Acta Phytopathologica et Entomologica Hungarica 53 (2), pp. 221–232 (2018)
DOI: 10.1556/038.53.2018.007

Composition, Repellent and Fumigant Toxicity of *Mentha longifolia* Essential Oil on *Tetranychus urticae* and Three Predatory Mites of the Family Phytoseiidae (Acari: Tetranychidae: Phytoseiidae)

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(Received: 20 February 2018; accepted: 3 May 2018)

The chemical composition of essential oil extracted from leaves of the medicinal plant *Mentha longifolia* (L.) Huds growing in Egypt, were determined through Gas Chromatography/Mass Spectrometry (GC/MS). The analyses revealed that the major component of *M. longifolia* was Monterpene ketone (piperitone oxide). *Mentha longifolia* was potent for the pest *Tetranychus urticae* Koch with a significant increase in repellency. In addition, it exhibited strong oviposition deterrence to the pest based on a 99.4% reduction of the total number of eggs on leaf discs treated with the oil. The LC_{50} values of *M. longifolia* against eggs, nymphs and females of *T. urticae* by fumigant application, were 2.95, 3.47, 3.74 µL / L, while the LC_{90} values were 8.99, 9.41, 11.01 µL/ L, respectively.

The toxicity of *M. longifolia* oil by fumigant application to females and eggs of 3 predatory phytoseiid mites was tested. *Neoseiulus californicus* (McGregor) is extremely insusceptible to *M. longifolia* oil than the pest *T. urticae* and both phytoseiid mites, *Neoseiuls barkeri* (Hughes) and *Typhlodromips swirskii* (Athias Henriot) under laboratory conditions. When both stages of tested predatory mites, exposed to fumigant of LC_{50} and LC_{90} µL/L values reported on *T. urticae*, female's mortality of *N. californicus* was lesser than that reported on *N. barkeri* and *T. swirskii.*

These show that the fumigant toxicity of *M. longifolia* oil has the highest lethal activity to the pest *T. urticae* and the least to the predatory mite *N. californicus*. Results indicated that the mode of delivery of the essential oil was largely a result of action in the vapor phase via respiratory system. Data was suggested that *M. longifolia* oil have the potential agent to be used in the maintainable management of *T. urticae* combined with *N. californicus.*

Keywords: Essential oil, *Mentha longifolia*, *Tetranychus urticae*, predatory phytoseiid mites, toxicity.

Tetranychus urticae Koch (Acari: Tetranychidae) is one of the greatest severe pest species infested many fruit tree, cotton, vegetables and a variety of greenhouse crops. This pest cause a small acne on the higher side of the leaf as a results of chlorophyll reduction, webbing, dry leaf-fall, up to necrosis in young leaves and stems, or even the plant death

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0238–1249/$ 20.00

in a severe mite-infestation (van der Geest, 1985). The complexity to manage this pest is its talent to build up multiple resistances to many acaricides (Lee et al., 2003; Kim et al., 2006). Besides, the broad uses to the synthetic pesticide cause an unpleasant effect on human being, predators as well parasites and the environment (Kumral et al., 2010).

Predatory phytoseiid mites were used in the control of pest mites in the field and greenhouses (McMurtry and Croft, 1997). Regardless of its action in controlling the pest, predatory mites cannot competent, to keep the pest population below the injure level and their sensitivity to the majority of chemical pesticides was an additional problem (Miresmailli and Isman, 2006).

The efficacious control of *T. urticae* is hard to succeed by only a single control method (Rhodes and Liburd, 2006). Therefore, combination of various control programs concerned, using selective release of single / multi-predators and relatively secure acaricides on these beneficial mites, this may bring an excellent control of *T. urticae* in the field (Rhodes et al., 2006). Both chemical and biological control agent may give benefits, which are relatively cheaper and more efficient to control pest mites than that provided by using chemical alone (Hosny et al., 2003).

Therefore, there is vital require to expand competent, secure and ecologically pleasant pesticides such as natural oil, to replace the conventional synthetic materials. However, the plant essential oils were suggested to be a good source of these alternative natural pesticides because their novel mode of actions includes its low toxicity to the beneficial organisms and low phytotoxicity (Isman, 2006). Taking into account that, the identifying a selective natural oil to be use in IPM program is very important to guard the predatory mites and reduce the environmental pollution.

Numerous essential oils of aromatic plants belonging to various families such as Lamiaceae, Asteraceae and Zingiberaceae have been cited to have a variety of biological activities against pest mites including repellence, feeding and oviposition deterrence and toxicity (Calmasur et al., 2006; Motazedian et al., 2012).

Neoseiulus barkeri (Hughes), *Neoseiulus californicus* (McGregor) and *Typhlodromips swirskii* (Athias-Henriot) are the main predators of pest mites and are widely found on various crops. Both *N. barkeri* and *T. swirskii* are generalist endogenous predators and they were able to control mite and insect pests of various families such as Tetranychiidae, Eriophyidae, Thripidae and Aleyrodidae (Hansen, 1988; Momen, 1995; Momen and Abdel-Khalek, 2008; Wimmar et al., 2008); *N. californicus* being specialist on *Tetranychus* sp. (McMurtry and Croft, 1997).

Although insecticidal activity of plant essential oils has well been documented by various authors; little intensive work has been published in relation to the activity of aromatic plants (oil/extract) on the tetranychid pests and its predatory phytoseiid mites (Choi et al., 2004; Miresmailli and Isman, 2006; El-Sharabasy, 2010; Han et al., 2010; Momen et al., 2014).

The present study has four objectives:

1) To determine the main component identified by GC/MS of an indigenous Egyptian plant, *Mentha longifolia* (L.) Huds (family Lamiacae) which is cultivated allover Egypt.
2) To test under laboratory conditions the level of activity of *M. longigolia* on various stages of the pest *T. urticae* and its behavior aspects through repellency and oviposition deterrence.

3) To test under laboratory conditions the toxicity of *M. longigolia* on various stages of the pest *T. urticae* in addition to test its repellency and oviposition deterrence activity against the pest.
4) Mortality level of tested predators were also investigated when they are sprayed by 2 efficient oil doses on the pest *T. urticae*.

Materials and Methods

Plant material

The aerial parts of *M. longifolia* was collected from plant originally grown in the Experimental Farm of (NRC) at Giza Governorate to obtain the essential oils.

Preparation of Mentha longifolia *oil*

The air-dried plant material (aerial parts) was pulverized and the essential oils isolated after hydro-distillation for 4 h in a steam distillation using a Clevenger apparatus. The oil collected was dehydrated over anhydrous sodium sulfate and subjected to GC/MS analysis.

Chromatographic investigation of the volatile oil

The obtained essential oil was subjected for GC/MS analysis under the following conditions:

GC/MS analyses were performed on a Thermo Scientific capillary gas chromatography (model Trace GC ULTRA) directly coupled to ISQ Single Quadruple MS. TG-5MS non-polar 5% Phenyl Methyl polysiloxane capillary column (30 m × 0.25 mm ID × 0.25 um) was used under the following conditions: oven temperature program from 40 °C (3 min) to 280 °C at 5 °C/min, then isothermal at 280 ºC for 5 min; carrier gas Helium, flow rate 1 mL/min; the volume of injected sample was 1 μl of sample in diethyl ether; splitless injection technique; ionization energy 70 eV, in the electronic ionization (EI) mode.

Identification of components

The components were identified based on the comparison of their relative retention time and mass spectra with those of standards, a computer library data of the GC/MS system and literature data (Adams, 2001).

Preparation of the primary emulsions

The primary emulsions of *M. longifolia* were in repellency test prepared by mixing of Triton-X 100. Different concentrations of this emulsion were prepared and tested against *T. urticae*.

Stock culture of the pest Tetranychus urticae

The colony was kept at 28 ± 2 °C and 70 ± 5 % relative humidity on kidney bean (*Phaseolus vulgaris*) plant without any exposure to any pesticides until they were used in experiments. The fresh un-infested kidney bean plants with four / five leaves were sited between the bean plants infected with *T. urticae* for 48 h. During this time, adults would move on to the un-infested plants, and the mites relocated to fresh bean leaves were used in subsequent experiments.

Rearing of the predatory mite species

Three phytoseiid species, i.e. *N. barkeri*, *N. californicus* and *T. swirskii,* were tested. Adult females of *N. barkeri* and *T. swirskii* were collected from heavily infested cucumber leaves in Giza Province of Egypt, while *N. californicus* used in the present study imported from France in 1999 and being established in most of agroecosystem in Egypt.

The stock colony of each predatory mite was maintained separately on leaves of kidney bean infested with mixed stages of *T. urticae* as prey. Each leaf was placed underside up on a wet cotton wool layer in a Petri dish (6 cm diameter), a water-saturated cotton strip was placed around the leaf margin to prevent escaping mites and to maintain the leaf fresh. Water supply was added daily and Petri dishes were kept in an incubator at 28 ± 2 °C, 70 ± 5% R.H. and L16: D8 h photoperiod. Predators were transferred to new and fresh infested leaf discs with *T. urticae* weekly to keep the culture healthy.

Repellency and oviposition deterrence activity for Tetranychus urticae *females*

Kidney bean leaf discs (4.5 cm in diameter) were placed with the lower surface upwards in a Petri dish lined with moist cotton wool. During the pre-experiments of each test using the oil, we were selected five constrictions in repellency test. According to pre-experiments, one-half of each disc was painted separately with selected concentrations of *Mentha* oil, while the other half served as a control. Twenty newly emerged females of *T. urticae* were introduced into the middle of each leaf disc. Each treatment comprised 5 replicates and repeated twice. Adult females were placed on the midrib and observations on repellency and oviposition were taken after 0.5, 1, 2, 4, 6 and 24 h after treatment, respectively. The deterrence index (DI) (mites which had left the treated sections were considered as repelled) was calculated according to Pascual and Robledo (1998). The number of eggs laid on both sides and the percentage mortality of adult females were recorded after 24 h. Mites found in the neutral area during the evaluation were considered as repelled or attracted based on their proximity to the control or to the treatment.

Treatments

Fumigant toxicity to egg, nymphal and female stages of the pest Tetranychus urticae

To obtain newly laid *T. urticae* eggs, females were placed on kidney bean discs (3 cm diameter), with a fine brush and allowed to lay eggs for 24 h, after which time,

females removed with aspirator. Leaf disks with eggs (0–24 h-old), mixed nymphal stages / females (2–3 d old) were placed on water-soaked cotton pads on glass chamber (9-cm long and 2.5-cm height). Various concentrations of oil were prepared by dissolving the requisite amounts in acetone, and then applied to filter papers. After drying in a fume hood for 2 min., each treated filter paper was attached to the downside of a lid with solid glue. It did not affect adversely *T. urticae*. The chamber was covered with lid. The mite-chambers were sealed with Par-film to prevent losing of the essential oils from the mite chamber. This prevented direct contact of tested various stages of *T. urticae* with the *Mentha* oil. Each treatment consisted of four concentrations, each with 4 replicates of the essential oil (25 eggs / nymphs / females / replicate were tested) and a control. All treatments were repeated twice. The control consisted of the same number of mites as the treatments; and was kept under the same conditions on leaf discs which not treated with any essential oil. Experiments were performed at 28±2 °C, 70 ± 5% R.H. and 16 L: 8 D -h photoperiod. To determine mortality, nymphal and female stages were touched with the tip of a fine hair-brush after 48 h. If the mite did not move, it was considered dead. The exposure period for assessing the ovicidal effects of the essential oil was 72 h for egg stage and 48 h for nymphal and female stages. Evaluation of the ovicidal action was based on hatching rate at each concentration.

Fumigant toxicity to egg and female stages of the predatory mites Typhlodromips swirskii, Neoseiulus californicus *and* Neoseiulus barkeri

Ten females of each predatory mite were transferred to the lower surface of *P. vulgaris* discs (3-cm in diameter) and left to oviposit for 24 h and removed thereafter. Leaf discs with eggs (0–24 h-old) / females (2–3 days-old) were resting on wet cotton pads in glass chamber (9-cm long and 2.5-cm height). Various concentrations of *M. longifolia* oil were prepared and used as above. Four concentrations each with 4 replicate (25 eggs/ females / replicate) were tested. All treatments were repeated twice. Mortality were recorded after 48 h for each predatory mite.

Efficiency of Mentha longifolia *oil (LC_{50} and LC_{90} values reported on the pest* Tetranychus urticae) *against eggs and females of the predatory mites,* Typhlodromips swirskii, Neoseiulus californicus and Neoseiulus barkeri

Two concentrations (LC_{50} and LC_{90} values that reported on *T. urticae* from its toxicity lines) were tested against the predatory mites to test if these concentrations are toxic or not to the tested predatory mites.

Ten females of each predatory mite were transferred to kidney bean leaf discs (3-cm in diameter) and allowed to oviposit for 24 h, which were then removed. Leaf discs with eggs (0–24 h-old) / females (2–3 days-old) were resting on wet cotton pads in glass chamber (9-cm long and 2.5-cm height). Two concentrations (LC_{50} and LC_{90} values reported on *T. urticae*) of *M. longifolia* oil were prepared and used as the method described above. Four replicates (25 eggs / females / replicate) were used / concentration. All treatments were repeated twice. Mortality were recorded after 48 h for each predatory mite. In each test, a control was included.

Statistical analysis

– The percentages of eggs, nymphs and females mortalities were calculated according to Abbott's formula (1925).
– The deterrence index (DI) was calculated using the following formula (Pascual and Robledo, 1998):

$$DI = [\frac{Control–Test}{Control+Test}] \times 100\ \%$$

Control = the number of specimens in the control.
Test = the number of specimens in the treated.

– The oviposition deterrence index (ODI) was calculated according to Lundgren (1975).

$$ODI = [\frac{B–A}{B+A}] \times 100$$

B = number of eggs in the control.
A = number of eggs in the treated.

* In repellency test, the differences between the tested concentrations and between the observation times in the number of *T. urticae* distributed on the treated leaf sections were studied using analysis of variance (ANOVA) and means were separated by Duncan's multiple range test (DMRT). In addition, the differences between the treated and untreated leaf sections in the number of eggs deposited / female were analyzed by T-test.

Results

Gas chromatography / mass spectrometry (GC / MS) analysis

The GC / MS analysis revealed that the main components identified from *M. longifolia* oil were piperitone oxide (83.32%), piperitenone oxide (4.80%), 2-methyl-5-(1-methylethyl) phenol (2.29%), and caryophyllene (1.58%). These four main components represented about 91.99% of the total *Mentha* oil content. All the chemical compounds identified in *Mentha* oil are shown in (Table 1).

Repellency and oviposition deterrence activity on Tetranychus urticae *females*

The essential oil of *M. longifolia* was repelled *T. urticae* females in all tested concentration and the deterrence index (DI) ranged from (82.00–98.00%).

With the exception of the concentration 0.3%, and among the different observation periods, insignificant differences were shown in the number of distributed *T. urticae* females on treated part (Table 2). The total number of eggs deposited by female *T. urticae* after 24 h of treatment was significantly lower on treated leaf sections with different concentrations of *Mentha* oil than on those of the untreated ones (Table 2).

Table 1

Percentage of chemical component identified in the essential oil of *Mentha longifolia* leaves by GC/MS

No	Compound identified	R .t.	(%) Area	Class
1	2,5-Diethyltetrahydrofuran	6.09	0.05	Other derivative
2	Alpha-Pinene	7.33	0.51	Monoterpenes
3	2-Beta-Pinene	8.87	0.60	Monoterpene
4	Beta-Myrcene	9.64	0.39	Monoterpene (Hydrocarbon)
5	3-Octanol	9.84	0.27	Ethylamylcarbinol (fatty tertiary alcohol)
6	1,8-Cineole	10.96	0.68	Monoterpenoid
7	3,7-Dimethyl-1,3,6-Octatriene	11.45	0.41	Monoterpenes
8	Isomyl-2-methylbutyrate	13.82	0.47	Other derivative
9	Cyclobutanecarboxylic acid, octyl ester	14.76	0.73	Aromatic Carboxylic Acids (Cycloalkanes)
10	**Piperitone oxide**	**19.20**	**83.32**	**Monoterpene ketone**
11	**2-Methyl-5-(1-methylethyl)Phenol**	**20.66**	**2.29**	**Monoterpenoid phenol (cymophenol)**
12	3-Methyl-6-(1-methylethylidene)-2-Cyclohexen-1-one	21.91	0.28	Monoterpenoid (piperitenone)
13	**Piperitenone oxide**	**22.85**	**4.80**	**Monoterpenoid ketone**
14	Tetrahydro-3-methyl-6-propyl-2H-Pyran-3-ol, acetate	23.39	0.30	Other derivative
15	2-(2-butenyl)-4-hydroxy-3-methyl-2-Cyclopenten-1-one	23.87	0.59	Other derivative
16	**Caryophyllene**	**24.49**	**1.58**	**Natural bicyclic Sesquiterpenes**
17	Alpha-Humulene	25.52	0.14	Monocyclic Sesquiterpenes
18	Beta-Farnesene	25.83	0.46	Sesquiterpenes
19	4-Chloro-2,3-dimethyl-1,3-hexadiene	26.05	0.36	Other derivative
20	Germacrene-D	26.38	0.72	Sesquiterpenes (volatile organic hydrocarbons)
21	Gamma-Elemene	26.84	0.57	Sesquiterpenes
22	Spathulenol	29.15	0.21	Other derivative
23	Alpha-Cadinol	30.95	0.25	Sesquiterpenes (Prenol Lipids)
			99.98	

Compounds listed in order of R.t. (retention times)

The highest oviposition deterrence index (ODI) value was detected on 1% concentration (99.43%), while 0.3% concentration being recorded the lowest ODI value (97.60%), respectively (Table 2).

Fumigant toxicity to egg, nymphal and female stages of the pest Tetranychus urticae

Based on the LC_{50} and LC_{90} values of *M. longifolia* oil on various stages of *T. urticae*, the egg was the most sensitive stage, while the female being the least one (Table 3).

Table 2

Relative distribution and fecundity of *Tetranychus urticae* exposed to the oil of *Mentha longifolia* with different concentrations

% Conc.	(%) Distribution of mites on treated part after							(%) DI	M (%) after 24 h	Average no. of eggs deposited / F after 24 h		T test	% ODI
	0.5 h	1 h	2 h	4 h	6 h	24 h	F			T	C		
1	0.00 ± 0.00Aa	0.00 ± 0.00Aa	0.00 ± 0.00Aa	0.00 ± 0.00Aa	1.00 ± 1.00Aa	1.00 ± 1.00Aa	0.80ns	98.00	6.00	0.01 ± 0.01	3.47 ± 0.19	18.43**	99.43
0.8	3.00 ± 1.23Aab	3.00 ± 1.23Aab	2.00 ± 1.23Aab	3.00 ± 1.23Ab	2.00 ± 1.23Aa	2.00 ± 1.23Aa	0.20ns	96.00	4.00	0.01 ± 0.01	2.94 ± 0.19	15.14**	99.32
0.5	5.00 ± 1.58Abc	5.00 ± 1.58Ab	4.00 ± 1.00Ab	6.00 ± 1.00Ac	5.00 ± 0.00Ab	6.00 ± 1.00Ab	0.43ns	88.00	3.00	0.02 ± 0.01	3.28 ± 0.15	21.36**	98.79
0.3	9.00 ± 1.87ABc	5.00 ± 1.58Ab	8.00 ± 1.23ABc	8.00 ± 1.23ABc	12.00 ± 1.23Bc	9.00 ± 1.00ABb	2.66*	82.00	4.00	0.05 ± 0.02	4.11 ± 0.22	18.56**	97.60
F	7.60**	3.44*	11.67**	12.25**	24.67**	12.15**							

DI = Deterrence index, ODI = Oviposition deterrence index, C = Control; T = Treated, M = Mortality after 24 h

Mean values within a row followed by the same uppercase letter (during experiment time) and mean values within a column followed by the same lowercase letter (at various concentrations) were not significantly different as determined by ANOVA and Duncan test ($p = 0.05$)

**Highly significant, *Significant, ns = non-significant

Fumigant toxicity to egg and female stages of the predatory mites Typhlodromips swirskii, Neoseiulus californicus *and* Neoseiulus barkeri

The LC_{50} and LC_{90} values of *Mentha* oil for *N. barkeri* females at 48 h post-treatment were 3.66 and 9.63 µ L/L, respectively. Results indicated that *N. californicus* females was the most insusceptible predatory mite (LC_{50} = 5.01 and LC_{90} =13.78 µ L/L) while *T. swirskii* females had the least insusceptibility to *Mentha* oil (Table 4). Likewise, eggs of *N. californicus* was the most insusceptible predatory eggs to *M. longifolia* oil while, *N. barkeri* eggs being the least insusceptible one (Table 4).

Efficiency of Mentha longifolia *oil (LC_{50} and LC_{90} values reported on the pest* Tetranychus urticae) *against eggs and females of the predatory mites,* Typhlodromips swirskii, Neoseiulus californicus *and* Neoseiulus barkeri

Based on both concentrations used with *Mentha* oil, results indicated that: the lowest percentage of mortality was recorded in *N. californicus* females and eggs while the highest mortality being recorded in both stages of *N. barkeri* (at LC_{90} of *Mentha* oil), respectively (Table 5).

Table 3

Fumigant effect of *Mentha longifolia* essential oil on various stages of the pest *Tetranychus urtica*

Tetranychus urticae	LC_{50} µL/L	Fiducial limits for LC_{50}	LC_{90} µL/L	Slope ± S.E.
Females	3.74	3.29–4.20	11.01	2.73 ± 0.23
Nymphs	3.47	3.06–3.89	9.41	2.96 ± 0.26
Eggs	2.95	2.54–3.38	8.99	2.65 ± 0.34

Table 4

Efficiency of *Mentha longifolia* oil on egg and female stages of the predatory mites, *Neoseiulus barkeri, Neoseiulus californicus* and *Typhlodromips swirskii*

Tested stage	Predatory mite	LC_{50} µl/L	Fiducial limits for LC_{50}	LC_{90} µl/L	Slope ± S.E.
Females	*N. barkeri*	3.66	3.24–4.09	9.63	3.045 ± 0.27
	N. californicus	5.01	4.47–5.63	13.78	2.92 ± 0.25
	T. swirskii	3.41	2.93–3.90	11.61	2.41 ± 0.24
Eggs	*N. barkeri*	3.01	2.57–3.47	9.93	2.47 ± 0.33
	N. californicus	4.51	3.97–5.11	14.03	2.60 ± 0.24
	T. swirskii	3.33	2.87–3.83	10.73	2.52 ± 0.33

Table 5

Efficiency of *Mentha longifolia* oil (LC_{50} and LC_{90} values of *T. urticae**) on females and eggs of the predatory phytoseiid mites, *Neoseiulus barkeri*, *Neoseiulus californicus* and *Typhlodromips swirskii*

Concentration* μL/L	% of corrected mortality**					
	N. barkeri		*N. californicus*		*T. swirskii*	
	Females	Eggs	Females	Eggs	Females	Eggs
LC_{50}	47.92	56.04	35.42	43.78	52.11	57.07
LC_{90}	91.15	90.11	77.60	80.00	86.84	89.13

*LC_{50} and LC_{90} values that recorded on *T. urticae* from its toxicity line
**Corrected mortality calculated using Abbott's formula

Discussion

Essential oils contain well complex combinations of hydrocarbons such as terpenes (monoterpenes, sesquiterpenes and diterpenes) and oxygenated compounds such as esters, ketones and alcohols phenols (Isman, 2006). Biological activity is affected by exchanges among structural component in the essential oil. Even insignificant compounds can have a serious function due to joined effects, additive action between chemical classes and synergy or antagonism (Attia et al., 2011).

Like many essential oils, *M. longgifolia* proved to have adulticidal, ovicidal, repellent, antifeedant and killing behavior against *T. urticae*. Similar to our results, Choi et al. (2004) and Han et al. (2010), indicated that many essential oils are effective against eggs and females of *T. urticae* lacking direct contact but by fumigant, resulted mode of delivery of the oil was largely caused by action in the vapor phase via the respiratory system.

Mentha longifolia oil was more effective against *T. urticae* than the predatory mite *N. californicus*. El-Sharabasy (2010) found that the LC_{50} value of ethanolic extract of *A. judaica* against *P. persimilis* was very low (167.3 gm / ml) as compared to the LC_{50} value of adult *T. urticae* which being 0.29 gm / ml. Moreover, effectiveness of other different *A. judaica* leaf extracts on *P. persimilis* mite was very low as compared to *T. urticae*. *Neoseiulus californicus* was 1-2 times more tolerant than *T. urticae* to 10 plant essential oils using direct spray or vapor-phase mortality bioassays (Han et al., 2010). In addition, with the exception of caraway seed, clove and basil oils, there were insignificant differences in toxicities between *T. urticae* and *N. californicus* with the other seven tested oils.

The essential oil of *Mentha* holds good mite repellency against *T. urticae* females. This action might due to the main components as piperitone oxide (Monoterpene ketone) as well as some other components. Monoterpenes have been well known as forceful fumigants, repellents, and insecticides toward stored-product insects (Papachristos et al., 2004). Given that the plant essential oil (Ariel part) is traditionally used in folk medicine, the oil can be considered safe for the health. On the other hand, the influence of oil on beneficial organisms like predatory mites was quite safe.

The essential oil from *M. longifolia* could become a practical substitute to conventional chemical control approaches. However, further studies need to be conducted in order to evaluate the safety of this oil before practical use in *T. urticae* control.

More work is essential to evaluate the cost / benefits of *M. longifolia* oil on wide scale to control the pest *T. urticae* in commercial greenhouses.

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