



Efficacy of selected plant-derived oils against Tetranychid Mite (*Tetranychus urticae*) (Acari: Tetranychidae), in laboratory and semi field conditions

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Abstract

Tetranychus urticae Koch, the two-spotted spider mite (Acari: Tetranychidae), is a major pest of mites in Egypt and most countries. This pest is currently controlled by synthetic acaricides. However, due to their potential impact on human health, environmental effect, and the potential for undesirable residues, the continued use of synthetic chemicals in different crops, is a growing concern around the world. Therefore, there was a need to improve new biological control methods for the management of mites. Essential oils may represent easy, effective, and natural alternatives as they have a minimum risk. Our study aimed to assess the acaricidal properties of three plant oils (eucalyptus oil, thyme oil, and garlic oil) *in vitro*. Semi-field tests were also used to determine the sensitivity of *T. urticae* adult females to various tested oils compared to the recommended pesticide Abamectin 1.8 EC. Mortality was detected after using four concentrations (1%, 0.5%, 0.25%, and 0.125%). Mite mortality was increased by increasing the concentration. *In vitro*, garlic oil was the most effective compound with a value of LC₅₀ (0.0912 %) followed by Thyme oil, and Eucalyptus oil, with values of LC₅₀ (0.182 and 0.232%), respectively 7 days after treatment. Under semi-field conditions all tested oils reduced mite numbers, nevertheless, Abamectin was found to be the most potent treatment against the spider mite, *T. urticae* as it caused a total reduction of 68.169% followed by eucalyptus oil where a value of total reduction was 65.741 %. Thyme and garlic oils were less toxic to *T. urticae* with a total reduction of 55.386 & 55.002 %, respectively. Eucalyptus oil, thyme oil, and garlic oil are useful to control the two-spotted spider mite *T. urticae*. They are hopeful candidates for tetranychids' biological control. Our study deduces the research directions needed to major knowledge and full evaluation of natural plant oils for future applications in IPM programs.

Keywords: acaricide, *Tetranychus urticae*, eucalyptus oil, thyme oil, garlic oil

Introduction

The two-spotted spider mites, (*Tetranychus urticae* Koch) have become a serious agricultural pest during the last century. Le Goff *et al.* (2009)^[27] recorded their riskiness because of causing severe loss to a wide range of hosts such as ornamentals, fruits, and vegetables. 1161 host plant species were reported around the world by Migeon and Dorkeld (2023)^[29] for *T. urticae* in 124 distribution places. Even though controlling spider mites is possible by using chemical acaricides below economic thresholds, the indiscriminate use of these chemicals leads to environmental pollution and inherent danger to humans, plants, and animals. They are also involved in the development of resistance phenomena to insecticides. Recently, Beers *et al.* (1998)^[10] listed that chemical acaricides resistance had been developed by populations of mites, and this may be because of having a short developmental period and high fecundity. Also, they can produce many consecutive generations making their management difficult. Integrated Pest Management programs, therefore, aim to reduce using acaricides to prevent ecosystem injury (Van Pottelberge *et al.* 2009)^[36]. Thus, the development of new methods to combat damage caused by spider mites, or at least limit their attacks was needed. Liu *et al.* (2000)^[28] reported that using a natural product instead of synthetic insecticides is one of the best alternatives to synthetic acaricides, as they are less toxic to humans, less polluting to the environment, and more compatible with environmental ingredients. Abd El-Moneim *et al.* (2012)^[2] proved the diverse acaricidal effects of

essential oils (chamomile, marjoram, and eucalyptus) against *T. urticae* (Koch).

Active ingredients of botanical insecticides are phytochemicals which synthesized as self-defense mechanisms by some plants against attack by pathogens and pests. These materials include so-called essential oils, which are mixtures of numerous low-molecular-weight complex compounds (Isman and Grieneisen, 2014)^[26]. Promising agents to control agricultural pests are essential oils, by acting on the nervous system of target insects' inducing responses in the pest physiology and behavior (Mossi *et al.* 2014)^[31]. Aissaoui *et al.* (2019)^[3] indicated that *Salvia officinalis* and *Eucalyptus globulus* essential oils can be used as acaricides of botanical origin for the management of *T. urticae* eco-friendly. Garlic is a food crop with proven therapeutic and insecticidal effects. Due to the action of various sulfur-containing compounds that have potent biological activity, it has been recognized as bactericide and fungicide. No evidence that using garlic oil and garlic poses any danger to the public. Baker and Grant (2018)^[7] recorded that garlic had antimicrobial, virucide, insecticide, nematocidal, acaricide, and molluscicide. Thyme oil and several of its key ingredients can act as plant acaricides. Wu *et al.* (2017)^[38] pointed out that thyme oil reported higher toxicity than any one of the major ingredients tested individually.

As a continuation of our efforts to update natural acaricide, the current study aimed to estimate the toxic action of Eucalyptus oil, Thyme oil, and Garlic oil *in vitro* and semi-field, against the tetranychid mite, *T. urticae*.

Materials and methods

Tested oils

Eucalyptus oil, Thyme oil, and Garlic oil were bought from Pure Life Company for Investment and Agricultural Development, 519 Ahram st., Giza, Egypt. Four concentrations (1%, 0.5%, 0.25%, and 0.125%) were prepared for all tested oils.

The structures of tested oils were identified by Pure Life Company. Tested oils were extracted by pressure, not refined (cold press) under scientific supervision. Active ingredients were recorded in Eucalyptus oil as 1,8-Cineole (eucalyptol) (45.38%), Limonene (10.16%), Myrcene (11.93%), β -Pinene (6.17%), Camphene (2.98%), α -Pinene (8.59%), and α -Thujene (3.05%). EMA, (2012)^[16] described the herbal component consisting of the fresh leaves of different species of Eucalyptus and recorded that all of them are rich in 1,8-cineole. Thyme oil's active ingredients were Thymol (1.28-7.6%), Carvacrol (75-81%), and Pinene (11-22%). This was in agreement with Sertkaya *et al.* (2010)^[33] who determined the chemical compositions of thyme oil using GC-MS analysis and recorded that Carvacrol was the main compound as it was 70.93%. For garlic oil, the active ingredients were Diallyl Disulfide (2.8-3%), Diallyl Trisulfide (24-37%), and Allicin (39-50%). Attia, *et al.* (2012)^[6], recorded Diallyl disulfide as the most abundant compound (10.8%). This mobilized us to search for the *in vitro* and semi-field miticidal effect of these oils against one of the maximum crucial agricultural pests the tetranychid mite *T. urticae*.

Evaluation of the miticidal activity of tested oils against the Tetranychid Mite (*T. urticae*)

Mite culture and rearing

T. urticae was gathered from an untreated castor bean plant in Egypt. Mite recognition was carried out at Plant Protection Research Institute (Acarology Laboratory), Agricultural Research Center (ARC) according to (Zhang & Jacobson 2000^[40]; Zhang 2003^[39]; Zhiqiang 2003^[41]). Mites rearing were carried out on green bean leaves (*Phaseolus vulgaris* L.) which were placed upside down on humidified cotton pads in glass Petri dishes. The edges of the leaves were covered with damp cotton to prevent the mites from escaping and to prevent the leaves from drying out. Cotton pads were moistened daily (Habashy *et al.* 2021)^[18]. Petri dishes were stored in boxes and placed in the Acarology Laboratory at 25±2°C, and 16:8 h (L:D). A saturated solution of NaCl was used to preserve moisture in the boxes at 75±5% RH (Winston, and Bates 1960)^[37]. Every 3 days tested mites were transferred to fresh green bean leaves.

Laboratory bioassay

Uninfected green bean leaves were carried to the laboratory and then cleaned with distilled water. A 2 cm diameter leaf disc was placed upside down on humidified cotton in Petri dishes. Ten newly adult females aged (0-48) hours were used and placed on each disc, and then sprayed with tested oils concentrations mentioned before, except the control which was sprayed with distilled water (Habashy *et al.* 2016)^[19]. The experiments were replicated four times. Mite mortality was checked daily for seven days. The experiment was carried out at room temperature (25±2°C, 60±5% RH).

Semi field studies

Bean (*Phaseolus vulgaris* L.) was used as the host plant prepared for outdoor potting at the Faculty of Agriculture, Mansoura University. Pots were separated from each other

to avoid contact and transfer of mites. Every pot contains 5 plants. Green beans (three adult-leaf stages) were invaded by the experimental mites (50 female/ pot) three weeks post-planting. After the mite's number ranged from 3 to 4 in one inch, the toxicity of concentration 1% of eucalyptus, thyme, and garlic oils were tested using five replicates for each treatment. Control was sprayed with distilled water. The recommended concentration of Abamectin 1.8% EC (40cm³/100L) was used for comparison. Five leaves were chosen randomly from each replicate and the number of all movable mite stages (immature and adult) was counted before spraying and 1, 3, 5, 7, 10, and 14 days post-spraying with the aid of a stereomicroscope.

Effect of treatments on green beans (*p. vulgaris* L.) plant growth

After two months of planting, a plant was randomly chosen from each replicate to determine Pods number/plant, Pods weight/plant, plant height, and plant weight.

Statistical analysis

The lethal effects of Eucalyptus, Thyme, and Garlic oils were estimated as a percentage of cumulative mortality. Mortality was corrected according to Abbott's formula (Abbott, 1925)^[11] for mortality in the control variant. The lethal effects of tested oils were evaluated based on LC₅₀ (median lethal concentration) 7 days of spraying, calculated by Finney's (1971)^[17] probit analysis. Corrected mortality and LC₅₀ were calculated using a computerized software program (Ldp line) (Ehab, M. Bakr, Institute for Plant Protection, Copyright ARC, Giza, Egypt) (Bakr 2005)^[9]. LC₅₀ confidence interval values were calculated at *p*-level < 0.05. The toxicity index (Ti) according to Sun's (1950)^[35] equation was calculated using the same program of the Ldp line as follows:

$$Ti = \frac{LC_{50} \text{ of the most toxic effect of tested compounds}}{LC_{50} \text{ of the less toxic effect of tested compounds}} \times 100$$

Henderson Tilton's formula (Henderson and Tilton 1955)^[21] was used to calculate the percentage of reduction in mite numbers caused by treatments as follows:

$$\text{reduction \%} = \left[1 - \left(\frac{n \text{ in co before treatment} \times n \text{ in T after treatment}}{n \text{ in co after treatment} \times n \text{ in T before treatment}} \right) \right] \times 100$$

Where (n) number of living mites, (co) control, and (t) treated

The values of movable mite mean numbers were statistically compared using one-way Analysis Of Variance (ANOVA) (Snedecor and Cochran 1980)^[34], followed by Multiple Range Test at *p*-level ≤ 0.05 to compare means (Duncan, 1955)^[15].

Results and discussion

Impact of tested oils against Tetranychid Mite *T. urticae*

The present study was carried out to estimate the acaricidal potential of four concentrations (1%, 0.5%, 0.25%, and 0.125%) of three examined oils (Eucalyptus, Thyme, and Garlic oil) to control the tetranychid mite *T. urticae*, *in vitro*, based on the median lethal concentration (LC₅₀) values which were calculated at *p*-level < 0.05. The results shown in Table (1) revealed that all screened oils decreased mite population. Garlic oil was the most effective compound for

T. urticae females with an LC₅₀ value of 0.0912 % and Ti (toxicity index) equal to 100 at seven days after treatment, followed by Thyme oil, and Eucalyptus oil, with LC₅₀ values of 0.182 and 0.232%, and Ti equal to (50 & 39.22), respectively for oils mentioned before.

The potency of the studied oils against *T. urticae* over time was also evaluated based on the values of LT₅₀ (median lethal time) calculated for the replicates sprayed with examined oils at concentrations 0.5% and 0.25% at *p*-level < 0.05 (Table 2). Garlic oil was the most effective compound for both concentrations where the values of LT₅₀ were equal to 1.34 and 3.24 with overlapped confidence intervals from (0.32 to 2.18) and (2.45 to 4.19) days for concentrations 0.5% and 0.25%, respectively. Followed by Eucalyptus oil where values of LT₅₀ were equal to 1.70 and 8.31 with overlapped confidence intervals from (0.68 to 2.57) and (6.12 to 18.51) days, respectively, at the same concentrations. Thyme oil was less effective to *T. urticae* over time, as the calculated values of LT₅₀ at a concentration of 0.5% was 2.89 days (confidence intervals from 2.14 to 3.73 days), (Table 2). The calculated confidence intervals of concentration 0.5% for all studied compounds are narrow indicating a balanced sensitivity to this concentration within the treated population of mites. For all evaluated oils the values of the slope were less than four. This showed that the studied oils will result in a small increase in the mortality of *T. urticae* over time.

The effect of *Eucalyptus oil* was studied also by Abd El-Moneim *et al.* (2012)^[2], they recorded that *Eucalyptus oil* had acaricidal activity as it caused 80.00 % mite mortality when concentration 4% was used, with LC₅₀ value for adult

2.18% after 24 h. Aissaoui *et al.* (2019)^[3] recorded 61.04 & 63.33% of *T. urticae* adults and larvae mortality, respectively after the application of eucalyptus oil at a dose of 1%. Also, they recorded a high reduction in the total number of eggs and a significant increase in repellency. Sertkaya *et al.* (2010)^[33] screened and confirmed that thyme and oregano essential oils had the highest acaricidal activity against (*Tetranychus cinnabarinus* Boisduval) the carmine spider mite causing high mortalities in adult mites at the lower concentrations with LC₅₀ 0.53 & 0.69 µg/mL than that observed with mint and lavender. The ability of garlic to act as a repellent to human ticks has also been shown by Catar (1954)^[13] and for *T. urticae* mites by Boyd & Alverson (2000)^[12] and Hincapié *et al.* (2008)^[22]. Dąbrowski and Seredyńska (2007)^[14] described the acaricidal properties of an aqueous extract of garlic (*Allium sativum* L.) to control *T. urticae*. Ismail *et al.* (2022)^[23] studied garlic oil nanoemulsion against *T. urticae* adult females reporting an LC₅₀ value of 210.37µg/mL.

Table 1: Toxicity of Eucalyptus oil, Thyme oil, and Garlic oil against females of *Tetranychus urticae*, seven days after spraying

Treatment	Lc ₅₀ (%) Confidence interval	Lc ₉₀ (%) Confidence interval	Slope ± S.E.	Toxicity index%
Eucalyptus oil	0.232 (0.144-0.326)	1.218 (0.707-5.016)	1.779±0.438	39.22
Thyme oil	0.182 (0.110-0.246)	0.815 (0.548-1.852)	1.967±0.415	50.00
Garlic oil	0.0912 (0.016-0.159)	0.773 (0.462-3.690)	1.380±0.414	100.00

Table 2: Median lethal time (lt₅₀, days) of eucalyptus oil, thyme oil, and garlic oil against females of *tetranychus urticae* at concentrations 0.5 and 0.25%

Treatment	Median lethal time (LT ₅₀) (days)							
	0.5%				0.25%			
	LT ₅₀	Confidence intervals		Slope ±S.E.	LT ₅₀	Confidence intervals		Slope ± S.E.
From		To	From			To		
Eucalyptus oil	1.70	0.68	2.57	1.35±0.38	8.31	6.12	18.51	2.39±0.66
Thyme oil	2.89	2.14	3.73	2.24±0.42	4.50	3.07	8.19	1.44±0.40
Garlic oil	1.34	0.32	2.18	1.22±0.38	3.24	2.45	4.19	2.30±0.44

Semi-field experiments

Data concerning the efficacy of the three examined oils compared to the recommended acaricide Abamectin 1.8% EC against *T. urticae*, showed mite infestation reduction under semi-field conditions (Table 3&4). There were no significant differences in the mean number of mites before treatment among Eucalyptus oil, Thyme oil, Garlic oil, Abamectin (recommended acaricide), and control. While very highly statistically significant differences in mite number showed by statistical analysis between control and other tested materials 14 days after treatment (Table 3). Abamectin was found to be the most potent treatment against the two-spotted spider mite, *T. urticae* as it caused 84.159, 83.811, and 70.015 percent reduction at one, three, and five days after treatment, respectively, with a total reduction of 68.169% (Table 4). This greater toxicity of the synthetic acaricide Abamectin to spider mites females may be due to its action as an agonist of the neurotransmitter GABA, with direct lethal effects (Biddinger and Hull 1995)^[11]. Eucalyptus oil resulted in 78.065% reduction 24 hours after treatment and increased over time as it caused 78.558, 70.094, 76.496, and 83.64% reductions at three,

five, seven, and fourteen days after treatment, respectively this with total reduction 65.741 %. Thyme and garlic oils were less toxic to *T. urticae* under semi-field conditions, as the initial reduction values one day after treatment were 63.439 & 68.747%, respectively with total reductions of 55.386 & 55.002 % (Table 4).

Although many studies (Amer *et al.*, 2001^[4], Momen *et al.*, 2001^[30], Pontes *et al.*, 2007^[32]) have proved the efficacy of contact or volatile essential oils derived from different plants, few studies have investigated the semi-field or field efficacy of essential oils against the two-spotted spider mite *T. urticae*. In this study, we estimated the miticidal effect of essential oils on *T. urticae* in laboratory and under semi-field conditions.

Hata, *et al.* (2016)^[20] evaluated the effects of garlic intercropping with strawberries on *T. urticae* numbers in the field and recorded a greater reduction of *T. urticae* numbers reaching 52% when populations are high. Habashy *et al.* (2016)^[19] studied the efficacy of garlic aqueous extract against two tetranychid mites (*T. urticae* and *T. cinnabarinus*) under semi-field conditions recording the highest reduction in mites' population as 89.75 & 80.14%, respectively one day after treatment.

Table 3: Mean number of *tetranychus urticae* (motile forms) on green beans before and after spraying abamectin, eucalyptus oil, thyme oil, and garlic oil under semi-field conditions

Treatment	The mean number of <i>T. urticae</i>						
	BT	1DAT	3DAT	5DAT	7DAT	10DAT	14DAT
control	5.114 ^a	1.464 ^a	1.728 ^a	2.102 ^b	4.396 ^{ab}	1.862 ^a	7.66 ^b
Abamectin	4.26 ^a	3.99 ^a	6.36 ^a	9.198 ^a	9.796 ^a	3.994 ^a	15.546 ^a
Eucalyptus oil	6.06 ^a	2.46 ^a	2.796 ^a	5.062 ^b	5.266 ^{ab}	3.00 ^a	3.33 ^b
Thyme oil	6.79 ^a	1.662 ^a	1.532 ^a	2.932 ^b	2.932 ^b	2.062 ^a	3.33 ^b
Garlic oil	2.99 ^a	1.358 ^a	2.66 ^a	1.664 ^b	2.264 ^b	1.262 ^a	2.13 ^b
LSD	5.899	2.586	3.695	3.477	4.507	2.761	4.819
F	0.558	1.571	2.428	6.8661	3.767	1.311	11.461
P	0.6959 ns	0.2206 ns	0.0815 ns	0.0012 **	0.0193 *	0.2999 ns	0.0001 ***

BT = before treatment; DAT = days after treatment.
Means that do not share the same letter(s) are significantly different.

Table 4: Efficiency of spraying Abamectin, Eucalyptus oil, Thyme oil, and Garlic oil against *Tetranychus urticae* according to Henderson-Tilton formula under semi-field conditions

Treatment	Percent control (Reduction %)						Total redaction%
	1DAT	3DAT	5DAT	7DAT	10DAT	14DAT	
Abamectin	84.159	83.811	70.015	55.015	65.295	50.716	68.169
Eucalyptus oil	78.065	78.558	70.094	76.496	73.333	83.64	65.741
Thyme oil	63.439	60.375	60.195	71.911	64.824	66.957	55.386
Garlic oil	68.747	65.32	55.365	49.358	56.002	90.221	55.002

DAT = days after treatment.

Influence of Treatments on Green beans (*P. vulgaris* L.) Plant Growth

The treatment effect on plant height and pods weight/plant was shown in Table (5). There were no significant differences in plant height and pods weight/plant among treatments with different tested oils mentioned before, recommended acaricide (Abamectin), and control. Plants' weight was significantly higher in those treated with thyme oil versus Abamectin and eucalyptus oil. No significant

difference observed in plants' weight between Abamectin and eucalyptus oil. Plants sprayed with garlic oil showed the highest number of pods /plant followed by that treated with thyme oil without significant differences (14.4 and 13.8 pods /plant), respectively. So, it could be concluded that application of natural oils such as Eucalyptus, thyme, and garlic oil does not adversely affect plants but it may be able to provide good plant growth.

Table 5: Influence of using Abamectin, Eucalyptus oil, Thyme oil, and Garlic oil on Green beans (*Phaseolus vulgaris* L.) Plant Growth under semi-field conditions

Treatment	Plant height (cm)	Plant weight (gm)	Pod No/plant	Pods weight/plant (gm)
control	35 ^a	15.2 ^c	9.4 ^b	22.6 ^a
Abamectin	33.2 ^a	20.4 ^{ab}	11.4 ^{ab}	24.2 ^a
Eucalyptus oil	35.4 ^a	19.2 ^{ab}	13.2 ^{ab}	26 ^a
Thyme oil	34.4 ^a	21.6 ^a	13.8 ^a	28.6 ^a
Garlic oil	31.4 ^a	17.6 ^{bc}	14.4 ^a	29.2 ^a
LSD	3.895	2.908	3.274	5.628
F	1.498	6.420	3.367	2.179
p	0.2406 ns	0.0017 **	0.0292 *	0.1084 ns

Means that do not share the same letter(s) are significantly different.

Plant extracts contain compounds that act as antifeedant, ovicidal, toxic, and repellent for insects (Isman, 2000^[24], Isman, 2006^[25], Bakkali *et al.*, 2008^[8]). Mites did not show resistance to essential oils, with different susceptibility to different types. Early use of potent essential oils to control the mite population conserves natural predators and maximizes the role of natural pest control. A rotation of different high-potency extracts may provide an effective method to combat tetranychid mites.

Wu *et al.* (2017)^[38] studied the commercial thyme oil chemical composition using GC/MS. They tested the acaricidal activities of thyme oil and blends of its major component against the tetranychid mite *T. cinnabarinus* (Boisduval). They proved that natural thyme oil had a greater potency than any single component or blended

components. Thymol was recorded as the most abundant component, and it had the strongest acaricidal activity against tested mites compared with other single components. Garlic had insect-repellent properties which were recognized before discovering its specific mechanism of action. Amonkar and Reeves (1970)^[5] discovered diallyl disulfide insecticidal properties. Attia *et al.* (2012)^[6] studied garlic acaricidal effect on two-spotted spider mites (*T. urticae*) and showed that it was susceptible to garlic extract. They recorded LD₅₀ as 7.5 mg/ml and also demonstrated that it decreased mite fecundity even at lower doses.

Conclusion

Eucalyptus, thyme, and garlic essential oils have miticidal activity against the tetranychid mite *T. urticae*. They are

promising for *T. urticae* control as an eco-friendly and effective acaricide in IPM programs. More research is needed to evaluate the mode of action and cost-effectiveness of these essential oils against various pests.

References

- Abbott WS. A method of computing the effectiveness of an insecticide, *J econ Entomol*,1925:1:18(2):265-7.
- Abd El Moneim A, Ali FS, Turkey AF. Control of *Tetranychus urticae* Koch by extracts of three essential oils of chamomile, marjoram and Eucalyptus, *Asian Pacific journal of tropical biomedical*,2012:01:2(1):24-30.
- Aissaoui AB, Zantra S, Elamrani A. Chemical composition and potential acaricide of *Salvia officinalis* and *Eucalyptus globulus* on *Tetranychus urticae* Koch (Acarina: Tetranychidae). *Journal of Applied Chemistry and Environment Protection*,2019:6;4(1).
- Amer SA, Refaat AM, Momen FM. Repellent and oviposition-detering activity of rosemary and sweet marjoram on the spider mites *Tetranychus urticae* and *Eutetranychus orientalis* (Acari: Tetranychidae), *Acta Phytopathologica et Entomologica Hungarica*,2001:1:36(1-2):155-64.
- Amonkar SV, Reeves EL. Mosquito control with active principle of garlic, *Allium sativum*. *Journal of economic entomology*,1970:1:63(4):1172-5.
- Attia S, Grissa KL, Mailleux AC, Lognay G, Heuskin S, Mayoufi S, *et al*. Effective concentrations of garlic distillate (*Allium sativum*) for the control of *Tetranychus urticae* (Tetranychidae). *Journal of Applied Entomology*,2012:136(4):302-12.
- Baker BP, Grant JA, *Garlic and Garlic Oil Profile*, New York State: IPM Progr; 2018.
- Bakkali F, Averbeck S, Averbeck D, Idaomar M. Biological effects of essential oils a review. *Food and chemical toxicology*,2008:1:46(2):446-75.
- Bakr EM. A new software for measuring leaf area, and area damaged by *Tetranychus urticae* Koch. *Journal of applied Entomology*,2005:129(3):173-5.
- Beers EH, Riedl H, Dunley JE. Resistance to abamectin and reversion to susceptibility to fenbutatin oxide in spider mite (Acari: Tetranychidae) populations in the Pacific Northwest. *Journal of Economic Entomology*,1998:1:91(2):352-60.
- Biddinger DJ, Hull LA. Effects of several types of insecticides on the mite predator, *Stethorus punctum* (Coleoptera: Coccinellidae), including insect growth regulators and abamectin. *Journal of Economic Entomology*,1995:1:88(2):358-66.
- Boyd Jr DW, Alverson DR. Repellency effects of garlic extracts on twospotted spider mite, *Tetranychus urticae* Koch, *Journal of entomological science*,2000:35(1):86-90.
- Catar G. Effect of phytoncides on *Ixodes ricinus* L. *Bratislavske lekarske listy*,1954:34(9):1004-10.
- Dąbrowski ZT, Seredyńska U. Characterisation of the two-spotted spider mite (*Tetranychus urticae* Koch, Acari: Tetranychidae) response to aqueous extracts from selected plant species. *Journal of Plant Protection Research*,2007:1:47(2).
- Duncan DB. Multiple range and multiple F tests. *Biometrics*,1955:1:11(1):1-42.
- EMA. Assessment Report on *Eucalyptus globulus* Labill., *Eucalyptus polybractea* RT Baker and/or *Eucalyptus smithii* RT Baker, *Aetheroleum*, 2012.
- Finney DJ. *Probit analysis*, Univ, Press Cambridge, 1971, 1-32.
- Habashy MG, Abou El, Atta DA, Ba FM, Gedara SR. Toxicological effects of compounds from the leaves of *schinus terebinthifolius* against two tetranychid mites (Acari: tetranychidae). *Emirates Journal of Food and Agriculture*,2021:18:613-20.
- Habashy MG, Al Akhdar HH, Boraie DM, Ghareeb ZE. Laboratory and Semi field evaluation of garlic aqueous extract as acaricide against two tetranychid mites (Acari: Tetranychidae), *Journal of Plant Protection and Pathology*,2016:1:7(10):623-8.
- Hata FT, Ventura MU, Carvalho MG, Miguel AL, Souza MS, Paula MT. Intercropping garlic plants reduces *Tetranychus urticae* in strawberry crop. *Experimental and Applied Acarology*,2016:69(3):11-21.
- Henderson CF, Tilton EW. Tests with acaricides against the brown wheat mite. *Journal of economic entomology*,1955:1:48(2):157-61.
- Hincapié CA, López GE, Torres RC. Comparison and characterization of garlic (*Allium sativum* L.) bulbs extracts and their effect on mortality and repellency of *Tetranychus urticae* Koch (Acari: Tetranychidae). *Chilean journal of agricultural research*,2008:1:68(4):317-27.
- Ismail T, Keratum A, El-Hetawy L. Formulation of abamectin and plant oil-based nanoemulsions with efficacy against the two-spotted spider mite *Tetranychus urticae* (Acari: Tetranychidae) under laboratory and field conditions. *Applied Biological Chemistry*,2022:65(1):1-8.
- Isman MB. Plant essential oils for pest and disease management. *Crop protection*,2000:12:19(8-10):603-8.
- Isman MB. Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. *Annu. Rev. Entomol*,2006:7:51:45-66.
- Isman MB, Grieneisen ML. Botanical insecticide research: many publications, limited useful data, *Trends in plant science*,2014:1:19(3):140-5.
- Le Goff G, Mailleux AC, Detrain C, Deneubourg JL, Clotuche G, Hance T. Spatial distribution and inbreeding in *Tetranychus urticae*. *Comptes rendus biologiques*,2009:1:332(10):927-33.
- Liu SQ, Shi JJ, Cao H, Jia FB, Liu XQ, Shi GL. Survey of pesticidal component in plant. In *Entomology in China in 21st Century*, Proceedings of Conference of Chinese Entomological Society, Science & Technique Press, Beijing, China,2000, 1098-1104.
- Migeon A, Dorkeld F. Spider Mites Web: a comprehensive database for the Tetranychidae [Internet]. [23 February 2023]. Available from: <http://www1.montpellier.inra.fr/CBGP/spm>
- Momen FM, Amer SA, Refaat AM. Influence of mint and peppermint on *Tetranychus urticae* and some predacious mites of the family Phytoseiidae (Acari: Tetranychidae: Phytoseiidae). *Acta Phytopathologica et Entomologica Hungarica*,2001:1:36(1-2):143-53.
- Mossi AJ, Zanella CA, Kubiak G, Lerin LA, Cansian RL, Frandoloso FS. Essential oil of *Ocotea odorifera*:

- An alternative against *Sitophilus zeamais*. *Renewable Agriculture and Food Systems*,2014:29(2):161-6.
32. Pontes WJ, Oliveira JC, Câmara CA, Gondim Júnior MG, Oliveira JV, Schwartz MO. Acaricidal activity of the essential oils leaves and fruits of *Xylopia sericea* St. Hill. on the two spotted spider mite (*Tetranychus urticae* Koch), *Quimica Nova*,2007:30:838-41.
 33. Sertkaya E, Kaya K, Soylu S. Acaricidal activities of the essential oils from several medicinal plants against the carmine spider mite (*Tetranychus cinnabarinus* Boisduval)(Acarina: Tetranychidae). *Industrial Crops and Products*,2010:1:31(1):107-12.
 34. Snedecor GW, Cochran WG. *Statistical methods*. 7th. Iowa State University USA, 1980, 80-6.
 35. Sun YP. Toxicity Index-an improved Method of comparing the relative toxicity of Insecticides. *Journal of Economic Entomology*, 1950, 43(1).
 36. Van Pottelberge S, Van Leeuwen T, Nauen R, Tirry L. Resistance mechanisms to mitochondrial electron transport inhibitors in a field-collected strain of *Tetranychus urticae* Koch (Acari: Tetranychidae). *Bulletin of entomological research*,2009:99(1):23-31.
 37. Winston PW, Bates DH. Saturated solutions for the control of humidity in biological research. *Ecology*,1960:1:41(1):232-7.
 38. Wu L, Huo X, Zhou X, Zhao D, He W, Liu S. Acaricidal activity and synergistic effect of thyme oil constituents against carmine spider mite (*Tetranychus Cinnabarinus* (Boisduval), *Molecules*,2017:1:22(11):1873.
 39. Zhang ZQ. *Systematic & Applied Acarology Volumes, cumulative index to authors*. *Systematic and Applied Acarology*,2003:8(1):193-208.
 40. Zhang ZQ, Jacobson RJ. Using adult female morphological characters for differentiating *Tetranychus urticae* complex (Acari: Tetranychidae) from greenhouse tomato crops in UK. *Systematic and Applied Acarology*,2000:5(1):69-76.
 41. Zhiqiang Z. *Mites of greenhouses: identification, biology and control*, CABI Publishing, Wallingford, 2003.