhexyl) phthalate, due to herbivory of mite infested leaves twice in a peak area of 20400249 mm<sup>2</sup> at 30.97 mins.

The hydrocarbons, hentriacontane and heneicosane, were emitted in next maximum quantity recording the next largest peak area of 15218660 mm<sup>2</sup> with a retention time of 33.10 mts and 931928 mm<sup>2</sup> at 30.84 seconds, followed by the hydrocarbons, tetracosane, tricosane and eicosane etc. Heneicosane was also detected in 1197206 and 1074991 mm<sup>2</sup> at 24.045 and 17.55 mins. The compound allyl isothiocyanate was detected in two spotted mite infested jasmine extracts at 4.307 mts in a peak area of 1664139 mm<sup>2</sup>. Allyl isothiocyanate, a naturally occurring organo-sulfur compound in mustard, radish and horseradish, is responsible for their pungent taste (Fig. 5a). It aids the plant to safeguard against herbivores (Romanowsk and Klenk, 2005; Zabza, 1989; Titayavan and Altieri, 1990). Application of allyl isothiocyanate to broccoli plants increased aphid parasitism from 8.5 per cent to 22.5 per cent (Williams *et al.*, 2008). Allyl isothiocyanate serves the plant as a defense against herbivores; since it is harmful to the plant itself, it is stored in the harmless form of the glucosinolate. When the plant is damaged, the enzyme myrosinase is released and acts on a glucosinolate known as sinigrin to give allyl isothiocyanate. Synthetic allyl isothiocyanate is used as an insecticide, bactericide and nematocide, and is used in certain cases for crop protection (Romanowsk and Klenk, 2005). Allyl isothiocyanate is detected in enormous quantity in mite infested jasmine plants. Napthalene (Fig. 5d), an aromatic hydrocarbon in mite infested jasmine leaf extract, at 11.657 mins in an area of 196523 mm<sup>2</sup>, which was reported to be a semiochemical attracting natural enemies of stemborer in maize ecosystem (Peshwin and Pimental, 2014). Napthalene is present in varying quantity due to herbivory of different pests of jasmine with excess quantity being recorded in mite damaged leaves.

The orientation response of the natural enemies to volatile organic compounds (VOC's) from healthy and herbivore infested plants revealed an affirmative trend. The orientation response showed more response of the predatory thrips, *Scolothrips sexmaculatus* on mite infested synomonal extracts revealing a positive tritrophic interaction. Bis (2-ethylhexyl) phthalate, a six-carbon compound present in abundance in synomonal extracts of mites might be the probable reason for attracting their natural enemies, which

has to be explored further. The six-spotted thrips, *Scolothrips sexmaculatus* being an effective predator of small insects and spider mites in flower plants were reported previously (Gilstrap, 1976; Hoy, 2016; Suman et al., 2018).

## Conclusion

Foraging ability can be enhanced in a natural enemy by manipulating their behaviour. To summarize, since the number of the predatory thrips, *S. sexmaculatus* oriented to the volatile fraction is prominent in olfactometer behavioural bioassay, the eminent compounds which could be the probable reason for their attraction through olfactory stimuli could be explored as lures in artificial attraction of predatory thrips in jasmine ecosystem.

## Declarations

### DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors

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### AUTHORS CONTRIBUTION

The sole author designed the experiment, conducted the research, recorded data, analyzed and scripted the draft and reviewed it.

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## Figures



**Shriveling and yellowing of leaves**



**Severe webbing and ballooning of flower buds**



**Crinkled leaf with webbing**



**Damaged Plant**



**Infested leaf -Abaxial and adaxial side**



**Mite population in leaves**



**Figure 1**

**Symptoms of damage of two spotted mite, *Tetranychus urticae***

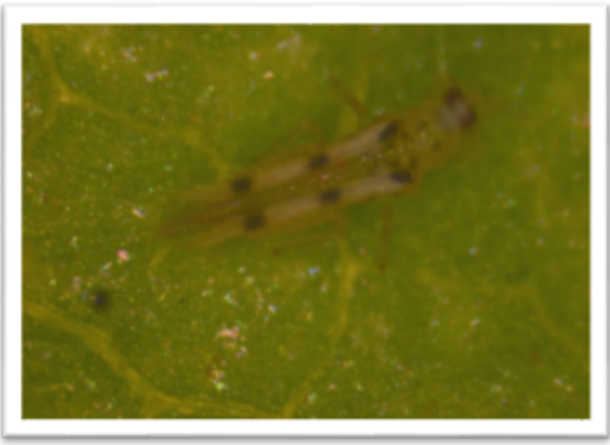


Figure 2

Six spotted predatory thrips, *Scolothrips sexmaculatus*



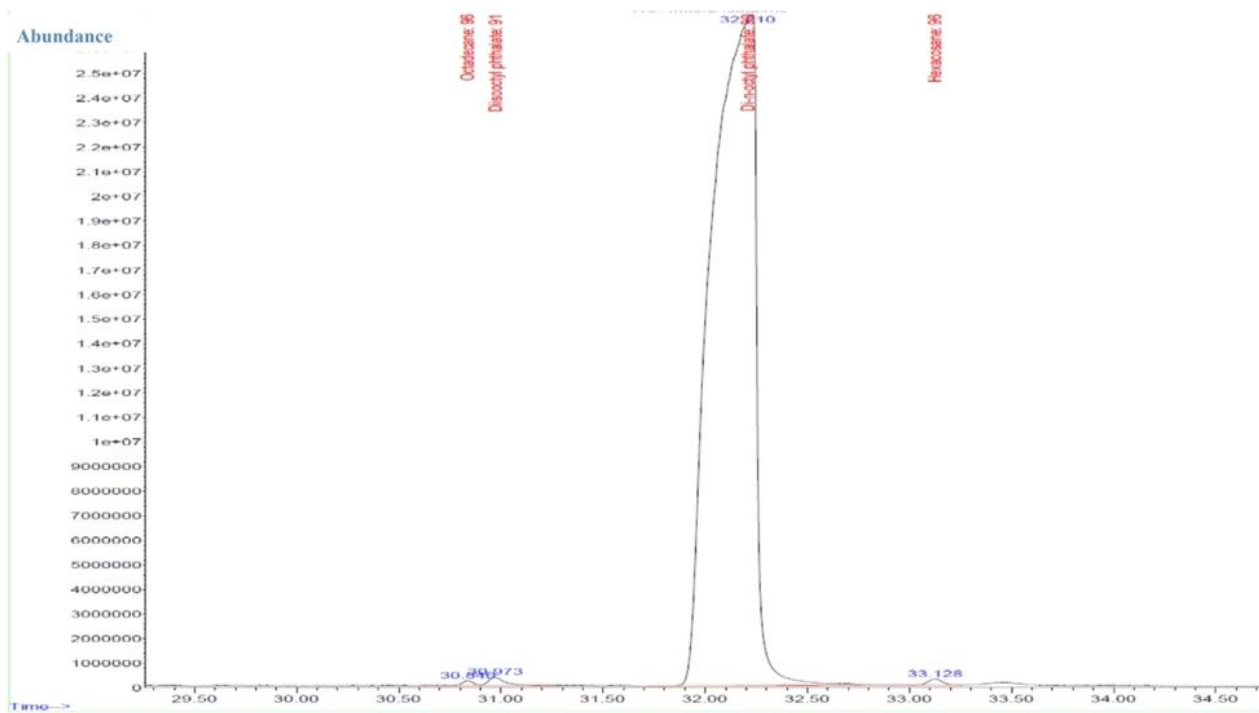
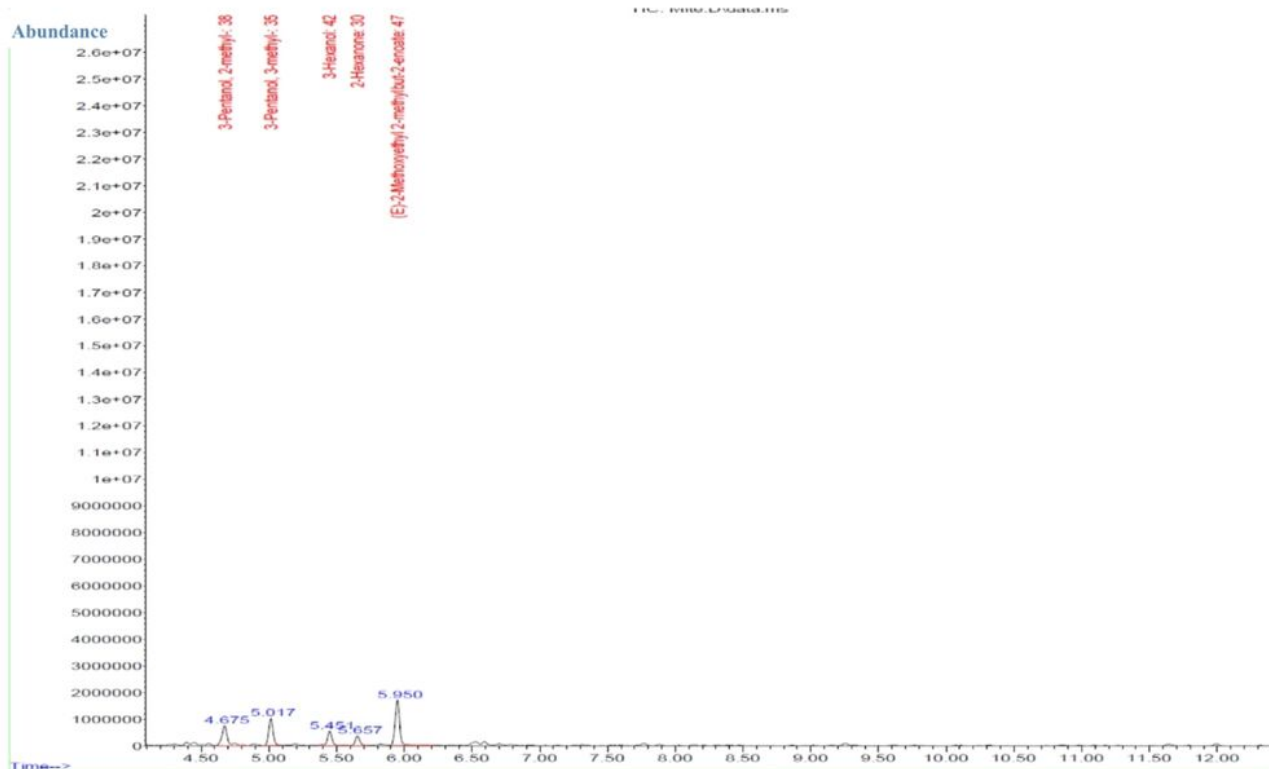


Figure 4

Chromatographic profiles of volatile hydrocarbons from two spotted mite, *Tetranychus urticae* infested jasmine leaves