International Journal of Agriculture and Plant Science
www.agriculturejournal.in
Online ISSN: 2664-7664, Print ISSN: 2664-7656
Received: 13-10-2023, Accepted: 28-10-2023, Published: 15-11-2023
Volume 5, Issue 4, 2023, Page No. 67-72

Reducing of the abamectin dose by mixture to mineral oil and jojoba extraction when control the spider mites *Tetranychus urticae* (Acari: Tetranychidae)

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Abstract
There is growing interest in using eco-friendly plant oils in the field of spider mite management due to the negative effects of synthetic chemical acaricides on ecosystems and human health. The current study set out to examine the effectiveness of Abamectin alone or in binary combinations with mineral oil and jojoba oil against *Tetranychus urticae* Koch (Acari: Tetranychidae) under spider mite individuals under laboratory conditions. The findings indicated that the most hazardous chemical against adults of *T. urticae* was an emulsion of Abamectin and jojoba extract, followed by an emulsion of abamectin and mineral oil. Mineral oil was the least toxicity and jojoba was in between. The following, in decreasing order, were the effects of the examined compound residues on egg deposition and egg hatching: Abamectin and jojoba emulsion>Abamectin and mineral oil emulsion>Abamectin>jojoba extraction >mineral oil emulsion. The findings of the current study show that jojoba extraction and mineral oil emulsion improved abamectin's biological activity. Additionally, jojoba extraction and mineral oil emulsions may be useful in integrated pest management programmes as eco-friendly acaricides. Meanwhile the eggs of the pest lose the ability to hatch when treated by the mineral oil but it have no a height rate on both of reduction rate effect on adult individuals and females fertility. Meanwhile jojoba extract led to a significant decrease in the egg hatching rate.

Keywords: Abamectin, Jojoba, oil, *Tetranychus urticae*, lab experiment

Introduction

Tetranychus urticae Koch (Acari: Tetranychidae) is a two-spotted spider mite that affects ornamental plants, field crops and vegetables. It is the most economically destructive arthropod pest to agriculture (Smith-Meyer, 1996) [29]. Over 1100 plant species have been recorded as being consumed by *T. urticae*, a highly polyphagous species (Dermauw *et al.* 2013) [13]. In order to manage pests, around 4 million tonnes of insecticides are used annually. While significant quantities of applied pesticides are discharged into the environment as potential environmental risks, very tiny amounts (1–25%) reach the target pests (Zhang, 2018) [35]. Recent studies have looked into ways to reduce the negative effects of conventional pesticides by creating novel formulations or providing eco-friendly pest management alternatives (Tedeschi *et al*. 2001) [32], synthetic pesticide use is linked to a number of environmental problems, such as insect resistance, pollution, and negative effects on human and animal health.

Avermectin B1a and B1b are mixed together during the fermentation process of the soil bacterium *Streptomyces avermitilis* to create abamectin, a member of the avermectin family. One of the most significant pesticides in use today, abamectin has a wide range of insecticidal and acaricidal activities with high efficacy and very low toxicity to mammals (Yu *et al*. 2017) [34]. Abamectin's water insolubility and uneven distribution across treated surfaces, however, could result in a greater release of hazardous organic solvents and high amounts of abamectin into the environment (Cui *et al*. 2018) [12].

The demand for botanical pesticides as an alternative pest management method has recently increased. Plant oils, especially essential oils, have been used as bio-pesticides, according to a number of studies. Because synthetic pesticides have downsides such pesticide resistance, harmful residues, and a high cost of production, interest in using plant oils for pest control has increased (Mossa *et al*. 2018). [21] Despite this potential, plant oils' high volatility and water-insoluble nature prevent them from being used in harsh environments (Massoud *et al*. 2018) [19]. Jojoba oil and mineral oil from plants have both been widely employed in pest management. The *Simmondsia chinensis* (Link) Schneider jojoba plant is regarded as having some of the most therapeutic qualities of any plant on Earth (Benzioni *et al*. 1999) [10]. As a broad-spectrum botanical pesticide, jojoba oil contains biologically active substances like wax esters, a small amount of free fatty acids, alcohols, hydrocarbons, sterols, vitamins with a small amount of triglyceride esters, flavonoids, and phenolic and cyanogenic compounds. These substances have repellent, antifeedant, growth-inhibiting, and insecticidal effects against a variety of arthropod species without having any negative (AboGhalia *et al*. 2011) [4]. The mineral oil was thought to be the best mite-controlling option. Although the population of spider mites expanded quickly and it was not particularly poisonous to the eggs, it required repeated application to keep the mite population under control (Madanlar *et al.* 2000) [2].

As a result, the current study was done to look at how mineral oil, jojoba extraction, and Abamectin are combined. Under laboratory conditions, the acaricidal potential of these formulations against T. urticae was compared to abamectin in emulsion form (recommended acaricide).

Materials and methods

Culture technique of spider mite

Tetranychus urticae (Koch) (Acarina: Tetranychidae), a two-spotted spider mite, was reared using the Dittrich method (Dittrich, 1962) [14]. In order to prevent contamination with pesticide residues, the colonies were collected from castor bean plants in the Giza Governorate and raised in a lab on the castor bean plant at 25±2 °C under a 16 h photoperiod and 70±5% relative humidity. 60 individuals that were treating 30 females and 30 males.

Abamectin

The Egyptian Ministry of Agriculture and Land Reclamation's Agricultural Pesticide Committee recommends using technical grade abamectin (95% w/w) as an acaricide (Agricultural Pesticide Committee (APC), 2021) and was kindly provided by the Egyptian company KZ Pesticides & Chemicals.

Preparation of Abamectin emulsion

Using a magnetic stirrer at 400 rpm for 30 minutes, methanol-dissolved Abamectin was mixed with Tween 80 (a non-ionic surfactant) in a 3:1 w/w ratio to create an organic phase. The process to prepare Abamectin involved adding the organic phase dropwise and applying a magnetic stirrer to distilled water at a ratio of 1:4 w/w at 100 W for 15 minutes.

Extraction of jojoba extraction

Simmondsia chinensis, or fresh jojoba seeds, were gathered from trees that had not received pesticide application (Agricultural Research Centre, Egypt). Jojoba seeds were ground into a powder after being dried at 50 °C for 48 hours. Using a Soxhlet system and 300 ml of ethanol, oil was extracted from 50 g of jojoba powder at a temperature of 68 °C. After solvent evaporation, jojoba extraction was produced using the previously described procedure (Bellirou *et al*. 2005) [9].

Preparation of mineral oil emulsion

Bioassay techniques

Emulsions that have been developed have acaricidal activity against adult two-spotted spider mite *T. urticae*. The two-spotted spider mite *T. urticae* was utilised to compare the acaricidal activity of prepared emulsions to abamectin in emulsion form using the leaf disc dip technique (Siegler, 1947) [28]. A range of concentrations that resulted in 10 to 90% mortality were chosen for bioassay experiments based on the findings of preliminary tests. To provide a range of active component concentrations, developed compounds were diluted in distilled water. The tested concentrations of mineral oil and jojoba extraction emulsions were 3, 4 and 5 µg/ml, and 4, 5 and 6 µg/ml, whereas the tested concentrations of Abamectin in emulsion were 2.6 1.8, and 2 µg/ml. When mixed, the tested concentrations were half the previous concentrations for each compound. Castor bean leaf discs of 35 mm in diameter were immersed for 5 s in each concentration before being allowed to dry. Then, ten mature mites were subsequently added to each disc. In Petri dishes (90 x 105 mm), discs were placed on wet philtre paper resting on wet cotton wool pads and kept in breeding room-like conditions. For all treatments, mite mortality was assessed 24 hours after treatment. Using data that has been graphed on log concentration probit paper and LC_{50} values that have been computed in accordance with Lichtfeld and Wilcoxon, 1949 [17]. Mortality rates were corrected against controls as previously described by Abbott (1925) [1] and each treatment was reproduced four times.

Statistical analyses and equations

The of reduction percentages of the fecundity had been calculating by Abbott's formula

$$Corrected\ (\%) = 1 - (N\ in\ T\ after\ treatment \div Nin\ Co\ after\ treatment\ \times)100$$

Where N=Insect population, T=treated, Co=control.

According to Sun, 1950 [30], the toxicity indexes of the investigated substances were calculated as follows:

$$Toxcicity\ index = (LC50\ of\ the\ most\ effective \div LC50\ of\ the\ tested\ compound) \times 100$$

Results

Toxicity of formulations tested against adult *T. urticae*

The goal of this study was to compare the acaricidal mortality of produced emulsions of oil, Jojoba extract, and abamectin. Table 1 presents the results of a 24, 48, and 72-hour treatment period for abamectin, jojoba, and oil. The results of 24-hour treatment period show that the most toxic ingredient to adult *T. urticae* was abamectin emulsion, which was followed by Jojoba extract (LC_{50} and LC_{95} values: 2.48– 661.7µg/mL and 6.27 –1317991 µg/mL, respectively). Oil exhibited a weak toxic ingredient (LC_{50} and LC_{95} values of 73.1–4800 µg/mL, respectively) when tested on adult *T. urticae*. The component that proved to be the most toxic to adult *T. urticae* was abamectin emulsion, with a toxicity slope number of 4±3. Jojoba extract came in second with a toxicity slope number of 0.49±1 followed by oil with a toxicity slope number of 0.9±1. According to the findings of the 48-hour treatment period, abamectin emulsion was the most toxic ingredient to adult *T. urticae*, followed by jojoba extract (LC_{50} and LC_{95} values: 2.1–4.25µg/mL and 13.9 –36.1 µg/mL, respectively). Testing on adult *T. urticae* revealed that the oil included a week toxic component (LC_{50} and LC_{95} values of 108.5–67717µg/mL, respectively). With a toxicity slope value of 1.9±2, abamectin emulsion was the ingredient that adult *T. urticae* found to be most toxic. Second place went to jojoba extract (toxicity slope number: 1.8±1), and oil (toxicity slope number: 0.5±1) after that. The most toxic ingredient to adult *T. urticae*, as determined by the results of the 72-hour treatment period, was abamectin emulsion, which was followed by jojoba extract (LC_{50} and LC_{95} values: 2.1–1.7 µg/mL and 3.6–984.5 µg/mL, respectively). A weak toxic component was found in the oil (LC_{50} and LC_{95} values of 84.1–650403µg/mL, respectively) when tested for adult *T. urticae*. Abamectin emulsion was the component that adult *T. urticae* found to be most toxic, with a toxicity slope value of 3.8+3. Jojoba extract came in second (toxicity slope number: 0.6±1), followed by oil (toxicity slope number: 0.4±2).

Table 1: Toxicity of prepared formulations (abamectin, Jojoba extract and oil) against adult of *T. urticae* by castor leaf disc technique after 24, 48 and 72 h.

After 24 hours						After48 hours			After72 hours		
Abamectin		Jojoba extract		Oil		Abamectin	Jojoba extract	Oil	Abamectin	Jojoba extract	Oil
Con.	Mortaliy	Con.	Mortaliy	Con.	Mortality	Mortality	Mortality	Mortality	Mortality	Mortality	Mortality
1.6	17.5	3	12.5	4	7.5	40	37.5	15	62.5	55	25
1.8	37.5	4	15	5	5	47.5	52.5	30	72.5	60	40
2	30	5	20	6	7.5	40	50	30	72.5	60	37.5
LC_{50}	2.48		661.7	2	73.1	2.1	4.25	108.5	1.2	1.7	84.1
LC_{95}	6.27		1317991	2.5	4800	13.9	36.1	67717	3.6	984.5	650403
Slope	4±3		0.49±1	3	0.9±1	1.9±2	1.8±1	0.5±1	3.8+3	0.6±1	0.4±2

* Higher mortality rates and greater impact are indicated by higher slope numbers.

The abamectin and jojoba mixture treatment results are shown in Table 2 after 24, 48, and 72 hours of treatment. Results from tests conducted on adult *T. urticae* after a 24 and 72-hour treatment period indicate high toxic component levels (LC_{50} and LC_{95} values of 0.28–0.29 µg/mL and 5.3–5.4 µg/mL, respectively). A 48-hour treatment period revealed a weak toxic component (LC_{50} and LC_{95} values of 0.6 and 168.6µg/mL, respectively). The 24-72 hour treatment with an abamectin and jojoba mixture showed to be the most toxic to adult T. urticae with an equivalent toxicity slope number of 1.3±1, while the 48-hour treatment came in second with a toxicity slope number of 0.7±0.9.

Table 2: Abamectin and jojoba mixture's toxicity against adult *T. urticae* after 24, 48, and 72 hours

Concentration %		After 24 hours				After 48 hours				After 72 hours			
Abamectin	Jojoba	Mortality %	LC_{50}	LC_{95}	Slope	Mortality %	LC_{50}	LC_{95}	Slope	Mortality %	LC_{50}	LC_{95}	Slope
0.7	1.9	32.5	0.28	5.3	1.3±1	55	0.6	168.6	0.7±0.9	75	0.29	5.4	1.3±1
0.9	2	45				62.5				85			
2	2.1	55				62.5				85			

* Higher mortality rates and greater impact are indicated by higher slope numbers.

The outcomes of treatment periods of 24, 48, and 72 hours for the combination of abamectin and oil are shown in Table 3. The results of 48-hour treatment period show that the most toxic ingredient to adult *T. urticae*, which was followed 24-hour treatment period (LC_{50} and LC_{95} values: 5.3–5.3µg/mL and 15.7–15.8µg/mL, respectively). When evaluated on adult *T. urticae*, the 72-hour treatment period revealed a weak toxic component (LC_{50} and LC_{95} values of 4.1–13.7µg/mL, respectively). With a toxicity slope number of 3.6, the 48-hour treatment containing an abamectin and oil mixture proved to be the most toxic to adult *T. urticae*, whereas the 24-hour treatment ranked second with a toxicity slope number of 3.5. A weakly toxic component with a toxicity slope number of 3.2 was discovered in the 72-hour treatment.

Table 3: Abamectin and oil mixture's toxicity against adult *T. urticae* after 24, 48, and 72 hours

Concentration %		After 24 hours				After 48 hours				After 72 hours			
Abamectin	Oil	Mortality %	LC_{50}	LC_{95}	Slope	Mortality %	LC_{50}	LC_{95}	Slope	Mortality %	LC_{50}	LC_{95}	Slope
0.7	2.4	32.5	5.3	15.8	3.5±2	47.5	5.3	15.7	3.6±2	75	4.1	13.7	3.2±1.5
0.9	2.5	37.5				55				82.5			
2	2.6	42.5				67.5				87.5			

***** Higher mortality rates and greater impact are indicated by higher slope numbers.

The impact of evaluated formulation residues on *T. urticae* adult female egg depositing

Because spider mites are highly fertile and produce a lot of eggs, it's critical to keep the quantity of viable eggs below thresholds that may jeopardize the economy. Hence, the impact of both synthetic and natural insecticides on mite egg deposition and hatchability is a critical concern in integrated pest control. One-fifth of each formulation's respective LC_{50} values were used to assess the impact of prepared formulations and the traditional abamectin emulsion on egg deposition in adult *T. urticae* females.

After adult female mites were treated with the investigated compounds at a daily rate using the leaf disc technique, the results are displayed in Table 4 and show the percentages of the deposit of eggs in a daily rate, hatching rate, and reduction in the number of eggs deposited. The deposit of eggs in a daily rate showed that the compounds that were examined shown a considerable reduction in the daily rate of egg deposit; the combination of abamectin and oil proved to be the most successful in lowering the daily rate of egg deposit (0.1%). In comparison to the control (2.9%), abamectin and jojoba mixture, abamectin, oil, and jojoba (0.3%, 0.7%, 1.5%, and 1.8%, respectively) all exhibited significant decreases in the daily rate of egg deposit. The daily rate of egg deposit for the formulations under examination demonstrated the following significant declines, in decreasing order: abamectin and oil mixture<abamectin and jojoba>abamectin<oil<jojoba.

In general, the compounds tested showed significant oviposition deterrent effects; abamectin and oil mixture was the most effective in reducing egg deposition (96.5%). Other compounds that showed significant reductions in egg deposition were abamectin and jojoba mixture, abamectin, oil, and jojoba (89.7%, 75.9%, 48.3%, and 37.9%, respectively). The formulations that were examined showed the following ovicidal effects, in decreasing order: abamectin and oil mixture<abamectin and jojoba>abamectin<oil<jojoba.

Table 4: The fecundity rate percentage and the percentage of eggs hatching of *T. urticae* females treated with prepared formulations on a daily basis

Treatment	Daily rate	Reduction of fecundity %	Hatching rate %
Abamectin	0.7	75.9	18
Jojoba extract	1.8	37.9	5
Mineral oil	1.5	48.3	70
Abamectin + jojoba extract	0.3	89.7	12
Abamectin + mineral oil	0.1	96.5	8
Control	2.9		

The impact of evaluated compositions on the hatching rate percentage of two-spotted spider mite eggs

In comparison to the control treatment, all tested formulations significantly reduced the daily rate of egg hatchability, as shown by Table 4. The following is a list of the investigated substances' ovicidal actions in decreasing order: jojoba<abamectin and oil<abamectin and jojoba>abamectin<oil. After being treated with abamectin, jojoba, oil, (abamectin and jojoba), and (abamectin and oil), the hatchability was 18%, 5%, 70%, 12%, and 8%, respectively. Oil emulsion had minimal effects on ovicidal activity 70%. The percentage of eggs that hatched on a daily basis showed that abamectin and oil mixture, abamectin and jojoba mixture, and abamectin were the most effective acaricide in terms of lowering the rate of egg hatching. In other words, abamectin emulsions and mixes are superior to oil emulsions as ovicides. Furthermore, the significant ovicidal deterrent effect of jojoba emulsion is higher.

Discussion

Currently, intensive and preventive chemical products ensure pest prevention in commercial orchards. Despite benefits including their ease of application and quick action in decreasing the quantity of pests as compared to natural plant extracts (Attia *et al*, 2013) [7]. This approach has numerous disadvantages; for example, 46% of acaricides are globally toxic to auxiliary arthropods and public health, according to a study of the action spectrum of the active ingredients used globally (Assouguem, 2022) [6]. Plant extracts have a surprising amount of poisons and inhibitors, and they can provide a variety of insecticidal and acaricidal compounds that can be used to manage pests (Abdelgaleil *et al*, 2019) [3]. Conversely, the issue of essential oils' volatility and expensive cost leads to various limitations in their use, as they lose their potency when exposed to certain environmental factors. Plant essential oils' ability to function as pesticides may be preserved by nanoformulation (Taban *et al*., 2020) [31]. Phytochemical products are widely accepted, inexpensive, biodegradable, easily prepared, target-specific, have fewer applications, are more widely accepted, and are suitable for rural areas. Botanicals are employed as a substitute for synthetic acaricides and are anticipated to be a useful tool in the fight against spider mites, which are the world's most common agricultural pests and extremely polyphagous herbivores that cause severe damage to crops.

The current findings against the spider mite, *T. urticae*, on castor leaves in the lab, regarding the relative potency of the tested compounds alone or in binary mixtures with specific materials (mineral oil or jojoba extraction), are consistent with those reported by Ruiter *et al*. (2016) [26], who discovered that adding an emulsifiable and esterified canola oil (Hasten NNP) to abamectin resulted in 90% control of mites at treatment. Also, emulsion increases an acaricide's surface area, water solubility, adhesiveness, and penetration into mites, all of which enhance its biological activity. While (Sabre Rasha, *et al*. 2017) demonstrated that combining oils with abamectin is helpful in reducing the effects of its high dose usage, a decrease in the pesticide used in control when increasing the effect of residues may have a positive environmental impact because it will reduce the possibility of repeating treatments on infected plants. The outcomes of this study have been confirmed in additional pest species. Whereas the impact of applying abamectin alone or in combination with plant oil on *Liriomyza huidobrensis* Blanchard, the leafminer fly, was assessed on bean plants in both laboratory and greenhouse settings; the integration effect of adding abamectin and plant oil resulted in a decrease in the commercially recommended dose of abamectin without compromising its ability to reduce by 60%, making it possible for more farmers to use abamectin to control leafminer fly, as (Mujica, Norma *et al*. 1999) confirmed. It is possible that the addition of mineral oils to abamectin enhances osmotic transfer and lengthens the plant's residence period, resulting in a notable decrease in the number of *T. urticae* (NONGXIN. Abamectin+Mineral Oil (nx-pesticide.com). Also, abamectin was found to be more toxic to female *T. urticae* than vertimec 1.8% EC by Abdel-Halim and Kalmosh in 2019. Using the slide-dip method, Badawy *et al*. 2022 [8] discovered that, after 24 hours, abamectin was the most harmful compound against the adults of *T. urticae* ($LC50=5.39$ mg/L), followed by chlorfenapyr ($LC50=106.51$ mg/L). The adulticide abamectin acaricide has a higher acaricidal activity against the adult female spider mite than mineral oil and jojoba extraction, according to the results of adulticide bioassays. This impact is probably the result of abamectin directly causing death by acting as an agonist of the neurotransmitter GABA (Biddinger and Hull, 1995) [11].

The laboratory conditions were used to examine the toxicity of the tested chemicals on the number of egg hatching of two spotted spider mites. According to Badawy *et al*. (2022) [8], pyridaben was the most harmless compound for eggs, whereas abamectin was the most toxic. Our results support the findings of Roy *et al*. (2018) [25], who hypothesised that red spider mites exposed to garlic and jatropha oils deposited a significantly smaller number of eggs than controls. Also, studies reveal that the addition of mineral oil to abamectin enhances its effects by raising surface tension. The current research is in line with findings reported by Mohammed *et al*. (2021) [20] regarding the relative potency of the tested compounds alone or in binary mixtures with specific materials (mineral oil or jojoba extraction) on the number of laid eggs. It's possible that this high combination's impact on the hatching rate is due to a higher concentration of residual pesticide.

In comparison to the other compounds examined, amectin is a good ovicide. In line with (Ismail *et al*, 2020) [16] this study examined the toxicity of the compounds under test in a laboratory setting on ovicide revealed that abamectin were the most successful compounds in reducing oviposition and hatchability in *T. urticae*. Also, jojoba and mineral oil exhibit noticeable insecticide-deterrent properties.

Furthermore, it was noted by Narahashi and Chambers (1989) that ovicides slow down the hatchability process by indirectly influencing oocyte growth and protein sequestration, which results in the production of non-viable eggs. Additionally, according to Woolley (1988) [33], the substances being studied might be hazardous if they chemosterilize an ovary or stop it from releasing eggs.

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