

Biodiversity of mites in mango orchards (*Mangifera indica* L.) and evaluation of some mineral and essential oils against *Cisaberoptus kenyae* Keifer (Acari: Eriophyidae) management

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Original research

ABSTRACT

Seasonal abundance of phytophagous, predacious, miscellaneous and soil mites associated with mango orchards were investigated in the Giza governorate. Samples were taken from five mango orchards with different cultivars during four seasons through the year 2020–2021. Different parts of the mango trees such as leaves, raceme, buds as well as underneath the trees were sampled at fortnightly intervals. In total, 17 species representing 16 genera and 12 families with different feeding habits were collected and identified during the study. The relationship between predacious and plant feeding mites in this agriculture eco-system was discussed. Family Phytoseiidae represented the largest diversity of mites reported herein, with four species records. We anticipate that the results reported in the current study may encourage the establishment of control programs for plant-feeding mites using phytoseiid mites. Different oils and pesticides and their combinations were used to control the eriophyid mite, *Cisaberoptus kenyae* Keifer on mango leaves “Ewais” cultivar. The lethal concentrations were 2, 1, and 0.5%. The results showed that the most effective compound was mineral oil and spiroadiclofen and the essential oil, *Thymus vulgaris* L. This is the first reported study demonstrating the control of *C. kenyae* using combinations of different oils, and a pesticide on mango leaves. These results can be used in future biological pest control programs.

Keywords ecology; predators; plant-feeding mites; feeding habits; biological control; Egypt

Introduction

Mango (*Mangifera indica* L., Anacardiaceae) is one of the most consumed fresh fruits in the world, with production occurring in more than 100 countries including Egypt. There are over 1000 different cultivars of mango, giving rise to various shapes, sizes, colours, textures and nutritional properties (Siddiq 2017). Egypt accounted for more than half of the total production of tropical fruits in 2012 (Siddiq 2017). Mango is currently grown throughout the Nile Valley, the Nile Delta, and Fayoum governorate (Saad *et al.* 2007). It covers about 135,524 ha with a total production of 1,473,538 tons in 2019 (FAO 2019) (this number includes guava and mangosteen fruits). Mango is one of the most important export fruits in Egypt, with a total

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exportation valued at 34.6 million dollars in 2018 (73% fresh mango and 27% mango juice) (Gabr 2019).

Mango is attacked by different insect and mite pests causing serious economic losses. Among them, four mite species are the most common pests on mango: broad mite, *Polyphagotarsonemus latus* (Banks); spider mite, *Oligonychus mangiferus* (Rhaman & Sapra); lychee erinose mite, *Aceria litchii* (Keifer) and mango bud mite, *Aceria mangiferae* Sayed. These mite pests prefer the upper surface of leaves causing chlorotic stippling on the leaves (Sarwar 2015). The infested leaves often become reddish or bronze in colour, may drop and yield can be greatly reduced. Damage caused by these mites to the leaves provides entry sites for fungi resulting in nutritional imbalances (Sarwar 2015). They cause huge economic losses which necessitates the search for effective, safe and eco-friendly control measures. The leaf coating mite, *Cisaberoptus kenyae* Keifer can be found under the epidermis of young leaves which resulted in a silvery appearance of the leaves. Leaf damage is concentrated at the base of the petiole and along the central veins. Narrow patches bordering the leaf margins and browning spots especially on “Hindi” and “Alphonso” cultivars can also occur (Abou-Awad *et al.* 2009).

Plant essential oils could be a potential alternative for mite control, as some are selective and biodegradable with low effects on non-target organisms and the environment, but effective on the mite pests (Isman and Machial 2006). Extracted essential oils apparently release fumes that can control the mites, as alternatives for pesticides.

The current study presents the biodiversity of different predatory, phytophagous, miscellaneous and soil mites and insects in the Giza governorate, and are evaluated for the efficacy of some essential oils to control *Cisaberoptus kenya*, that cause serious damage to mango orchards, economic importance and eco-friendliness.

Material and Methods

Biodiversity

Mango orchards comprising of five cultivars (“Hindi”, “Zebda”, “Alphonso”, “Ewais” and “Sedika”) were sampled fortnightly at Abo Ruwaysh (29°40’07” N, 31°13’28” E), Baydaf, Al Ayat in the Giza governorate, Egypt for a full year from February 2020 to January 2021. Samples were taken from leaves, raceme, buds, debris and soil. A 5-acre block of mango trees was set apart for this study. Randomly 30 trees were selected but concentrating on trees showing symptoms or which seem under stress. Ten leaves, ten raceme and ten buds were taken from each tree (total 300 for each plant part) on each sampling date. Leaves, raceme, and buds were placed in polyethylene bags and transferred to the laboratory for direct examinations under a stereo-microscope (Olympus SZ-ST, SZ40). The mite density on leaves, raceme and buds from each tree was recorded according to Sarwar (2015). Debris and soil samples weighing about 0.25 Kg were collected underneath mango trees, placed in polyethylene bags and then the mites were extracted using a modified Tullgren funnel (Krantz and Walter 2009). All mite specimens were then mounted on glass slides in Hoyer’s medium and examined under a phase contrast (Olympus BHA) research microscope. The eriophyid mites were mounted in modified Hoyer’s medium (10 ml of fresh prepared Hoyer’s medium and 0.1 g Methylene blue under heating and Magnetic stirrer for 15 minutes, then put in a glass bottle after 2 hours) (modified in the current study). Mites were identified using Zaher 1984, 1986; Summers and Price 1970; Abo-Shnaf and Moraes 2014; Maśán 2017).

To record populations of two eriophyid mites: *Cisaberoptus kenyae* Keifer and *Aceria mangiferae* Sayed, leaves and buds were collected randomly from other trees during five months at irregular intervals to check their numbers. Twenty leaves were selected, for each leaf about 3 inches were chosen and examined according to Elhalawany (2001) with some modifications. Ten buds were checked directly under a stereo-microscope.

Management study

Mango leaves of the “Ewais” cultivar infested with *C. kenya* were collected from Abo Ruwaysh, Baydaf, Al Ayat in the Giza governorate, Egypt. The collected mites were directly used in the study in two assessments: 1) mineral oil, orange oil (a clear, mobile liquid, with a yellow-to-orange colour, having a high terpene monoterpene hydrocarbon content, the main constituent is (+)-limonene (93–96%), obtained from “Top Chemical” company, Egypt), and lastomide 24% (spirodiclofen); combinations of these oils with the pesticide; 2) essential oils of *Geranium robertianum* L. (Geraniaceae), *Salvia rosmarinus* Spenn., *Thymus vulgaris* L. (Lamiaceae), and *Syzygium aromaticum* (L.) Merr. & L.M. Perry (Myrtaceae), all were obtained from “Ayurveda” company, Egypt. In assessment (1), fifty (± 5) individuals of *C. kenya* were placed on each leaf disc (3 inches/ disc), placed on wet cotton pads in foam trays. Six replicates were used for each application in addition to the control. In assessment (2), the same trend was followed except that 80 (± 5) individuals of eriophyid mite were used in four replicates. Three concentrations (2, 1, and 0.5%) were used. Each concentration was mixed with 6 surfacta rTA – 100 and applied by spraying the mites with a manual pump onto plant leaves. Discs were examined under a stereo-microscope in the laboratory to determine the mortalities. All discs were kept in an incubator ($25^{\circ}\text{C} \pm 5$). Twenty-four hours after the application, the mortality rate of the mites was recorded daily for four days.

Statistical analysis

Anova test with Randomized Complete Block Design (RCBD) with one factor was used for analysis of all data with different applications for each species. Relationship among studied traits was done according to Steel *et al.* (1997). The treatment means were compared with Least Significant Difference (L.S.D.) test as given by Snedecor and Cochran (1994) using Assistat program.

The LC_{50} , LC_{95} , chi square (X^2), fiducial limits, and slope values were estimated according to probit analysis (Finney 1971) using Ldp line software according to Bakr (2000).

Results and discussion

Biodiversity of mites associated with mango orchards in Ayat, Giza governorate was carried out during the year 2020–2021, numbers of mites vary because of sampling time and micro agriculture eco-system. Our results agree with Peña *et al.* (2005) who mentioned that mite densities in mango orchards in Florida vary according to season and sampling unit. Based on previous studies, about 67 identified mite species in 52 genera and 30 families were previously reported from mango orchards in Egypt (Marei *et al.* 2020).

Our survey in the mango orchards resulted in 17 species and 16 genera in 12 families representing Mesostigmata, Prostigmata, Astigmatina and Oribatida groups (Table 1). Insects and woodlice were also found during this study (Table 2). Our results are in parallel with Marei *et al.* (2020) who collected the same mite families inhabiting mango orchards at Assiut governorate, Egypt.

Statistical analysis confirm the significant differences in mite biodiversity (F value = 8.06, P value = 0.0000), these differences are due to biotic factors (food type) and abiotic factors (temperature, relative humidity and soil type) which reflect on agriculture eco-system in mango cultivation. These results agree with Manu (2013) who stated that development of mite communities is influenced by biotic and abiotic factors. The present results proved that numbers of ten species were homogenous at alpha (0.05) and critical value (2.048), except for *Tydeus oregonensis* Baker (Tydeidae) which reached 71% during the time of study (Figure 1).

Phytoseiid mites are important biological control candidates of mite pests, thrips, whiteflies, small arthropods and nematodes. They are implemented in biological control programs (Gerson *et al.* 2003). Phytoseiids are important natural enemies against phytophagous mites in agro-ecosystems, a total of 166 specimens were collected and identified to species level during this

Table 1 Incidence of phytophagous and predaceous mites associated with mango orchards in Ayaat, Giza governorate.

Mite behaviour	Family	Species	Habitat				
			Leaves	Soil	Raceme	Debris	Buds
Phytophagous mites	Tetranychidae	<i>Tetranychus urticae</i> Koch	++	+			
	Eriophyidae	<i>Cisaberoptus kenya</i> Keifer	+++				
		<i>Aceria mangiferae</i> Sayed					+++
		Tarsonemidae	<i>Tarsonemus</i> spp.	++			
	Phytoseiidae	<i>Euseius scutalis</i> (Athias-Henriot)	+++	++			
		<i>Neoseiulus zaheri</i> (El-Borolossy)	+++	+			
		<i>Typhlodromus</i> (<i>Anthoseius</i>) <i>egypticus</i> El-Badry	++				
<i>Typhlodromus</i> (<i>Typhlodromus</i>) <i>athiasae</i> Porath & Swirski		++					
Predacious mites	Laelapidae	<i>Laelaspis astronomicus</i> (Koch)				++	
	Pachylaelapidae	<i>Pachylaelaps aegypticus</i> Hafez & Nasr				++	
	Cheyletidae	<i>Cheletominus bakeri</i> (Ehara)	++	+			
<i>Acaropsella</i> spp.		++					
Miscellaneous mites	Stigmaeidae	<i>Agistemus exsertus</i> Gonzalez	+++	+	+		++
	Ameroseiidae	<i>Kleemannia wahabi</i> Ibrahim & Abdel-Samed		+		+	
	Tydeidae	<i>Tydeus oregonensis</i> Baker	+++	+	+		+
Soil mites	Acaridae	<i>Tyrophagus putrescentiae</i> (Schrack)	++	+			
	Haplozetidae	<i>Xylobates souchnaiensis</i> Abdel Hamid		+			

+: Few numbers (1–4 individuals/fronds)

++: Moderate numbers (5–10 individuals/fronds)

+++ : High numbers (>10 individuals/fronds)

study, resulted in the absence of spider mites. Thus, phytoseiid mites play an important role in Integrated Pest Management programs.

McMurtry (2010) evaluated food habits of phytoseiids. Some are often found in homogeneous, while others in non-homogeneous microhabitats. Still others are commute between plant microhabitats looking for food or protection (McMurtry *et al.* 2013). Phytoseiids actually prefer feeding on egg and immature stages of thrips, whiteflies, scale insects and tetranychids

Table 2 Insects found through the biodiversity study.

Insect behaviour	Family	Order	Species
Predacious insects	Thripidae	Thysanoptera	<i>Scolothrips longicornis</i> Priesner
	Chrysopidae	Neuroptera	<i>Chrysoperla carnea</i> (Stephens)
Phytophagous insects	Thripidae	Thysanoptera	<i>Scirtothrips dorsalis</i> Hood
	Margarodidae	Hemiptera	<i>Drosicha mangiferae</i> Stebbins
	Diaspididae	Hemiptera	<i>Aspidiotus destructor</i> Signoret
Phytophagous animal	Porcellionidae	Isopoda	<i>Porcellio scaber</i> Latreille

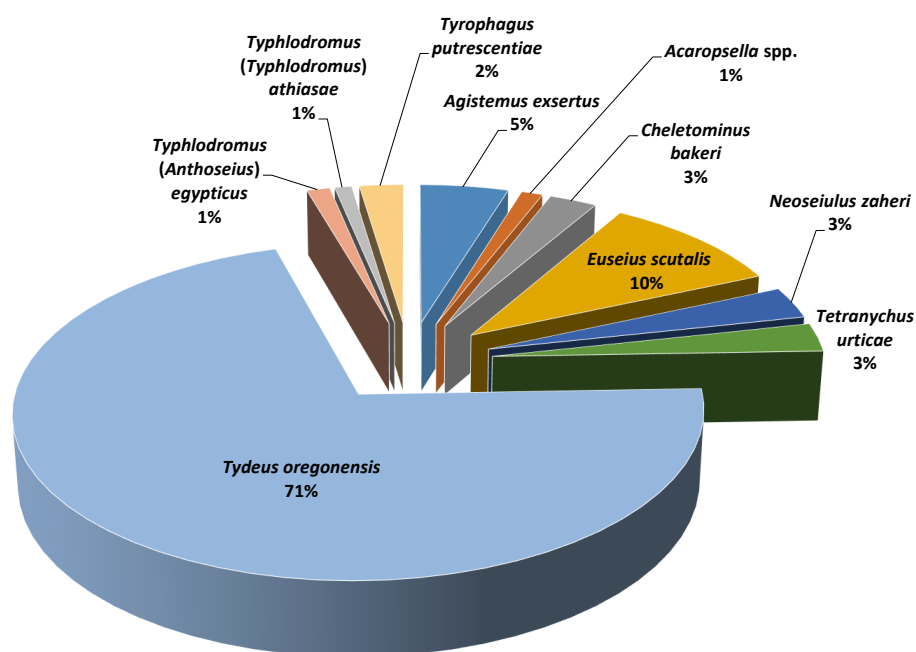


Figure 1 The homogenous of some species during 2020–2021 year.

(Muma 1971). *Euseius scutalis* (Athias-Henriot) is a promising control candidate for such pests (Al-Shammery 2010).

The importance of predaceous mites as biological control agents against phytophagous mites and economically important insects including the scale insect, *Aspidiotus destructor* Signoret (Diaspididae) and mealy bug, *Drosicha mangiferae* Stebbins (Margarodidae) benefits agriculture eco-systems. Our results concluded that *E. scutalis* feeds on egg and immature stages of *A. destructor*, apparently the dominant species in neighboring agro-ecosystem where it was found in high numbers. Our findings confirm that of Abou-Ellella *et al.* (2013) that *E. scutalis* feeds also on eggs of scale insects. The thrips, *Scirtothrips dorsalis* Hood (Thripidae) was found as prey source for *E. scutalis* collected in this study (Chowdhury 2015). Strangely, *Amblyseius swirskii* Athias-Henriot was not collected during this study.

The abiotic factors in studied area affected the numbers of eriophyids and the phytoseiids in mango orchards. Abou-Awad *et al.* (2011) found the latter as important influences on population abundance of the eriophyids on mango, distribution and predation by *Typhlodromus mangiferus* Zaher & El-Borolossy (junior synonym of *Typhlodromus (Anthoseius) egypticus* El-Badry according to Abo-Shnaf and Moraes 2014).

Tarsonemidae, Tydeidae and Eriophyidae were found as prey for both phytoseiid mites, *Typhlodromus (Typhlodromus) athiasae* Porath & Swirski and *Neoseiulus zaheri* (El-Borolossy) collected in all our samples. This result agrees with McMurtry and Croft (1997) who reported that *Typhlodromus* species feed on tarsonemids, tydeids and eriophyids. Momen (2009) found that *T. (T.) athiasae* females feed on nymphs of *Tetranychus urticae* Koch (Tetranychidae) and *Eriophyes dioscoridis* Soliman & Abou-Awad (Eriophyidae).

Our results showed that the predatory mite, *Agistemus exsertus* Gonzalez (Stigmaeidae) peaked during fall and winter seasons, preying on eriophyid mites and a scale insect, *Parlatoria pergandii* Comstock (Diaspididae) on mango leaves. This agrees with El-Sawi and Momen (2006) who found *A. exsertus* completing its life span feeding on eggs and crawlers of both scale insects, *Chrysomphalus ficus* Ashmead and *Parlatoria blanchardi* (Targioni Tozzetti)

(Diaspididae).

Peña *et al.* (2005) reported that *Aceria mangiferae* Sayed occurred mostly in apical buds rather than in lateral buds. Our results showed that *A. exsertus* effectively controlled this mite in the lateral and apical buds. Osman and Zaki (1986) found that *A. exsertus* also effectively control the tomato rust mite, *Aculops lycopersici* (Massee).

The numbers of cheyletid mite, *Cheletomimus bakeri* (Ehara) increased from 5 to 23 individuals in November. The predator's increase was synchronized with the decrease in *T. urticae* numbers. This agrees with Ray and Hoy (2014) who found that *T. urticae* is a good food source for *C. bakeri* and *Hemicheyletia wellsina* (De Leon), suggesting that *C. bakeri* could be used in an augmentative or classical biological control programs, its use in biological control of crops or in orchards could be beneficial as well. Something that can also be followed up in the control of *T. urticae* in local mango orchards.

The present results showed that numbers of *T. urticae* was also very low because of the presence of the predatory thrips, *Scolothrips longicornis* Priesner (Thripidae). This result agrees with Masarovic *et al.* (2013) who reported *S. longicornis* in Slovakia is best predator for many spider mites including *T. urticae*.

Family Pachylaelapidae are found in many habitats including organic matter, soil and debris (Mašán 2007; Mašán and Halliday 2014), they are predators of a wide range of micro invertebrates (Lindquist *et al.* 2009). This may be the role they also played in the soil and debris underneath mango trees in this study.

According to Flechtmann (1985) and Mašán (1998) the ameroseiids we found in our mango orchards may also be fungivorous.

Laelaspis astronomicus (Koch) (Laelapidae) was collected from soil underneath mango trees in this study as did Zaher *et al.* (1986) and Rasmy *et al.* (1987) who collected this mite species from organic matter in Egypt.

Our results suggest that oribatids including *Xylobates souchnaiensis* Abdel Hamid (Haplozetidae) collected in this study may also feeds on fungi (Schneider *et al.* 2004).

The tydeid, *T. oregonensis* was collected on the mango leaves. It was previously reported by Elmoghazy (2014) from Egypt on date palm, olive and citrus trees.

Carrillo and Elanov (2004) and Uddin *et al.* (2019) reported the common green lacewing, *Chrysoperla carnea* (Stephens) (Chrysopidae) as a predator of many pests including aphids, white flies, thrips, mealy bugs, as well as eggs of different arthropods. This species was also recorded in our study.

Soil samples contained also woodlice identified as *Porcellio scaber* Latreille (Porcellionidae) feeding on organic matter. Hutchins (2003) and Zimmer *et al.* (2003) reported that *P. scaber* is detritivorous, saprophagous and coprophagous as they prefer decaying organic matter. Therefore, this species contributes towards a healthy soil.

Springtails or collembola are primitive, wingless micro-arthropods, closely related to insects were also collected in soil during the current study. They are supplementary food for many predators, e.g., *E. scutails*. Walter and Lindquist (1989) reported that other mesostigmatid mites such as *Lasioseius* spp. (Blattisociidae) also feeds on springtails and other small arthropods.

Biodiversity of eriophyid mites on three cultivars of mango orchards

The abundance of eriophyid mites was noticeable only on three mango cultivars ("Hindi", "Alphonso" and "Ewais") when temperature decreased because they prefer low temperature (Table 3).

No significant differences at 0.01 level were found between relative humidity and numbers of *Cisaberoptus kenyae* Keifer. In contrast, significant differences were found for *A. mangiferae* on "Hindi" and "Alphonso" cultivars, but in-significant on "Ewais" at 0.01 level (Table 3).

Statistical analysis showed that there were significant differences in temperature at 0.01 level between the two eriophyid mite species (*A. mangiferae* and *C. kenyae*) on the mango cultivars "Ewais", "Hindi" and "Alphonso", which resulted in the presence of the two eriophyids

Table 3 The correlation coefficient between temperatures, relative humidity and two eriophyid mites infested three mango cultivars.

Correlations		Max. Temp.	Min. Temp.	Relative Humidity	Ewais		Hindi		Alphonso	
					<i>C. kenya</i>	<i>A. mangiferae</i>	<i>C. kenya</i>	<i>A. mangiferae</i>	<i>C. kenya</i>	<i>A. mangiferae</i>
Maximum Temperature	Pearson Correlation	1	0.979**	0.678	-0.281	-0.324	-0.299	-0.37	-0.386	-0.448
	Sig. (2-tailed)	----	0	0.065	0.5	0.434	0.472	0.366	0.345	0.266
Minimum Temperature	Pearson Correlation		1	0.726*	-0.184	-0.236	-0.2	-0.276	-0.292	-0.336
	Sig. (2-tailed)	---		0.042	0.663	0.573	0.635	0.509	0.483	0.416
Relative Humidity	Pearson Correlation			1	-0.294	-0.292	-0.265	-0.334	-0.344	-0.402
	Sig. (2-tailed)				0.479	0.483	0.525	0.418	0.404	0.324
<i>C. kenya</i>	Pearson Correlation				1	0.979**	1	0.983**	1	0.979**
	Sig. (2-tailed)					0		0		0
<i>A. mangiferae</i>	Pearson Correlation					1	0.983**	1	0.979**	1
	Sig. (2-tailed)						0		0	

*: Correlation is significant at the 0.05 level (2-tailed)

**: Correlation is significant at the 0.01 level (2-tailed)

through the year; also minimum and maximum temperatures were significantly different at 0.01 level. This indicates that the mango cultivar “Ewais” affected by degrees of temperatures where the highest numbers of *C. kenya* recorded (250 individuals/ 3 inches/ 20 leaves) during November when temperature reached 15°C (Tables 3 and 4).

Our results agree with Abdallah (2007) who recorded the maximum number of *C. kenya* on “Ewais” cultivar, reaching 12000 and 14880 individuals/ 100 leaves, respectively at 25 and 27°C during November 2003 and 2004. Also the same author recorded the maximum number of *A. mangiferae* (405 and 375 individuals/ 100 leaves) on respectively “Alphonso” and “Ewais” cultivars. The highest number of *A. mangiferae* averaged (420 individuals/ 3 inches/ 20 leaves) on “Alphonso” in our study (Table 4).

Management study

This is the first report showing management of *C. kenya* using combinations between different oils and a pesticide on mango leaves.

Toxicity of different oils, pesticide and their combinations. The current work demonstrated that *A. mangiferae* found on small leaves around the bud can be controlled by oils during spring before buds opening. Because the oils being hard to penetrate the buds to act, it is useful to control this mite on the leaves before it goes inside the buds.

The corresponding LC₅₀ values after 24 h of treatment (six replicates) against the *C. kenya* adults were respectively 1.803, 2.033, 1.734, 1.415, 1.520 and 1.543%. The consequent LC₉₅ values were respectively 17.427, 15.746, 22.488, 14.671, 17.87 and 15.304%. Mineral oil alone

Table 4 Average numbers of two eriophyid mites on three mango cultivars during 2020 year.

Sampling date	Ewais		Hindi		Alphonso	
	<i>C. kenya</i>	<i>A. mangiferae</i>	<i>C. kenya</i>	<i>A. mangiferae</i>	<i>C. kenya</i>	<i>A. mangiferae</i>
29.02.2020	70	33	65	40	61	55
04.09.2020	120	105	110	110	90	140
04.10.2020	175	170	165	185	150	210
24.10.2020	190	240	180	250	170	280
13.11.2020	250	370	240	385	230	420
28.11.2020	230	290	220	340	210	400
12.12.2020	180	193	160	235	155	300
28.12.2020	165	170	160	190	155	285
Average±SE	172.50±20.27	196.38±37.14	162.50±19.78	216.88±39.93	152.63±19.78	261.25±43.66

recorded the highest slope values after 24 and 48 h (1.850 & 1.702), respectively. The lowest slope was for spirodiclofen (1.478 & 1.618) after 24 and 48 h, respectively. On the other hand, the corresponding LC₅₀ values after 72 h were 0.592, 0.671, 0.557, 0.395, 0.414 and 0.415%, respectively for orange oil, mineral oil, spirodiclofen, mineral oil + spirodiclofen, orange oil + spirodiclofen, and orange oil + mineral oil. The consequent LC₉₅ values were respectively 4.226, 4.099, 3.723, 2.903, 3.021 and 3.926%. The slope values of regression line were 1.927, 2.092, 1.993, 1.899, 1.907 and 1.686, respectively for the same previous treatments.

Our results showed that the most effective compound is mineral oil + spirodiclofen that cause the highest toxicity, while the lowest one was for mineral oil alone (Table 5). The orange oil + spirodiclofen and orange oil + mineral oil gave the same results and was the second best effective. The orange oil and spirodiclofen alone gave the same results and was the third best effective.

Abou-Awad *et al.* (2009) tested the effect of some pesticides on *C. kenya* during 2005 season. The application of Abamectin resulted in a promising control against this mite followed by Chlorfenapyr and Sulphur. Azadirachtin, Methoxyfenozide and Spinosad were less effective.

Therefore, we can report that mineral oil + spirodiclofen gave the best results, followed by orange oil + spirodiclofen or orange oil + mineral oil. Mineral oil was the least effective.

The minor difference between mineral or orange oils and spirodiclofen is due to the toxicity of mineral oil on mango leaves as it affected its texture, thus orange oil can be used instead. Our results indicated that plant oils are more recommended than mineral oils in the Integrated Pest Management programs as promising compounds against the eriophyid mite, *C. kenya* in mango orchards in Egypt.

Toxicity of different essential oils. The corresponding LC₅₀ values after 24 h of treatment (four replicates) against *C. kenya* adults were respectively 2.213, 2.560, 1.605 and 2.311%. The consequent LC₉₅ values were respectively 63.77, 38.74, 77.45 and 39.84%. *Salvia rosmarinus* Spenn. (Lamiaceae) oil recorded the highest slope values after 24 and 48 h (1.394 & 1.801), respectively. Whereas, the lowest slope was for *Thymus vulgaris* L. (Lamiaceae) oil (0.977 & 1.238) after 24 and 48 h, respectively (Table 6).

On the other hand, the corresponding LC₅₀ values after 96 h were 0.269, 0.415, 0.234 and 0.364% and the consequent LC₉₅ values were respectively 3.134, 4.90, 1.83 and 3.94%. The slope values of regression line were 1.542, 1.534, 1.842 and 1.5892 for respectively *Geranium robertianum* L. (Geraniaceae), *S. rosmarinus*, *T. vulgaris* and *Syzygium aromaticum* (L.) Merr. & L.M. Perry (Myrtaceae) oils.

The results proved that the highest toxicity was for *T. vulgaris* oil and the lowest toxicity was for *S. rosmarinus* oil (Table 6). The result agrees with Allam *et al.* (2020) who found that *T. vulgaris* is a highly toxic oil in controlling *Phyllotetranychus aegypticus* Sayed (Tetranychidae).

Our results indicated that LC₅₀ and slope for *S. rosmarinus* oil after 24 and 48 h were about double in values of that of Elhalawany and Dewidar (2017) as the LC₅₀ was 0.96 and 0.72, the slope was 0.92 and 0.97, respectively for the first and second day on *T. urticae*. The toxicity of *S. rosmarinus* oil is less on *C. kenya* adults than on *T. urticae*, this could be due to *C. kenya* living under a coating silvery layer. The sprayed oil stay on this layer then penetrates the mite, *C. kenya*, while this mite needs a higher dose to be killed. Mossa *et al.* (2018) evaluated the affectivity of nano emulsion of garlic essential oil on two eriophyid olive mites, *Aceria oleae* (Nalepa) and *Tegolophus hassani* (Keifer) and showed high acaricidal activity against both mites, with LC₅₀ 298.225 and 309.634 µg/ml, respectively.

Patnaik *et al.* (2011) tested the efficiency of some aromatic and medicinal essential oils against *Aceria guerreronis* Keifer on coconut resulting in a significant control of this eriophyid mite. This agrees with our results except that the essential oils used in our study differ from theirs.

Elhalawany and Dewidar (2017) suggested that chamomile, coriander, spearmint and rosemary essential oils have the potential to control *T. urticae*, as it effectively decreased oviposition with increasing concentration, the highest decrease was observed on females

treated with 4% coriander (4.7 eggs/ female compared with 44.3 eggs/ female in untreated females).

Using orange oil instead of *T. vulgaris* oil and avoiding using the mineral oils in controlling eriophyid mites in mango orchards is highly preferable for agriculture eco-system. The mango producers can choose the most suitable treatment according to their targets (i.e., organic farming, low cost products, safety control materials) in order to keep agriculture eco-friendly and pesticide-free products for both local and foreign markets.

Table 5 LC₅₀, LC₉₅, chi square (X²), fiducial limits, degrees of freedom, and slope of different oils and chemical pesticide and their combinations against eriophyid mite, *Cisaberoptus kenyae* on mango leaves “Ewais” cultivar.

Treatment n = 6	Time	LC ₅₀	LC ₉₅	Slope±SE	Fiducial limits (slope)		X ²	DF
					Lower	Upper		
Orange oil	24	1.803 (1.427–2.701)*	17.427 (7.978–95.033)	1.670±0.330	1.35	1.99	0.058	2
	48	0.911 (0.732–1.108)	7.871 (4.499–24.234)	1.756±0.310	1.446	2.066	0.106	2
	72	0.592 (0.435–0.722)	4.226 (2.801–9.286)	1.927±0.326	1.602	2.253	1.038	2
Mineral oil	24	2.033 (1.61–3.049)	15.746 (7.731–68.146)	1.850±0.333	1.517	2.183	0.278	2
	48	1.045 (0.849–1.299)	9.671 (5.212–34.616)	1.702±0.309	1.393	2.011	0.103	2
	72	0.671 (0.528–0.798)	4.099 (2.812–8.103)	2.092±0.326	1.767	2.418	1.896	2
Spirodiclofen	24	1.734 (1.347–2.746)	22.488 (8.977–201.14)	1.478± 0.313	1.165	1.79	0.326	2
	48	0.846 (0.654–1.043)	8.789 (4.717–33.341)	1.618 ±0.308	1.31	1.926	0.613	2
	72	0.557 (0.406–0.681)	3.723 (2.543–7.629)	1.993±0.332	1.662	2.325	1.275	2
Mineral oil + Spirodiclofen	24	1.415 (1.144–1.938)	14.671 (6.957–74.24)	1.619±0.311	1.308	1.931	0.279	2
	48	0.772 (0.596–0.939)	6.813 (3.989–20.185)	1.739±0.312	1.427	2.051	1.092	2
	72	0.395 (0.237–0.518)	2.903 (2.016–6.051)	1.899±0.353	1.547	2.252	3.634	2
Orange oil + Spirodiclofen	24	1.52 (1.209–2.197)	17.87 (7.807–118.13)	1.537±0.311	1.226	1.848	0.129	2
	48	0.792 (0.603–0.975)	8.096 (4.437–29.186)	1.630±0.309	1.32	1.939	0.993	2
	72	0.414 (0.256–0.537)	3.021 (2.089–6.307)	1.907±0.348	1.558	2.255	2.387	2
Orange oil + Mineral oil	24	1.543 (1.243–2.167)	15.304 (7.241–76.796)	1.651±0.314	1.339	1.965	0.171	2
	48	0.846 (0.654–1.043)	8.789 (4.717–33.341)	1.618±0.308	1.31	1.926	0.613	2
	72	0.415 (0.237–0.552)	3.926 (2.496–10.489)	1.686±0.335	1.35	2.021	3.641	2

*: Upper and lower limits

LC50: The median Lethal Concentration (Concentration till death 50%)

LC95: The median Lethal Concentration (Concentration till death 95%)

Table 6 LC₅₀, LC₉₅, chi square (X²), fiducial limits, degrees of freedom, and slope of different essential oils against eriophyid mite, *Cisaberoptus kenya* on mango leaves “Ewais” cultivar.

Treatment n = 4	Time	LC ₅₀	LC ₉₅	Slope±SE	Fiducial limits (slope)		X ²	DF
					Lower	Upper		
<i>Geranium robertianum</i>	24	2.213 (1.535–5.887)*	63.77 (14.82–7869.4)	1.127±0.310	0.817	1.437	0.048	2
	48	0.706 (0.483–0.897)	10.23 (4.93–60.0)	1.417±0.307	1.109	1.724	0.316	2
	72	0.398 (0.207–0.543)	4.45 (2.69–14.3)	1.567±0.332	1.236	1.899	0.175	2
	96	0.269 (0.096–0.410)	3.134 (2.00–9.6)	1.542±0.357	1.184	1.899	0.594	2
<i>Salvia rosmarinus</i>	24	2.56 (1.813–5.670)	38.74 (12.40–787.6)	1.394±0.324	1.07	1.718	0.16	2
	48	1.264 (1.046–1.609)	10.34 (5.63–34.8)	1.801±0.313	1.489	2.114	0.066	2
	72	0.633 (0.422–0.804)	8.04 (4.21–36.1)	1.490±0.311	1.179	1.801	0.213	2
	96	0.415 (0.218–0.564)	4.9 (2.88–17.0)	1.534±0.328	1.207	1.862	0.003	2
<i>Thymus vulgaris</i>	24	1.605 (1.135–3.826)	77.45 (14.82–59551.2)	0.977±0.301	0.676	1.278	0.003	2
	48	0.483 (0.2257–0.669)	10.31 (4.55–107.5)	1.238±0.311	0.927	1.549	0.142	2
	72	0.248 (0.060–0.407)	4.49 (2.48–25.6)	1.308±0.342	0.966	1.651	0.463	2
	96	0.234 (0.085–0.358)	1.83 (1.33–3.7)	1.842±0.412	1.43	2.254	0.857	2
<i>Syzygium aromaticum</i>	24	2.311 (1.658–4.964)	39.84 (12.32–975.8)	1.330±0.317	1.013	1.648	0.021	2
	48	1.069 (0.862–1.351)	11.02 (5.623–46.4)	1.624±0.308	1.316	1.932	0.044	2
	72	0.537 (0.338–0.692)	6.11 (3.46–22.0)	1.558±0.318	1.24	1.875	0.146	2
	96	0.364 (0.179–0.506)	3.94 (2.44–11.9)	1.589±0.338	1.259	1.928	0.216	2

*: Upper and lower limits

LC₅₀: The median Lethal Concentration (Concentration till death 50%)

LC₉₅: The median Lethal Concentration (Concentration till death 95%)

Conclusion

The current study concluded that using mineral oil + spiroadiclofen affected on the eriophyid mite, *C. kenya*, while using only safty essential oils will be highly recommended instead in order to keep the environement clean and protect the predators for organic production activities followed in mango orchards. Thus, complementary investigations concerning field application of these oils to evaluate their efficacy on mite pests and their accociated predators is still needed. The GC-MS of the active ingredients of these oils is also necessary.

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