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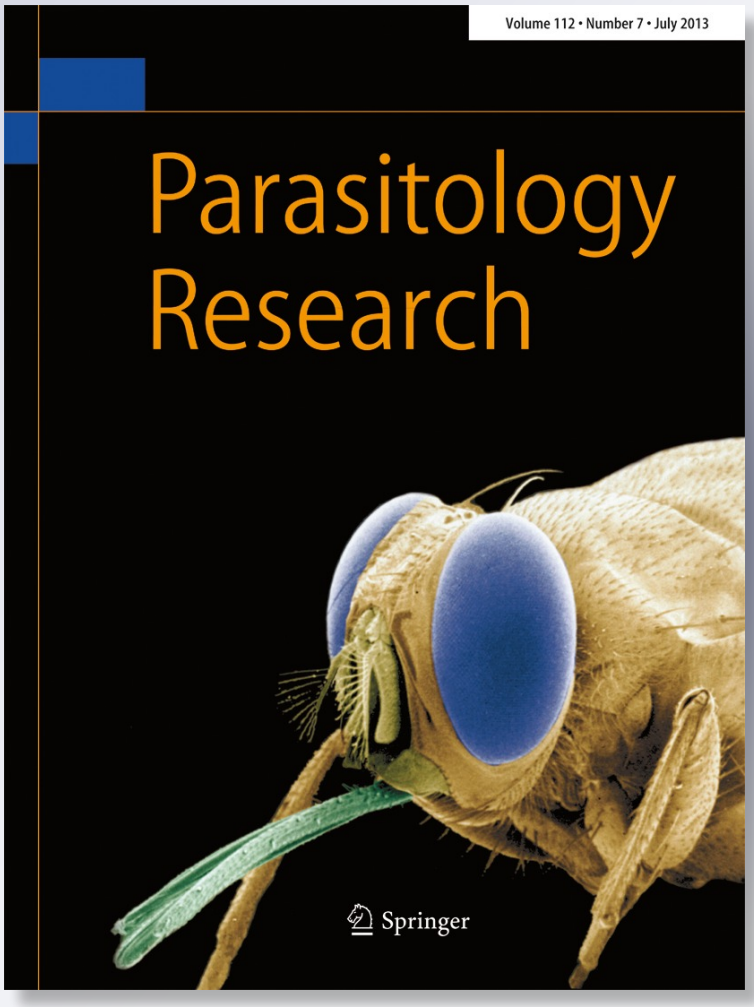

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ORIGINAL PAPER

In vitro control of the camel nasal botfly, *Cephalopina titillator*, with doramectin, lavender, camphor, and onion oils

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Abstract Camels are very important livestock particularly in arid and semiarid lands. The oestrid fly, *Cephalopina titillator* (Clark), causes nasopharyngeal myiasis in camels, and it is widely distributed in many camel breeding areas triggering health hazards and severe economic losses in camels. The prevalence of infestation of camels (slaughtered at Tokh's slaughterhouse, Qalyubia Governorate, Egypt, during the period from September 2011 to March 2012) was 41.67 % (100 out of 240). Most infested camels developed clinical signs of nasal discharge, restlessness, loss of appetite, difficulty in breathing, frequent sneezing, and snoring. Postmortem examination of infested camels explained that breathing of the animal is greatly impaired because of blockage of the nasopharynx by larvae and/or mucofibrinous secretions. The larval count per camel ranged from 1 to 250 (mean 28.45±6.48). In vitro larval immersion tests were carried out to determine the efficacy of doramectin (0.003 %) as well as some essential oils (50 % each) such as lavender, camphor, and onion oils against the second and third larval stages (L2 and L3) of *C. titillator*. Another trial had been done for imitating what could happen if the area around camels were treated with an insecticide or an insect repellent. All treated L2 died 18 h posttreatment (PT) with both doramectin and lavender, and 100 % mortality was reached for L3 after 24 and 30 h PT with lavender and doramectin, respectively. Doramectin and lavender induced the highest response against *C. titillator* as their lethal time (LT_{50}) values after treatment of L2 were 3.40 and 3.60 h, respectively, and those of L3 were 4.99 and 5.53 h, respectively. Against both L2 and L3 of *C. titillator* and based on LT_{50} values of onion oil and those of other applied materials, doramectin and lavender oil were four times more effective than onion oil, and camphor oil was two times more effective than onion oil. Based on LT_{50} values of essential oils and those of doramectin, as a reference substance, the relative speed of efficacy indicated that camphor and onion oils were, respectively, two and four times less effective than doramectin and lavender. With regard to fumigant technique, neither the insecticide, New Pyrosol®, nor the insect repellent, Keto®, was effective in controlling *C. titillator* larvae. Our results indicated that doramectin and lavender could be selected as drugs of choice for controlling *C. titillator*, but it is not permitted to use doramectin on dairy animals during lactation. Lavender (50 %) has a great potential to be developed as a novel larvicide and could be used as nasal drench against nasal botfly which will reflect on camel production and the national economy.

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Introduction

Dromedary camels, *Camelus dromedarius*, are important species of livestock in arid and semiarid environments. Camels are raised basically for meat, milk, and hide. Camel nasopharyngeal myiasis is caused by larvae of the camel nasal botfly, *Cephalopina titillator* (Clark 1797) (Oestridae: Diptera), which attacks only camels (Hussein et al. 1982; Higgins 1985).

The female fly darts towards the nostrils of camels and deposits its larvae which crawl up to the nasopharynx and sometimes the paranasal sinuses. Spratt (1984) reported the occurrence of the oestrid botfly from the frontal sinuses, nasal cavities, and tracheae of *C. dromedarius*.

Larvae molt twice while attached to the nasopharyngeal and paranasal mucous membranes (Hussein et al. 1982). Moreover, Zayed (1998) reported that the first molt occurred in the labyrinth of the ethmoid bone and the second molt was observed in both the labyrinth of the ethmoid bone and

the pharyngeal cavity. Larvae remain attached to the mucous membrane of these organs for up to 11 months, during which they feed and cause extensive irritation and tissue damage (Hussein et al. 1982). Larvae grow up to 0.7, 15, and 35 mm for the first, second, and third larval stages. When mature larvae are ready to pupate, they crawl back to the nasal passage and are expelled when the animal sneezes and then burrow into the soil.

The intensity of clinical signs depends on the number and damage caused by migrating larvae. Larvae lead to extensive irritation, tissue damage, and respiratory disorders (Droandi 1936; Hussein et al. 1982; Musa et al. 1989).

Camel botfly causes severe economic losses to the camel industry in many camel-producing areas of the world. These infestations impair animal welfare, reduce host physiological functions (El Bassiony et al. 2005), destroy host tissues, and cause significant economic losses to livestock through reduction of milk production and losses in terms of weight gain (Hall and Wall 1995; Otranto 2001). Pathological lesions caused by *C. titillator* were observed by Hussein et al. (1982) and Musa et al. (1989).

Reports from Egypt and neighboring countries showed that the fly is a common parasite of camels which indicates that it is capable of thriving in wavering environmental conditions (Table 1). Over the past years, research on myiasis has mainly focused on development of synthetic chemical control products, especially macrocyclic lactones.

Botanicals could be used effectively and safely for controlling endo- and ectoparasites (Abdel-Ghaffar et al. 2010; Khater 2011, 2012, 2013; Seddiek et al. 2011, 2013; Kumar et al. 2013). The ancient Egyptians may have been the first to discover the potential of essential oils (EOs) which developed also in the middle ages by Arabs. EOs are known for their antiseptic and medicinal properties and their fragrance. In addition, they are used in embalmment, in preservation of foods, and as antimicrobial, analgesic, sedative, anti-inflammatory, spasmolytic, and local anesthetic remedies. In recent times, EOs are produced commercially for pharmaceutical, sanitary, cosmetic, perfume, agricultural, and food industries, as food preservers and additives (Khater 2013).

EOs could be suitable alternative products for pest control. EOs are produced commercially from several botanical sources, mainly from members of the mint family. Some EOs have many compounds that adversely affect growth and development (Khater et al. 2009, 2011; Liu et al. 2013; Khater 2012, 2013; Kumar et al. 2013) and alter feeding, mating, and oviposition behaviors (Khater 2011, 2012, 2013).

Some EOs, applied in the present study, kill and repel insects, such as onion (Khater 2003; Khater et al. 2009), camphor (Mazyad and Soliman 2001; Khater et al. 2009), and lavender (Jaenson et al. 2006). None of the previously mentioned oils were applied against *C. titillator*

Despite severe clinical signs and even death of highly infested camels, few epidemiological surveys have been carried out in Egypt to study the prevalence of the nasal botfly infestation. In addition, there is a lack of information about in vitro and in vivo treatment of such infestation. Therefore, this in vitro study was carried out, for the first time, for controlling second and third larval instars of *C. titillator* with doramectin and some essential oils such as lavender, camphor, and onion oils. A fly insect killer and an insect repellent were also applied as fumigants.

Table 1 Prevalence of infestation with nasal myiasis in Egypt and other countries

Location	Prevalence (%)	Reference
Egypt	41.67	The present study (in Qalyubia Governorate)
	37.91	Ramadan (1997) (in Qalyubia Governorate)
	25	Morsy et al. (1998) (in Al Arish, North Sinai)
Sudan	74	Steward (1950)
Libya	79	Abd El-Rahman (2010)
Ethiopia	71.7	Bekele (2001)
	85.3	Wosen and Alemargot (1989)
Jordan	33	Al-Rawashdeh et al. (2000)
Iraq	42.43	Atiyah et al. (2011)
	47	Abul Hab and Al Affass (1977)
Saudi Arabia	41	Alahmed (2002) (in Riyadh, the middle province)
	52	Fatani and Hilali (1994) (in the eastern province)
	87.7	Hussein et al.(1983) (in imported camels in Riyadh)
	91.43	Hussein et al. (1982) (in Jeddah and Riyadh)
Iran	58.1	Oryan et al. (2008) (in the eastern areas)
	80.72	Shakerian et al. (2011) (in Najafabad)

Material and methods

Animals

The study was carried out on 240 camels slaughtered at Tokh's slaughterhouse (35 km North Cairo), Qalyubia Governorate, Egypt, during the period from September 2011 to March 2012. The animals (5–15 years old) were brought originally for slaughtering from Sudan and Saini. It is worth mentioning that no information on prior parasitic treatment was obtained. Considering parasitic fauna of infested animals and absence of dead larvae in inspected camel heads, it is unlikely that they had received any treatment for controlling *C. titillator*. Symptoms of suspected animals were recorded prior to slaughtering, and accurate diagnosis was confirmed at postmortem (PM) examination.

Applied materials

- Doramectin, Dectomax®, Pfizer Inc., packed by Pfizer Egypt, S.A.E., Cairo A.R.E.
- Lavender oil, *Lavandula angustifolia*, El-Captain Co., Cairo, Egypt.
- Camphor oil, *Cinnamomum camphora*, El-Captain Co., Cairo, Egypt.
- Onion oil, *Allium cepa*, El-Captain Co., Cairo, Egypt.
- New Pyrosol®, a flying insect killer, El-Nasr Co. for Intermediate Chemicals, Egypt. It contains Neo-Pynamin forte (0.02 %), sumithrin (0.075 %), isopropyl alcohol (0.26 %), perfume (0.52 %), kerosene (41.055 %), and propane/butane (57.89 %).
- Kito® Mosquito Deterrent, an electric area repellent, new Japanese formula, Sumitomo Chemical Co., Japan, and Kabnoury Co., Egypt. It is authorized by the Egyptian Ministry of Health. The duration of a tablet is 10 h. Kitomat blue tablets contain prallethrin (ETOC) (10 %), isopropyl myristate (69 %), butylated hydroxytoluene (10 %), methylene blue (0.60 %), floral fragrance Puokia (0.04 %), and piperonyl butoxide (10 %).

Collection of larvae

The heads were separated from the body of slaughtered camels. Each head was incised sagittally to expose different regions of the nasal and pharyngeal cavities and pharynx. The presence of second- and third-stage larvae (L2 and L3) were checked, and then the recovered larvae were removed and identified in the laboratory according to Zumpt (1965). Larval counts had been done among 100 infested camels.

In vitro treatments

Dipping technique

In vitro larval immersion tests were carried out, according to Khater et al. (2013), to determine the efficacy of doramectin (0.003 %) as well as some essential oils (50 % each), according to Khater et al. (2009), such as lavender, camphor, and onion oils against the second and third larval stages of *C. titillator*. Concentrations were freshly prepared in distilled water. Few drops of Tween 80 were added as an emulsifier to essential oils.

Ten larvae of *C. titillator* were used per replicate in each test. Each group of larvae was placed in a mesh cloth piece and immersed for 60 s in a 100-ml solution of each drug, and then the solution was continuously stirred during the process. The positive control group was treated with doramectin (0.003 %). The negative control group was treated with distilled water and few drops of Tween 80.

The immersed larvae were kept in Petri dishes having filter papers (Whatman No. 1). Petri dishes were kept at 27± 2 °C and 80±5 % relative humidity (RH). The mortality of larvae in all dishes was observed after different time intervals (0.5, 1, 1.5, 3, 6, 12, 18, 24, and 48 h). Each concentration was tested in five replicates (i.e., 50 larvae for each concentration).

Alive and dead larvae were counted. Larvae were considered alive if they exhibited normal behavior when breathed upon or physically stimulated with wooden dowels; larvae which were incapable of movement, maintaining any signs of life, were considered moribund or dead (Khater and Ramadan 2007; Khater et al. 2013).

Fumigant technique

The fumigant technique was made according to Manzoor et al. (2012) with some modifications. In a trial for imitating what could happen if the area around camels were treated with an insecticide or an insect repellent, 50 s and third larval stages of *C. titillator* were placed in plastic containers, without covers, in a tightly closed compartment (1×4×4 m^3) at 27±2 °C and 80±5 % RH. The compartment was sprayed for 5 min with New Pyrosol®. In another trial, Kito® electric device was applied for 10 h in the previously mentioned compartment. Larval mortality counts were recorded 24 h posttreatment (PT).

Statistical analysis

Live and dead larvae were counted to determine the mortality percentages. Larval mortality counts were subjected to probit transformation followed by regression analysis to determine

the lethal time (LT) values using a computer program, BioStat 2009 Professional 5.8.4, following Finney (1971).

Results

The present study revealed that the prevalence of infestation of camels with *C. titillator* was 41.67 % (100 out of 240). Most infested camels, inspected just before slaughtering, showed loss of appetite, restlessness, difficulty in breathing, snoring, and sneezing. In heavy infestations, the breathing of the animals was greatly impaired. The larval count per camel ranged from 1 to 250. The mean number of larvae per camel (L/C) was 28.45±6.48, and most larvae were attached to the mucosa of the nasopharynx. In a sporadic case, an emergent slaughtering was carried out in a heavily infested camel (8-year-old male having 250 larvae) which showed severe cough, ejection of the soft palate (called *doula* in Arabic) and larvae, convulsions, and circling movement, and then the camel fell on the ground.

Data of the present study indicated the in vitro efficacy of the applied materials against larvae of *C. titillator*. After treatment for 24 h with doramectin, lavender, camphor, and onion oils, the mortality percentages of L2 were 100, 100, 80, and 52 %, respectively, whereas those of L3 were 80, 100, 68, and 52 %, respectively. No mortalities were observed in the negative control group (Table 2).

The LT_{50}, LT_{90}, and LT_{99} values of doramectin, lavender, camphor, and onion oils after treatment of L2 were 3.40, 13.13, and 39.51 h; 3.60, 12.06, and 32.31 h; 6.58, 51.67, and 277.38 h; and 14.24, 120.73, and 689.66 h, respectively. The corresponding values after treatment of L3 were 4.99, 22.95, and 79.66 h; 5.53, 18.71, and 50.55 h; 9.28, 88.76, and 559.34 h; and 19.33, 155.33, and 849.63 h, respectively (Table 3).

Based on LT_{50} values of onion oil and those of the other applied materials against larvae of *C. titillator*, doramectin and lavender oil were four times more effective than onion oil, and camphor oil was two times more effective than onion oil against both L2 and L3 of *C. titillator*. Based on LT_{50} values of EOs and those of doramectin, as a reference substance, the relative speed of efficacy indicated that camphor and onion oils were, respectively, two and four times less effective than doramectin and lavender oil (Table 3). With regard to fumigant technique, neither the insecticide, New Pyrosol®, nor the insect repellent, Keto®, was effective in controlling *C. titillator* larvae.

Table 2 Mortality percentages of *C. titillator* after treatment with doramectin and some essential oils

Time (h)	Doramectin		Lavender		Camphor		Onion	
	L2	L3	L2	L3	L2	L3	L2	L3
0.5	0	0	0	0	0	0	0	0
1	18	0	10	0	10	8	6	2
1.5	30	20	22	18	20	16	16	10
3	34	42	44	28	30	26	18	14
6	58	66	58	46	52	48	30	24
12	82	72	84	72	64	52	34	32
18	100	80	100	82	70	60	42	40
24	100	80	100	100	80	68	52	52
30	100	100	100	100	82	80	78	66
48	100	100	100	100	90	82	86	78

Fifty larvae were treated for each concentration. The concentrations of the applied materials were 0.003 % for doramectin and 50 % for essential oils. No mortalities were observed in the negative control group

L2 second larval instars, *L3* third larval instars

Discussion

C. titillator causes health hazards in camels. The prevalence of infestation was 41.67 %. Higher prevalences were recorded in the neighboring countries as shown in Table 1. The discrepancy between our results and the others findings might be due to ecological variations, geographical location, and methods of animal husbandry.

In the present study, most infested camels, inspected prior to slaughtering, developed clinical signs of nasal discharge, restlessness, loss of appetite, difficulty in breathing, frequent sneezing, and snoring. Analogous observations were reported (Zumpt 1965; Spratt 1984; Al-Ani et al. 1998). The disease could be confused with rabies, *Coenurus cerebralis*, intoxications and other neurological disorders like "Shimbir" (Moallin 2009). The accurate identification of camel infestation with *C. titillator* is confirmed at necropsy.

PM examination of the infested camels explained that breathing of the animal was greatly impaired because of blockage of the nasopharynx by larvae and/or mucofibrinous secretions. Similar observation was also reported by Zumpt (1965), Hussein et al. (1982), Spratt (1984), and Al-Ani et al. (1998). In a sporadic case, a male camel showed abnormal behavior resembling cranial coenuriasis. Alike finding was described by Zumpt (1965), Burgemeister et al. (1975), and Moallin (2009), and camels may finally die from meningitis caused by secondary bacterial or viral infections (Burgemeister et al. 1975; Musa et al. 1989).

Our data indicated that L/C was 28.45±6.48. Lower mean of larval count (19.29±1.08) was recorded (Fatani and Hilali 1994). The range of counted larvae per camel, in our study, was 1–250. The maximum larval count was 110 (Fatani and Hilali 1994), 165 (Spratt 1984), and 243 (Musa et al. 1989). Such difference of larval count may be

Table 3 Lethal time of the applied materials

LT	Doramectin		Lavender		Camphor		Onion	
	L2	L3	L2	L3	L2	L3	L2	L3
25	1.67±0.34	2.23±0.54	1.91±0.20	2.91±0.51	2.23±0.36	2.83±0.47	4.63±1.52	6.46±0.85
50	3.40±0.51	4.99±0.88	3.60±0.30	5.53±0.75	6.58±0.73	9.28±1.08	14.24±2.91	19.33±2.34
60	4.44±0.63	6.74±1.14	4.57±0.37	7.03±0.93	9.88±1.09	14.49±1.80	21.72±4.82	29.16±4.18
70	5.91±0.87	9.31±1.65	5.90±0.50	9.10±1.25	15.28±1.87	23.36±3.45	34.13±9.45	45.31±7.99
75	6.92±1.06	11.13±2.08	6.80±0.60	10.50±1.51	19.45±2.61	30.44±5.04	43.84±13.92	57.84±11.41
80	8.26±1.35	13.59±2.75	7.96±0.74	12.311.89	25.46±3.81	40.87±7.67	57.94±21.34	75.92±16.85
84	9.70±1.70	16.30±3.57	9.20±0.91	14.23±2.34	32.56±5.41	53.51±11.22	74.77±31.30	97.36±23.91
90	13.13±2.66	22.95±5.91	12.06±1.36	18.71±3.51	51.67±10.37	88.76±22.55	120.73±62.91	155.33±45.33
95	19.26±4.69	35.38±11.08	16.99±2.27	26.43±5.89	92.71±23.04	168.37±52.87	221.33±146.80	280.50±99.03
99	39.51±13.09	79.66±34.42	32.31±5.72	50.55±15.07	277.38±95.81	559.34±243.01	689.66±667.92	849.63±45.33
RF1	1	1	1.06	1.11	1.93	1.86	4.19	3.88
RF2	4	4	4	3	2	2	1	1

Fifty larvae were treated for each concentration. The concentrations of the applied materials were 0.003 % for doramectin and 50 % for essential oils

L2 second larval instars, *L3* third larval instars, *RF1* relative speed of efficacy based on LT_{50} values of EOs and that of doramectin, as a reference substance, *RF2* relative speed of efficacy based on LT_{50} values of used materials and that of onion oil, as a reference substance

attributed to different age, sex, breed, season, and climatic and management conditions.

Regarding our in vitro treatments, all treated L2 died 18 h PT with doramectin and lavender, whereas 100 % mortality was reached for L3 after 24 and 30 h PT with lavender and doramectin, respectively. Doramectin and lavender induced the highest response against *C. titillator* as their LT_{50} values after treatment of L2 were 3.40 and 3.60 h, respectively, and those of L3 were 4.99 and 5.53 h, respectively. The relative speed of efficacy indicated that lavender had similar potency as doramectin but camphor, and onion oils were, respectively, two and four times less effective than doramectin and lavender. Doramectin and lavender oil were four times swifter than onion oil.

All applied materials were more effective against L2 than L3, which could be explained that L3 are larger in size than L2 and probably need higher doses to get similar results.

Most previous studies, shown in Table 1, recommended treatment of *C. titillator* without referring to a certain medicament. This work is very unique as it focused on in vitro controlling of the camel nasal botfly which had been done for the first time, to our knowledge. Furthermore, using doramectin as well as EOs as larvicides against *C. titillator* has not been done before. Therefore, we faced a shortage of literature about the used materials against *C. titillator*. Consequently, we discussed our results with those for other insects, especially myiasis-producing flies.

There is extensive evidence of the activity of macrocyclic lactones, such as ivermectin, doramectin, abamectin, and eprinomectin, when they are used as systemic parasiticides for controlling nematodes and arthropods (Marley and Conder 2002). Generally, there are few studies that deal with in vivo treatment and control of myiasis-producing maggots with macrocyclic lactones. To our knowledge, there is only one study that controlled *C. titillator* in vivo and showed that ivermectin was effective (87.1 %; Robin et al. 1989).

Regarding treatment of obligate-myiasis-producing parasites, doramectin was efficacious in the treatment of the New World screwworm, *Cochliomyia hominivorax* (Moya Borja et al. 1993, 1997; Anziani et al. 2000a); the warble fly larvae, *Hypoderma bovis*, infesting cattle (Hendrickx et al. 1993); and the flesh fly, *Wohlfahrtia magnifica* (Sotiraki et al. 2003). Moreover, doramectin controlled endo- and ectoparasites infesting cattle (Leite et al. 2000) and the horn fly, *Haematobia irritans*, infesting steers and in the feces of doramectin-treated animals (Anziani et al. 2000b).

This would erase some ecological and safety concerns about using doramectin as a parasiticide as most macrocyclic lactones have been shown to be highly toxic for the dung beetle, *Onthophagus taurus*, as a non-target organism (Wardhaugh et al. 2001; Lumaret and Errouissi 2002). Moreover, it is not permitted to use doramectin on dairy animals during lactation. The repeated as well as duplication of the therapeutic dose levels of doramectin leads to some adverse effects on the female genital organs of guinea pigs (Al-Hizab and Hassieb 2010).

Obligate-myiasis-producing flies were effectively controlled by EOs, such as camphor, *Eucalyptus globulus*, against *Oestrus ovis* (Mazyad and Soliman 2001) and betel

against *Chrysomya bezziana* (Wardhana et al. 2007). In addition, Wenqi et al. (1991) treated bovine hypodermiasis with the extract from dried tangerine peel.

Relating to control of facultative-myiasis-producing flies which is of medical and veterinary importance, larvae of the green blowfly, *Lucilia sericata*, which infests suppurative wounds had been controlled efficiently by some EOs, for example, fenugreek (*Trigonella foenum-graecum*), celery (*Apium graveolens*), radish (*Raphanus sativus*), and mustard (*Brassica campestris*) (Khater and Khater 2009); lettuce (*Lactuca sativa*), chamomile (*Matricaria chamomilla*), anise (*Pimpinella anisum*), and rosemary (*Rosmarinus officinalis*) (Khater et al. 2011); the American wormseed (*Chenopodium ambrosioides*) and thyme (*Thymus vulgaris*) (Morsy et al. 1998); and dill (*Anthem graveolens*) and burnoof (*Conyza dioscoridis*) (Mazyad et al. 1999).

After treatment with EOs, the number of emerged males exceeded the number of females, which could lead to population decline. Morphologic abnormalities of larvae, pupae, and adults were recorded after treatment of *L. sericata* with EOs (Khater and Khater 2009; Khater et al. 2011). Tea tree oil from *Melaleuca alternifolia* (terpinen-4-ol chemotype) induced insecticidal action against the Australian sheep blowfly, *Lucilia cuprina*, eggs and larvae, stimulating larvae to leave the wound (Callander and James 2012).

Essential oils are also highly effective in controlling insects other than myiasis-producing flies: sesame (*Sesamum indicum*), nigella (*Nigella sativa*), and onion oils against *Culex pipiens* and *Musca domestica* (Khater 2003); camphor, onion, rosemary, peppermint (*Mentha piperita*), and chamomile (*M. chamomilla*) oils induced pronounced in vitro and in vivo pediculicidal activity against the buffalo louse, *Haematopinus tuberculatus* (Khater et al. 2009). The previously mentioned oils also showed significant repellent activity against some nuisance flies (*Musca domestica*, *Stomoxys calcitrans*, *H. irritans*, and *Hippobosca equina*) infecting buffaloes in Egypt for almost 6 days PT (Khater et al. 2009). Moreover, some EOs were effective as alternative mosquito repellents, such as *Zanthoxylum piperitum* (Kamsuk et al. 2007) and *Coriandrum sativum* (Benelli et al. 2013).

In addition to direct toxicity and chemosterilant activity, EOs induce oviposition and feeding deterrence, repellence, and fumigant and sterilizing effects. Moreover, some oils cause larvicidal effect and the capacity to delay development and suppress emergence of adult flies (Khater 2003; Shalaby and Khater 2005; Khater and Shalaby 2008; Khater and Khater 2009; Khater et al. 2009, 2011; Khater 2011, 2012, 2013).

The oils are generally composed of complex mixtures of monoterpenes. Some EOs are useful against pests that are resistant towards synthetic pesticides because EOs are a complex mixture of components including minor constituents, whereas synthetic pesticides are based on single products. Components of EOs act synergistically within the plant as a defense strategy. Hence, it is likely that they are more durable towards pests evolving resistance (Feng and Isman 1995).

The mode of actions of EOs has been reviewed in detail by Bakkali et al. (2008), Khater (2011, 2012, 2013), and Regnault-Roger et al. (2012). It is expected that the anti-inflammatory and antimicrobial properties of EOs would stimulate wound healing caused by myiasis-producing maggots (Callander and James 2012).

Concerning safety of EOs, it had been reported that no adverse effects were noted on either animals or on operators after exposure to the EOs (Khater et al. 2009). In recent years, the use of EOs as low-risk insecticides has increased considerably owing to their popularity with organic growers and environmentally conscious consumers. Natural insect control using EOs is safer to the user because EOs induce low mammalian toxicity and break down into harmless compounds within hours or days in the presence of sunlight. They are also very close chemically to those plants from which they are derived, so they are easily decomposed by microbes common in most soils. In contrast to doramectin, non-target organisms such as predator, parasitoid, and pollinator insect populations will be less impacted on account of the minimal residual activity of EOs (Khater 2013).

EOs and products based on them are mostly non-toxic to mammals, birds, and fish (Stroh et al. 1998; Isman 2000). Many of the commercial products that include EOs are on the Generally Recognized as Safe list fully approved by the Food and Drug Administration and the Environmental Protection Agency in the USA for food and beverage consumption (Khater 2013).

Conclusions

C. titillator adversely affected the health of infested camels in the present study. Doramectin and lavender oil were selected to be drugs of choice for controlling *C. titillator*, but it is not permitted to use doramectin on dairy animals during lactation. Doramectin could be used to protect males. Lavender is much safer, regarding health and environmental issues, than doramectin.

Adult fly has two generations per year (Fatani and Hilali 1994; Alahmed 2002). Accordingly, EOs (50 %) could be used safely as nasal drench to repel adult flies and kill exiting larvae, at least, twice a year. The greatest benefits from EOs might be achieved in situations where human and animal health are of premium concern. Lavender, a natural product, could be developed as a novel larvicide against this parasite.

Further studies are needed to give details about the life cycle and economic impact of infestation with *C. titillator*. In

addition, in vivo studies are crucial to determine the effect of doramectin and lavender against *C. titillator* larvae to perform health and welfare to camels which will reflect on camel production as well as on the national economy.

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