



Effect of certain pesticides and their alternatives on the two-spotted spider mite *Tetranychus urticae* Koch on tomato crop under laboratory and greenhouse conditions

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Abstract

The purpose of this study was to determine the toxicity of fenpyroximate, bifenthrin, emamectin benzoate, buprofezin, sulfur, K. Z oil, and chili nanosilver (AgNPs) extract against the two-spotted spider mite (*Tetranychus urticae*) associated with tomato plants (*Lycopersicon esculentum*) during the summer cultivations of 2017/2018 and 2018/2019 seasons. The bioassay revealed that the tested pesticides were in the same order of efficacy at both the LC50 and LC90 levels. The pesticides that were tested could be sorted in the following order: fenpyroximate > bifenthrin > emamectin benzoate > buprofezin > sulfur > K. Z oil > chili AgNPs extract. The corresponding LC50 values were 90.02, 112.18, 131.96, 154.60, 220.14, 269.48 and 314.44 ppm, while the LC90 values were 4403.98, 742.45, 756.11, 1293.59, 914.76, 1568.16 and 1500.05ppm, respectively. On the other hand, χ^2 values were 2.09, 1.68, 2.65, 2.96, 2.75, 5.20, and 5.24 respectively. The field experiments show that fenpyroximate, bifenthrin, emamectin benzoate, buprofezin, sulfur, K. Z oil, and chili AgNPs succeeded in controlling *T. urticae*, where the means of reduction percentages of infestation were 76.91, 67.00, 71.64, 55.54, 69.40, 64.96 and 72.23 % in 2017/2018 season, respectively. While the means of reduction percentages of infestation were 83.55, 80.55, 78.62, 77.30, 78.29, 73.20, and 72.37 % in the 2018/2019 season, respectively.

Keywords: Alternatives; Chili AgNPs tomato; Pesticide; Two-spotted spider mite; *T. urticae*.

1. Introduction

The tomato (*Lycopersicon esculentum* Mill.) is the most widely cultivated vegetable on a global scale. Egypt is one of the world's leading tomatoes producing and exporting countries. Major producers in the Mediterranean basin are Turkey, Egypt, Italy, Spain, and Morocco according to the Food and Agriculture Organization Statistics (FAOSTAT, 2022). Tomatoes are a fruit veggie that may be eaten raw or cooked and are used to make a variety of products. Tomato puree, sauces, paste, juice,

powder, and ketchup are all made from ripe tomatoes, which can also be bottled whole.

The two-spotted spider mite (*Tetranychus urticae*) is a serious tomato pest (Rapucel *et al.*, 2021). It causes substantial harm to tomatoes by lowering output and lowering quality. A mite-induced physiological shock can diminish tomato yields, resulting in smaller and fewer fruits, as well as sun-scalded fruits due to leaf loss. (Manoj and Patil, 2021). Most farmers' typical management tactics for vegetable pests, particularly mites, rely primarily on the administration of very toxic acaricides regularly with often ineffective spraying equipment and dose. Because of their short life cycle and rapid reproductive rates, mite resistance to chemicals

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Received: April 6, 2022; Accepted: April 17, 2022;

Published online: April 18, 2022.

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has developed faster than that of other insects, as seen with *T. urticae* (James and Price, 2006; Rapucel *et al.*, 2021). Although many studies on the toxicity of Pesticides to tetranychid mites have been conducted. Pesticide resistance has also been found in *T. urticae* (Kolmes, 1994; Muhammad *et al.*, 2021). Chemical pesticides are still the most widely used and most effective methods of pest management. Pesticide resistance develops quickly in spider mites including neurotoxic compounds such as abamectin (Stumpf and Nauen, 2002), bifenthrin (Van Leeuwen *et al.*, 2005), and malathion (Ali *et al.*, 2020) especially when pesticides are used for multiple seasons in a row. To avoid or postpone the development of resistance, it is required to rotate acaricides with diverse chemical compositions. In Egypt, synthetic acaricides are frequently used to control spider mites. However, because of negative consequences such as pollution and the development of pest resistance, their use is becoming increasingly unpopular. Biological pesticides, unlike synthetic pesticides, are environmentally harmless and leave no toxic residues on crops. They have also been demonstrated to be safer, selectively harmful, and have a brief environmental persistence (Muhammad *et al.*, 2021).

Pesticide resistance develops because of the continued usage of synthetic pesticides (Rapucel *et al.*, 2021). As a result, it's become necessary to search for alternate spider mite control measures that are both safe and environmentally acceptable.

In recent years, the emphasis on crop and pest control has shifted to more specialized, environmentally friendly, natural, and biological pesticides that are not harmful to human or animal health (Ki-Hyun *et al.*, 2017; Manoj and Patil, 2021). Mineral oils and nanosilver extracts have gotten the most attention from entomologists all over the world among these pesticides (Asgar *et al.*, 2021). Because the extracts contain insecticidal, antifeedant, and growth-inhibiting activities, they are used in this approach. Studies on the efficiency of mineral oils and nanosilver extract against spider mites will not only assist to solve the mite problem on tomatoes, but they will also ensure human and animal safety and have fewer harmful effects on ecosystems. If these alternatives prove to be effective, they could eventually replace many synthetic pesticides that have been phased out due to food safety and environmental concerns.

2. Materials and methods

The goal of this research was to determine the toxicity of fenpyroximate, bifenazate, emamectin benzoate, buprofezin, sulfur, K. Z oil, and chili AgNps against the two-spotted spider mites (*T. urticae*) associated with tomato plants (*L. esculentum*) during the summer cultivations of 2017/2018 and 2018/2019 seasons at the Experimental Farm, Faculty of Agriculture, South Valley University, Qena, Egypt. Tomato cultivars (Super Jakal) were cultivated in the last week of October. an analytical balance. Juice volume of arils was determined in ml by the Graduated cylinder.

Table 1. List of tested compounds against *Tetranychus urticae*

Trade name	Common name	Rate/Fed.
Acari Z 5% EC	Fenpyroximate	60 cm/100 L water
Acramite 48% SC	Bifenazate	35 cm/100 L water
Excellent 1.9% EC	emamectin benzoate	70 cm/200 L water
Buprolord 25% SC	buprofezin	400 cm/200 L water
Delmite 7.5% SC	sulfur	1 L/200 L water
K. Z oil	mineral oil	1 L/200 L water
Chili AgNPs	nano silver Plant extract	1 L/200 L water

2.1. Tests proving the formation of AgNPs

This research used a detailed study on the production of silver nanoparticles by the chili pepper *Capsicum annum*. When aqueous silver ions were introduced to plant extracts, they were converted to silver nanoparticles. After 24 hours of the reaction, the color of the solution changed from red to dark brown, indicating the creation of silver nanoparticles. UV-vis spectrophotometer analysis was used to track the generation and stability of reduced silver nanoparticles in colloidal solution. The greatest absorbance at 420 nm was seen in the UV-vis

spectra, which increased with the time spent incubating silver nitrate with the plant extract. FTIR analysis of silver nanoparticles confirmed the dual activity of the plant extract as a reducing and capping agent, as well as the presence of certain functional groups. The size, shape, and morphology of nanoparticles have been determined using transmission electron microscopy (TEM). It shows that the silver nanoparticles are well diffused and generally spherical, although some of the NPs have irregular shapes, as illustrated in Figure (1) (Indrakumar, 2016).

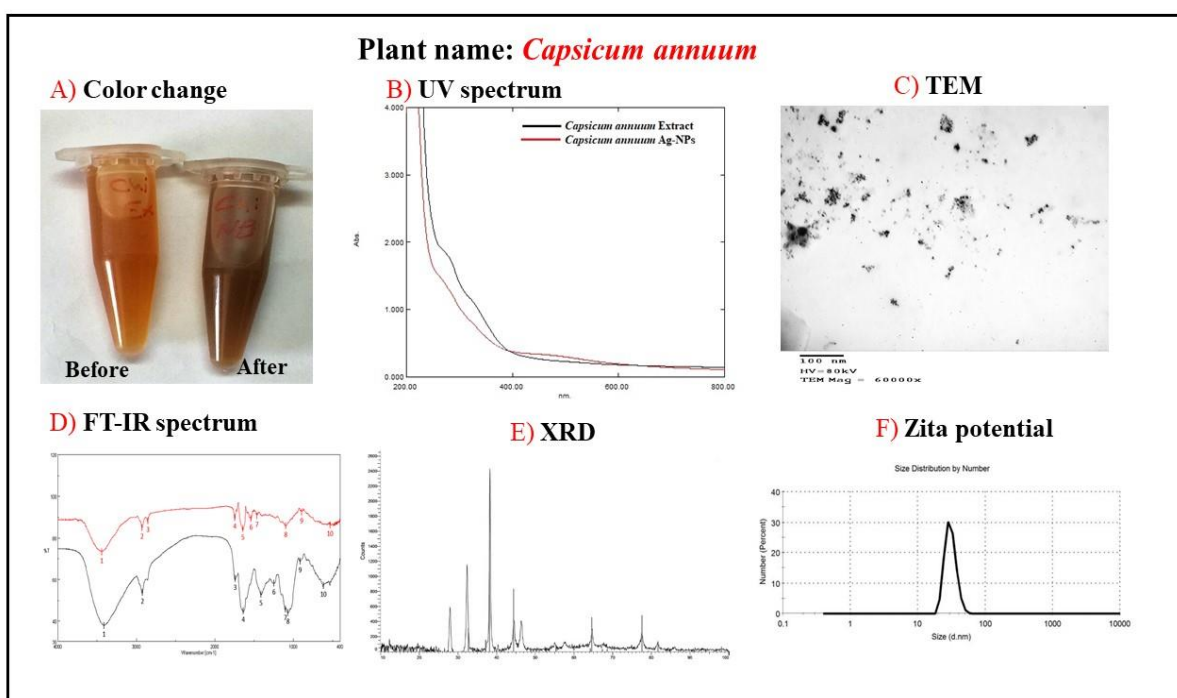


Figure 1. Tests of silver nanoparticles formation by aqueous extract of chili pepper (*Capsicum sp.*)

2.2. Bioassay experiments

Individual mites were gathered and transferred from infected leaves to leaf discs with the use of a fine hairbrush and a microscope. Because the mites are soft, care has been taken not to harm them. The 10 adult mites were transferred to Petri dishes and kept in the incubator for 24 hours under specified conditions: 25-27°C, 60%

relative humidity, and a photoperiod of 12/12 hours.

Leaf discs are dipped in pesticide solutions for 5 seconds before being placed upside down in glass Petri plates with moistened cotton wool. five different concentrations of each compound were used as follows, fenpyroximate, bifentazate, emamectin benzoate, buprofezin, sulfur, K. Z oil, and chili AgNPs (1000, 500, 250, 125, and 50 ppm). For 15 minutes, the Petri dishes are

allowed to dry at room temperature. A tiny brush is used to put adult mites onto each leaf disc. After that, the mites were transferred to the discs. When the mites did not respond to gentle poking with a camel hairbrush or escaped those trapped in the cotton wool after 24 hours, they were recorded as dead. After excluding mites that moved away from the leaf discs, percentage mortalities were calculated.

2.3. Field experiments

To determine the number of mites, 5 plants were sampled per plot and from each plant, three-terminal leaflets were obtained from one leaf at the top, middle and lower sections. The leaflets were kept separately in labeled paper bags and carried in a cool box maintained at 4 °C to a laboratory at Plant Protection Dept. Faculty of Agriculture, South Valley University, where counting was done using a microscope.

The pesticides and their alternatives were sprayed using a knapsack sprayer with one nozzle, as foliar treatment, diluted with water at the rate of 200-liter spray liquid per feddan. Two sprays were applied. The control plots were sprayed with water. Furthermore, care was taken to avoid any drift among the treated plots. The experiment was established with a randomized complete block design (RCBD) was performed with each treatment replicated 3 times. The control treatment was sprayed with deionized water as untreated. The outer plants were never sampled to avoid border effects. Samples were randomly collected at cross directions per plot. Counting was always performed only in the morning. The leaves represent the upper, middle, and lower leaves of the chosen shoots. The infestation was checked just before spraying, as well as 1 hour, 1, 3, 5, 7, 10, and 15 days later. Henderson and Tilton (1955) equation was used to compute the percent reduction in the infestation.

% Reduction Percentage

$$= 100 \{ 1 - (Cb / Ca \times Ta / Tb) \}$$

Where:

T a = Mean % of infestations in treated plots after spray.

C b = Mean % of infestations in check plots before spray.

T b = Mean % of infestations in treated plots before spray.

C a = Mean % of infestations in check plots after spray.

3. Results and discussion

Data in Table (2) and Figure. (2) represented the relative toxicity of the toxic action of fenpyroximate, bifenazate, emamectin benzoate, buprofezin, sulfur, K. Z oil, and chili AgNPs against *T. urticae*.

The order of efficiency of the tested pesticides was the same at both the LC₅₀ and LC₉₀ levels, according to the data. The pesticides that were tested could be sorted in the following order: fenpyroximate, bifenazate, emamectin benzoate, buprofezin, sulfur, K. Z oil, and chili AgNPs. The corresponding LC₅₀ values were 90.02, 112.18, 131.96, 154.60, 220.14, 269.48 and 314.44 ppm, while the LC₉₀ values were 4403.98, 742.45, 756.11, 1293.59, 914.76, 1568.16 and 1500.05ppm, respectively. On the other hand, χ^2 values were 2.09, 1.68, 2.65, 2.96, 2.75, 5.20, and 5.24 respectively.

When comparing the confidence limits and their overlapping with others, it was obvious that fenpyroximate pesticide is overlapped with bifenazate, emamectin benzoate, buprofezin, sulfur, K. Z oil, and chili AgNPs, but there are no overlapped between bifenazate, emamectin benzoate, and chili AgNPs. Thus, we can say there is no significant difference between fenpyroximate pesticides and the other tested pesticides at higher doses, but they are significantly different between bifenazate, emamectin benzoate, and chili AgNPs.

Table 2. Toxicity of tested pesticides against *Tetranychus urticae*.

Pesticides	χ^2	LC ₅₀ *ppm	Confidence limits of LC ₅₀ ·S. *ppm		LC ₉₀ *ppm	Slope	Index (T.I.)	Folds (R.R.)
			Lower	Upper				
fenpyroximate	2.09	90.02	15.79	172.67	4403.98	0.76±0.24	100	1
bifenazate	1.68	112.18	68.71	158.26	742.45	1.56 ±0.28	80.25	1.25
Emamectin benzoate	2.65	131.96	88.11	180.16	756.11	1.69 ±0.28	68.22	1.47
buprofezin	2.96	154.60	97.24	221.67	1293.59	1.39 ±0.26	58.23	1.72
Sulfur	2.75	220.14	166.93	286.59	914.76	2.07 ±0.30	40.89	2.45
K. Z oil	5.20	269.48	196.45	373.95	1568.16	1.67 ±0.27	33.41	2.99
chili AgNPs	5.24	314.44	237.22	427.25	1500.05	1.89 ±0.29	28.63	3.49

T.I. - Toxicity index compared with fenpyroximate

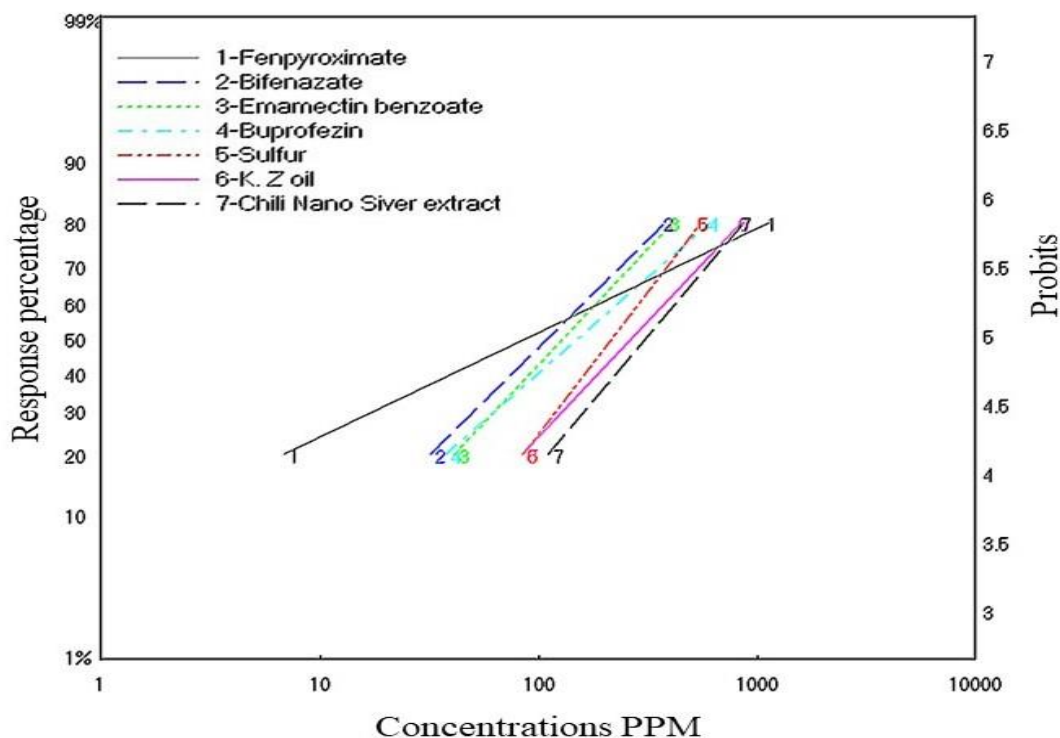
R.T. - No. of folds compared with chili nanosilver extract

χ^2 = Chi-square

* = ppm based on a:I

It is also obvious, as shown in Table (2) and Figure. (2), that fenpyroximate pesticide had the steepest toxicity line and chili AgNPs had the flattest, however bifenazate, emamectin

benzoate, buprofezin, sulfur, and K. Z oil lie in between. This reflects the superiority of fenpyroximate pesticides and the inferiority of chili AgNPs.

**Figure 2.** Toxicity lines of tested pesticides against *Tetranychus urticae*

Data in Table (2) show that the toxicity index of bifenazate, emamectin benzoate, buprofezin, sulfur, K. Z oil, and chili AgNPs were, 80.25, 68.22, 58.23, 40.89, 33.41, and 28.63 as toxic as

fenpyroximate pesticide (highest toxic) at the LC₅₀ level, respectively. On the ground potency levels (Relative activity, RT) of fenpyroximate, bifenazate, emamectin benzoate, buprofezin,

sulfur, and K. Z oil were 1, 1.25, 1.47, 1.72, 2.45, and 2.99 folds as effective as chili AgNPs (least toxic), respectively, at the LC₅₀ level, respectively. It was obvious that fenpyroximate pesticide was the highest toxic compound, whereas chili AgNPs were the least toxic one.

This result is compatible with Boyd and Alverson (2000) found that garlic is ineffective against rose spider mites *T. urticae*. Low residual action is beneficial since crops have fewer residues when consumed, presenting a lower danger to human health. This is one of the beneficial properties of botanical biopesticides, which are becoming increasingly popular in this era of health concerns. Regardless of how it was applied to the leaf discs, the synthetic acaricide (fenpyroximate) caused the most spider mite deaths. This result is consistent with Blair (1989), who evaluated 62 acaricide formulations against *T. evansi* on tobacco in the lab and found dimethoate and thiophosphates to be ineffective. Jensen and Mingoichi (1988) discovered that dimethoate and organophosphates were ineffective in controlling *T. evansi*, but that cyhexatin and propargite were successful. As a synthetic acaricide with extended persistence, as

demonstrated in this study, fenpyroximate herbicide may pose health hazards. It may also be unappealing to many consumers who have recently grown more health-conscious.

3.1. Evaluation of certain pesticides on *T. urticae* in tomato plants cultivated in the field

The effects of seven Pesticides (fenpyroximate, bifenazate, emamectin benzoate, buprofezin, sulfur, K. Z oil, and chili AgNPs) against *T. urticae* were evaluated. Reductions in percentages of infestation of *T. urticae* due to the application of tested pesticides are shown in Tables 3 and 4. The obtained results indicated that fenpyroximate pesticide was the most effective one in reducing the infestation, exhibiting 83.75, 84.88, 88.73, 74.18, 70.44, 70.19, and 66.21 % reduction at first spray during the 2017/2018 season on tomato plants on 1 hr., 1, 3, 5, 7, 10 and 15 days respectively. Meanwhile, 83.85, 88.27, 71.96, 70.62, 76.50, 63.99 and 76.96% reduction were obtained during 2018/2019 season on tomato plants on 1 hr., 1, 3, 5, 7, 10 and 15 days, respectively.

Table 3. The reduction percentage of tested pesticides against *T. urticae* for the 2017/2018 season.

Compounds	Rate / Fd.	Pre-spry count	% Reduction post-treatment (day)							Mean
			1 hr.	1	3	5	7	10	15	
fenpyroximate	60 cm/100 L water	65.00	83.75	84.88	88.73	74.18	70.44	70.19	66.21	76.91
bifenazate	35 cm/100 L water	42.33	79.96	75.02	68.45	66.34	53.58	53.28	72.39	67.00
emamectin benzoate	70 cm/200 L water	44.33	75.00	78.82	75.60	71.71	72.54	61.66	66.15	71.64
buprofezin	400 cm/200 L water	36.67	74.07	63.31	62.93	50.94	44.29	41.18	52.07	55.54
Sulfur	1 L/200 L water	40.33	73.78	77.20	73.48	69.80	60.29	57.93	73.31	69.40
K. Z oil	1 L/200 L water	47.33	72.06	71.98	68.13	62.22	59.78	52.09	68.43	64.96
Chili AgNPs	1 L/200 L water	72.67	71.34	69.52	75.85	80.98	66.63	59.49	81.78	72.23

The rest of the tested materials could be arranged in descending order according to their potency as follows: fenpyroximate > bifentazate > emamectin benzoate > buprofezin > sulfur > K. Z oil > chili AgNPs.

Data in Tables 3 and 4 show that fenpyroximate, bifentazate, emamectin benzoate, buprofezin, sulfur, K. Z oil, and chili AgNPs succeeded in

controlling *T. urticae*, where the means of reduction percentages of infestation were 76.91, 67.00, 71.64, 55.54, 69.40, 64.96 and 72.23 % in 2017/2018 season, respectively. While the means of reduction percentages of infestation were 83.55, 80.55, 78.62, 77.30, 78.29, 73.20, and 72.37 % in the 2018/2019 season, respectively

Table 4. The reduction percentage of tested pesticides against *T. urticae* for the 2018/2019 season

Compounds	Rate / Fd.	Pre-spry count	% Reduction post-treatment (day)							Mean
			1 hr.	1	3	5	7	10	15	
fenpyroximate	60	83.55	83.85	88.27	71.96	70.62	76.50	63.99	76.96	83.55
	cm/100 L water									
bifenazate	35	80.55	77.72	70.35	68.51	58.96	62.40	68.94	69.63	80.55
	cm/100 L water									
emamectin benzoate	70	78.62	80.03	78.46	62.52	78.04	76.59	69.61	74.84	78.62
	cm/200 L water									
buprofezin	400	77.30	79.83	68.84	69.73	71.33	74.30	72.49	73.40	77.30
	cm/200 L water									
Sulfur	1 L/200 L water	78.29	83.70	81.84	78.31	79.41	76.32	76.93	79.26	78.29
K. Z oil	1 L/200 L water	73.20	68.23	67.91	63.76	62.02	54.74	51.33	63.03	73.20
Chili AgNPs	1 L/200 L water	72.37	72.91	73.17	71.43	59.57	58.94	71.71	68.58	72.37

Mortality resulting from 1-hour residual effect of mineral oils (K. Z oil) and chili nanosilver extract were 72.06 and 71.34, respectively, compared to 83.75 and 83.85 for the first and second spray, respectively caused by the synthetic acaricide (fenpyroximate pesticide). Although not as effective as the synthetic acaricide, the alternatives of pesticides can be included in the modern pest management programs where the use of synthetic pesticides is not required or is restricted.

Mineral oils (K. Z oil) and chili AgNPs extract give some protection against spider mites, according to the results of this study *T. urticae*. The protection, however, is not as effective as a synthetic acaricide. Propargite has been proven

to have effective ovicidal and adulticidal effects on spider mites in previous studies (Blair, 1989). It can be concluded that there is a need to evaluate the action of the concentrations of biopesticides tested in this study on the other motile stages and the eggs of *T. urticae*. Low mortalities in the current study could be because botanical pesticides dissolve quickly when sprayed on plants and hence have a shorter environmental persistence than synthetic acaricides.

In both laboratory and greenhouse experiments, mineral oils (K. Z oil) and chili AgNPs extract treatments consistently showed lower populations of spider mites compared to traditional pesticides. Oils have also been

reported to have direct mortality effects on mites (Sridharan *et al.*, 2015; Asgar *et al.*, 2021) studied the effects of oils in increasing efficacy and mortality of mites and other pests as the better performance than traditional pesticides. Similar observations were obtained by many scientists, who confirmed the effectiveness of neem oils and other oils and increased the efficacy caused by silver nanoparticles, oils and plants extracts are believed to be mediated by increased penetration and persistence of pesticides into crops and pests when directly applied (Manoj and Patil, 2021; Husham *et al.*, 2021; Abd-Allah *et al.*, 2022).

4. Conclusion

These results concluded that alternative Pesticides, particularly K. Z oil and chili nanosilver extract, have the potential to control the two-spotted spider mites on tomatoes, although not as effective as synthetic acaricides, can be used in recent pest management programs when the use of synthetic pesticides is undesired or restricted.

Authors' Contributions

All authors contributed to this research.

Funding

There is no funding for this research.

Institutional Review Board Statement

All Institutional Review Board Statements are confirmed and approved.

Data Availability Statement

Data presented in this study are available at fair request from the respective author.

Ethics Approval and Consent to Participate

This work carried out at the plant protection and Zoology departments and followed all the departments instructions.

Consent for Publication

Not applicable.

Conflicts of Interest

The authors declare no conflict of interest.

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