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Article

Potential volatiles emitted from jasmine plants infested by *Tetranychus urticae* (Acari: Tetranychidae) and its attraction to predatory *Scolothrips sexmaculatus* (Thysanoptera: Thripidae)

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ABSTRACT

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* and analyzed through Gas Chromatography-Mass spectrometry (GC-MS) to determine volatile hydrocarbon profile in them. Further, olfactometer behavioral bioassay was conducted to investigate the preference of the predator, *Scolothrips sexmaculatus* to the emitted volatiles. The results revealed that both the healthy and plants infested with two-spotted mites had emitted organic volatile compounds (VOC's) numbering 19 and 31 respectively and some compounds were detected twice or even thrice. The variation in the volatile constituents of healthy and damaged plants clearly depicts the emission of volatiles responsible for attracting beneficials witnessing tritrophic interactions in jasmine ecosystem. The mite infested plants emanated potential natural enemy attractants such as ally isothocyanate, styrene, naphthalene, Bis (2-ethylhexyl) phthalate and several other organic compounds. The compound allyl isothiocyanate was detected in two-spotted mite infested jasmine extracts at 4.307 mts in a peak area of 1664139 mm^2. Allyl isothiocyanate serves the plant as a defense against herbivores; since it is harmful to the plant. Bis (2-ethylhexyl) phthalate, a six-carbon compound was detected due to herbivory of mite infested plants in a peak area of 4112779391 mm^2 implying its maximum presence. Dicacodyl phthalate, another compound, was detected in a peak area of 20400249 mm^2 at 30.97 mins. The healthy jasmine plants emanated natural enemy attractants, linalool, methyl salicylate and alpha-farnesene, aside from other volatile organic compounds. In the olfactometer behavioural bioassay studies, maximum number of released mite predator, *S. sexmaculatus*, oriented on mite infested jasmine plant volatiles (18.5 nos), and healthy plant volatiles (5.5 nos). The volatile organic compounds detected in enormous quantities in mite infested jasmine plants is a positive cue for commercial preparation of artificial lures to attract mite natural enemies in jasmine ecosystem. The predatory thrips lured to mite infested volatiles enrolls an encouraging sign to be exploited in integrated management of mites to enhance the efficacy of potential natural enemies of two-spotted spider mites.

KEYWORDS: GC-MS, herbivore induced volatiles, jasmine, olfactometer, thrips, two-spotted spider mite.

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INTRODUCTION

Sambac jasmine, *Jasminum sambac* (L.) (Lamiales: Oleaaceae) 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 concentrates and oils from jasmine flowers (Prakash and Muniyandi 2014). In addition, the need for the mesmerizing jasmine flowers for diverse necessities like religious

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ceremonies, official and home decorations, weddings, funerals, etc. is ever rising (Thakur *et al*. 2014). 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 (Acari: Tetranychidae) is one of the prime pests which devastates the productivity of the crop (Sadeghi *et al*. 2016). 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. In case of severe infestation, the whole plant becomes pale in color, 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 (Sarwar 2020). 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 *et al*. 2004).

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 becomes 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 responses 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, recently. Inventory on the predatory complex is a vital component to identify the locally adapted, dominant, efficient species that can be promoted as promising candidate predators 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 biological control of tetranychid spider mite, *T. urticae* is predominantly associated with predatory mites. However, the six spotted thrips, *Scolothrips sexmaculatus* (Pergande) (Thysanoptera: Thripidae), is gaining importance as a primary mite predator (Haviland 2021). The six-spotted thrips, *S. sexmaculatus* is considered to be an effective predator against small insects and spider mites.

Jasmine is known for its fragrance. The chief volatile compounds present are α-farnescene, Z-3-hexenyl benzoate, linalool, benzyl alcohol, benzyl acetate, methyl anthranilate and indole (Maeda and Junji 2001; Kuroda *et al*. 2005; Dai and Xu 2008; Lin *et al*. 2013; Tang *et al*. 2016; Chen *et al*. 2017; Li *et al*. 2018; Marwa *et al*. 2020). Predatory mites locate herbivorous mites and their prey by the aid of herbivore-induced plant volatiles (HIPV). *Phytoseiulus persimilis* Athias-Henriot, is a predatory mite that preys on the highly polyphagous herbivore, *T. urticae* through olfactory cues as they are blind significantly. They discern the mite infested plants largely through compounds like octan-1-ol, cis-3-hexen-1-ol and methyl salicylate (De Bruijn *et al*. 2008). Yet, the studies on attraction of the predatory thrips to volatiles from mite infested plants are scarce.

In view of the above, the hexane leaf extracts of jasmine damaged by two-spotted spider mite and healthy leaves were analyzed through GC-MS to determine the mite induced volatile profile in them in the present study. Then, the behavior of the predator, *S. sexmaculatus* encountered to the volatiles emitted from *T. urticae* infected leaves was investigated.

MATERIAL AND METHODS

Volatile extraction

A volatile collection unit is used for collection of volatiles. The two-year old, healthy potted plant of *J. sambac* with flower buds was kept inside an air-tight glass jar and 10 mites/leaf were placed inside each bud using a camel hairbrush and the mites were allowed to feed overnight. The potted jasmine plants were obtained from a greenhouse in TNAU, Botanical garden. The field collected two-spotted mites were reared under laboratory conditions and used for the experiment. A mixture of both male and female (50%:50%) mites were used in the experiment. The jasmine buds about to bloom the next day were opened manually and the mites were released in the bud using the camel brush and allowed to infest 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 in 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 two h and stopped for half an hour and again collected for another two h. The pumping was stopped to prevent accumulation of moisture inside the VCU and to prevent excess heat generation 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 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 Um film thickness run in constant flow mode (1.0 ml/min helium). Oven temperature programmed at 60 ℃ (1 min. hold), then to 220 ℃ at 10 ℃/min. rate (5 min. hold) and then to 240 ℃ at 50 ℃/min. rate (8 min. hold). Injector temperature was set at 275 ℃. One microliter of the volatiles were injected using auto sampler into the GC-MS system for analysis. Injections were done in split 10:1 mode (Coon *et al.* 2021). Sjimadzu 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 *S. sexmaculatus* 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, towards the volatile fractions was studied using eight arm olfactometer under laboratory condition at 26 ± 2 °C and 65 ± 5% RH and 150 lux light density. The saturated test fraction from two-spotted mite of jasmine in 50 µl and a positive control with water and a negative control with hexane were dropped on filter paper strips of 30 mm × 10 mm (odor source). After permitting the solvent to evaporate for 2 min., the filter paper strip was inserted in to the connector tubes of length 15 cm, from which insects were physically excluded to avoid contamination. Fifty-one day starved, five days old, *S. sexmaculatus* adults of both sexes 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 two and four h 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 at 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 Chi-square test. The data on the efficacy of synomones from the mite induced volatiles on the attraction of *S. sexmaculatus* 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 (Seenivasagan *et al*. 2009; Asmoro *et al*. 2021).

A list of abbreviations used in this article is as follows: **GC-MS**: Gas Chromatography-Mass spectrometry; **VOC's**: Volatile Organic Compounds; **HIPVs**: Herbivore-Induced Plant Volatiles; **VCU**: Volatile Collection Unit; **CRD**: Completely Randomized Design; **HAT**: Hours After Treatment; **WFT**: Western Flower Thrips.

RESULTS

GC-MS analysis of volatiles emanated from healthy jasmine plants

The volatile profile emitted from healthy jasmine plants is presented in Table 1. Linalool was in maximum quantity of 4942096 mm^2. Methyl salicylate and alpha-farnesene were detected in a peak area of 263826 and 215542 mm^2 respectively.

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* (min.)	**Area (mm^2)**	**Name of the compound**	**RT (min.)**	**Area (mm^2)**	**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

* RT: Retention Time

Table 1. Continued.

Healthy plant			Mite damaged plant		
RT* (min)	**Area (mm^2)**	**Name of the compound**	**RT (min)**	**Area (mm^2)**	**Name of the compound**
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
			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

* RT: Retention Time

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

The volatile profile emitted from mite infested jasmine plants is shown in Table 1. The compounds with probability to attract natural enemies including styrene, naphthalene and azulene were detected in mite induced volatile compounds along with bis (2-ethylhexyl) phthalate, recorded a peak area of 4112779391 mm^2 representing a maximum quantity of 93.44%.

DISCUSSION

Jasmine, the queen of flowers, is intricately fragranced and esteemed for its unique aroma. J. sambac (L.) Aiton commonly known as Arabian Jasmine (Holmes 1998) is widely utilized for the production of perfumes in cosmetic industries. Linalool and benzyl benzoate are the major volatiles distinguished in jasmine flowers in most research studies (Pragadheesh *et al*. 2017). Benzyl benzoate, isophytol,

phytol acetate and methyl jasmonate are noticed in Egyptian jasmine flowers (Zhou *et al*. 2019). In the present investigation, the healthy jasmine plants emitted 19 compounds including the natural enemy attractants, linalool, methyl salicylate and alpha-farnesene, apart from other volatile organic compounds (VOC). The existence of linalool in jasmine plant corroborates with the results of earlier investigations. 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, and significantly repels *Myzus persicae* (Sulzer) aphids, due to attraction of natural enemies that naturally check the aphids. Methyl salicylate and alpha farnesene, were also found to be emitted from healthy jasmine plants, whose ability to attract natural enemies was substantiated by different studies. Alpha-farnesene caused a 2-to-3-fold elevation in egg parasitism of *Lygus lineolaris* in a cotton field.

Plants infested with two-spotted mite, *T. urticae* may indirectly save themselves by releasing volatiles that attract their natural enemies including predatory mites (Van den Boom *et al*. 2007). The tritrophic system between two-spotted mites and the predatory mite (*P. persimilis*) is well demonstrated in lima bean plants (*Phaseolus lunatus*). The volatiles involved in attraction of the specialist predatory mites (*P. persimilis*) were linalool, *E*)-β-ocimene, (*E*)-4,8-dimethyl-1,3,7-nonatriene (DMNT) and methyl salicylate. On the other hand, the volatile compounds involved in the attraction of the generalist mite predator (*Neoseiulus californicus* (McGregor)) were linalool, methyl salicylate, (*Z*)-3-hexen-1-ol, (*E*)-2-hexenal, and (*Z*)-3-hexenyl acetate (Yamane *et al*. 2010). In the present investigation, 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 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 compounds, 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* (Gennadius) on cabbage and *T. vaporariorum* Westwood 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. The hydrocarbons, hentria-contane and heneicosane, were emitted in second maximum quantity recording the next largest peak area, followed by the hydrocarbons, tetracosane, tricosane and eicosane etc. Henecoisane was also detected.

The compound allyl isothiocyanate was detected in two-spotted spider mite infested jasmine extracts at 4.307 mts in a peak area of 1664139 mm^2. Allyl isothiocyanate, a naturally occurring organo-sulfur compound in mustard, radish and horseradish, is responsible for their pungent taste. It aids the plant to safeguard against herbivores (Zabża 1989; Titayavan and Altieri 1990; Romanowski and Klenk 2000). 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 produce allyl isothiocyanate. Synthetic allyl isothiocyanate is used as an insecticide, bacteriocide and nematicide, and is used in certain cases for crop protection (Romanowski and Klenk 2000). Allyl isothiocyanate is detected in enormous quantities in mite infested jasmine plants. Napthalene, an aromatic hydrocarbon in mite infested jasmine leaf extract, was at 11.657 mins. in an area of 196523 mm^2, which was reported to be a semiochemical attracting natural enemies of stemborer in maize ecosystem (Peshin and Pimentel 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, *S. 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, *S. sexmaculatus* being an effective predator of small insects and spider mites in flower plants was reported previously (Gilstrap and Oatman 1976; Hoy 2016; Sanjta *et al*. 2018).

CONCLUSION

Foraging ability can be enhanced in a natural enemy by manipulating their behavior. To summarize, since the number of the predatory thrips, *S. sexmaculatus* oriented to the volatile fraction is prominent in olfactometer behavioral 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.

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بررسی مواد فرار بالقوه القایی گیاهان یاس آلوده به *Tetranychus urticae* (Acari: Tetranychidae) و جلب شکارگر *Scolothrips sexmaculatus* (Thysanoptera: Thripidae)

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چکیده

مواد فرار ناشی از گیاهخوار از گیاهان یاس سالم تازه (*Jasminum sambac* L.) و گیاهان یاس آلوده خسارت دیده توسط کنهٔ تارتن دولکه‌ای، *Tetranychus urticae* استخراج شد و از طریق کروماتوگرافی گازی- طیف سنجی جرمی (GC-MS) برای تعیین پروفایل هیدروکربن در آنها مورد تجزیه و تحلیل قرار گرفت. افزون بر این، سنجش زیستی رفتاری بویایی‌سنجی برای بررسی ترجیح شکارگر، *Scolothrips sexmaculatus* به مواد فرار ساطع شده انجام شد. نتایج نشان داد که هر دو گیاه سالم و آلوده به کنه‌های دولکه‌ای، ترکیبات فرار آلی (VOC's) به ترتیب ۱۹ و ۳۱ منتشر کرده و برخی از ترکیبات دو یا حتی سه بار شناسایی شدند. تنوع در ترکیبات فرار گیاهان سالم و خسارت دیده به وضوح انتشار مواد فرار مسئول جلب شکارگر را نشان می‌دهد که شاهد برهم‌کنش‌های سه گانه در اکوسیستم یاس هستند. گیاهان آلوده به کنه، جلب‌کننده‌های دشمن طبیعی بالقوه‌ای مانند ایزوتوسیانات، استایرن، نفتالین، بیس (۲-اتیل هگزیل) فتالات و چندین ترکیب آلی دیگر را تولید کردند. ترکیب آلیل ایزوتیوسیانات در دو عصارهٔ یاس آلوده به کنه تارتن دولکه‌ای در ارتفاع ۴/۳۰۷ متری در منطقهٔ حداکثر ۱٦٦٤۱۳۹ میلیمتر مربع شناسایی شد. آلیل ایزوتیوسیانات به عنوان دفاعی در برابر گیاهخواران عمل می‌کند هرچند برای گیاه مضر است. بیس (۲-اتیل هگزیل) فتالات، ترکیب شش کربنه به دلیل گیاهخواری گیاهان آلوده به کنه در منطقهٔ حداکثر ٤۱۱۲۷۷۹۳۹۱ میلیمتر مربع شناسایی شد که حاکی از حداکثر حضور آن است. دیکاکودیل فتالات، ترکیب دیگری در منطقهٔ حداکثر ۲۰٤۰۰۲٤۹ میلیمتر مربع در مدت ۳۰/۹۷ دقیقه شناسایی شد. گیاهان سالم یاس، جدا از سایر ترکیبات آلی فرار، جلب کننده‌های دشمنان طبیعی، لینالول، متیل سالیسیلات و آلفا فارنزین را تولید می‌کردند. در مطالعات سنجش زیستی رفتاری بویایی‌سنج، حداکثر تعداد شکارگر رها شده کنهٔ تارتن، *Scolothrips sexmaculatus*، جهت‌گیری کرده به سمت مواد فرار گیاه یاس آلوده به کنه ۱۸/۵ فرد، و مواد فرار گیاه سالم ۵/۵ فرد بودند. ترکیبات آلی فرار که به مقدار زیاد در گیاهان یاس آلوده به کنه شناسایی شده‌اند، نشانه مثبتی برای تهیه تجاری جلب کننده‌های مصنوعی برای جلب دشمنان طبیعی کنه در اکوسیستم یاس است. تریپس‌های شکارگر جلب شده به مواد فرار گیاهان آلوده به کنه، علامت تشویق کننده‌ای را ثبت می‌کنند تا در مدیریت تلفیقی کنه‌ها برای افزایش کارایی دشمنان طبیعی بالقوه کنه تارتن دولکه‌ای مورد بهره برداری قرار گیرند.

واژگان کلیدی: GC-MS، مواد فرار القایی گیاهخوار، یاس، بویایی‌سنج، تریپس، کنهٔ تارتن دولکه‌ای.

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