Specificity and Time-dependent Toxicity of Some Acaricides Against the Developmental Stages of the Two-Spotted Spider Mite, *Tetranychus urticae* Koch (Acari: Tetranychidae)

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ABSTRACT: Bioassay studies were conducted to determine LC_{50} and to evaluate the toxicity of seven acaricides against the developmental stages of *T. urticae* under laboratory conditions. The results illustrated the importance of considering time-dependent toxicity in acaricide selection, with abamectin, chlorfenapyr, and fenpyroximate offering the most robust control against adult *T. urticae* over extended periods. The rapid-knockdown acaricides (chlorfenapyr, fenpyroximate) were optimal for severe infestations, while the delayed-action compounds (bifenazate, pyridaben, abamectin, fenbutatin oxide, etoxazole) proved superior in extended toxicity scenarios. Although etoxazole acted slowly, it resulted in a 23-fold decrease in LC_{50}, reducing the value from 100.24 to 4.41 µg ml^{-1} over 144 hours. For the immature stage, bifenazate was the most initially toxic, followed by chlorfenapyr, fenpyroximate, and fenbutatin oxide, revealing LC_{50} values of 9.44, 10.45, 12.28 µg ml^{-1}, and 14.08, respectively. Abamectin showed moderate initial toxicity, while etoxazole and pyridaben were the least effective. However, bifenazate achieved the highest long-term toxicity (LC_{50} = 0.71 µg ml^{-1}), a 13-fold improvement from its initial value. Chlorfenapyr, fenpyroximate, abamectin, and fenbutatin oxide also demonstrated late-period potency, and progressive improvements ranged between 13- and 17-fold. Etoxazole showed slowest substantial enhancement, while pyridaben exhibited moderate residual toxicity. For the egg stage, fenbutatin oxide and fenpyroximate had the highest acute ovicidal activity, with LC_{50} values of 5.29 and 5.97 µg ml^{-1}. They also showed strong delayed ovicidal activity (5.29 and 5.97 µg ml^{-1}), which makes them especially useful for integrated mite management programs that target egg stages. These results support the use of time-stratified rotation programs to improve mite control and resistance management, and they emphasize the significance of taking into account both immediate and long-term toxicity as well as the specificity when choosing acaricides.

Keywords: *Two-spotted spider mite, Tetranychus urticae, acaricides, bioassay, toxicity, eggs, immatures, adults, specificity, IPM, ovicidal, acute toxicity, long-term toxicity, LC_{50}.*

INTRODUCTION

The two-spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae), is a highly polyphagous pest that infests a wide range of economically important crops, including vegetables, fruits, and ornamental plants (Grbić et al., (2011). *T. urticae*'s rapid reproduction rate, short life cycle, and ability to develop resistance to acaricides make it a persistent threat to agricultural productivity (De Rouck et al., 2023).

Effective management of *T. urticae* is further complicated by its ability to infest multiple plant growth stages, with different life stages (eggs, immatures, and adults) exhibiting varying susceptibility to chemical treatments (Nicastro et al., 2013; Puspitarini et al., 2021).

The piercing-sucking feeding behavior of *T. urticae* damages plant cells, leading to reduced photosynthesis, leaf yellowing, defoliation, and stunted growth. Severe infestations can result in yield losses of up to 50–70% in susceptible crops such as tomatoes, strawberries, beans, and cotton. Additionally, mites' rapid reproduction and resistance to many pesticides increase control costs for farmers (Afzal et al., 2023).

Due to aesthetic damage, infested crops often lose their market value, and in some cases,

entire harvests may face rejection. The global economic impact of *T. urticae* is estimated to be in billions of dollars annually, making it one of the most economically damaging mite species in agriculture. Additionally, *T. urticae* can transmit plant viruses (e.g., tomato spotted wilt virus) via feeding, further harming crops. Effective management strategies, including integrated pest management (IPM), are essential to mitigate these losses (Attia et al., 2013; Assouguem et al., 2022).

T. urticae is a pervasive pest requiring integrated management strategies to mitigate resistance and ensure sustainable crop protection. Chemical control relies on synthetic acaricides such as etoxazole, bifenazate, and fenpyroximate, which disrupt mite growth, respiration, or neural function (Bhana, 2007).

Chemical control remains a primary strategy for managing *T. urticae* populations. Chemical control of *T. urticae* relies on several pesticide groups, including acaricides, and insecticides. However, overuse has led to resistance, prompting the integration of biological controls and rotation of chemical modes of action to enhance efficacy and delay resistance development (Jakubowska et al., 2022; Makwarela et al., 2025).

Overuse of acaricides has led to widespread resistance, reducing the efficacy of many active ingredients. Resistance development is particularly concerning for mites due to their short generation time and high genetic variability (Adesanya et al., 2021).

Understanding the stage-specific efficacy of these acaricides is essential for developing targeted control strategies, as certain compounds may be more effective against eggs (ovicidal activity) or mobile stages (larvicidal/adulticidal activity). Additionally, assessing their toxicity across different life stages can help identify potential gaps in control and guide rotation schemes to delay resistance development (Khajehali et al., 2011; AnnaDurai et al., 2024).

This study investigates the efficacy of some selected common acaricides that are used in Egypt related to different chemical groups with various sites of action against *T. urticae* at three developmental stages: eggs, immatures (larvae and nymphs), and adults. Thus, evaluating the specificity and toxicity of acaricides across different developmental stages of the two-spotted spider mite is crucial for designing effective resistance management strategies and optimizing integrated pest management (IPM) programs.

MATERIALS & METHODS:

Host plant used for leaf-spray technique:

Seeds of the common kidney bean (*Phaseolus vulgaris* L.) were placed in small boxes lined with moist, dark absorbent tissue paper and incubated at 25°C for approximately 72 hours to promote germination. Germinated seeds were then individually transplanted into 500 mL plastic pots filled with a soil-to-vermicompost mixture at a 3:1 ratio. The pots were irrigated as needed and maintained in a climate-controlled chamber (25 ± 2 °C; 60 ± 5% relative humidity; photoperiod: 16 h light: 8 h dark) at the Department of Plant Protection, Faculty of Agriculture Saba Basha, Alexandria University. Seedlings that were three weeks old were used for subsequent experiments.

Susceptible *Tetranychus urticae* strain:

The laboratory strain of *Tetranychus urticae* used in this study was originally collected from infested cucumber plants (*Cucumis sativus* L.) in greenhouses located in El Ayat, in the central region of Giza Governorate, Egypt. These plants had never been exposed to pesticides. A stock culture of the mites was maintained on kidney bean (*Phaseolus vulgaris* L.) seedlings in a climate-controlled room.

Acaricides used:

The tested acaricides were abamectin (Crater® 3.37% EC), bifenazate (Acramite® 48% SC), chlorfenapyr (Challenger Super® 24% SC), etoxazole (Baroque® 10% SC), fenbutatin oxide (Damper® 55% SC), fenpyroximate (Ortus® 5% SC), and pyridaben (Sanmite® 20% WP), which mostly differed in their chemical group, specific targeted mite stage, product formulation, systemic activity, and mode of action.

Bioassay experiment:

In the bioassay, a range of concentrations for synthetic acaricides were tested. The synthetic acaricides included Baroque® 10% SC (etoxazole) at doses ranging from 2.5 to 640 ppm, abamectin (Crater® 3.37% EC) from 0.5 to 128 ppm, chlorfenapyr (Challenger Super® 24% SC) from 0.5 to 128 ppm, Acramite® 48% SC (bifenazate) from 0.5 to 128 ppm, Ortus® 5% SC (fenpyroximate) from 0.5 to 128 ppm, Sanmite® 20% WP (pyridaben) from 0.5 to 2560 ppm, and Dumper® 55% SC (fenbutatin oxide) from 0.5 to 128 ppm.

The leaf-spray technique, recognized as a standard routine test by the IOBC/WPRS Working Group on "Pesticides and Beneficial Arthropods," was employed in this study (Helle and Overmeer, 1985). All tested compounds were bioassayed against different stages of *T. urticae.* Four replicates were used for each prepared concentration of the tested acaricides in distilled water, causing 10–90% mortality, compared with

their counterparts in the untreated check (Tang et al., 2014).

Determination toxicity of acaricides against the adult and immature stages:

The toxicity of acaricides on adult and immature stages of *T. urticae* was evaluated. Ten spider mite individuals from each stage were transferred to bean leaves prepared as a 2 cm diameter disc and placed on wet cotton wool in a Petri dish (9 cm diameter). Petri dishes were surrounded with Vaseline to prevent mite escaping. Following that, pre-prepared acaricide concentrations were sprayed with a manual sprayer at a rate of 1 ml per plate (for four replicates of each concentration) and allowed to be dried for 1 h. In contrast, the control treatment was treated with only distilled water. The petri dishes were incubated at 25 ± 2°C, 60 ± 5% R.H., and a photoperiod of 16 h:8 h (L:D) (Jakubowska et al., 2022).The number of surviving mites was recorded from 1 to 6 days after treatment (Villanueva & Walgenbach, 2006).

Determination toxicity of acaricides against the egg stage:

The toxicity of acaricides on the egg stage of *Tetranychus urticae* was evaluated using the same methods and procedures described above. Ten eggs were transferred onto each bean leaf disc. The prepared acaricide concentrations were then sprayed onto the discs and allowed to dry. The untreated check group was treated with distilled water only. Egg hatching rates were recorded on the third, fourth, fifth, and sixth days after treatment. Throughout the experiment, the leaf discs were kept moist and replaced as needed.

Statistical analysis:

The mortality rate of eggs, immatures, and matures of the tested acari was estimated and corrected according to the formula (Abbott, 1925) as follows:

$$\text{Mortality \%} = \frac{(\text{Mortality\% of treated acari} - \text{Mortality\% of control}}{(100 - \text{Mortality \% of control})} \times 100$$

The LC_{50}, chi-square ($\chi 2$), fiducial limits, and slope values were estimated using probit analysis (Finney, 1971) with Ldp line software, as described by (Bakr, 2000). (Available from: https://www.ehabsoft.com/).

RESULTS

Bioassay studies

Bioassay studies were conducted to determine LC_{50} and to evaluate the toxicity of seven acaricides against the developmental stages (mature, immature, and egg stages) of *T. urticae* under laboratory conditions. The tested acaricides were abamectin (Crater®), bifenazate (Acramite®), chlorfenapyr (Challenger®), etoxazole (Baroque®), fenbutatin oxide (Damper®), fenpyroximate (Ortus®), and pyridaben (Sanmite®), which mostly differed in their chemical group, specific targeted mite stage, and mode of action.

Toxicity of the tested acaricides on *T. urticae* developmental stages:

Against the adults:

Data in Table 1 showed that the toxicity of seven acaricides against adult *Tetranychus urticae* was evaluated over 144 hours, revealing distinct time-dependent efficacy patterns.

At 24 hours post-treatment, chlorfenapyr showed the highest toxicity (LC_{50} = 10.07 µg ml^{-1}), followed by fenpyroximate (12.60 µg ml^{-1}) and bifenazate (16.98 µg ml^{-1}). Abamectin (22.70 µg ml^{-1}) and fenbutatin oxide (19.0 µg ml^{-1}) exhibited moderate efficacy, while pyridaben and etoxazole were the least effective revealing high LC_{50} of 33.54 and 100.24 µg ml^{-1}, respectively. Tawfik & Elgohary (2015)

At 48 hours, toxicity increased for most acaricides. Chlorfenapyr maintained its leading efficacy (LC_{50} = 7.10 µg ml^{-1}), with fenpyroximate (LC_{50} = 7.36 µg ml^{-1}) and abamectin (LC_{50} = 12.06 µg ml^{-1}) showing notable improvements. Etoxazole, though still the slowest acting, began to display reduced LC_{50} value of 62.68 µg ml^{-1}.

At 72, 96, and 120 hours, efficacy trends became more pronounced. Chlorfenapyr, fenpyroximate, and fenbutatin oxide emerged as the most effective compounds, while abamectin demonstrated strong delayed toxicity. Etoxazole and pyridaben continued to lag but showed gradual improvements. Dose-response reliability remained consistently high throughout this period.

At 144 hours, all acaricides reached their peak cumulative toxicity. Abamectin showed the highest overall efficacy (LC_{50} = 0.83 µg ml^{-1}), a 27-fold improvement from its 24-hour value, followed closely by chlorfenapyr (0.75 µg ml^{-1}) and fenpyroximate (0.87 µg ml^{-1}). Fenbutatin oxide exhibited significant delayed toxicity, while etoxazole and pyridaben remain the least effective, despite some progress.

In conclusion, the results illustrated the importance of considering time-dependent toxicity in acaricide selection, with abamectin, chlorfenapyr, and fenpyroximate offering the most robust control against adult *T. urticae* over extended periods. The rapid-knockdown agents (chlorfenapyr, fenpyroximate) were optimal for acute infestations, while the delayed-action

compounds (bifenazate, pyridaben, abamectin, fenbutatin oxide, etoxazole) proved superior in extended toxicity scenarios. Although etoxazole acted slowly, it resulted in a 23-fold decrease in LC_{50}, reducing the value from 100.24 to 4.41 µg ml^{-1} over 144 hours. Moreover, most compounds demonstrated strong dose-response relationships (R^2 ranged between 0.97 and 0.99) along the bioassay intervals, confirming result reliability.Several reports, such as Weidong (2002), found that the LC_{50} values of abamectin ranged between 0.122 and 7.656 mg/L on the eggs and adults of *T. urticae*. Abamectin has been shown to be more effective than other compounds at reducing the mite population at all dosages. The difference may be because of the GABA-agonist mechanism of action and the translaminar efficacy that offers long-lasting effectiveness against feeding mites. Saber et al. (2018) found that the LC_{25} values of abamectin and pyridaben (0.04, and 136.96 µg/ml, respectively) were used for sublethal studies.

Table 1: Comparative toxicity of some acaricides against susceptible *T. urticae* adults under laboratory conditions.

Treatment	T.(h) (hours)	LC_{50} (µg/ml^{-1}) (Fiducial Limits)	Slope ± SE	χ^2 (df)	h	g	R^2
Abamectin	24	22.70 (18.0 -27.80)	1.07 ± 0.07	5.60 (7)	0.80	0.02	0.99
	48	12.06 (9.80-14.97)	1.01 ± 0.07	5.36 (7)	0.77	0.02	0.99
	72	7.29 (5.98-8.87)	1.09 ± 0.07	5.82 (7)	0.83	0.01	0.99
	96	5.38 (4.39-6.56)	1.07 ± 0.07	8.13 (7)	1.16	0.02	0.98
	120	1.65 (1.13-2.23)	0.79 ± 0.09	4.59 (5)	0.92	0.05	0.97
	144	0.83 (0.42-1.28)	0.66 ± 0.11	0.74 (4)	0.19	0.10	0.99
Bifenazate	24	16.98 (13.85-21.13)	1.06 ± 0.07	4.16 (7)	0.59	0.016	0.99
	48	11.73 (9.54-14.44)	1.07 ± 0.08	3.07 (7)	0.51	0.0196	0.99
	72	9.51(7.87-11.51)	1.14 ± 0.07	4.46 (7)	0.64	0.0141	0.99
	96	7.61(6.32-9.16)	1.17 ± 0.07	5.76 (7)	0.82	0.0137	0.99
	120	5.64(4.60-6.88)	1.09 ± 0.07	8.75 (7)	1.25	0.0158	0.99
	144	4.29(3.57-5.14)	1.27 ± 0.08	9.7951(6)	1.6336	0.0161	0.98
Chlorfenapyr	24	10.07(8.39 -12.14)	1.19 ± 0.07	1.86 (7)	0.27	0.01	1.00
	48	7.10(5.86-8.58)	1.14 ± 0.07	8.81 (7)	1.26	0.01	0.99
	72	5.39(4.45-6.49)	1.14 ± 0.07	10.97 (7)	1.57	0.01	0.98
	96	3.66(3.00-4.42)	1.19 ± 0.07	9.44 (7)	1.35	0.01	0.99
	120	1.85(1.45-2.30)	1.13 ± 0.08	2.58 (6)	0.43	0.02	0.99
	144	0.75(0.49-1.02)	1.01 ± 0.12	3.74 (4)	0.94	0.05	0.97
Etoxazole	24	100.24(80.93 -126.54)	1.02 ± 0.07	4.64 (7)	0.66	0.02	0.99
	48	62.68(51.63-76.66)	1.11 ± 0.07	4.99 (7)	0.71	0.01	0.99
	72	43.60(35.69-53.35)	1.06 ± 0.07	7.55 (7)	1.08	0.02	0.98
	96	22.36(11.00-40.61)	1.08 ± 0.08	7.315(7)	1.045	0.18	0.98
	120	8.83(6.56-11.37)	0.95 ± 0.08	4.84 (6)	0.81	0.03	0.99
	144	4.41(3.10-5.86)	1.02 ± 0.08	1.46 (6)	0.24	0.02	0.99
Fenbutatin Oxide	24	19.0(15.1-24.3)	0.90 ± 0.07	7.50 (7)	1.10	0.01	1.00
	48	12.74(10.23-16.03)	0.95 ± 0.07	7.57 (7)	1.08	0.02	0.99
	72	5.93(4.82-7.26)	1.05 ± 0.07	8.65 (7)	1.24	0.02	0.99
	96	4.69(3.82-5.70)	1.08 ± 0.07	6.88 (7)	0.98	0.01	0.98
	120	2.75(2.16-3.43)	1.02 ± 0.08	3.27 (6)	0.54	0.02	0.99
	144	1.68(1.20-2.22)	0.86 ± 0.11	1.62 (4)	0.41	0.06	0.99
Fenpyroximate	24	12.60(10.23-15.67)	1.01 ± 0.07	4.18 (7)	0.60	0.02	0.99
	48	7.36(5.99-9.03)	1.04 ± 0.07	7.63 (7)	1.09	0.02	0.98
	72	5.60(4.59-6.79)	1.11 ± 0.07	8.86 (7)	1.27	0.01	0.98
	96	3.66(3.00-4.41)	1.19 ± 0.08	4.13 (7)	0.59	0.01	0.99
	120	1.47(1.11-1.86)	1.06 ± 0.08	2.80 (6)	0.47	0.02	0.99
	144	0.87(0.62-1.14)	1.10 ± 0.10	2.07 (5)	0.41	0.03	0.99

Pyridaben	**24**	33.54(27.90-40.46)	1.12 ± 0.06	12.83 (7)	1.43	0.01	0.99
	48	30.0(27.76-37.77)	0.92 ± 0.05	6.34 (7)	0.70	0.01	0.99
	72	18.13(14.69-22.35)	0.94 ± 0.05	8.16 (7)	0.91	0.01	0.98
	96	10.57(8.56-12.99)	0.99 ± 0.06	2.34 (7)	0.29	0.01	0.99
	120	5.81(4.69-7.11)	1.05 ± 0.07	5.56 (7)	0.79	0.02	0.99
	144	4.03(3.16-5.04)	0.98 ± 0.07	10.09 (6)	1.68	0.02	0.97

LC_{50}: median lethal concentration (concentration until death 50%), (X^2) chi-square, (df) degrees of freedom, (SE) standard error, (h) heterogeneity factor, (g) value goodness of fit, and (R^2) the coefficient of determination.

Furthermore, Maleknia et al. (2016) found that fenpyroximate was the most effective tested acaricide, showing the lowest LC_{50} values (1.59-2.32 mg/L). In addition, Fatemi et al. (2021) found that abamectin and fenproxymate showed the highest toxicity for *T. urticae* adult females with LC_{50}s of 1.61 and 1.16 mg ai/L, respectively. Moreover, Hosny et al. (2010) showed that the LC_{50} values of abamectin against *T. urticae* adults were 0.03 mg/L, which supports our findings.

Alpkent & Ferizli (2024) referred to the LC_{50} values as 156 mg/L for pyridaben and 0.4 mg/L for abamectin against adults of *T. urticae*. With the same average efficacy rate as our results, Abdel-Wali et al. (2012) found that chlorfenapyr demonstrated high efficacy, with 92–98% mortality after one day and 48–68% after 15 days. Arain (2015) found that the highest LC_{50} values of pyridaben (Sanmite)® 15% EC were 29.85 on the first day and 11.34 mg/L for the second and third days after the application on adults of *T. urticae*.

4.1.1.1. Against the immatures

Data in Table 2 illustrates the toxicity of the acaricides against the immature stage of *T. urticae* over a 144-hour period, showing clear time-dependent efficacy. At 24 hours, bifenazate was the most toxic (LC_{50} = 9.44 µg ml^{-1}), followed by chlorfenapyr, fenpyroximate, and fenbutatin oxide (10.45, 12.28, and 14.08 µg ml^{-1}, respectively). Abamectin showed moderate initial toxicity (22.05 µg ml^{-1}), while etoxazole (52.35 µg ml^{-1}) and pyridaben (54.54 µg ml^{-1}) were the least effective.

At 48 hours, toxicity increased for all acaricides. Bifenazate maintained its leading efficacy (LC_{50} = 6.46 µg ml^{-1}), with chlorfenapyr and fenpyroximate remaining highly effective. Abamectin showed a notable 50% improvement, while etoxazole and pyridaben, though still lagging, demonstrated reduced LC_{50} values.

At 72, 96, and 120 hours, the efficacy trends intensified. Bifenazate, chlorfenapyr, and fenpyroximate sustained their strong performance, while abamectin and fenbutatin oxide exhibited significant delayed toxicity, showing 4-fold improvements by 96 hours. Etoxazole, consistent with its growth-inhibiting mode of action, progressed slowly but steadily, and pyridaben displayed moderate activity.

At the end of the 144-hour period, all acaricides reached their peak cumulative toxicity. Bifenazate achieved the highest overall efficacy (LC_{50} = 0.71 µg ml^{-1}), a 13-fold improvement from its initial value. Chlorfenapyr, fenpyroximate, abamectin, and fenbutatin oxide also demonstrated remarkable late-time potency, achieving LC_{50} values of 1.56, 1.14, 1.30, and 1.66 µg ml^{-1}, respectively, with a range of 13 and 17-fold and progressive improvements over those obtained at 24 hours. Etoxazole, though still the slowest acting, showed substantial enhancement, while pyridaben exhibited moderate residual efficacy.

Table 2.: Comparative toxicity of some acaricides against susceptible *T. urticae* immatures under laboratory conditions.

Treatment	T.(h) (hours)	LC_{50} (µg/ml^{-1}) (Fiducial Limits)	Slope ± SE	χ^2 (df)	h	g	R^2
Abamectin	**24**	22.05(18.17--27.18)	1.18 ± 0.07	0.96 (7)	0.14	0.02	1.00
	48	11.05(8.99-13.68)	1.02 ± 0.07	6.67(7)	0.95	0.02	0.99
	72	8.24(6.67-10.19)	0.99 ± 0.07	6.77(7)	0.97	0.02	0.99
	96	5.69(4.58-7.01)	1.00 ± 0.07	7.78(7)	1.11	0.02	0.99
	120	2.50(1.05-4.95)	1.07 ± 0.10	16.3(6)	4.07	0.23	0.93
	144	1.30(0.87-1.77)	0.82 ± 0.11	2.86(6)	0.72	0.07	0.98
Bifenazate	**24**	9.44(7.75-11.54)	1.07 ± 0.07	2.64(7)	0.38	0.02	1.00

	48	6.46(5.33-7.81)	1.13 ± 0.07	3.74(7)	0.53	0.10	0.99
	72	5.27(4.23-6.50)	1.02 ± 0.07	8.43(7)	1.20	0.02	0.99
	96	3.65(2.98-4.42)	1.16 ± 0.07	3.13(7)	0.45	0.01	0.99
	120	0.96(0.72-1.22)	1.22 ± 0.12	3.43(4)	0.86	0.04	0.98
	144	0.71(0.49-0.92)	1.25 ± 0.15	2.42(3)	0.81	0.06	0.98
Chlorfenapyr	**24**	10.45(8.74-12.53)	1.23 ± 0.07	0.84(7)	0.12	0.01	1.00
	48	6.95(5.70-8.45)	1.09 ± 0.07	4.11(7)	0.59	0.01	0.99
	72	6.06(4.98-7.34)	1.12 ± 0.07	4.24(7)	0.61	0.01	0.99
	96	4.96(3.97-6.13)	1.01 ± 0.07	7.39(7)	1.06	0.02	0.99
	120	2.70(2.15-3.32)	1.09 ± 0.08	7.17(6)	1.20	0.02	0.98
	144	1.56(1.15-2.01)	0.97 ± 0.10	2.98(5)	0.60	0.03	0.99
Etoxazole	**24**	52.35(42.99-64.04)	1.08 ± 0.07	2.59(7)	0.37	0.02	0.99
	48	34.03(27.89-41.42)	1.09 ± 0.07	4.00(7)	0.57	0.01	0.99
	72	30.10(24.43-36.95)	1.06 ± 0.07	10.08(7)	1.44	0.02	1.00
	96	21.51(17.82-25.75)	1.24 ± 0.07	4.80(7)	0.69	0.01	0.99
	120	9.31(7.08-11.80)	1.00 ± 0.08	8.29(6)	1.38	0.02	0.97
	144	6.11(4.46-7.88)	1.04 ± 0.09	4.06(5)	0.81	0.03	0.99
Fenbutatin Oxide	**24**	14.08(11.51-17.39)	1.06 ± 0.07	7.89(7)	1.13	0.02	0.99
	48	11.64(9.41-14.51)	0.98 ± 0.07	7.43(7)	1.06	0.02	0.99
	72	7.86(6.43-9.60)	1.07 ± 0.08	3.97(7)	0.57	0.02	0.99
	96	4.98(4.17-5.93)	1.29 ± 0.08	5.91(7)	0.84	0.01	0.99
	120	3.41(2.74-4.20)	1.10 ± 0.08	2.44(6)	0.41	0.02	0.99
	144	1.66(1.26-2.11)	1.03 ± 0.09	0.42(4)	0.08	0.03	1.00
Fenpyroximate	**24**	12.28(9.88-15.42)	0.96 ± 0.07	3.23(7)	0.46	0.02	0.99
	48	8.11(6.66-9.88)	1.08 ± 0.07	5.71(7)	0.82	0.01	0.99
	72	6.05(4.98-7.32)	1.13 ± 0.07	1.56(7)	0.22	0.01	1.00
	96	4.73(3.91-5.67)	1.21 ± 0.07	3.68(7)	0.53	0.01	0.99
	120	2.14(1.64-2.70)	1.01 ± 0.09	9.05(6)	1.51	0.02	1.00
	144	1.14(0.88-1.42)	1.27 ± 0.11	1.93(5)	0.39	0.03	1.00
Pyridaben	**24**	54.54(45.21-66.07)	1.08 ± 0.05	12.4(7)	1.24	0.01	0.98
	48	30.68(24.88-37.95)	1.02 ± 0.05	14.0(7)	1.75	0.01	0.98
	72	16.72(13.81-20.28)	1.09 ± 0.06	11.0(7)	1.38	0.01	0.99
	96	10.10(7.11-14.36)	1.13 ± 0.07	15.7(7)	2.24	0.05	0.98
	120	6.10(3.46-10.12)	1.00 ± 0.07	28.1(7)	4.01	0.09	0.95
	144	1-6.674)	0.96 ± 0.07	17.362(6)	2.89	0.10	0.958

LC_{50}: median lethal concentration (concentration till death 50%), (X^2) chi-square, (df) degrees of freedom, (SE) standard error, (h) heterogeneity factor, (g) value goodness of fit, and (R^2) the coefficient of determination.

In conclusion, bifenazate was the most initially toxic, followed by chlorfenapyr, fenpyroximate, and fenbutatin oxide, revealing LC_{50} values of 9.44, 10.45, 12.28 µg ml^{-1}, and 14.08, respectively. Abamectin showed moderate initial toxicity, while etoxazole and pyridaben were the least effective. However, bifenazate achieved the highest overall efficacy (LC_{50} = 0.71 µg ml^{-1}), a 13-fold improvement from its initial value. Chlorfenapyr, fenpyroximate, abamectin, and fenbutatin oxide also demonstrated remarkable late-stage potency, and progressive improvements ranged between 13- and 17-fold. Etoxazole was still the slowest acting, showing substantial enhancement, while pyridaben exhibited moderate residual efficiency. All compounds exhibited strong dose-response relationships (R^2) ranged between 0.97 and 0.98), confirming the reliability of the results.

These results support the use of time-stratified rotation programs to improve mite control and resistance management, and they emphasize the significance of taking into account both immediate and long-term toxicity when choosing acaricides.

These findings concur with those of Taha (2017) and Ochiai et al. (2007), who discovered that etoxazole was successful in managing the larval stage of *T. urticae*. The highest mortality in the immature stage of *T. urticae* was observed at a concentration of 0.50 mL/L after 72 hours of treatment, which was 94%. The effect of fenpyroximate increased with

increasing concentration and duration (Hanash et al., 2020). Bifenazate totally inhibited the development of immature *T. urticae*, preventing it from progressing to the nymphal stage, according to Kim & Yoo (2002).

4.1.1.2. Against the eggs

Table 3 presents the toxicity of seven acaricides against *T. urticae* eggs, revealing distinct time-dependent toxicity patterns across three periods of 96, 120, and 144 hours of exposure. At 96 hours of post-treatment, bifenazate, fenbutatin oxide, and fenpyroximate demonstrated the highest toxicity against *T. urticae* eggs, with LC_{50} values of 8.76, 8.51, and 9.89 µg ml^{-1}, respectively. Chlorfenapyr showed moderate efficacy (LC_{50} = 13.23 µg ml^{-1}), while abamectin was less effective (LC_{50} = 17.89 µg ml^{-1}). Etoxazole and pyridaben exhibited the lowest toxicity, requiring substantially higher concentrations for 50% mortality.

All acaricides exhibited increased ovicidal activity at 120 hours. The most efficient compounds were fenpyroximate and fenbutatin oxide, w56

120 hours LC_{50} values dropped to 6.61 and 6.59 µg ml^{-1}, respectively. While abamectin an chlorfenapyr demonstrated moderate to negligible improvements, bifenazate consistently maintained high toxicity (LC_{50} = 8.31 µg ml^{-1}). Pyridaben showed a significant relative improvement, but it was still one of the least toxic compounds. Etoxazole showed some progressive toxic activity.

At 144 hours, ovicidal activity reached peak efficacy. Fenbutatin oxide emerged as the most toxic compound (LC_{50} = 5.29 µg ml^{-1}), followed closely by fenpyroximate (LC_{50} = 5.97 µg ml^{-1}). Bifenazate demonstrated stable long-term efficacy, while abamectin and chlorfenapyr showed progressive toxicity. Etoxazole, despite a 36% total reduction of its 96-hour LC_{50}, remained the least effective compound, while pyridaben showed substantial late-stage activity with a 63% total toxicity increase from 96 hours.

All bioassays demonstrated excellent dose-response relationships (R^2 = 0.99:1.00), confirming the reliability of the results. The results show that fenbutatin oxide and fenpyroximate had the highest initial ovicidal activity, with LC_{50} values of 5.29 and 5.97 µg ml^{-1}. They also showed strong delayed ovicidal activity (5.29 and 5.97 µg ml^{-1}), which makes them especially useful for integrated mite management programs that target egg stages.

Table 3. Comparative toxicity of some acaricides against susceptible *T. urticae* eggs under laboratory conditions.

Treatment	T.(h) (hours)	LC_{50} (µg/ml^{-1}) (Fiducial Limits)	Slope ± SE	χ^2 (df)	h	g	R^2
Abamectin	96	17.89(14.94-21.64)	1.25 ± 0.08	0.90(7)	0.13	0.01	1.00
	120	14.06(11.92-16.66)	1.39 ± 0.08	5.00(7)	0.71	0.01	0.99
	144	11.51(9.72-13.67)	1.33 ± 0.08	3.62(7)	0.52	0.01	0.99
Bifenazate	96	8.76(7.35-10.46)	1.26 ± 0.08	5.52(7)	0.79	0.01	0.99
	120	8.31(6.97-9.92)	1.26 ± 0.08	6.35(7)	0.91	0.01	0.99
	144	8.02(6.63-9.77)	1.18 ± 0.08	2.17(6)	0.36	0.02	1.00
Chlorfenapyr	96	13.23(10.91-16.17)	1.12 ± 0.07	7.81(7)	1.12	0.01	0.99
	120	13.01(10.70-15.96)	1.10 ± 0.07	9.22(7)	1.32	0.02	0.99
	144	11.50(9.48-14.03)	1.11 ± 0.07	8.80(7)	1.26	0.01	0.99
Etoxazole	96	52.98(44.08-63.92)	1.18 ± 0.07	7.40(7)	1.06	0.01	0.99
	120	42.82(35.86-51.19)	1.26 ± 0.07	3.55(7)	0.51	0.01	0.99
	144	33.64(27.97-40.59)	1.23 ± 0.08	2.25(6)	0.37	0.02	1.00
Fenbutatin Oxide	96	8.51(6.98-10.37)	1.08 ± 0.07	2.97(7)	0.42	0.01	1.00
	120	6.59(5.45-7.94)	1.16 ± 0.07	2.75(7)	0.39	0.01	1.00
	144	5.29(4.40-6.35)	1.25 ± 0.08	3.45(6)	0.57	0.02	0.99
Fenpyroximate	96	9.89(8.20-11.96)	1.15 ± 0.07	2.96(7)	0.42	0.01	1.00
	120	6.61(5.38-8.09)	1.04 ± 0.07	6.04(7)	0.86	0.02	0.99
	144	5.97(4.87-7.28)	1.09 ± 0.07	3.51(7)	0.50	0.02	0.99
Pyridaben	96	46.59(33.30-66.97)	0.98 ± 0.05	18.81(9)	2.09	0.03	0.97
	120	29.86(23.80-38.41)	0.98 ± 0.07	1.02(8)	0.15	0.02	1.00
	144	17.32(14.28-21.05)	1.08 ± 0.06	5.06(8)	0.63	0.01	0.99

LC_{50}: median lethal concentration (concentration till death 50%), (X^2) chi-square, (df) degrees of freedom, (SE) standard error, (h) heterogeneity factor, (g) value goodness of fit, and (R^2) the coefficient of determination.

The results are aligned with Ochiai et al. (2007), who found that etoxazole was highly effective in controlling the egg stage of *T. urticae*. Similarly, Kim & Yoo (2002) found that the LC_{50} of abamectin and bifenazate were 0.56 ml/L and 0.81 ml/L, respectively, suggesting that the tested acaricides were effective against eggs and adult females of the *T. urticae*. The calculated LC_{50} of etoxazole (3.99 ml/L) was more effective against the egg stage of *T. urticae* (Basak et al., 2021). Fenpyroximate was the most toxic compound against the egg stage of spider mite *T. urticae,* with LC_{50} values of 3.98 and 8.54 ppm (Derbalah et al., 2013).

In conclusion, the challenge of establishing a successful program for controlling plant mites stems from reliance on a limited number of acaricides, their repeated use, the development of resistance, and the inability to select the appropriate acaricide based on the severity of the infestation and the current stage of the mites.

The obtained results proved that the toxicity of the tested acaricides varied due to their chemical composition, mode of action, and their specificity on the target acari stage. Although some acaricides had similar modes of action, they differed in toxicity levels because of variations in their chemical composition and specificity for the targeted stage. The results also indicated that some acaricides had acute toxicity, which could be suitable for controlling severe infestations, while other acaricides had a prolonged toxicity, which is ideal for long-term control, and some pesticides exhibit higher specificity for certain stages than others.

These results support the use of time-stratified rotation programs to improve mite control and resistance management, emphasizing the importance of considering both immediate and long-term toxicity, as well as specificity, when selecting acaricides for developing an IPM strategy to control polyphagous acari.

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المستخلص العربي

الانتقائية والسمية المعتمدة على الزمن لبعض المبيدات الأكاروسية ضد الأطوار التطورية لأكاروس العنكبوت الأحمر ذو البقعتين *Tetranychus urticae* Koch (Acari: Tetranychidae)

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تم إجراء دراسات الاختبار الحيوي لتحديد الجرعة المركزة المميتة لنسبة 50% من الكائنات وتقييم السمية لسبعة مبيدات أكاروسية ضد الأطوار التطورية للعنكبوت الأحمر ذو البقعتين (*T. urticae*) تحت الظروف المعملية.

أظهرت النتائج الأهمية البالغة لمراعاة السمية المعتمدة على الزمن في اختيار المبيد الأكاروسي، حيث حققت مبيدات الأبامكتين والكلورفينابير الفينبيروكسيمات أعلى قدرة على المكافحة ضد الأكاروسات البالغة لفترات ممتدة.

كانت المبيدات سريعة التأثير (الكلورفينابير والفينبيروكسيمات) الأمثل في حالات الإصابة الشديدة، بينما تفوقت المركبات متأخرة المفعول (البيفينازات والبيريدابين والأبامكتين والفينبيوتاتين أوكسيد والإيتوكسازول) في سيناريوهات السمية الممتدة.

على الرغم من البطء النسبي في عمل الإيتوكسازول، إلا أنه أدى إلى انخفاض قيمة الجرعة المميتة لنصف العشيرة من 100.24 إلى 4.41 ميكروغرام/مل خلال 144 ساعة.

في الطور غير البالغ، سجل البيفينازات أعلى سمية ابتدائية، يليه الكلورفينابير والفينبيروكسيمات والفينبيوتاتين أوكسيد، حيث بلغت قيمة الجرعة المميتة لنصف العشيرة على التوالي9.44، 10.45، 12.28، و14.08 ميكروغرام/مل.

أظهر الأبامكتين سمية ابتدائية متوسطة، بينما كان الإيتوكسازول والبيريدابين الأقل فعالية.

ومع ذلك، حقق البيفينازات أعلى سمية على المدى الطويل قيمة الجرعة المميتة لنصف العشيرة (0.71ميكروغرام/مل)، بمقدار تحسن يصل إلى 13 ضعفاً مقارنة بقيمته الابتدائية.

كما أظهرت مبيدات الكلورفينابير والفينبيروكسيمات والأبامكتين والفينبوتاتين أوكسيد فعالية ملحوظة في الفترات المتأخرة، مع تحسن تدريجي تراوح بين 13 و17 ضعفاً.

سجل الإيتوكسازول أبطأ تحسن ملحوظ، بينما أظهر البيريدابين سمية متأخرة متوسطة.

في طور البيضة، سجل الفينبيوتاتين أوكسيد والفينبيروكسيمات أعلى نشاط قاتل حاد للبيض، بقيمة الجرعة المميتة لنصف العشيرة بلغت 5.29 و5.97 ميكروغرام/مل على التوالي.

كما أظهرا نشاطاً قاتلاً متأخراً قوياً للبيض (بنفس القيم السابقة)، مما يجعلهما خياراً مثالياً في برامج الإدارة المتكاملة للعنكبوت الأحمر ذو البقعتين التي تستهدف أطوار البيض.

وتدعم هذه النتائج تطبيق برامج المكافحة المعتمدة على التناوب الزمني في استخدام المبيدات لتحسين السيطرة على الأكاروس وإدارة مقاومته، كما تؤكد على أهمية مراعاة كل من السمية الفورية والممتدة إضافةً إلى الانتقائية عند اختيار المبيد الأكاروسي المناسب.