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Acaricidal efficiency of solar 50 % new emulsifiable concentrate formulation against the two-spotted spider mite (TSSM) *Tetranychus urticae* Koch (Acari: Tetranychidae) under laboratory and greenhouse conditions

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Abstract

Oils are some of the most efficient and secure alternatives to synthetic fungicides, acaricides and insecticides used as pesticides for decades. Around the world, mineral oils are a potential pesticide against many pests. To provide novel active ingredients and new pesticide formulations to the pesticide industry, the major goal of this research was to formulate one of the petroleum fractions and test its acaricidal efficiency against two-spotted spider mite (TSSM), *Tetranychus urticae* Koch (Acari: Tetranychidae). Solar's physical features were put to the test. Then, it was prepared as an emulsifiable concentrate following the guidelines provided by specialized pesticide organizations for this kind of formulation. The novel formulation was subsequently biologically tested against *T. urticae* adults in the lab, and it demonstrated good acaricidal activity with an LC_{50} of 4548 ppm. Under greenhouse conditions, it was also tested against *T. urticae* immature, adults (males and females) and number of deposited eggs. There was a direct correlation for all stages between concentration, the percentage of immature and adult mortality, and the percentage of egg-hatching inhibition. In the case of the immature, 100% mortality was shown after 7 days of treatment. However, in the case of adult males and females, 100% mortality was shown after 3 days of treatment. Additionally, after 14 days from treatment, it entirely stopped egg depositing. The new formulation might be applied to manage the TSSM.

Keywords: Biological efficiency, Emulsifiable concentrate, Formulation, Solar, *Tetranychus urticae*

INTRODUCTION

The two-spotted spider mite (TSSM) *Tetranychus urticae* Koch (Acari: Tetranychidae) is considered one of the most destructive agricultural pests worldwide. This mite can harm more than 1100 plant species, including various varieties of eggplant (Rakha *et al.,* 2017). Spider mites have needle-like mouthparts for sucking and piercing. These mites are primarily located on the underside of leaves and feed by piercing plant tissue with their mouthparts. Although they favour young, nitrogen-rich leaves, older leaves in established colonies quickly develop the infection (Sandeepa *et al.,* 2019). All spider mites produce fine threads of webbing on the host plant, hence their name. The feeding of the mites causes the leaves to turn grey or yellow. In the more advanced phases of leaf destruction, necrotic areas appear. A browning and withering of the petals that resemble a spray burn are caused by mite damage to the open flower (Thomas and Denmark, 2016).

In light of the widespread use of pesticides, which pose a threat to human health, produce environmental pollution, and have given rise to resistance, there has recently been a significant interest in the adoption of alternative ways for controlling pests that infest various crops (Taha *et al.,* 2019). Around the world, numerous substances with various chemical structures and modes of action have been employed against *T. urticae*. Since the first significant and widespread outbreaks of spider mite populations in the 1950s, acaricides have taken the place of organophosphorous and other neuroactive insecticides. (Vassiliou and Kitsis, 2013). The two-spotted spider mite has developed widespread resistance against a number of novel acaricides and insecticides during the 1990s. (Arthropod Pesticide Resistance Database, http://www.pesticideresistance.org). The prevalence of acaricide resistance in phytophagous mites is alarmingly rising, particularly in *T. urticae* and other Tetranychids, which have a remarkable ability for rapid resistance evolution (Van Leeuwen, *et al.,* 2009).

Insect and mite pests have long been managed with the help of various oils. On fruit trees, shade trees, and woody ornamental plants, oils continue to be a significant tool for managing insect issues like scales, aphids, and mites (Kirk, 2020).

Mineral oils are also employed to control insect pests (Nikolova and Georgieva, 2018). Perhaps blockage of the trachea or respiratory apertures is the primary factor in arthropod deaths from mineral oil, and lack of oxygen kills insects (Stejskal *et al.,* 2021) Mineral oils, however, also impact integration, causing cell membranes to rupture and turn brown. These oils have the typical repellent effects on oviposition and nutrition and influence on the neurological system, affecting insect behavior (Lazarević *et al.,* 2020; Valizadeh *et al.,* 2021).

Oils are relatively safe for humans and the majority of desirable species, such as the beneficial natural enemies of insect pests. Oils can so easily combine with biological controls. Oils have low toxicity, at least as compared to alternative insecticides, and they evaporate quickly, leaving little residue behind. Additionally, oils are simple to use with existing spray equipment and can be combined with a variety of insecticides to increase their effectiveness (Isman, 2020).

Pesticides come in a variety of "formulas". The form of a product offered for sale is simply referred to as a formulation. To obtain a safe, practical, and efficient technique of pest management in an affordable manner, the pesticide must first be put into a form that can be conveniently produced, stored, transported, and sprayed. This process is known as pesticide formulation (Hazra and Purkait, 2019). Some of the earliest formulations of pesticides created for the agricultural sector (such as granules, aqueous solutions, dust, powders, and mineral oil in water emulsions) were based on straightforward technologies. However, the pesticide industry has made enormous achievements in developing novel formulations since the 1980s, concentrating in particular on the search for improved chemical stability, optimization of biological activity, differentiation, and greater safety in usage (Carmine, 2014). In addition, the development of novel formulations has also been a major emphasis in the effort to lower the dose needed per acre to reduce the number of pesticides dispersed in the environment (Knowles, 2008; Lagaly, 2001). The key determinants of formulation design Interdisciplinary are the active ingredients (AI) solubility properties, manufacturing costs, and the intended usage, so interdisciplinary sciences are therefore necessary for developing any new formula (Kah *et al.,* 2013).

This study aimed to evaluate a novel formulation of one of the petroleum oil fractions and assess its effectiveness against the two-spotted spider mite *T. urticae* under both laboratory and green house conditions as a new step in the further development of new acaricides for use in the field of pest management.

MATERIALS AND METHODS

Tested chemicals

a) Solar (fraction from petroleum oil): Supplied by Gas Station, Nadi El Seid St. –Dokki - Giza.

b) Surface active agents: Supplied by EL-Gomhoria Chemicals Company Cairo, Egypt.

Physico-chemical properties

Active ingredients

a) **Solubility:** One gram of the substance was evaluated for total solubility or miscibility at 20 °C by calculating the amounts of distilled water, ethanol, acetone, xylene, and DMF (Nelson and Fiero, 1954). The % solubility was calculated using the equation shown below-

Percent solubility = W/V x 100 …….. Eq. 1

Where

W= active ingredient weight

V= volume of solvent required for complete solubility

b) Free acidity or alkalinity: It was assessed using the method specified in the World Health Organization (1979).

Surface active agents

a) Surface tension: According to American Society of Testing Materials ASTMD-1331 (2001), it was assessed using a Du-Nouy tensiometer for solutions containing 0.5 % (W/V) surface active agent.

b) Hydrophilic-lipophilic balance (HLB): A surfactant's solubility in water is recognized as a good approximation to its hydrophilic-lipophilic balance (Lynch and Griffin, 1974).

c) Critical micelle concentration (CMC): Using the approach outlined by (Osipow, 1964), the concentration of the tested surfactants at which the solution's surface tension does not decrease as the surfactant concentration increases (CMC), was calculated.

d) Free acidity or alkalinity: It was determined as per WHO recommendations (1979).

Formulating solar as emulsifiable concentrate (EC) formulation

Solar was formulated as EC according to the method described by Soliman (2005), which included adding the emulsifying agent to solar, stirring the mixture for an hour, and dissolving the petroleum fraction used in a sufficient amount of solvent. The following physico-chemical parameters for emulsifiable concentrate formulation were then ascertained after the solution had been diluted to 100 mL using the same solvent used for dissolving violently agitated to assure homogeneity, filtered out, and kept in a tightly sealed vial:

a) Emulsion stability test: It was carried out in accordance with Food and Agricultural Organization, World Health Organization MT 36.3. (2010).

b) Accelerated storage: It was assessed using Collaborative International Pesticides Analytical Council (1995).

Spray solution

The spray solution physico-chemical characteristics were identified as follows:

a) Surface tension: It was carried out as mentioned before.

b) Viscosity: The viscosity was determined using a Brookfield viscometer model DVII+Pro, with centipoise serving as the unit of measurement in accordance with American Society of Testing Materials ASTM D-2196 (2005).

c) Electrical conductivity: It was assessed using a Cole-Parmer PH/Conductivity meter 1484-44, where mhos is the unit of measurement for electrical conductivity (Dobrat and Martijn, 1995).

d) pH: pH was measured according to Cole-Parmer PH conductivity meter 1484-44's evaluation (Dobrat and Martijn, 1995).

Bioassay

A) Rearing Two-Spotted Spider Mite (TSSM)

Source of *T. urticae*

The two-spotted spider mite was gathered from infected castor plants, *Ricinus communis* L. which are raised in Egypt's Fayoum governorate. At the faculty of agriculture's acarology laboratory, mites were raised on the upper surface of *Acalypha* leaves kept on a moist cotton wool pad in Petri dishes. Using a delicate hair brush, the adult females were moved and left to lay eggs. Every day, water was used to wet the cotton pad to keep it moist. The *Acalypha* leaves were changed every week to provide mites with new fresh leaves.

A) Laboratory experiment

The acaricidal effect of solar on *T. urticae* was carried out according to the leaf disc assay conducted according to the method described by Pree *et al.,* 1989. The median lethal concentration of solar was determined using the spraying technique and using six serial concentrations (8000, 7000, 6000, 5000, 4000 and 3000 ppm). Three replicates (10 individuals in each disc) of *T. urticae* adult females at the same age totalled thirty. In addition to the control, each treatment was repeated three times for each concentration to calculate LC_{50}. On mites on the upper surface of an *Acalypha* leaf disc (2 cm in diameter), each concentration was sprayed using an atomizer, except the control, which was sprayed with distilled water. After 24, 48, and 72 hours of treatment, living and dead mites were counted in the treatment and control groups (Finney, 1971).

B) Greenhouse experiment

White eggplant seedlings were planted in 15 x 20 cm containers. Each pot housed a plant that continued to grow in a lab environment (22 - 26 °C and 60-70 % RH). To protect plants against natural infection, four groups of pots were set up and covered with a thin net cloth. After 45 days of seedling, adult females *T. urticae* were infesting all groups. The first group received no treatment (control), whereas the other groups received treatments of 0.75, 1.5, and 3 percent. All plants were treated with a hand sprayer. Three randomly chosen one inch^2 leaves from each group of plants were taken ten days after infestation. Before spraying and then 3, 7, and 14 days later, the number of eggs, immature adult females, and adult males were counted.

Statistical analysis

Henderson and Tilton equation (1955) was used to calculate the reduction percentages in mite stages as follows:

Reduction% = (1 - (n. in Co. before treatment) X (n in T after treatment) / (n in Co. after treatment) X (n in T before treatment) * 100 … Eq. 2

Where

n = Insect population

T = treated

Co = control

RESULTS AND DISCUSSION

Formulation part

The physico-chemical features of the solar are shown in Table 1. It demonstrated total solubility in acetone and xylene but none in water. It also exhibited acidic characteristics due to its 0.0098 free acidity compared to sulfuric acid. In addition to determining the type of additives that will be added to the active ingredient, the determined values for solubility and free acidity or alkalinity also determined the type of formulation that might be produced (Food and Agricultural Organization/World Health Organization) (FAO/ WHO Meeting (2002). Due to the solubility of solar in xylene, emulsifiable concentrate formulation was found to be the best option for formulating this chemical (Hamouda *et al.,* 2022). In addition, because the active ingredient had an acidic value, the additives utilised should also have an acidic pH to guarantee perfect compatibility and prevent the possibility of any chemical reactions between the formula's components (Abd-Alla and Hamouda, 2021).

Table 2 displays the physical characteristics of the three surfactants Tween 80, poly ethylene glycol 600 monolaurate (PEG) 600 ML, and K sulphonate that were suggested for use in formulating the petroleum fraction under study. All of them had hydrophilic-lipophilic balance values of more than 13, indicating that they can all be employed to prepare emulsifiable concentrates as emulsifiers and as dispersing agents. The three surfactants also demonstrated acidic characteristics derived from their free acidity values as sulfuric acid. The lowest surface tension was demonstrated by potassium sulphonate, which was followed by PEG 600 ML and Tween 80, which demonstrated the highest surface tension. The critical micelle concentration was considered, and the three surfactants showed essentially the same values. Tween 80 and K sulphonate both displayed a value of 0.5, while P.E.G. 600 ML displayed a value of 0.3. In order to achieve the most crucial condition for combining ingredients to formulate an active ingredient in the form of an emulsifiable concentrate, preventing any potential chemical reaction between the formulation components (active ingredient and additives), the physico-chemical properties of the tested surface active agents were carefully examined to select the most suitable surfactant to use in the processes of formulation (Griffin, 1954). The active ingredient solar, which has acidic properties, necessitates using an acidic surfactant. Since all of the tested surfactants were acidic, any one of them may be employed in this case.

Table 3 displays the physical characteristics of the newly prepared solar emulsifiable concentrate formulation before and after accelerated storage. Before storage, the new formulation demonstrated perfect spontaneity in both soft and hard water, revealing the formulation's ability to generate spontaneous emulsification when added directly to water. The new formulation passed the emulsion stability test without any precipitates, creamy layers, or aggregates (Australian Pesticides Veterinary Medicines Authority, 2015; Food and Agriculture Organization of the United Nations, 2010). The new emulsifiable concentrate formulation demonstrated an acidic property derived from sulfuric acid acidity with very low values of foam on both types of water used. On storage under accelerated conditions, the new emulsifiable concentrate formulation showed perfect

Table 1. Physico-chemical properties of solar as an active ingredient

Solubility % (W/V)			Free acidity as %H_2SO_4
Water	**Acetone**	**Xylene**	
Insoluble	100	100	0.0098

*: means insoluble.

Table 2. Phsico-chemical properties of the tested surface active agents.

Surfactants	HLB	CMC	Free acidity as H_2SO_4	Surface tension Dyne/cm
Tween 80	>13	0.5	0.50	39.2
P.E.G 600 ML.*	>13	0.3	0.882	30.64
K. sulphonate	>13	0.5	0.245	28.5

P.E.G 600 ML.*: poly ethylene glycol 600 monolaurate

Table 3. Physico-chemical properties of the locally prepared 50 % Emulsifiable concentrate formulation (EC) before and after accelerated storage

Before storage							After storage						
Spontaneity %		Emulsion stability		Foam (cm^3)		Free acidity as H_2SO_4	Spontaneity %		Emulsion stability		Foam (cm^3)		Free acidity as H_2SO_4
Hard	Soft	Hard	Soft	Hard	Soft		Hard	Soft	Hard	Soft	Hard	Soft	
100	100	pass	pass	1	2	0.49	100	100	pass	pass	-	-	0.784

spontaneity and emulsion stability without any observable precipitation or cream separation in both hard and soft water. After being stored in a hot condition, it also demonstrated an acidic property. But after storage, it revealed almost no foam in either hard or soft water, in contrast to the pre-storage conditions. The new formulation results showed that it could maintain its characteristics before and after storage under accelerated temperatures (El-Sharkawy *et al.,* 2020).

The spray solution's physico-chemical characteristics are displayed in Table 4 at a concentration of 0.5% (field dilution rate). The spray solution displayed low surface tension, a high conductivity and viscosity value, and an acidic pH value. The biological activity of the formulation in the field is significantly influenced by the spray solution's physical characteristics. According to Pereira *et al.,* (2016), a low value of surface tension in the spray solution can cause an increase in spreading across the treated surface, resulting in an increase in pesticidal efficiency. The new formula showed low surface tension (36.97 dyne/cm) and the lower the surface tension, the higher the expected biological efficacy. The spray solution had an acidic PH value (low value), which is desirable for any spray solution to have in order to be used successfully in the field because these attributes directly affected how the new formulation behaved. According to El-Sisi *et al.* (2011), the spray solution's high electrical conductivity and low pH value would enhance the insecticides deionization, increase deposits and penetration into the treated surface, and be expected to improve pesticidal efficiency. The spray solution's increased viscosity value also influences its biological effectiveness by decreasing pesticidal drift and enhancing the formulation's stickiness on the treated surface (Spanoghe e*t al.,* 2007).

Biological activity

Tetranychus urticae was used to investigate the biological effects of solar emulsifiable concentrate in the lab at concentrations of 3000, 4000, 5000, 6000, 7000, and 8000 ppm Table 5. The results obtained 3 days after the beginning of the treatment showed that with an increase in concentration, the mortality percentage gradually increased. The new emulsifiable concentrate formulation showed mortality values of 36.6, 40, 53.33, 63.33, 66.77, and 71.49%, corresponding to the previous serial concentrations.There was generally a direct, increasing relationship between concentration and mortality %. The LC$_{50}$ value was found to be 4550 ppm and the LC$_{90}$ value was 16280 ppm based on the mortality percentages obtained, with a sharp slope value of 2.3 suggesting considerable toxicity of the novel formula against the pest under study. Kavya and Bhaska (2020) investigated the effectiveness of horticulture mineral oil (HMO) against egg and gravid females of *T. truncatus*, both alone and in combination with neem oil, at various concentrations. For adults, HMO 3.0% recorded considerable mortality of 65.33% one day after treatment, followed by HMO 2.5% (54.67). A maximum mortality of 73.33% was also seen with HMO 3.0% on the second day of treatment. After three days of treatment, HMO 3.0% dramatically increased maximum mortality to 77.33%, while HMO 0.5% alone resulted in just 18.67% mortality. Maximum mortality in HMO was 3.0% (81.33%) on the fourth day of treatment. These results lined up exactly with the ones that were collected and reported above. Additionally, Kavya and Bhaskars (2020) demonstrated that the acaricidal action of HMO was concentration and time-dependent. The results of the present investigation agreed with these findings.

Oils have a preference for the surface of the insect or mite's body and penetrate its cuticle (Stadler and Buteler, 2009), penetrate core cell structures (Taverner *et*

Table 4. Physico-chemical properties of solar 50 % (EC) spray solution at field dilution rate.

Surface tension dyne/cm	Viscosity cm/poise	Electrical conductivity µ mhos	Potential of hydrogen (pH)
36. 97	1.47	320	6.47

Table 5. Effect of solar 50 % emulsifiable concentrate formulation on *Tetranychus urticae* under laboratory conditions

Concentration of solar 50 % emulsifiable concentrate (ppm)	Mortality % after days	Lethal concentration parameters (LCP line parameters)		
	3 days	LC$_{50}$	LC$_{90}$	Slope
3000	36.66	4548.8972	16279.9249	2.3144+/- 0.3663
4000	40.0			
5000	53.33			
6000	63.33			
7000	66.77			
8000	71.49			
Control	0.0			

al., 2001; Taverner, 2002) and eventually destroy internal lipids (Taverner *et al.,* 1999).

The biological efficiency of solar emulsifiable concentrate was tested on *T. urticae* immature, males, females and egg hatching under greenhouse conditions. Table 6 shows the effect of the new formula on the immature with serial concentration (0.75, 1.5 and 3 %). The mortality percentage increased directly with the increase in concentration for all treatment periods. After 3 days from treatment, mortality increased from 73.15 to 77.14 to 89.16 % for 0.75, 1.5 and 3 %, respectively. After 7 and 14 days from treatment, it was relatively the same results, as the mortality percentage increased from 73.08 to 81.61 to 100 % after 7 days and from 81.86 to 83.27 to 100 % after 14 days for the same respective concentrations.

Furthermore, it was observed that the effect increased within the same concentration with the increase in the period of treatment. The percentage of mortality of immature was 77.14 % after 3 days from treatment, increased to 81.61 % after 7 days from treatment, and increased to 83.27 % after 14 days.

Generally, there was direct proportion either between the same concentration and the increase in the exposure time or between the increase in concentration and the percentage of mortality. Approximately 100% of eggs, nymphs, and adults died 7 days following direct exposure to various mineral oil-derived products examined at concentrations ranging from 0.5% to 3.0% (Chueca *et al.* 2010).

Table 7 shows the results of three treatment periods with the new EC formulation of solar on male and female adults of *T. urticae* under greenhouse conditions. The percentage of mortality for each treatment was directly proportional to the increase in concentration for females. After three days of treatment, the mortality % for 0.75, 1.5 and 3 % rose from 86.02 to 89.46 to 100%, respectively. The same results were observed with an increase in concentration and an increase in the proportion of mortality after the two additional treatment periods. As in the case of females, it was revealed that there was a direct proportion between the increase in concentration and the increase in the percentage of mortality for each period of treatment. Relatively the obtained results for males confirmed the ability of the new formulation to suppress the growth of *T. urticae* adults. For correspondingly 0.75, 1.5 and 3 %, the mortality % rose from 73.75 to 89.68 to 100%. Additionally, the experiment's highest concentration (3%) resulted in the highest proportion of mortality during both research stages after 14 days from treatment. The effect of mineral oils on the mortality of the two-spotted spider mite may be attributed to how mineral oils work, commonly thought to be suffocation by spiracle blockage (Taverner *et al.,* 2001). The cell membrane breakdown and darkening have been seen on the integument of *Aphis gossypilii* Glover on cotton following topical application of low-lethal concentrations of oils (Najar-Rodríguez *et al.,* 2007). The petroleum-based horticulture accumulates in cell membranes due to their lipophilic nature, which affects their structural and functional characteristics. Furthermore, *in vitro*, oils are able to

Table 6. Effect of solar 50 % emulsifiable concentrate formulation on *Tetranychus urticae* immature under greenhouse conditions

Concentration of solar 50 % emulsifiable concentrate (%)	Mortality % after days		
	3	7	14
0.75	73.15	73.08	81.86
1.5	77.14	81.61	83.27
3	89.16	100	100

Table 7. Effect of solar 50 % emulsifiable concentrate formulation on *Tetranychus urticae* adults (females and males) under greenhouse conditions

Concentration of solar 50 % emulsifiable concentrate (%)	Mortality % of adult					
	Females			Males		
	Days			Days		
	3	7	14	3	7	14
0.75	86.02	77.04	72.57	73.75	93.63	85.56
1.5	89.46	90.1	73.63	89.68	100	100
3	100	100	100	100	100	100

Table 8. Effect of the new local prepared solar 50 % emulsifiable concentrate formulation on egg depositing of *Tetranychus urticae* under greenhouse conditions

Solar 50 % emulsifiable concentrate (%)	**% of inhibition after days**		
	3	**7**	**14**
0.75	78.75	73.32	61.18
1.5	89.06	91.83	83.82
3	93.75	95	100

enter cell membranes, aggregate inside the cytoplasm, and induce cell dehydration, DNA condensation inside the nucleus (Roy *et al.,* 2015).

In the case of females, the mortality dropped from 77.04 after 7 days to 72.57% after 14 days following treatment with 0.75 %. With 1.5 % during the same treatment period, the same outcome was observed. These outcomes may be explained by the new formulations potential dual modes of action, the first of which is a caricide and the second of which, at low concentrations, is a caristatic. Also, the same observation was reported at the concentration of 0.75 % in the case of males.

Under greenhouse conditions, the new 50% emulsifiable concentrate formulation was also tested on female fecundity. Three successive concentrations were used to evaluate the new formulation (0.75, 1.5 and 3 %). Each concentration's effect after the three treatment periods differed from that of the other concentrations or the effects of the three concentrations after the same treatment period. With 0.75 %, there was an inverse relationship between the duration of treatment and the percentage of egg depositing inhibition, with the percentage of inhibition falling from 78.75 to 73.32 to 61.18% after 3, 7, and 14 days respectively. 1.5 % had a distinct impact, with the percentage of inhibition rising from 89.06% after three days of treatment to 91.83% after seven days before falling back to 83.82% after 14 days. The third concentration, 3 %, demonstrated a different pattern because it demonstrated a direct correlation between the increase in the treatment period and the increase of the number of eggs deposited, which changed from 93.75 to 95 to 100% after the three treatment periods, respectively. The impact on egg depositing increased as the concentration level rose. After three days of treatment, the percentage of egg hatching rose from 78.75 to 89.06 to 93.75% as the concentration was increased from 0.75 to 1.5 to 3 %, respectively and after 7 days therapy, from 73.32 to 91.83 to 95%, respectively and after 14 days treatment, from 61.18 to 83.82 to 100% respectively. The percentage of inhibition of egg deposit and concentration were often directly proportional (Table 8).

Mineral oils' ovicidal effects may be caused by their respiratory effects on eggs, which appear to impede embryonic development and destroy the embryo within the eggs (Mead *et al.,* 2016). Mineral oils, however, also have an impact on integration, causing cell membranes to rupture and turn brown. These oils have the typical repellent effects on oviposition and eating, as well as influence on the neurological system, which affects insect behavior (Seham, 2021).

Conclusion

Solar was formulated as a 50% emulsifiable concentrate as new formulation to test its efficacy on TSSM *Tetranychus urticae*. Under laboratory conditions, the novel formulation showed encouraging results. Under greenhouse conditions, it was tested on the two-spotted spider mite at three different life stages (egg, adult, and immature). The new formulation showed a direct correlation between concentration increases and mortality % for immature and adults, as well as an increase in the percentage of egg-depositing inhibition of TSSM. After taking into account the other necessary research related to toxicology and pesticide residues, the novel emulsifiable concentrate formulation might be employed to control TSSM, *T. urticae*.

Conflict of interest

The authors declare that they have no conflict of interest.

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