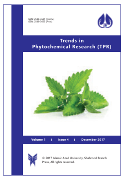
Trends Phytochem. Res. 1(4) 2017 183-198

Trends in Phytochemical Research (TPR)

Journal Homepage: http://tpr.iau-shahrood.ac.ir



Review Paper

Acaricidal activity of essential oils

Cicera Janaine Camilo[1], Carla de Fatima Alves Nonato[1], Fábio Fernandes Galvão-Rodrigues[1], Wegila Davi Costa[1], Georgia Gualberto Clemente[2], Mellyssa Ayêska Custódio Sobreira Macedo[2], Fabíola Fernandes Galvão Rodrigues[1,2] and José Galberto Martins da Costa[1,2, ✉]

[1]Department of Biological Chemistry, Laboratory of Research in Natural Products, Program of Post-Graduation in Molecular Bioprospection, Regional University of Cariri, 63105-000, Crato, CE, Brazil

[2]Pharmacy Course, Juazeiro do Norte College, 63010-520, Juazeiro do Norte, CE, Brazil

ABSTRACT

The environmental problems caused by the uncontrolled use of synthetic pesticides in crop production around the world has increased the search for new plant species that have this activity. As a result, studies with essential oils extracted from plants intensify because they present, among other biological properties, insecticidal and acaricidal activities. This study analyzes the use of essential oils with acaricidal potential based on reports in the literature, showing the importance of the search for alternative means to the use of chemical pesticides. Studies related to the acaricidal activity of essential oils in 121 species distributed in 25 families, Lamiaceae and Myrtaceae being the largest number of species that demonstrate this activity is due to their bioactive compounds and their interactions, where carvacrol and limonene are the most common monoterpenes cited.

ARTICLE HISTORY

Received: 28 July 2017
Revised: 04 September 2017
Accepted: 11 October 2017
ePublished: 09 December 2017

KEYWORDS

Acaricidal
Essential oils
Bioactive compounds
Lethal concentration

1. Introduction

Essential oils are complex mixtures of volatile, lipophilic, commonly odoriferous and liquid compounds. Chemically, they consist of terpenes, mainly monoterpenes and sesquiterpenes, and phenylpropanoids. These chemical constituents act ecologically in the interaction of plants with the environment, performing functions such as attracting pollinators, protecting against predators, water loss, UV rays, inhibiting germination, among others (Simões and Spitzer, 2002; Oliveira et al., 2006; Hüsnü et al., 2007; Scherer et al., 2009; Silva et al., 2009; Silva et al., 2013).

Plants with higher levels of essential oils are found in tropical and temperate regions. The oils may be contained in either specialized parts of the vegetable like in the glandular or oil channels, or in organs such as stem, leaves, roots, flowers, fruits or seeds. Several processes can be used to extract these products, such as enfleurage, solvent extraction, supercritical CO_2 extraction, expression (citrus fruit pericarp) and steam distillation or hydrodistillation, a commonly used technique that can also be aided by microwaves (Simões and Spitzer, 2002; Bizzo et al., 2009; Dunning, 2013; Silva et al., 2013; Mohammadhosseini, 2017a, 2017b).

Regarding industrial applications, essential oils stand out due to the use of their essence in perfumeries and food products, whereas in pharmaceutics they are widely used for their diversity of biological activities, such as antioxidant, antimicrobial, anti inflamatory and acaricidal features. These activities are related to a variety of chemical constituents and structures (Bertin et al., 2005; Castro et al., 2006; Morais et al., 2006; Ramos et al., 2006).

In Brazil and other tropical countries, the great majority of mites are among the main causers of respiratory diseases and are also related to agricultural losses, being considered as one of the main pests of economic importance (Nicastro et al., 2010), highlighting the species *Rhipicephalus* (*Boophilus*) *microplus* Canestrini and *Tetranychus urticae* Koch. The

---

✉ Corresponding author: José Galberto Martins da Costa
Tel: +55-88-31021212; Fax:
E-mail address: galberto.martins@gmail.com

first mite cited is well-known for its wide geographical distribution (Andreotti et al., 2013), leading to huge economic losses, valued at US$ 3.236,35 million per year (Grisi et al., 2014). *Tetranychus urticae* Koch, popularly known as spider mite, is considered as one of the main pests present in agriculture. In 2013, almost 80% of the total world market for pesticides (around 900 million EUR) was spent on mite control, being *Tetranychus* spp., with *T. urticae* as the main species, representing 62% (372 million EUR) (Van Leeuwen et al., 2015).

The use of synthetic acaricides, substances or mixtures that prevent, destroy, repel or mitigate pests has been their main way of combating mites, such as organophosphates, synthetic pyrethroids, amitraz and ivermectin. A number of problems are associated with the indiscriminate use of these products, such as high cost, environmental pollution and the rapid resistance of the species, also damaging their natural predators

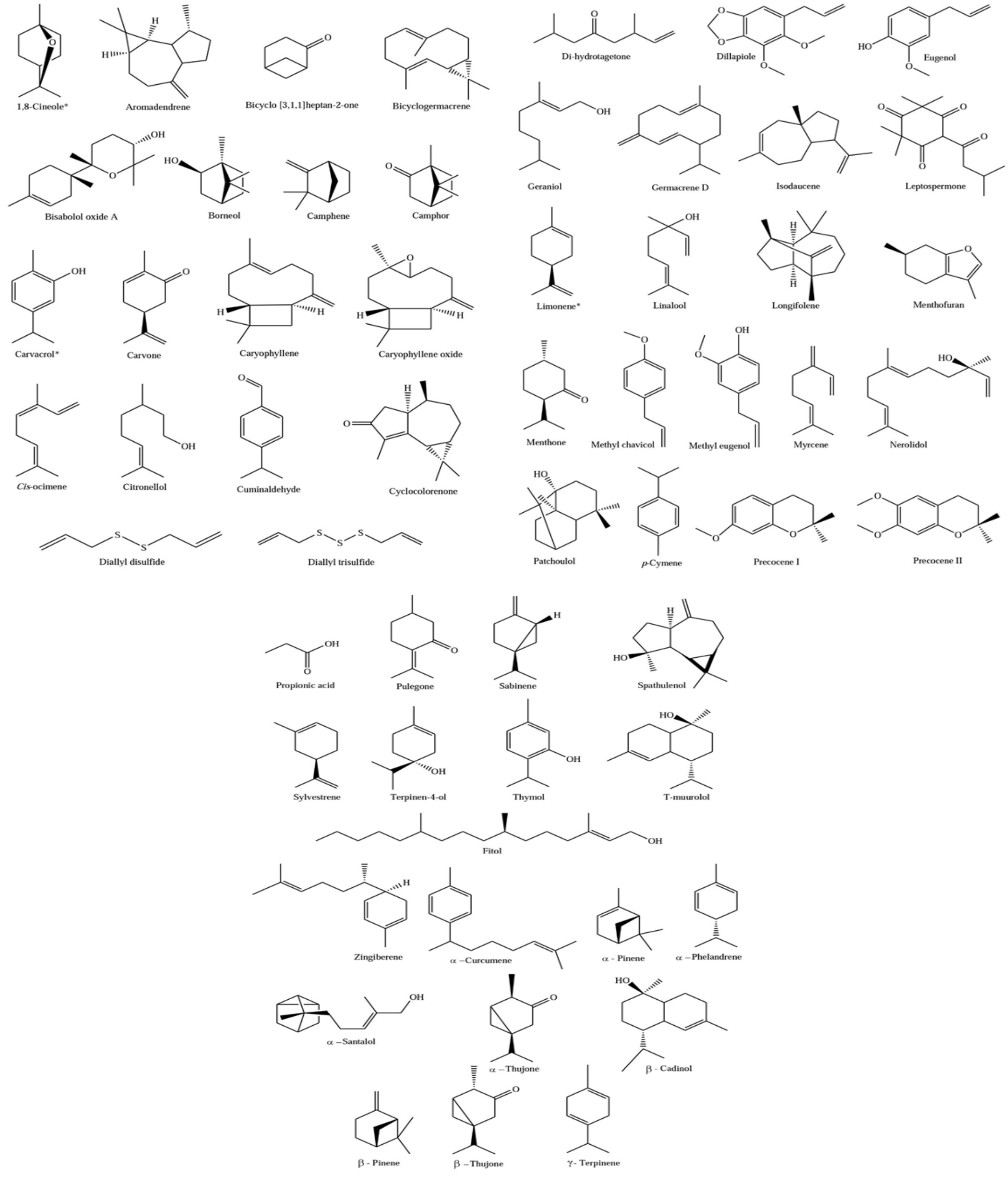


Fig. 1. Chemical structures of the major compounds present in the plant species cited in Table 1. *most frequent compounds.

(Klafke et al., 2010; Nicastro et al., 2010; Ribeiro et al., 2011; Settimi et al., 2016).

An alternative to the synthetic acaricides is the use of plant oils and extracts and the relevant derived products, due to the compatibility with the natural predators and for having short residual effect and low toxicity to man (Chiasson et al., 2004; Hincapié et al., 2008; Bernardi et al., 2010). Studies with essential oils demonstrate good acaricidal activity, such as the oils of species *Lippia alba* (Mill.) N.E. Br. ex Britton & P. Wilson and *Lippia sidoides* Cham., where this activity was attributed to the presence of the chemical constituents carvacrol, thymol and 1,8-cineole (Cavalcanti et al., 2010; Cruz et al., 2013). Studies report different neurotoxic acaricidal mechanisms of action of the essential oils such as inhibition of acetylcholinasterase (AChE), antagonism with the receptors of the octopamine neurotransmitter and the closure of the chloride channels by GABA (Isman, 2006; Badawy et al., 2010; Marcic, 2012; Regnault-Roger et al., 2012).

This review aims to provide a thorough survey on essential oils of various plant species with acaricidal activity, highlighting the botanical families, species of Acari, the LC_{50}, major components and parts of the plant used.

2. Materials and Methods

Data obtained from the following databases was used for realization of this work: Web of Science (WOS), ScienceDirect, Scielo and PubMed, concerning acaricidal activity of essential oils of various species from different regions of the world. On that occasion, 96 published studies were analyzed in the last 18 years (1998-2016). The terms "essential oils" and "acaricidal activity" (alone or combined) were used as keywords. In this research, sources originating from books, dissertations, theses, abstracts, reviews and articles that did not report the origin of the essential oils used or did not tested the oil were excluded.

The plant species were arranged in a table according to their respective families, in alphabetical order, also containing the species of Acari, the values of the lethal concentration for 50% mortality (LC_{50}), major chemical compounds and parts of plants used. The following databases were used for verification of the plant species' scientific names: "Lista de Espécies da Flora do Brasil (http://floradobrasil.jbrj.gov.br/)", "Tropicos of the Missouri Botanical Garden (http://www.tropicos.org/)" and "The Plant List (http://www.theplantlist.org/)".

3. Results and Discussion

3.1. Essential oils and larvicidal activity

In this bibliographic survey, 121 species were identified, 73 genus distributed in 25 families, with the Lamiaceae and Myrtaceae families having the highest number of species with 37 and 20, respectively, as shown in Table 1. In most of the works analyzed, the essential oils were composed mainly of monoterpenes, having their structures shown in Fig. 1.

3.2. Plant species and major compounds

Among the compounds shown in Table 1, carvacrol and limonene appeared more frequently, followed by 1,8-cineole. The toxic action of these monoterpenes in conjunction with other components such as phenylpropanoids has increased the acaricidal activity of the essential oils, since the relations of these compounds with the defense of plants are well established (Chagas et al., 2002).

The major chemical compound mostly found in essential oils of species of the Lamiaceae family was carvacrol, monoterpene synthesized from γ-pinene (Kintzios, 2002). It is used as a disinfectant, fungicide, anthelmintic, in insect control, in the perfume industry, with applications in food, recommended by the Federal Drug Administration and the Council of Europe. Its biological activities are widely studied, with antimicrobial, acaricidal, anticancerous, antioxidant, anti-inflammatory and antiplatelet activities already proven (Andersen, 2006; Suntres et al., 2015).

The essential oils that contain high carvacrol levels are considered more effective in acaricidal activity (Koc et al., 2013), where the toxicity of this compound against mite species is demonstrated in several studies, showing effectiveness at low concentrations (Cetin et al., 2010; Cruz et al., 2013; Koc et al., 2013). In the work of Ramírez et al. (2016), the action of this constituent against the *Rhipicephalus* (*Boophilus*) *microplus* Canestrini species was confirmed.

In the Myrtaceae family, the *Eucalyptus* genus is one of the largest genera, with about 900 species, standing out for a variety of antibacterial, antifungal, antiseptic and insecticide activities (Rossi and Palacios, 2015). Studies with essential oils of various species of this genus reported the presence of the compound 1,8-cineole, monoterpene used in the pharmaceutical industry by having antimicrobial activity, in the treatment of respiratory diseases, as well as having applicability as an acaricide (Estanislau et al., 2001; Chagas et al., 2002; Franco et al., 2005; Ramos et al., 2015; Rossi and Palacios, 2015).

In the study of Roh et al. (2013), the constituents limonene and 1,8-cineole were tested against eggs of the *Tetranychus urticae* Koch mite, obtaining a significant reduction in the number of eggs, being considered potent repellents. In the work of Prates et al. (1998), the compound 1,8-cineole showed high acaricidal activity, killing 100% of the larvae of the *Rhipicephalus* (*Boophilus*) *microplus* Canestrini mite.

These constituents may act by inhibiting cytochrome P450 enzymes or interfering in the nervous system, damaging biochemical and physiological functions of

Table 1

Plant essential oils with repellent activity against mites.

Family/Plant species	Species (Acari)	LC_{50}	Major compound	Plant part	References
Anarcadiaceae					
Schinus molle L.	*Varroa destructor* (Anderson & Trueman)	-	Sabinene (51.0%); β-pinene (11.2%)	Leaves Fruits Stems	Guala et al., 2014
Schinus terebinthifolius Raddi	*Suidasia pontifica* Oudemans *Tetranychus urticae* Koch *Tyrophagus putrescentiae* (Schrank)	0.0048 µL/mL -	Limonene (44.1%); α-phellandrene (15.7%)	Leaves Fruits	Assis et al., 2011; Nascimento et al., 2012
Apiaceae					
Carum carvi L.	*Neoseiulus californicus* (Mcgregor) *Tetranychus urticae* Koch	22.4 µg/mL	-	Seeds	Han et al., 2010
Coriandrum sativum L.	*Dermanyssus gallinae* (De Geer) *Tetranychus urticae* Koch	-	-	Leaves	George et al., 2010a
Cuminum cyminum L	*Rhipicephalus* (*Boophilus*) *microplus* Canestrini	-	γ-Terpinene (15.6%); cuminaldehyde (22.0%)	Leaves Seeds	Martinez-Velazquez et al., 2011a
Deverra scoparia Coss. & Durieu	*Tetranychus urticae* Koch	1.79 µg/mL	α-Pinene (31.9%); sabinene (17.2%)	Aerial parts	Attia et al., 2011
Ferula assa-foetida L.	*Varroa destructor* (Anderson & Trueman)	0.0024 µL/mL	-	Leaves Roots	Ghasemi et al., 2011
Foeniculum vulgare Mill.	*Tyrophagus putrescentiae* (Schrank)	-	Carvone (44.8%); D-limonene (25.5%)	Seeds	Lee et al., 2006
Araucariaceae					
Agathis moorei (Lindl.) Mast.	*Rhipicephalus* (*Boophilus*) *microplus* Canestrini	-	-	Heartwood Resin	Lebouvier et al., 2013
Agathis ovata (*C. Moore* ex Vieill.) Warb.	*Rhipicephalus* (*Boophilus*) *microplus* Canestrini	-	-	Heartwood Resin	Lebouvier et al., 2013
Araucaria columnaris (Forst.) Hooker	*Rhipicephalus* (*Boophilus*) *microplus* Canestrini	1620 µg/mL	Aromadendrin (23.8%); bicyclogermacrene (16.0%)	Heartwood Resin	Lebouvier et al., 2013
Aristolochiaceae					
Asarum sieboldii Miq.	*Dermatophagoides farinae* Hughes	-	Eugenol (42.1%)	Root	Wu et al., 2012[a]
Asteraceae					
Ageratum houstonianum Mill.	*Rhipicephalus lunulatus* (Neumann)	20 µL/mg	Precocene I (40.0%); Precocene II (36.5%)	Flowers Leaves	Pamo et al., 2004; Pamo et al., 2005
Artemisia absinthium L.	*Tetranychus urticae* Koch	-	β-Thujone (32.1%)	Whole plant	Chiasson et al., 2001
Artemisia annua L.	*Rhipicephalus* (*Boophilus*) *annulatus* (Say)	-	-	Stem Leaves	Pirali-Kheirabadi et al., 2011
Artemisia gmelinii Weber ex Stechm. var. *gmelinii*	*Dermatophagoides farinae* Hughes *Dermatophagoides pteronyssinus* (Troussart)	-	Camphor (25.4%); 1,8-cineole (13.4%)	Whole plant	Jeon et al., 2014
Artemisia sieberi Besser	*Callosobruchus maculates* (Fabr.) *Sitophilus oryzae* (L.) *Tribolium castaneum* (Herbst.)	1.45 µL/mL 3.86 µL/mL 16.76 µL/mL	Camphor (54.7%); camphene (11.7%)	Aerial parts	Negahban et al., 2007
Baccharis dracunculifolia DC.	*Rhipicephalus* (*Boophilus*) *microplus* Canestrini	-	Nerolidol (22,3%)	Leaves	Lage et al., 2015
Calea serrata Less.	*Rhipicephalus* (*Boophilus*) *microplus* Canestrini	0.28 µL/mL	Germacrene D (26.4%); precocene II (29.2%)	Leaves	Ribeiro et al., 2011
Chamomilla recutita (L.) Rauschert	*Tetranychus urticae* Koch	-	Bisabolol oxide A (35.2%)	Whole plant	Afify et al., 2012
Hertia cheirifolia (L.) Kuntze	*Tetranychus urticae* Koch	3.43 µg/mL	Thymol (61%)	Stem Leaves	Attia et al., 2012
Santolina africana Jord. & Fourr.	*Dermanyssus gallinae* (De Geer) *Tetranychus urticae* Koch;	2.35 µg/mL	Terpinen-4-ol (54.9%)	Stem Leaves	Attia et al., 2012
Tagetes erecta L.	*Rhipicephalus sanguineus* Latreille	-	-	Stem Flowers Leaves	Politi et al., 2013

Table 1 (Continued)

Family/Plant species	**Species (Acari)**	**LC$_{50}$**	**Major compound**	**Plant part**	**References**
Tagetes minuta L.	*Amblyomma cajennense* (Fabricius) *Argas miniatus* Koch *Hyalomma rufipes* Enigk & Grittner *Rhipicephalus (Boophilus) microplus* Canestrini *Rhipicephalus sanguineus* Latreille	52 µL/mL 84 µL/mL	di-Dydrotagetone (54.2%); *cis*-ocimene (28.5%); limonene (6.9%)	Stem Flowers Leaves	Garcia et al., 2012; Nchu et al., 2012; Andreotti et al., 2013
Tanacetum vulgare L.	*Tetranychus urticae* Koch	-	β-Thujone (92.2%)	Whole plant	Chiasson et al., 2001
Burseraceae					
Protium heptaphyllum (Aubl.) Marchand	*Tetranychus urticae* Koch	-	α-Terpinene (47.6%)	Leaves Fruits	Pontes et al., 2007
Caryophyllaceae					
Dianthus caryophyllus L.	*Ixodes ricinus* L.	-	-	Flowers	Tunón et al., 2006
Cleomaceae					
Cleome gynandra L.	*Rhipicephalus appendiculatus* Neumann	-	Carvacrol (29.2%); *trans*-phytol (24.7%)	Leaves	Lwande et al., 1999
Cupressaceae					
Callitris sulcata Schltr.	*Rhipicephalus (Boophilus) microplus* Canestrini	650 µg/mL	-	Heartwood Resin	Lebouvier et al., 2013
Chamaecyparis obtusa (Siebold & Zucc.) Endl.	*Callosobruchus chinensis* (L.) *Sitophilus oryzae* (L.).	-	Limonene (13.4%)	Leaves	Park et al., 2003
Juniperus oxycedrus L.	*Dermanyssus gallinae* (De Geer)	-	-	Commercial	George et al., 2010ab
Neocallitropsis pancheri (Carrière) de Laub.	*Rhipicephalus (Boophilus) microplus* Canestrini	550 µg/mL	-	Heartwood Resin	Lebouvier et al., 2013
Taiwania cryptomerioides Hayata	*Dermatophagoides farinae* Hughes *Dermatophagoides pteronyssinus* (Troussart)	-	β-Cadinol (36.8%); T-muurolol (17.1%)	Heartwood	Chang et al., 2001
Euphorbiaceae					
Croton malambo H. Karst.	*Dermatophagoides farinae* Hughes	-	Methyl eugenol (68.4%)	Stem Branch	Mendoza-Meza et al., 2014.
Geraniaceae					
Pelargonium roseum Willd.	*Rhipicephalus (Boophilus) annulatus* (Say)	-	-	Leaves Stems	Pirali-Kheirabadi et al., 2009
Lamiaceae					
Cunila angustifolia Benth.	*Rhipicephalus (Boophilus) microplus* Canestrini	-	Sabinene (32.1%); spathulenol (10.0%)	Aerial parts	Apel et al., 2009
Cunila incana Benth.	*Rhipicephalus (Boophilus) microplus* Canestrini	-	β-Pinene (27.5%); α-pinene (26.7%)	Aerial parts	Apel et al., 2009
Cunila spicata Benth.	*Rhipicephalus (Boophilus) microplus* Canestrini	-	Borneol (19.7%); menthofuran (34.8%)	Aerial parts	Apel et al., 2009
Dorystoechas hastata Boiss. et Heldr. ex Benth.	*Rhipicephalus turanicus* Pom.	-	-	Aerial parts	Koc et al., 2012
Hesperozygis ringens (Benth.) Epling	*Rhipicephalus (Boophilus) microplus* Canestrini	0.541 µL/mL	Pulegone (86%)	Leaves	Ribeiro et al., 2010
Hyptis suaveolens (L.) Poit.	*Amblyomma cajennense* (Fabricius)	-	-	Aerial parts	Soares et al., 2010
Lavandula angustifolia Mill.	*Dermanyssus gallinae* (De Geer) *Rhipicephalus (Boophilus) annulatus* (Say)	-	-	Commercial Aerial parts	George et al., 2010a; Pirali-Kheirabadi et al., 2010
Lavandula dentata L.	*Dermanyssus gallinae* (De Geer)	-	-	Commercial	George et al., 2010^{a}
Lavandula officinalis Chaix	*Dermanyssus gallinae* (De Geer); *Tetranychus urticae* Koch	-	-	Commercial	George et al., 2010a
Lavandula stoechas L. subsp. *stoechas*	*Tetranychus cinnabarinus* (Boisduval)	2.92 µg/mL	α-Thujone (65.7%)	Stems Leaves	Sertkaya et al., 2010
Melissa officinalis L.	*Tetranychus urticae* Koch	-	α-Curcumene (14. 3%); caryophyllene oxide (10.8%)	Aerial parts	Momen et al., 2014
Mentha longifolia (L.) L.	*Rhipicephalus turanicus* Pom.	-	-	Aerial parts	Koc et al., 2012

Table 1 (Continued)

Family/Plant species	**Species (Acari)**	**LC_{50}**	**Major compound**	**Plant part**	**References**
Mentha pulegium L.	*Dermanyssus gallinae* (De Geer) *Dermatophagoides pteronyssinus* Trouessart *Dermatophagoides farinae* Hughes *Neoseiulus californicus* (Mcgregor) *Tetranychus urticae* Koch	23.7 µg/mL	Pulegone (99%)	Commercial Flowers Leaves Seeds	Rim and Jee, 2006; George et al., 2009; George et al 2010a; Han et al., 2010
Mentha spicata L.	*Ixodes ricinus* L. *Tetranychus cinnabarinus* Boisd *Tetranychus urticae* Koch	0.5 µg/mL	Carvone (54.7%; 59.3%)	Stems Commercial Leaves	Sertkaya et al., 2010; El-Seedi et al., 2012
Mentha x piperita L.	*Dermanyssus gallinae* (De Geer) *Neoseiulus californicus* (Mcgregor) *Tetranychus urticae* Koch	22.8 µg/mL	-	Commercial Leaves Seeds	George et al., 2010a; Han et al., 2010
Nepeta cataria L.	*Dermanyssus gallinae* (De Geer) *Rhipicephalus appendiculatus* Neumann	-	-	Flowers	Birkett et al., 2011
Ocimum basilicum L.	*Bemisia tabaci* Genn *Dermanyssus gallinae* (De Geer) *Dermatophagoides farina* Hughes *Rhipicephalus* (*Boophilus*) *microplus* Canestrini *Tetranychus urticae* Koch	39.5 µg/mL	Linalool (30.6%); methyl chavicol (76.3%)	Commercial Leaves Fruits Aerial parts Seeds	Han et al.,2010; Martinez-Velazquez et al., 2011a; Perumalsamy et al., 2014
Ocimum gratissimum L.	*Rhipicephalus* (*Boophilus*) *microplus* Canestrini	-	γ-Terpinene (33.0%)	Leaves	Hüe et al., 2015
Ocimum urticaefolium Hort. Ex Benth.	*Rhipicephalus* (*Boophilus*) *microplus* Canestrini	-	Eugenol (33.0%)	Leaves	Hüe et al., 2015
Origanum bilgeri P.H. Davis	*Rhipicephalus turanicus* Pom.	-	Carvacrol (93.0%)	Aerial parts	Koc et al., 2013
Origanum majorana L.	*Tetranychus urticae* Koch	-	*p*-Cymene (23.4%); terpinen-4-ol (23.8%)	Whole plant	Afify et al., 2012
Origanum minutiflorum O. Schwarz & P.H. Davis	*Rhipicephalus turanicus* Pom.	20000 µL/mL	Carvacrol (85.1%)	Aerial parts	Cetin et al., 2009
Origanum onites L.	*Tetranychus cinnabarinus* (Boisduval)	0.69 µg/mL	Carvacrol (68.2%)	Stems Leaves	Sertkaya et al., 2010
Origanum vulgare L.	*Tetranychus urticae Koch*	-	-	Aerial parts	Çalmaşur et al., 2006
Pogostemon cablin (Blanco) Benth.	*Dermatophagoides farinae* Hughes	-	Patchoulol (32.9%)	Aerial parts	Wu et al., 2012b
Rosmarinus officinalis L.	*Ixodes ricinus* L. *Rhipicephalus* (*Boophilus*) *microplus* Canestrini *Tetranychus urticae* Koch *Tyrophagus putrescentiae* (Schrank)	0.041 µg/mL	α-Thujone (42.3%) 1,8-cineole (26.7%-51.8%) thymol (24.5%)	Commercial Leaves Aerial parts	Miresmailli and Isman, 2006; Martinez-Velazquez et al., 2011b; El-Seedi et al., 2012; Laborda et al., 2013
Salvia officinalis L.	*Tetranychus urticae* Koch	63.7 µg/mL	α-Thujone (42.3%)	Aerial parts	Han et al., 2010; Laborda et al., 2013
Satureja hortensis L.	*Dermanyssus gallinae* (De Geer) *Tetranychus turkestani* Ugarov Nikolskii; *Tetranychus urticae* Koch	0.0094 µL/mL	Carvacrol (38.3%)	Leaves Aerial parts	Zandi-Sohani and Ramezani, 2015
Satureja thymbra L.	*Hyalomma marginatum rufipes* Koch	-	-	Aerial parts	Cetin et al., 2010
Schizonepeta tenuifolia Briq.	*Dermatophagoides pteronyssinus* (Troussart) *Dermatophagoides farinae* Hughes *Tyrophagus putrescentiae* (Schrank)	-	Menthone (50.2%)	Aerial parts	Yang et al., 2013

Table 1 (Continued)

Family/Plant species	Species (Acari)	LC_{50}	Major compound	Plant part	References
Tetradenia riparia (Hochst.) Codd	*Rhipicephalus* (*Boophilus*) *microplus* Canestrini	110000 µg/mL	-	Leaves	Gazim et al., 2011
Thymbra capitata Cav.	*Dermanyssus gallinae* (De Geer)	-	-	Commercial	Ghrabi-Gammar et al., 2009
Thymbra spicata L. subsp. *spicata*	*Tetranychus cinnabarinus* (Boisduval)	0.53 µg/mL	Carvacrol (70.9%)	Stems Leaves	Sertkaya et al., 2010
Thymus kotschyanus Boiss. & Hohen.	*Varroa destructor* (Anderson & Trueman)	0.001 µL/mL	-	Leaves	Ghasemi et al., 2011
Thymus sipyleus Boiss. subsp. *sipyleus*	*Rhipicephalus turanicus* Pom.	-	-	Aerial parts	Koc et al., 2012
Thymus vulgaris L.	*Dermanyssus gallinae* (De Geer); *Neoseiulus californicus* (Mcgregor); *Tetranychus urticae* Koch; *Varroa destructor* (Anderson & Trueman)	22.7 µg/mL	Thymol (65.3%)	Commercial Leaves Aerial parts Seeds	Çalmaşur et al., 2006; Damiani et al., 2009; George et al., 2009; George et al., 2010ab; Han et al., 2010
Zataria multiflora Bioss.	*Rhipicephalus* (*Boophilus*) *annulatus* (Say) *Tetranychus turkestani* Ugarov Nikolskii	0.0055 µL/mL	Carvacrol (22.1%); Thymol (30.2%)	Stem Leaves	Pirali-Kheirabadi et al., 2011; Zandi-Sohani and Ramezani, 2015
Lauraceae					
Cinnamomum zeylanicum Blume	*Dermanyssus gallinae* (De Geer); *Psoroptes cuniculi* Delafond *Suidasia pontifica* Oudemans; *Tyrophagus putrescentiae* (Schrank);	0.00082 µL/mL 0.079 µL/mL 0.021 µL/mL	Eugenol (76.1%); β-caryopyllene (6.7%)	Leaves	Fichi et al., 2007a; George et al., 2010; Assis et al., 2011
Litsea cubeba (Lour.) Pers.	*Luciaphorus perniciosus* Rack		-	Fruits	Pumnuan et al., 2010
Litsea salicifolia (J. Roxb. ex Nees) Hook. f.	*Luciaphorus perniciosus* Rack	-	-	Fruits	Pumnuan et al., 2010
Liliaceae					
Allium sativum L.	*Dermanyssus gallinae* (De Geer) *Rhipicephalus* (*Boophilus*) *microplus* Canestrini *Varroa destructor* (Anderson & Trueman)	-	Diallyl disulfide (30.9%); Diallyl trisulfide (33.5%)	Bulbs Commercial Leaves	George et al., 2010a; Martinez-Velazquez et al., 2011b
Meliaceae					
Azadirachta indica A. Juss	*Sarcoptes scabiei* var. *Cuniculi* De Geer	-	-	Seeds	Xu et al., 2010
Carapa guianensis Aubl.	*Rhipicephalus sanguineus* Latreille	-	-	Seeds	Vendramini et al., 2012
Myrtaceae					
Callistemon viminalis (Sol. ex Gaertn.) G. Don	*Tetranychus urticae* Koch	-	1,8-Cineole (54.4%); Limonene (14.4%)	Leaves Branches	Roh et al., 2013
Corymbia citriodora (Hook.) K.D. Hill & L.A.S.Johnson	*Amblyomma cajennense* (Fabricius) *Anocentor nitens* Neumann *Neoseiulus californicus* (Mcgregor) *Dermanyssus gallinae* (De Geer) *Rhipicephalus* (*Boophilus*) *microplus* Canestrini *Tetranychus urticae* Koch	19.3 µg/mL 8700 µg/mL	Citronellol (94.9%)	Commercial Leaves Seeds	Chagas et al., 2002; Clemente et al., 2010; George et al., 2010a; Han et al., 2010; Chagas et al., 2014
Eucalyptus approximans Maiden	*Tetranychus urticae* Koch		1,8-Cineole (61.1%); limonene (14.5%)	Leaves	Roh et al., 2013
Eucalyptus bicostata Maiden, Blakely & Simmonds	*Tetranychus urticae* Koch	-	1,8-Cineole (63.0%); limonene (10.9%)	Leaves	Roh et al., 2013
Eucalyptus camaldulensis Dehnh.	*Varroa destructor* (Anderson & Trueman)	0.0017 µL/mL		Leaves	Ghasemi et al., 2011
Eucalyptus globulus Labill.	*Tetranychus urticae* Koch	-	-	Leaves	Hussein et al., 2013
Eucalyptus maidenii F. Muell.	*Tetranychus urticae* Koch	-	1,8-Cineole (59.8%); limonene (17.2%)	leaves	Roh et al., 2013
Eucalyptus sideroxylon A. Cunn. ex Woolls	*Tetranychus urticae* Koch	-	1,8-Cineole (54.4%); limonene (11.9%)	Leaves	Roh et al., 2013
Eucalyptus sp	*Tetranychus urticae* Koch	-	-	Leaves	Afify et al., 2012

Table 1 (Continued)

Family/Plant species	**Species (Acari)**	**LC_{50}**	**Major compound**	**Plant part**	**References**
Eucalyptus staigeriana F. Muell. ex F.M. Bailey	*Rhipicephalus* (*Boophilus*) *microplus* Canestrini	-	-	Commercial	Chagas et al., 2002
Eugenia langsdorffii O. Berg	*Tetranychus urticae* Koch	0.0015 µL/mL	Bicyclogermacrene (15.0%); spathulenol (11.0%)	Leaves	Ribeiro et al., 2016
Eugenia lutescens Cambess.	*Tetranychus urticae* Koch	0.0025 µL/mL	α-Pinene (12.9%); β-pinene (24.0%)	Leaves	Ribeiro et al., 2016
Eugenia pyriformis Cambess.	*Suidasia pontifica* Oudemans *Tyrophagus putrescentiae* (Schrank)	0.0037 µL/mL	Caryophyllene oxide (52.2%)	Leaves	Assis et al., 2011
Leptospermum scoparium J.R. Forst. & G. Forst.	*Dermanyssus gallinae* (De Geer) *Dermatophagoides farinae* (Hughes) *Dermatophagoides pteronyssinus* (Troussart) *Tyrophagus putrescentiae* (Schrank)	-	Leptospermone (57.8%)	Commercial Leaves Seeds	George et al., 2009; Jeong et al., 2009; George et al., 2010a
Melaleuca alternifolia Cheel	*Dermanyssus gallinae* (De Geer) *Ixodes ricinus* L. *Rhipicephalus* (*Boophilus*) *microplus* Canestrini	-	Terpinen-4-ol (42.3%)	Commercial Aerial parts	Iori et al., 2005; Williamson et al., 2007; George et al., 2010a; Pazinato et al., 2014
Melaleuca cajuputi Powell	*Luciaphorus perniciosus* Rack	-	-	Fruits	Pumnuan et al., 2010
Melaleuca quinquenervia (Cav.) S.T. Blake	*Panonychus citri* (Mcgregor) *Raoiella indica* Hirst *Tetranychus tumidus* Banks *Tetranychus urticae* Koch	-	Longifolene (32.9%); 1,8-cineole (25.4%)	Leaves	Pino et al., 2011a
Myrtus communis L.	*Dermanyssus gallinae* (De Geer)	-	-	Commercial	Ghrabi-Gammar et al., 2009
Pimenta dioica (L.) Merr.	*Dermanyssus gallinae* (De Geer) *Rhipicephalus* (*Boophilus*) *microplus* Canestrini	-	Methyl eugenol (62.7%)	Commercial Leaves Fruits Seeds	George et al., 2010a; Martinez-Velazquez et al., 2011a
Syzygium aromaticum (L.) Merr. & L.M. Perry	*Dermanyssus gallinae* (De Geer) *Dermatophagoides pteronyssinus* (Troussart) *Neoseiulus californicus* (Mcgregor) *Psoroptes cuniculi* Delafond *Rhipicephalus* (*Boophilus*) *microplus* Canestrini *Tetranychus urticae* Koch *Varroa destructor* (Anderson & Trueman)	23.6 µg/mL	Eugenol (59.3%); β-Caryophyllene (24.9%)	Floral buttons Flowers Commercial	Fichi et al., 2007b; George et al., 2010a; Han et al., 2010; Maggi et al., 2012; Hussein et al., 2013; Mahakittikun et al., 2013; Mello et al., 2014
Pinaceae					
Pinus sylvestris L.	*Dermanyssus gallinae* (De Geer)	-	-	Commercial	George et al., 2010a
Piperaceae					
Piper aduncum L.	*Tetranychus urticae* Koch	-	Dillapiole (79.0%)	Leaves	Araújo et al., 2012
Piper aduncum var. *ossanum* (C. DC.) Saralegui	*Varroa destructor* (Anderson & Trueman)	-	-	Leaves	Pino et al., 2011b
Piper amalago L.	*Rhipicephalus* (*Boophilus*) *microplus* Canestrini	-	Limonene (20.5%)	Aerial parts	Ferraz et al., 2010
Piper mikanianum (Kunth) Steud.	*Rhipicephalus* (*Boophilus*) *microplus* Canestrini	2.33 µg/mL	(*E*)-Caryophyllene (3.6%)	Aerial parts	Ferraz et al., 2010
Piper xylosteoides (Kunth) Steud.	*Rhipicephalus* (*Boophilus*) *microplus* Canestrini	6.15 µg/mL	Zingiberene (9.2%)	Aerial parts	Ferraz et al., 2010
Poaceae					
Cymbopogon citratus (DC.) Stapf	*Dermanyssus gallinae* (De Geer) *Tetranychus urticae* Koch	-	-	Commercial	George et al., 2010a
Cymbopogon martini (Roxb.) Will. Watson	*Dermanyssus gallinae* De Geer	-	-	Commercial	George et al., 2010a
Cymbopogon nardus (L.) Rendle	*Amblyomma cajennense* (Fabricius) *Anocentor nitens* Neumann	22.5 µg/mL 46500 µg/mL	-	Commercial Leaves Aerial parts Seeds	Clemente et al., 2010; George et al., 2010a; Han et al., 2010;

Table 1 (Continued)

Family/Plant species	Species (Acari)	LC_{50}	Major compound	Plant part	References
	Dermanyssus gallinae (De Geer); *Neoseiulus californicus* (Mcgregor) *Rhipicephalus* (*Boophilus*) *microplus* Canestrini *Tetranychus urticae* Koch		-		Chagas et al., 2014
Cymbopogon winterianus Jowwiit ex Bor	*Rhipicephalus* (*Boophilus*) *microplus* Canestrini	49900 µg/mL	-	Commercial Leaves Aerial parts	Agnolin et al., 2014; Chagas et al., 2014; Mello et al., 2014
Melinis minutiflora P. Beauv.	*Rhipicephalus* (*Boophilus*) *microplus* Canestrini	-	Propionic acid (43.0%); 1,8-Cineole (10.6%)	Stems Leaves	Prates et al., 1998
Triticum aestivum L.	*Tetranychus urticae* Koch	-	-	Seeds	Hussein et al., 2013
Rosaceae					
Rosa x damascena Mill.	*Tetranychus urticae* Koch	-	Geraniol (34.9%); citronellol (23.4%)	Flowers	Salman and Erbaş, 2014
Rutaceae					
Zanthoxylum caribaeum Lam.	*Rhipicephalus* (*Boophilus*) *microplus* Canestrini	-	Isodaucene (8.3%); sylvestrene (11.3%)	Leaves	Nogueira et al., 2014
Santalaceae					
Santalum austrocaledonicum Vieill.	*Tetranychus urticae* Koch	-	α-Santalol (45.8%)	Bark	Roh et al., 2011
Solanaceae					
Solanum sarrachoides Sendtn.	*Tetranychus evansi* Baker & Pritchard	-	Camphor (34.0%)	Leaves Fruits	Murungi et al., 2013
Verbenaceae					
Lippia alba (Mill.) N.E. Br. ex Britton & P. Wilson	*Rhipicephalus* (*Boophilus*) *microplus* Canestrini	8800 µg/mL	Carvone (63.4%); geraniol (46.2%)	Leaves	Peixoto et al., 2015
Lippia gracilis Schauer	*Rhipicephalus* (*Boophilus*) *microplus* Canestrini	2000 µg/mL 650 µg/mL	Carvacrol (48.9%); thymol (59.2%)	Leaves	Cruz et al., 2013; Costa-Júnior et al., 2016
Lippia graveolens Kunth	*Rhipicephalus* (*Boophilus*) *microplus* Canestrini	-	Carvacrol (24.5%); thymol (24.5%)	Leaves	Martinez-Velazquez et al., 2011b
Lippia javanica (Burm f.) Spreng.	*Hyalomma marginatum rufipes* Koch	-	Bicyclo (3.1.1) heptan-2-one (20.8%); myrcene (13.4%)	Flowers Leaves Branches	Magano et al., 2011
Lippia sidoides Cham.	*Dermacentor nitens* (Neumann) *Rhipicephalus* (*Boophilus*) *microplus* Canestrini *Tetranychus urticae* Koch	-	Thymol (69.9%)	Leaves	Cavalcanti et al., 2010; Gomes et al., 2012; Monteiro et al., 2014
Lippia triplinervis Gardner	*Rhipicephalus* (*Boophilus*) *microplus* Canestrini	-	Carvacrol (31.9%); thymol (30.6%)	Aerial parts	Lage et al., 2013
Winteraceae					
Drimys brasiliensis Miers	*Rhipicephalus* (*Boophilus*) *microplus* Canestrini *Rhipicephalus sanguineus* Latreille	-	Cyclocolorenone (30.4%)	Leaves Stem barks	Ribeiro et al., 2008

these ectoparasites (Baldin et al., 2010). The effectiveness of the essential oils can vary depending on the dosage of the product, application surface, the route and method of application (Garcia et al., 2012; Vieira et al., 2012). Lima et al. (2011) have stated that these compounds could be considered as potent insecticides and can be used to control agricultural pests.

These compounds are also reported as potent acetylcholinesterase (AChE) inhibitors, with carvacrol having an AChE inhibitory effect 10-fold higher than its thymol isomer, which demonstrates that the position of the hydroxyl group in its structure plays a key role in this. In addition, the phenolic grouping of this compound may play an important role in the elimination of ticks and mites through action on the GABA receptor and the octopamine receptor (Jukic et al., 2007; López and Pascual-Villalobos, 2010; Shang et al., 2016; Rey-Valeirón et al., 2017).

The *Cinnamomum zeylanicum* Blume species presented the best value of LC_{50} (0.0008 µL/mL) when compared to the other species. This activity may be related to the presence of the compound eugenol, in which Assis et al. (2011) have reported the direct relationship between the concentration of this compound and the mortality values. Some studies report various activities associated with this compound, such as antioxidant, anti-inflammatory, antimicrobial and larvicidal, as well (Pereira et al., 2014; Lee et al., 2016; Modjinou et al., 2016).

3.3. Commercialization and formulation

There are three important issues for the commercialization of natural products used in the agribusiness: scarcity of the natural resource, the need for chemical standardization and quality control. In addition to these, there are some challenges like long term stability, storage and transportation. Although essential oils are relatively stable, they are susceptible to oxidation and due to the volatility of their constituents, need to be stored with porous and chemically inert materials. Another challenge is the persistence of effective activity in target areas. It is necessary to extend the residual life of oil-based pesticides in open areas where their efficacy is evidently not based on smoking activity (Isman, 2000, 2016).

New advances in the formulation of acaricides, such as microencapsulation and nanoformulation, provide clues to solving problems with essential oil-based products, such as the residual activity and phytotoxicity of some compounds used in high concentrations (Isman, 2016).

3.4. Future perspectives

Most studies on acaricidal activity report the screening and bioactivity of oils and their compounds against mites, but there is a minority of reports about the end of the development of natural acaricides. Most of this knowledge in research is protected by intellectual property, only arriving at the scientific literature when protected by patent, which is fair. However, the discrepancy of the reports on successful products based on essential oils and those on their bioactivity is striking (Isman, 2016).

In addition to the studies that show the repellent and toxic properties of the essential oils and their monoterpenes as an alternative, such as the ones mentioned in Table 1, new studies should report the structure-activity relationship of compounds associated with acaricidal activity, where many compounds that act on the same target or mechanism of action can act synergistically combined and improved. In addition, studies are needed to reduce the impact of conventional management techniques, such as the use of synthetic pesticides, on predator populations, where researchers on selectivity of acaricides and insecticides should work together with those in the biological control area (Pallini et al., 2007; Shang et al., 2016).

4. Concluding remarks

Thus, it can be confirmed that the use of essential oils with acaricidal activity represents an important alternative to the use of synthetic acaricides for presenting bioactive compounds that reduce the resistance, environmental damage and risks to human health. Studies on this activity have been growing and deepening on a large scale over the years, but some challenges still have to be reached for the effective use of these resources. It is noteworthy that this work is pioneering in compiling data on acaricidal activity, serving as a basis for further studies aimed at seeking natural products with potential acaricidal activity that can replace synthetic products.

Conflict of interest

The authors declare that there is no conflict of interest.

References

Afify, A.E.M.M., Ali, F.S., Turky, A.F., 2012. Control of *Tetranychus urticae* Koch by extracts of three essential oils of chamomile, marjoram and *Eucalyptus*. Asian Pac. J. Trop. Biomed. 2(1), 24-30.

Agnolin, C.A., Olivo, C.J., Parra, C.L.C., Aguirre, P.F., Bem, C.M., Zeni, D., Morel, A. F., 2014. Eficácia acaricida do óleo de citronela contra o *Rhipicephalus* (*Boophilus*) *microplus*. Rev. Bras. Saúde Prod. Anim. 15(3), 604-612.

Andersen, A., 2006. Final report on the safety assessment of sodium *p*-chloro-*m*-cresol, *p*-chloro-*m*-cresol, chlorothymol, mixed cresols, *m*-cresol, *o*-cresol, *p*-cresol, isopropyl cresols, thymol, *o*-cymen-5-ol, and carvacrol. Int. J. Toxicol. 25(1), 29-127.

Andreotti, R., Garcia, M.V., Cunha, R.C., Barros, J.C., 2013. Protective action of *Tagetes minuta* (Asteraceae) essential oil in the control of *Rhipicephalus microplus* (Canestrini, 1887) (Acari: Ixodidae) in a cattle pen trial. Vet. Parasitol. 197(1-2), 341-345.

Apel, M.A., Ribeiro, V.L.S., Bordignon, S.A., Henriques, A.T., Poser, G., 2009. Chemical composition and toxicity of the essential oils from *Cunila* species (Lamiaceae) on the cattle tick *Rhipicephalus* (*Boophilus*) *microplus*. Parasitol Res. 105(3), 863-868.

Araújo, M.J.C., Câmara, C.A.G., Born, F.S., Moraes, M.M., Badji, C.A., 2012. Acaricidal activity and repellency of essential oil from *Piper aduncum* and its components against *Tetranychus urticae*. Exp. Appl. Acarol. 57(2), 139-155.

Assis, C.P.O., Gondim, M.G., Siqueira, H.A., Câmara, C.A., 2011. Toxicity of essential oils from plants towards *Tyrophagus putrescentiae* (Schrank) and *Suidasia pontifica* Oudemans (Acari: Astigmata). J. Stored. Prod. Res. 47(4), 311-315.

Attia, S., Grissa, K.L., Mailleux, A.C., Heuskin, S., Lognay, G., Hance, T., 2012. Acaricidal activities of *Santolina africana* and *Hertia cheirifolia* essential oils against the two-spotted spider mite (*Tetranychus urticae*). Pest. Manag. Sci. 68(7), 1069-1076.

Attia, S., Grissa, K.L., Lognay, G., Heuskin, S., Mailleux, A.C., Hance, T., 2011. Chemical composition and acaricidal properties of *Deverra scoparia* essential oil (Araliales: Apiaceae) and blends of its major constituents against *Tetranychus* *urticae* (Acari: Tetranychidae). J. Econ. Entomol. 104(4), 1220-1228.

Badawy, M.E.I., El-Arami, S.A.A., Abdelgaleil, S.A.M., 2010. Acaricidal and quantitative structure activity relationship of monoterpenes against the two-spotted spider mite, *Tetranychus urticae*. Exp. Appl. Acarol. 52(3), 261-274.

Baldin, E.L.L., Dal-Pogetto, M.H.F.A., Pavarini, D.P., Lopes, N.P., Lopes, J.L.C., 2010. Composition and acaricidal activity of the essential oil of *Lychnophora ericoides* Mart. to *Tetranychus urticae* Koch (Acari: Tetranychidae). Bol. San. Vegetal Plagas 36(1), 127-134.

Başer, K.H.C., Demirci, F., 2007. Chemistry of Essential Oils, in: Berger, R.G. (Ed.), Flavours and Fragrances, Springer, Berlin Heidelberg, pp. 43-86.

Bernardi, D., Botton, M., Cunha, U.S., Nava, D.E., Garcia, M.S., 2010. Bioecologia, monitoramento e controle do ácaro-rajado com o emprego da azadiractina e ácaros. Embrapa Uva e Vinho, Circular Técnica.

Bertin, L.M., Pereira, A.F., Oliveira, C.L.L., Menezes, E.A., Morais, S.M., Cunha, F.A., Cavalcanti, E.S.B., 2005. Perfil de sensibilidade de bactérias frente a óleos essenciais de algumas plantas do Nordeste do Brasil. Infarma 17(3-4), 80-83.

Birkett, M.A., Hassanali, A., Hoglund, S., Pettersson, J., Pickett, J.A., 2011. Repellent activity of catmint, *Nepeta cataria*, and iridoid nepetalactone isomers against Afro-tropical mosquitoes, ixodid ticks and red poultry mites. Phytochemistry 72(1), 109-114.

Bizzo, H.R., Hovell, A.M.C., Rezende, C.M., 2009. Óleos essenciais no Brasil: aspectos gerais, desenvolvimento e perspectivas. Quim. Nova 32(3), 588-594.

Çalmaşur, O., Aslan, Í., Şahin, F., 2006. Insecticidal and acaricidal effect of three Lamiaceae plant essential oils against *Tetranychus urticae* Koch and *Bemisia tabaci* Genn. Ind. Crops Prod. 23(2), 140-146.

Castro, D.P., Cardoso, M.G., Morais, J.C., Santos, N.M., Baliza, D.P., 2006. Não preferencia de *Spodoptera frugiperda* (lepidóptera: Noctuidae) por óleos essenciais de *Achllea millefolium* L. e *Thymus vulgaris* L. Rev. Bras. Plantas Med. 8(4), 27-32.

Cavalcanti, S.C.H., Niculau, E.S., Blank, A.F., Câmara, C.A.G., Araújo, I.N., Alves, P. B., 2010. Composition and acaricidal activity of *Lippia sidoides* essential oil against two-spotted spider mite (*Tetranychus urticae* Koch). Bioresour. Technol. 101(2), 829-832.

Cetin, H., Cilek, J.E., Aydin, L., Yanikoglu, A., 2009. Acaricidal effects of the essential oil of *Origanum multiflorum* (Lamiaceae) against *Rhipicephalus turanicus* (Acari: Ixodidae). Vet. Parasitol 160(3-4), 359-361.

Cetin, H., Cilek, J.E., OZ, E., Aydin, L., Deveci, O., Yanikoglu, A., 2010. Acaricidal activity of *Satureja thymbra* L. essential oil and its major components, carvacrol and γ-terpinene against adult *Hyalomma marginatum* (Acari: Ixodidae). Vet. Parasitol. 170(3-4), 287-290.

Chagas, A.C.S., Domingues, L.F., Fantatto, R.R., Giglioti, R., Oliveira, M.C., Oliveira, D.H., Jacob, R.G., 2014. *In vitro* and *in vivo* acaricide action of juvenoid analogs produced from the chemical modification of *Cymbopogon* spp. and *Corymbia citriodora* essential oil on the cattle tick *Rhipicephalus* (*Boophilus*) *microplus*. Vet. Parasitol. 205(1-2), 277-284.

Chagas, A.C.S., Passos, W.M., Prates, H.T., Leite, R.C., Furlong, J., Fortes, I.C.P., 2002. Efeito acaricida de óleos essenciais e concentrados emulsionáveis de *Eucalyptus* spp em *Boophilus microplus*. Braz. J. Vet. Res. Anim. Sci. 39(5), 247-253.

Chang, S.T., Chen, P.F., Wang, S.Y., Wu, H.H., 2001. Antimite activity of essential oils and their constituents from *Taiwania cryptomerioides*. J. Med. Entomol. 38(3), 455-457.

Chiasson, H., Bélanger, A., Bostanian, N., Vincent, C., Poliquin, A., 2001. Acaricidal properties of *Artemisia absinthium* and *Tanacetum vulgare* (Asteraceae) essential oils obtained by three methods of extraction. J. Econ. Entomol. 94(1), 167-171.

Chiasson, H., Bostanian, N.J., Vincent, C., 2004. Acaricidal properties of a *Chenopodium*-based botanical. J. Econ. Entomol. 97(4), 1373-1377.

Clemente, M.A., Monteiro, C.M.O., Scoralik., M.G., Gomes, F.T., Prata, M.C.A., Daemon, E., 2010. Acaricidal activity of the essential oils from *Eucalyptus citriodora* and *Cymbopogon nardus* on larvae of *Amblyomma cajennense* (Acari: Ixodidae) and *Anocentor nitens* (Acari: Ixodidae). Parasitol. Res. 107(4), 987-992.

Costa-Júnior, L.M., Miller, R.J., Alves, P.B., Blan, K.A.F., Li, A.Y., León, A.A.P., 2016. Acaricidal efficacies of *Lippia gracilis* essential oil and its phytochemicals against organophosphate-resistant and susceptible strains of *Rhipicephalus* (*Boophilus*) *microplus*. Vet. Parasitol. 228, 60-64.

Cruz, E.M.O., Costa-Junior, L.M., Pinto, J.A.O., Santos, D.A., Araujo, S.A., Arrigoni-Blank, M.F., Bacci, L., Alves, P.B., Cavalcanti, S.C.H., Blank, A.F., 2013. Acaricidal activity of *Lippia gracilis* essential oil and its major constituents on the tick *Rhipicephalus* (*Boophilus*) *microplus*. Vet. Parasitol. 195(1-2), 198-202.

Damiani, N., Gende, L.B., Bailac, P., Marcangeli, J.A., Eguaras, M.J., 2009. Acaricidal and insecticidal activity of essential oils on *Varroa destructor* (Acari: Varroidae) and *Apis mellifera* (Hymenoptera: Apidae). Parasitol. Res. 106(1), 145-152.

Dunning, T., 2013. Aromatherapy: overview, safety and quality issues. OA Altern. Med. 1(1), 1-6.

El-Seedi, H.R., Khalil, N.S., Azeem, M., Taher, E.A., Goransson, U., Palsson, K., Borg-Karlson, A.K., 2012. Chemical composition and repellency of essential oils from four medicinal plants against *Ixodes ricinus* Nymphs (Acari: Ixodidae). J. Med. Entomol. 49(5), 1067-1075.

Estanislau, A.A., Barros, F.A.S., Peña, A.P., Santos, S.C., Ferri, P.H., Paula, J.R., 2001. Composição química e atividade antibacteriana dos óleos essenciais de cinco espécies de *Eucalyptus* cultivadas em Goiás. Rev. Bras. Farmacogn. 11(2), 95-100.

Ferraz, A.B.F., Balbino, J.M., Zini, C.A., Ribeiro, V.L.S., Bordignon, S.A.L., Poser, G.V., 2010. Acaricidal activity and chemical composition of the essential oil from three *Piper* species. Parasitol. Res. 107(1), 243-248.

Fichi, G., Flamini, G., Giovanelli, F., Otranto, D., Perrucci, S., 2007b. Efficacy of an essential oil of *Eugenia caryophyllata* against *Psoroptes cuniculi*. Exp. Parasitol. 115(2), 168-172.

Fichi, G., Flamini, G., Zaralli, L.J., Perrucci, S., 2007a. Efficacy of an essential oil of *Cinnamomum zeylanicum* against

Psoroptes cuniculi. Phytomedicine 14(2-3), 227-231.

Franco, J., Nakashima, T., Franco, L., Boller, C., 2005. Composição química e atividade antimicrobiana *in vitro* do óleo essencial de *Eucalyptus cinerea* F. Mull. Ex Benth., Myrtaceae, extraído em diferentes intervalos de tempo. Rev. Bras. Farmacogn. 15(3), 191-194.

Garcia, M.V., Matias, J., Barros, J.C., Lima, D.P., Lopes, R.S., Andreotti, R., 2012. Chemical identification of *Tagetes minuta* Linnaeus (Asteraceae) essential oil and its acaricidal effect on ticks. Rev. Bras. Parasitol. Vet. 21(4), 405-411.

Gazim, Z.C., Demarchi, I.G., Lonardoni, M.V.C., Amorim, A.C.L., Hovell, A.M.C., Rezende, C.M., Ferreira, G.A., Lima, E.L., Cosmo, F.A., Cortez, D.A.G., 2011. Acaricidal activity of the essential oil from *Tetradenia riparia* (Lamiaceae) on the cattle tick *Rhipicephalus* (*Boophilus*) *microplus* (Acari; Ixodidae). Exp. Parasitol. 129(2),175-178.

George, D.R., Olatunji, G., Guy, J.H., Sparagano, O.A.E., 2010b. Effect of plant essential oils as acaricides against the poultry red mite, *Dermanyssus gallinae*, with special focus on exposure time. Vet. Parasitol. 169(1-2), 222-225.

George, D.R., Smith, T.J., Shiel, R.S., Sparagano, O.A.E., Guy, J.H., 2009. Mode of action and variability in efficacy of plant essential oils showing toxicity against the poultry red mite, *Dermanyssus gallinae*. Vet. Parasitol. 161(3-4), 276-282.

George, D.R., Sparagano, O.A.E., Port, G., Okello, E., Shiel, R.S., Guy, J.H., 2010a. Environmental interactions with the toxicity of plant essential oils to the poultry red mite *Dermanyssus gallinae*. Med. Vet. Entomol. 24(1), 1-8.

Ghasemi, V., Moharramipour, S., Tahmasbi, G., 2011. Biological activity of some plant essential oils against *Varroa destructor* (Acari: Varroidae), an ectoparasitic mite of *Apis mellifera* (Hymenoptera: Apidae). Exp. Appl. Acarol. 55(2), 147-154.

Ghrabi-Gammar, Z., George, D.R., Daoud-Bouattour, A., Jilani, I.B.H., Saad-Limam, S.B., Sparagano, O.A., 2009. Screening of essential oils from wild-growing plants in Tunisia for their yield and toxicity to the poultry red mite, *Dermanyssus gallinae*. Ind. Crops Prod. 30(3), 441-443.

Gomes, G.A., Monteiro, C.M.O., Senra, T.O.S., Zeringota, V., Calmon, F., Matos, R.S., Carvalho, M.G, Daemon, E., Gois, R.W.S., Santiago, G.M.P., Carvalho, M.G., 2012. Chemical composition and acaricidal activity of essential oil from *Lippia sidoides* on larvae of *Dermacentor nitens* (Acari: Ixodidae) and larvae and engorged females of *Rhipicephalus microplus* (Acari: Ixodidae). Parasitol. Res. 111(6), 2423-2430.

Grisi, L., Leite, R.C., Martins, J.R.S., Barros, A.T.M., Andreotti, R., Cançado, P.H.D., León, A.A.P., Pereira, J.B., Villela, H.S., 2014. Reassessment of the potential economic impact of cattle parasites in Brazil. Braz. J. Vet. Parasitol. 23(2), 150-156.

Guala, M.S., Lapissonde, M.O., Elder, H.V., Pérez, G.A., 2014. Efecto acaricida del acl'eite esencial de aguaribay (*Schinusmolle* L.) y sus fracciones em colmenares de abejas (*Apis mellifera*) em relacióncon la composición química. Inf. Tecnol. 25(2), 151-156.

Han, J., Choi, B.R., Lee, S.G., Kim, S.I., Ahn, Y.J., 2010. Toxicity of plant essential oils to acaricide-susceptible and-resistant *Tetranychus urticae* (Acari: Tetranychidae) and *Neoseiulus californicus* (Acari: Phytoseiidae). J. Econ. Entomol. 103(4), 1293-1298.

Hincapié, C.A., López, G.E., Torres, R., 2008. Comparison and characterization of garlic (*Allium sativum* L.) bulbs extracts and their effect on mortality and repellency of *Tetranychus urticae* Koch (Acari: Tetranychidae). Chil. J. Agric. Res. 68(4), 317-327.

Hüe, T., Cauquil, L., Fokou, J.H., Dongmo, P.J., Bakarnga-Via, I., Menut, C., 2015. Acaricidal activity of five essential oils of *Ocimum* species on *Rhipicephalus* (*Boophilus*) *microplus* larvae. Parasitol. Res. 114(1), 91-99.

Hüsnü, K., Baser, C., Demisci, F., 2007. Chemistry of Essential Oils, in: Berger, R.G. (Ed.), Flavours and Fragrances, Springer, Berlin Heidelberg, pp. 43-86.

Hussein, H., Reda, A., Momen, F., 2013. Repellent, antifeedent and toxic effects of three essential oils on the two spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae). Acta. Phytopathol. Hun. 48(1), 177-186.

Iori, A., Grazioli, D., Gentile, E., Marano, G., Salvatore, G., 2005. Acaricidal properties of the essential oil of *Melaleuca alternifolia* Cheel (tea tree oil) against nymphs of *Ixodes ricinus*. Vet. Parasitol. 129(1-2), 173-176.

Isman, M.B., 2000. Plant essential oils for pest and disease management. Crop Prot. 19(8-10), 603-608.

Isman, M.B., 2006. Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. Annu. Rev. Entomol. 51, 45-66.

Isman, M.B., 2016. Pesticides Based on Plant Essential Oils: Phytochemical and Practical Considerations, in: Jeliazkov, V.D., Cantrell, C.L. (Eds.), Medicinal and Aromatic Crops: Production, Phytochemistry, and Utilization, American Chemical Society, pp. 13-26.

Jeon, J., Kim, M., Lee, H., 2014. Acaricidal activities of bicyclic monoterpene ketones from *Artemisia iwayomogi* against *Dermatophagoides* spp. Exp. Appl. Acarol. 62(3), 415-422.

Jeong, E.Y., Kim, M.G., Lee, H.S., 2009. Acaricidal activity of triketone analogues derived from *Leptospermum scoparium* oil against house-dust and stored-food mites. Pest Manag. Sci. 65(3), 327-331.

Jukic, M., Politeo, O., Maksimovic, M., Milos, M., Milos, M., 2007. *In vitro* acetylcholinesterase inhibitory properties of thymol, carvacrol and their derivatives thymoquinone and thymohydroquinone. Phytother. Res. 21(3), 259-261.

Kintzios, S.E., 2002. Oregano: The Genera Origanum and Lippia. Taylor & Francis, New York, NY, USA.

Klafke, G.M., Albuquerque, T.A., Miller, R.J., Schumaker, T.T.S., 2010. Selection of an ivermectin-resistant strain of *Rhipicephalus microplus* (Acari: Ixodidae) in Brazil. Vet. Parasitol. 168(1-2), 97-104.

Koc, S., Oz, E., Aydin, L., Cetin, H., 2012. Acaricidal activity of the essential oils from three Lamiaceae plant species on *Rhipicephalus turanicus* Pom. (Acari: Ixodidae). Parasitol. Res. 111(4), 1863-1865.

Koc, S., Oz, E., Cinbilgel, I., Aydin, L., Cetin, H., 2013. Acaricidal activity of *Origanum bilgeri* PH Davis (Lamiaceae) essential oil and its major component, carvacrol against adults *Rhipicephalus turanicus* (Acari: Ixodidae). Vet. Parasitol. 193(1-3), 316-319.

Laborda, R., Manzano, I., Gamón, M., Gavidia, I., Pérez-Bermúdez, P., Boluda, R., 2013. Effects of *Rosmarinus officinalis* and *Salvia officinalis* essential oils on *Tetranychus urticae* Koch (Acari: Tetranychidae). Ind. Crops Prod. 48, 106-110.

Lage, T.C.A., Montanari, R.M., Fernandes, S.A., Monteiro, C.M.O., Senra, T.O.S., Zeringota, V., Calmon, F., Matos, R.S., Daemon, E., 2013. Activity of essential oil of *Lippia triplinervis* Gardner (Verbenaceae) on *Rhipicephalus microplus* (Acari: Ixodidae). Parasitol. Res. 112(2), 863-869.

Lage, T.C.A., Montanari, R.M., Fernandes, S.A., Monteiro, C.M.O., Senra, T.O.S., Zeringota, V., Matos, R.S., Daemon, E., 2015. Chemical composition and acaricidal activity of the essential oil of *Baccharis dracunculifolia* De Candole (1836) and its constituents nerolidol and limonene on larvae and engorged females of *Rhipicephalus microplus* (Acari: Ixodidae). Exp. Parasitol. 148, 24-29.

Lebouvier, N., Hue, T., Hnawia, E., Lesaffre, L., Menut, C., Nour, M., 2013. Acaricidal activity of essential oils from five endemic conifers of New Caledonia on the cattle tick *Rhipicephalus* (*Boophilus*) *microplus*. Parasitol Res. 112(4), 1379-1384.

Lee, C.H., Sung, B.K., Lee, H.S., 2006. Acaricidal activity of fennel seed oils and their main components against *Tyrophagus putrescentiae*, a stored-food mite. J. Stored Prod. Res. 42(1), 8-14.

Lee, J.H., Lee, H.H., Kim, K.N., Kim, K., 2016. Citotoxicity and anti-inflammatory effects of zinc ions and eugenol during setting of ZOE in immortalized human oral keratinocytes grown as three-dimensional spheroids. Dent. Mater. 32(5), 93-104.

Lima, R.K., Cardoso, M.G., Morais, J.C., Carvalho, S.M., Rodrigues, V.G., Guimarães, L.G.L., 2011. Chemical composition and fumigant effect of essential Oil of *Lippia sidoides* Cham. and monoterpenes against *Tenebrio molitor* (L.) (Coleoptera: Tenebrionidae). Ciênc. Agrotec. 35(4), 664-671.

López, M.D., Pascual-Villalobos, M.J., 2010. Mode of inhibition of acetylcholinesterase by monoterpenoids and implications for pest control. Ind Crops Prod. 31(2), 284-288.

Lwande, W., Ndakala, A.J., Hassanali, A., Moreka, L., Nyandat, E., Ndungu, M., Amiani, H., Gitu, P.M., Malonza, M.M., Punyua, D.K., 1999. *Gynandropsis gynandra* essential oil and its constituents as tick (*Rhipicephalus appendiculatus*) repellents. Phytochemistry 50(3), 401-405.

Magano, S.R., Nchu, F., Eloff, J.N., 2011. *In vitro* investigation of the repellent effects of the essential oil of *Lippia javanica* on adults of *Hyalomma marginatum rufipes*. Afr. J. Biotechnol. 10(44), 8970-8975.

Maggi, M., Peralta, L., Ruffinengo, S., Fuselli, S., Eguaras, M., 2012. Body size variability of *Varroa destructor* and its role in acaricide tolerance. Parasitol. Res. 110(6), 2333-2340.

Mahakittikun, V., Soonthornchareonnon, N., Foongladda, S., Boitano, J.J., Wangapai, T., Ninsanit, P., 2014. A preliminary study of the acaricidal activity of clove oil, *Eugenia caryophyllus*. Asian Pac. J. Allergy 32(1), 46-52.

Marcic, D., 2012. Acaricides in modern management of plant-feeding mites. J. Pest Sci. 85(4), 395-408.

Martinez-Velazquez, M., Castillo-Herrera, G.A., Rosario-Cruz, R., Flores-Fernandez, J.M., Lopez-Ramirez, J., Hernandez-Gutierrez, R., Lugo-Cervantes, E.C., 2011a. Acaricidal effect and chemical composition of essential oils extracted from *Cuminum cyminum*, *Pimenta dioica* and *Ocimum basilicum* against the cattle tick *Rhipicephalus* (*Boophilus*) *microplus* (Acari: Ixodidae). Parasitol. Res. 108(2), 481-487.

Martinez-Velazquez, M., Rosario-Cruz, R., Castillo-Herrera, G., Flores-Fernandez, G., Alvarez, A.H., Lugo-Cervantes, E., 2011b. Acaricidal Effect of Essential Oils from *Lippia graveolens* (Lamiales: Verbenaceae), *Rosmarinus officinalis* (Lamiales: Lamiaceae), and *Allium sativum* (Liliales: Liliaceae) against *Rhipicephalus* (*Boophilus*) *microplus* (Acari: Ixodidae). J. Med. Entomol. 48(4), 822-827.

Mello, V., Prata, M.C.A., Silva, M.R., Daemon, E., Silva, L.S., Guimarães, F.G., Mendonça, A.É., Folly, E., Vilela, F.M.P., Amaral, L.H., Cabral, L.M., Amaral, M.D.P.H., 2014. Acaricidal properties of the formulations based on essential oils from *Cymbopogon winterianus* and *Syzygium aromaticum* plants. Parasitol. Res. 113(12), 4431-4437.

Mendoza-Meza, D., Benavides-Henríquez, H., Taborda-Martínez, M.E., 2014. Actividad acaricida del aceite esencial de lacorteza de *Croton malambo* H. Karst, metil-eugenol y metil-isoeugenol contra *Dermatophagoides farinae* Hughes, 1961. B. Latinoam. Caribe Pl. 13(6), 537-544.

Miresmailli, S., Isman, M.B., 2006. Efficacy and persistence of rosemary oil as an acaricide against twospotted spider mite (Acari: Tetranychidae) on greenhouse tomato. J. Econ. Entomol. 99(6), 2015-2023.

Modjinou, T., Versace, D.L., Abbde-Andallousi, S., Bousserrhine, N., Dubot, P., Langlois, V., Renard, E., 2016. Antibacterial and antioxidant bio-based network derived from eugenol using photo-activated thiol-ene reaction. React. Funct. Polym. 101, 47-53.

Mohammadhosseini, M., 2017a. Essential oils extracted using microwave-assisted hydrodistillation from aerial parts of eleven *Artemisia* species: Chemical compositions and diversities in different geographical regions of Iran. Rec. Nat. Prod. 11(2), 114-129.

Mohammadhosseini, M., 2017b. The ethnobotanical, phytochemical and pharmacological properties and medicinal applications of essential oils and extracts of different *Ziziphora* species. Ind Crops Prod. 105, 164-192.

Momen, F., Rahman, H.A., Samour, E.A., Aly, S.M., Fahim, S.F., 2014. Acaricidal activity of *Melissa officinalis* oil and its formulation on *Tetranychus urticae* and the predatory mite *Neoseiulus californicus* (Acari: Tetranychidae and Phytoseiidae). Acta Phytopathol. Hun. 49(1), 95-115.

Monteiro, C.M.O., Araújo, L.X., Gomes, G.A., Senra, T.O.S., Calmon, F., Daemon, E., Carvalho, M.G., Bittencourt, V.R.E.P., Furlong, J., Prata, M.C.A., 2014. Entomopathogenic nematodes associated with essential oil of *Lippia sidoides* for control of *Rhipicephalus microplus* (Acari: Ixodidae). Parasitol. Res. 113(1), 189-195.

Morais, S.M., Catunda-Júnior, F.E.A., Silva, A.R.A., Martins-Neto, J.S., Rondina, D., Cardoso, J.H.L., 2006. Atividade antioxidante de óleos essenciais de espécies de *Croton* do nordeste do Brasil. Quim. Nova 29(5), 907-910.

Murungi, L.K., Kirwa, H., Torto, B., 2013. Differences in essential oil content of berries and leaves of *Solanum* *sarrachoides* (Solanaceae) and the effects on oviposition of the tomato spider mite (*Tetranychus evansi*). Ind. Crops Prod. 46, 73-79.

Nascimento, A.F., Camara, C.A., Moraes, M.M., Ramos, C.S., 2012. Essential oil composition and acaricidal activity of *Schinus terebinthifolius* from Atlantic Forest of Pernambuco, Brazil against *Tetranychus urticae*. Nat. Prod. Commun. 7(1), 129-132.

Nchu, F., Magano, S.R., Eloff, J.N., 2012. *In vitro* anti-tick properties of the essential oil of *Tagetes minuta* L. (Asteraceae) on *Hyalomma rufipes* (Acari: Ixodidae). Onderstepoort J. Vet. Res. 79(1), 01-05.

Negahban, M., Moharramipour, S., Sefidkon, F., 2007. Fumigant toxicity of essential oil from *Artemisia sieberi* Besser against three stored-product insects. J. Stored Prod. Res. 43(2), 123-128.

Nicastro, R.L., Sato, M.E., Silva, M.Z., 2010. Milbemectin resistance in *Tetranychus urticae* (Acari: Tetranychidae): selection, stability and cross-resistance to abamectin. Exp. Appl. Acarol. 50(3), 231-241.

Nogueira, J., Vinturelle, R., Mattos, C., Tietbohl, L.A.C., Santos, M.G., Vaz, I.D.S., Folly, E., 2014. Acaricidal properties of the essential oil from *Zanthoxylum caribaeum* against *Rhipicephalus microplus*. J. Med. Entomol. 51(5), 971-975.

Oliveira, R.A.G., Lima, E.O., Vieira, W.L., Freire, K.R.L., Trajano, V.N., Lima, I.O., Souza, E.L., Toledo, M.S., Silva-Filho, R.N., 2006. Estudo da interferência de óleos essenciais sobre a atividade de alguns antibióticos usados na clínica. Rev Bras. Farmacogn. 16(1), 77-82.

Pallini, A., Fadini, M.A.M., Venzon, M., Moraes, G.J., Barros-Battesti, D.M., 2007. Demands and perspectives to acarology in Brazil. Neotrop Biol Conservat. 2(3), 169-175.

Pamo, E.T., Tendonkeng, F., Kana, J.R., Payne, V.K., Boukila, B., Lemoufouet, J., Miegoue, E., Nanda, A.S., 2005. A study of the acaricidal properties of an essential oil extracted from the leaves of *Ageratum houstonianum*. Vet. Parasitol. 128(3-4), 319-323.

Pamo, T.E., Tendonkeng, F., Kana, J.R., Tenekeu, G., Tapondjou, L.A., Payne, V.K., 2004. The acaricidal effect of the essential oil of *Ageratum houstonianum* Mill. flowers on ticks (Rhipicephalus lunulatus) in Cameroon. S. Afr J. Anim. Sci. 34(5), 244-247.

Park, I., Lee, S., Choi, D., Park, J., Ahn, Y., 2003. Insecticidal activities of constituents identified in the essential oil from leaves of *Chamaecyparis obtusa* against *Callosobruchus chinensis* (L.) and *Sitophilus oryzae* (L.). J. Stored Prod. Res. 39(4), 375-384.

Pazinato, R., Klauck, V., Volpato, A., Tonin, A.A., Santos, R.C., Souza, M.E., Vaucher, R.A., Raffin, R., Gomes, P., Felippi, C.C., Stefani, L.M., Silva, A.S., 2014. Influence of tea tree oil (*Melaleuca alternifolia*) on the cattle tick *Rhipicephalus microplus*. Exp. Appl. Acarol. 63 (1), 77-83.

Peixoto, M.G., Costa-Júnior, L.M., Blank, A.F., Lima, A.S., Menezes, T.S.A., Santos, D.A., Alves, P.B., Cavalcanti, S.C.H., Bacci, L., Arrigoni-Blank, M.F., 2015. Acaricidal activity of essential oils from *Lippia alba* genotypes and its major components carvone, limonene, and citral against *Rhipicephalus microplus*. Vet. Parasitol. 210(1-2), 118-122.

Pereira, A.I.S., Pereira, A.G.S., Lopes-Sobrinho, O.P., Cantanhede, E.K.P., Siqueira, L.F.S., 2014. Atividade antimicrobiana no combate as larvas do mosquito *Aedes aegypti*: homogeneização dos óleos essenciais do linalol e eugenol. Ed. Quim. 25(4), 446-449.

Perumalsamy, H., Kim, J.Y., Kim, J., Hwang, K.N.R., Ahn, Y., 2014. Toxicity of basil oil constituents and related compounds and the efficacy of spray formulations to Dermatophagoides farinae (Acari: Pyroglyphidae). J. Med. Entomol. 51(3), 650-657.

Pino, O., Sánchez, Y., Rodríguez, H., Correa, T.M., Demedio, J., Sanabria, J.L., 2011b. Caracterización química y actividad acaricida del aceite esencial de *Piper aduncum* subsp. *ossanum* frente a *Varroa destructor*. Rev. Prot. Veg. 26(1), 52-61.

Pino, O., Sánchez, Y., Rojas, M.M., Rodríguez, H., Abreu, Y., Duarte, Y., Martínez, B., Peteira, B., Correa, T.M., Martínez, D., 2011a. Composición química y actividad plaguicida del aceite esencial de *Melaleuca quinquenervia* (Cav) ST Blake. Ver. Prot. Veg. 26(3), 177-186.

Pirali-Kheirabadi, K., Razzaghi-Abyaneh, M., Halajian, A., 2009. Acaricidal effect of *Pelargonium roseum* and *Eucalyptus globulus* essential oils against adult stage of *Rhipicephalus* (*Boophilus*) *annulatus in vitro*. Vet. Parasitol. 162(3-4), 346-349.

Pirali-Kheirabadi, K., Silva, J.A.T., 2010. *Lavandula angustifolia* essential oil as a novel and promising natural candidate for tick (*Rhipicephalus* (*Boophilus*) *annulatus*) control. Exp. Parasitol. 126(2), 184-186.

Pirali-Kheirabadi, K.H., Silva, J.T., 2011. *In-vitro* assessment of the acaricidal properties of *Artemisia annua* and *Zataria multiflora* essential oils to control cattle ticks. Iranian J. Parasitol. 6(1), 58-65.

Politi, F.A.S., Souza-Moreira, T.M., Rodrigues, E.R., Queiroz, G.M., Figueira, G.M., Januário, A.H., Berenger, J.M., Socolovschi, C., Parola, P., Pietro, R.C.L.R., 2013. Chemical characterization and acaricide potential of essential oil from aerial parts of *Tagetes patula* L. (Asteraceae) against engorged adult females of *Rhipicephalus sanguineus* (Latreille, 1806). Parasitol. Res. 112(6), 2261-2268.

Pontes, W.J.T., Oliveira, J.C.G., Câmara, C.A.G., Lopes, A.C.H.R., Júnior, M.G.C.G., Oliveira, J.V., Barros, R., Schwartz, M.O.E., 2007. Chemical composition and acaricidal activity of the leaf and fruit essential oils of *Protium heptaphyllum* (Aubl.) Marchand (Burseraceae). Acta Amaz. 37(1), 103-109.

Prates, H.T., Leite, R.C., Craveiro, A.A., Oliveira, A.B., 1998. Identification of some chemical components of the essential oil from molasses grass (*Melinis minutiflora* Beauv.) and their activity against cattle-tick (*Boophilus microplus*). J. Braz. Chem. Soc. 9(2), 193-197.

Pumnuan, J., Chandrapatya, A., Insung, A., 2010. Acaricidal activities of plant essential oils from three plants on the mushroom mite, *Luciaphorus perniciosus* Rack (Acari: Pygmephoridae). Pak. J. Zool. 42(3), 247-252.

Ramírez, C., Ibarra, F., Pérez, H.I., Manjarrez, N., Salgado, H.J., Ortega, L., 2016. Assessment and determination of LC_{50} of carvacrol and salicylic acid analogueswith acaricide activity in larvae and adult ticks of *Rhipicephalus* (*Boophilus*) *microplus*. Parasite Epidemiol. Control. 1(2), 72-77.

Ramos, A.S., Ribeiro, J.B., Teixeira, B.G., Ferreira, J.L.P., Silva, J.R.A., Ferreira, A.A., Souza, R.O.M.A., Amaral, A.C.F., 2015.

Hydroxylation of 1,8-cineole by *Mucor ramannianus* and *Aspergillus niger*. Braz. J. Microbiol. 46(1), 261-264.

Ramos, M.F.S., Siani, A.C., Souza, M.C., Rosas, E.C., Henriques, M.G.M.O., 2006. Avaliação da atividade antiinflamatória dos óleos essenciais de cinco espécies de Myrtaceae. Rev. Fitos 2(2), 58-66.

Regnault-Roger, C., Vincent, C., Arnason, J.T., 2012. Essential oils in insect control: low-risk products in a high-stakes world. Annu. Rev. Entomol. 57, 405-424.

Rey-Valeirón, C., Guzmán, L., Saa, L.R., López-Vargas, J., Valarezo, E., 2017. Acaricidal activity of essential oils of *Bursera graveolens* (Kunth) Triana & Planch and *Schinus molle* L. on unengorged larvae of cattle tick *Rhipicephalus* (*Boophilus*) *microplus* (Acari: Ixodidae). J. Essent. Oil Res. 29(4), 344-350.

Ribeiro, P.H.S., Santos, M.L., Camara, C.A.G., Born, F.S., Fagg, C.W., 2016. Seasonal chemical compositions of the essential oils of two *Eugenia* species and their acaricidal properties. Quim. Nova 39(1), 38-43.

Ribeiro, V.L.S., Santos, J.C., Martins, J.R., Schripsema, J., Siqueira, I.R., Von-Poser, G.L., Apel, M.A., 2011. Acaricidal properties of the essential oil and precocene II obtained from *Calea serrata* (Asteraceae) on the cattle tick *Rhipicephalus* (*Boophilus*) *microplus* (Acari: Ixodidae). Vet. Parasitol. 179(1-3), 195-198.

Ribeiro, V., Vanzella, C., Moysés, F.S., Santos, J.C., Martins, J.R.S., Poser, G.L., Siqueira, I.R., 2011. Effect of *Calea serrata* Less. *n*-hexane extract on acetylcholinesterase of larvae ticks and brain Wistar rats. Vet. Parasitol. 189(2-4), 322-326.

Ribeiro, V.L.S., Santos, J.C., Bordignon, S.A., Apel, M.A., Henriques, A.T., Von-Poser, G.L., 2010. Acaricidal properties of the essential oil from *Hesperozygis ringens* (Lamiaceae) on the cattle tick *Riphicephalus* (*Boophilus*) *microplus*. Bioresour. Technol. 101(7), 2506-2509.

Rim, I., Jee, C., 2006. Acaricidal effects of herb essential oils against *Dermatophagoides farinae* and *D. pteronyssinus* (Acari: Pyroglyphidae) and qualitative analysis of a herb *Mentha pulegium* (pennyroyal). Korean J. Parasitol. 44(2), 133-138.

Roh, H.S., Lee, B.H., Park, C.G., 2013. Acaricidal and repellent effects of myrtacean essential oils and their major constituents against *Tetranychus urticae* (Tetranychidae). J. Asia Pac. Entomol. 16(3), 245-249.

Roh, H.S., Lim, E.G., Kim, J., Park, C.G., 2011. Acaricidal and oviposition deterring effects of santalol identified in sandalwood oil against two-spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae). J. Pest Sci. 84(4), 495-501.

Rossi, Y.E., Palacios, S.M., 2015. Insecticidal toxicity of *Eucalyptus cinerea* essential oil and 1,8-cineole against *Musca domestica* and possible uses according to the metabolic response of flies. Ind. Crops Prod. 63, 133-137.

Salman, S.Y., Erbaş, S., 2014. Contact and repellency effects of *Rosa damascena* Mill. essential oil and its two major constituents against *Tetranychus urticae* Koch (Acari: Tetranychidae). Turk. J. Entomol. 38(4), 365-376.

Scherer, R., Wagner, R., Duarte, M.C.T., Godoy, H.T., 2009. Composição e atividades antioxidante e antimicrobiana dos óleos essenciais de cravo-da-índia, citronela e palmarosa. Rev. Bras. Plantas Med. 11(4), 442-449.

Sertkaya, E., Kaya, K., Soylu, S., 2010. Acaricidal activities of the essential oils from several medicinal plants against the carmine spider mite (*Tetranychus cinnabarinus* Boisd.) (Acarina: Tetranychidae). Ind. Crops Prod. 31(1), 107-112.

Settimi, L., Orford, R., Davanzo, F., Hague, C., Desel, H., Pelclova, D., Dragelyte, G., Mathieu-Nolf, M., Adams, R., Duarte-Davidson, R., 2016. Development of a new categorization system for pesticides exposure to support harmonized reporting between EU Member States. Environ. Int. 91, 332-340.

Shang, X., Wang, Y., Zhou, X., Guo, X., Dong, S., Wang, D., Zhang, J., Pan, H., Zhang, Y, Miao, X., 2016. Acaricidal activity of oregano oil and its major component, carvacrol, thymol and p-cymene against *Psoroptes cuniculi in vitro* and *in vivo*. Vet. Parasitol. 226, 93-96.

Silva, C.B., Simionatto, E., Hess, S.C., Peres, M.T.L.P., Simionatto, E.L., Júnior, A.W., Poppi, N.R., Faccenda, O., Cândido, A.C.S., Scalon, S.P.Q., 2009. Composição química e atividade alelopática do óleo volátil de *Hydrocotyle bonariensis* LAM (Araliaceae). Quim. Nova 32(9), 2373-2376.

Silva, F., Park, K.J., Magalhães, P.M., Martins, G.N., Gama, E.V.S., 2013. Avaliação do teor de óleo essencial de *Baccharis trimera* (Less.) DC. em diferentes embalagens durante o armazenamento. Ver. Bras. Plantas Med. 15(1), 54-58.

Simões, C.D.O., Spitzer, V., 2002. Óleos voláteis, in: Simões, C.M.O., Schenkel, E.P., Gosmann, G., Mello, J.C.P., Mentz, L.A., Petrovick, P.R. (Eds.), Farmacognosia: da planta ao medicamento. Editora da UFRGS, Porto Alegre, pp. 397-425.

Soares, S.F., Borges, L.M.F., Braga, R.S., Ferreira, L.L., Louly, C.C.B., Tresvenzol, L.M.F., Paula, J.R., Ferri, P.H., 2010. Repellent activity of plant-derived compounds against *Amblyomma cajennense* (Acari: Ixodidae) nymphs. Vet. Parasitol. 167(1), 67-73.

Suntres, Z.E., Coccimiglio, J., Alipour, M., 2015. The bioactivity and toxicological actions of carvacrol. Crit. Rev. Food Sci. 55(3), 304-318.

Tunón, H., Thorsell, W., Mikiver, A., Malander, I., 2006. Arthropod repellency, especially tick (*Ixodes ricinus*), exerted by extract from *Artemisia abrotanum* and essential oil from flowers of *Dianthus caryophyllum*. Fitoterapia 77(4), 257-261.

Van Leeuwen, T., Tirry, L., Yamamoto, A., Nauen, R., Dermauw, W., 2015. The economic importance of acaricides in the control of phytophagous mites and an update on recent acaricide mode of action research. Pestic. Biochem. Physiol. 121, 12-21.

Vendramini, M.C.R., Mathias, M.I.C., Faria, A.U., Furquim, K.C.S., Souza, L.P., Bechara, G.H., Roma, G.C., 2012. Action of andiroba oil (*Carapa guianensis*) on *Rhipicephalus sanguineus* (Latreille, 1806) (Acari: Ixodidae) semi-engorged females: Morphophysiological evaluation of reproductive system. Microsc. Res. Techniq. 75(12), 1745-1754.

Vieira, G.H.C., Andrade, W.P., Nascimento, D.M., 2012. Uso de óleos essenciais no controle do ácaro *Varroa destructor* em *Apis melífera*. Pesq. Agropec. Trop. 42(3), 317-322.

Williamson, E.M., Priestley, C.M., Burgess, I.F., 2007. An investigation and comparison of the bioactivity of selected essential oils on human lice and house dust mites. Fitoterapia 78(7-8), 521-525.

Wu, H., Li, J., Zhang, F., Li, L., Liu, Z., He, Z., 2012a. Essential oil components from *Asarum sieboldii* Miquel are toxic to the house dust mite *Dermatophagoides farinae*. Parasitol. Res. 111(5), 1895-1899.

Wu, H., Li, L., Li, J., He, Z.D., Liu, Z.G., Zeng, Q.Q., Wang, Y.S., 2012b. Acaricidal activity of DHEMH, derived from patchouli oil, against house dust mite, *Dermatophagoides farinae*. Chem. Pharm. Bull. 60(2), 178-182.

Xu, J., Fan, Q.J., Yin, Z.Q., Li, X.T., Du, Y.H., Jia, R.Y., Wang, K.Y., Lv, C., Ye, G., Geng, Y., Su, G., Zhao, L., Hu, T.X., Shi, F., Zhang, L., Wu, C.L., Tao, C., Zahng, Y.X.T., Shi, D.X., 2010. The preparation of neem oil microemulsion (*Azadirachta indica*) and the comparison of acaricidal time between neem oil microemulsion and other formulations *in vitro*. Vet. Parasitol. 169(3-4), 399-403.

Yang, J.Y., Lee, H.S., 2013. Changes in acaricidal potency by introducing functional radicals and an acaricidal constituent isolated from *Schizonepeta tenuifolia*. J. Agric. Food Chem. 61(47), 11511-11516.

Zandi-Sohani, N., Ramezani, L., 2015. Evaluation of five essential oils as botanical acaricides against the strawberry spider mite *Tetranychus turkestani* Ugarov and Nikolskii. Int. Biodeter. Biodegr. 98, 101-106.