Pol. J. Environ. Stud. Vol. XX, No. X (XXXX), 1-10
DOI: *10.15244/pjoes/205260* ONLINE PUBLICATION DATE: 2025-07-21

Original Research

Efficacy of some Acaricides Against *Tetranychus urticae* Koch on *Phaseolus vulgaris* Plants

Rancy El-Demerdash[1], Attiah Keratum[2], Maryam M. Alomran[3], Nadi A. Al-Harbi[4], Mervt Almostafa[5], Khaled Abdelaal[6O]*, Mohammed Abdelmohssen[2], Hassan El-Nenaey[1], El-Sayeda El-Kasser[1]

[1]Plant Protection Research Institute, Agricultural Research Center, Egypt
[2]Pesticides Chemistry and Toxicology Department, Faculty of Agriculture Kafer El Sheikh University, Egypt
[3]Department of Biology, College of Science, Princess Nourah bint Abdulrahman University, P.O. Box 84428, Riyadh 11671, Saudi Arabia
[4]Biology Department, University College of Tayma, University of Tabuk, Tabuk 47512, Saudi Arabia.
[5]Department of Chemistry, College of Science, King Faisal University, Al-Ahsa 31982, Saudi Arabia
[6]EPCRS Excellence Center, Plant Pathology and Biotechnology Lab., Faculty of Agriculture, Kafrelsheikh University, 33516, Egypt

Received: 10 February 2025
Accepted: 17 May 2025

Abstract

Overcoming the bulk of the challenges posed by using ordinary pesticides necessitates employing developed, safe, distinctive, and selective chemicals. Because of their clear mechanism of action on pests and lower toxicity to vertebrates than traditional pesticides, the effects of the new reduced-risk acaricides abamectin, fenpyroximate, and chlorfenapyr against the two-spotted spider mite, *Tetranychus urticae* Koch, were evaluated under laboratory and field conditions. The effects on development and life table parameters were also studied under laboratory conditions. Abamectin was the most toxic to *T. urticae* females, followed by fenpyroximate and chlorfenapyr with LC_{50} values of 0.01, 19.86, and 29.66 mg a.i./L, respectively. Under field conditions, abamectin, fenpyroximate, and chlorfenapyr, respectively, caused a significant difference in the mean reduction percentage of *T. urticae* on *Phaseolus vulgaris* in 2020 (92.83, 86.57, and 80.43); nevertheless, in 2021 the differences were not significant (86.85, 80.38, and 76.13). Fenpyroximate-treated females had the highest egg, total immature, and postoviposition durations. Females treated with abamectin showed the longest durations of deutonymph, preoviposition, and female longevity. Chlorfenapyr was the most effective in reducing the net reproductive rate, intrinsic rate of natural increase, finite rate of increase, and female sex ratio. The present study revealed that these acaricides (abamectin, fenpyroximate, and chlorfenapyr) can alternatively be used for effective and sustainable management of the mites.

Keywords: toxicity effect, *Tetranychus urticae*, chemical control, development, life table parameters

*e-mail: khaled.elhaies@gmail.com
°ORCID iD: 0000-0001-7295-6560

Introduction

The kidney bean, *Phaseolus vulgaris* L., is an annual leguminous plant (Family: Fabaceae). It is one of the most important economic vegetable crops cultivated in many countries worldwide [1]. Yield production suffers from many stresses [2-6], such as drought [7], salinity [8, 9], and biotic stress, including plant diseases [10-12] and insects [13, 14]. Kidney bean plants are liable to infestation by many phytophagous pests, such as mites. The two-spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae), is a pest of more than 1100 plant species. Controlling *T. urticae* with acaricides is challenging because of its high reproduction rate and easy development of acaricide resistance. [15-18]. This pest lowers the quality and quantity of the host plant yield by sucking out the cell contents of the leaf, causing death in heavy infestations. The main method for mite control is chemical acaricide [19, 20]. *Tetranychus urticae* Koch is the most harmful pest to many plants globally [21]. Abamectin (Vertimec 1.8 EC) acaricide's acaricidal efficacy at various concentrations, where the LC_{50} values were 1.02, 2.74, and 1.65 after one day, two days, and three days, respectively. Furthermore, adult fecundity, repellency, and hatchability under Vertimec varied substantially with concentration [21]. Overcoming or reducing the majority of difficulties caused by using common pesticides requires using developed, secure, unique, and selective organic compounds. Due to their clear mechanism of action on pests and lower poisonousness towards vertebrates than conventional insecticides, juvenile hormone analogs appear promising as an example of insect growth regulators [22]. The latent effects of the examined synthesized compounds on various biological parameters, including adult longevity, pupal weight, proportion of normal adult emergence, and egg hatchability, were evaluated in an additional effort to improve insecticidal compounds slightly. Seven target synthesized compounds were subjected to a molecular docking analysis against glutamate-activated chloride channels. Twelve artificial compounds with the PDB ID of 4COF were subjected to a molecular docking study against the gamma-aminobutyric acid receptor (GABA) [23]. Environmental pollutants and climate change are the major causes of abiotic stresses. Ahmad et al. 2022 [24]. Pesticides are mainly used to protect crop plants from pests and pest-transmitted diseases. However, the active ingredients of the pesticides are also a source of crop toxicity and food contamination. The persistent nature of the chemicals makes them stable against environmental degradation processes, and they continue to be in the form of pesticide residues in different plant tissues. Pesticides are mainly used to protect crop plants from pests and pest-transmitted diseases. However, the active ingredients of the pesticides are also a source of crop toxicity and food contamination. The persistent nature of the chemicals makes them stable against environmental degradation processes, and they continue to be in the form of pesticide residues in different plant tissues [25].

Abamectin (avermectin B1) belongs to the macrocyclic lactones [26]; it is one of the most commonly applied for pest control because of its broad-spectrum action [27, 28]. It is the major fermentation component of avermectins derived from a soil actinomycete (*Streptomyces avermitilis*) with strong insecticidal, nematicidal, and acaricidal activity [29]. Abamectin is a risk-reducing neuroactive pesticide (chloride channel activator) [30]. Fenpyroximate (pyrazole), which causes inhibition of mitochondrial electron transport at complex I, shows high efficacy with a quick knockdown effect against both tetranychid and eriophyid mites. Under the application of fenpyroximate, a significant reduction was recorded in the intrinsic rate, net reproductive rate, and finite rate of increase; however, the mean generation time in the LC_{10} treatment was lower than that in the other treatments [31]. Chlorfenapyr is a novel broad-spectrum insecticide derived from natural pyrrole derivatives produced by *Streptomyces* spp. It is a pyrrole compound, a broad-spectrum insecticide at a biochemical level, and acts as an uncoupler of oxidative phosphorylation via disruption of the proton gradient [32]. Therefore, this study aimed to evaluate the toxic effects of three new reduced-risk acaricides with different modes of action: abamectin (Vertimec 1.8% EC), chlorfenapyr (Challenger 24% SC), and fenpyroximate (Ortus 5% SC) against *T. urticae* under laboratory and field conditions associated with their effects on the developmental stages and life table parameters of *T. urticae*.

Materials and Methods

Rearing of Host Plant

Kidney bean seeds, *Phaseolus vulgaris* L. var Nebraska, were sown in seed trays until they reached 5-6 true leaves. Thereafter, the seedlings were transplanted into plastic pots containing peat moss and kept in a glass house at 27-30°C. Plants were irrigated whenever needed and kept pesticide-free during the rearing period.

Tetranychus urticae Culture

A laboratory strain of *T. urticae* was obtained from the Acarology Laboratory of the Plant Protection Research Institute, Egypt, and reared on *P. vulgaris.* var Nebraska in a growth chamber at 25±5ºC, 60±10% RH, and 12:12 L:D photoperiod for several generations before use in experiments. Bioassays were performed under the same conditions in the Virus Laboratory, Tanta Agriculture Directorate, El-Gharbia Governorate, Egypt.

Pesticides

According to IRAC [33], the Insecticide Resistance Action Committee, three reduced-risk acaricides with different modes of action were selected for the bioassay.

Abamectin: a risk-reduced neuroactive acaricide that allosterically activates glutamate-gated chloride channels (GluCls), causing paralysis.

Fenpyroximate: 21A mitochondrial complex I electron transport inhibitors inhibit electron transport complex I, preventing the utilization of energy by the cells.

Chlorfenapyr: a pyrrole compound commercialized in 1995 that, at a biochemical level, acts as an uncoupler of oxidative phosphorylation via disruption of the proton gradient. This compound is a pro-acaricide activated by N-dealkylation. Chlorfenapyr is effective against all stages of spider mites and eriophyid mites. Chlorfenapyr is included in the EPA list as an alternative to organophosphorous compounds (EPA 2011) but is not approved under Regulation 1107/2009 (EU 2011).

This study used commercial abamectin, chlorfenapyr, and fenpyroximate, which are detailed in Table 1.

Toxicity to *T. urticae* Adult Females under Laboratory Conditions

The standard method of the leaf disc dip technique described by Pree [34] was adopted. Leaf discs (2.5 cm diameter) of *P. vulgaris* L. were dipped in serial concentrations of each pesticide. Abamectin 1.8% EC (0.001, 0.01, 0.1, 1, 10) mg/mL, Fenpyroximate 5% SC (10, 20, 40, 80, 100) mg/mL, and Chlorfenapyr 24% SC (10, 20, 40, 80, 100) mg/mL for 20 seconds. Ten adult females (one day old) of *T. urticae* were transferred on each disc with a camel hair brush. Four replicates were done for each concentration. Control discs were dipped in distilled water. The treated discs were placed on a moist sponge, covered with a moist paper tissue, and kept in a growth chamber at 25±2ºC, 65±5% R.H., and 12:12 L:D photoperiod. Mortality of treated mites was recorded after 24, 48, and 72 h of exposure. Mites were considered dead when appendages did not move when probed with a fine camel hair brush.

The toxicity index was calculated according to the equation of Sun [35] as follows:

$$\text{Toxicity Index} = \frac{LC_{50} \text{ of the most effective compound} \times 100}{LC_{50} \text{ of the tested compound}}$$

Toxicity to *T. urticae* Moving Stages under Field Conditions

The experiments were carried out on 15th February 2020 and 16th February 2021 on the newly reclaimed lands of the 11th branch, Badr region, El-Beheira Governorate, Egypt, using a complete randomized block design with three replications/treatments. The total area of the experiment (700 m^2) was divided into 4 equal parts (175 m^2) for 3 acaricides and control, each part divided into 3 plots (3 replications/treatment), and the plot area was 56 m^2. Row spacing, plant spacing, and seasonal maintenance procedures were conducted following the recommended agronomic practices. The 3 pesticides at their recommended rates were sprayed by a motor sprayer (20-liter capacity) with 16.67 liters of water/175 m^2 on 22nd March; the control was sprayed with water only. Thirty leaves were taken randomly from each replicate just before and at 3, 7, and 14 days after treatment. The leaves were placed individually in paper bags and transferred to the laboratory. The moving stages of *T. urticae* were counted on the lower surface of the leaf using a stereo binocular microscope (25X). The reduction percentages of the mite population were calculated according to Henderson and Tilton [36] as follows:

$$\%\,\text{population reduction} = 100\left[1 - \frac{B \times A'}{A \times B'}\right]$$

Where, A = Number of individuals in treatment before pesticide application, A' = Number of individuals in treatment after pesticide application, B = Number of individuals in the control before pesticide application, B' = Number of individuals in the control after pesticide application.

Effects on the Developmental Stages and Life Table Parameters of *T. urticae* Females

Thirty pre-ovipositing females of *T. urticae* were placed singly each on 30 leaf discs treated with LC_{50} of 1 tested pesticide. Control discs were dipped in distilled water in 30 replications. After 24 h of exposure, the surviving females were placed individually on untreated leaf discs. The leaf discs were checked daily, and immature stages were monitored using a stereo binocular microscope (25X). Immature mites were allowed to develop to adulthood, and females were left

Table 1. Commercial abamectin, chlorfenapyr, and fenpyroximate, and their details.

Common name and formulation	Trade name	Application rate	Company
Abamectin1.8% EC	Vertimec	380.8 cm/ha	Syngenta®, Germany
Chlorfenapyr24% SC	Challenger	571.2 cm/ha	BASF® America
Fenpyroximate 5% EC	Ortus	476 cm/ha	Nichino America, Inc. (NAI), America

to deposit eggs. Leaf discs were changed every 3 to 4 days to maintain their freshness. The duration of egg incubation, larval, protonymphal, and deutonymphal developmental periods, and adult preoviposition, oviposition, and postoviposition periods were recorded. The average number of eggs/female/day and total number of eggs/female were calculated. Life table parameters of *T. urticae* were estimated using a specific age class (lx) and the offspring produced/female in each age class (mx), the net reproductive rate (R_o), the mean generation time (T), the intrinsic rate of increase (r_m), and the finite rate of increase (λ) according to Birch [37]. The mean and standard error values of demographic parameters were determined using the computer program of Abou-Setta et al. [38].

Statistical Analysis

The mortality percentage of spider mites was corrected using Abbott's [39] formula. Values of LC_{50} and LC_{90} values, along with their corresponding 95% confidence limits, were calculated by probit analysis using "Ldp line" software (http://www.ehabsoft.com/ldpline/), Bakr [40]. The standard errors between replications and significance between means of treatments were analyzed by Anova and Duncan [41] at a 5% level (confidence interval 95%) using IBM SPSS Statistics 16.

Results and Discussion

The objective of this study was to investigate the toxic effects of 3 new reduced-risk acaricides with different modes of action: abamectin (Vertimec 1.8% EC), chlorfenapyr (Challenger 24% SC), and fenpyroximate (Ortus 5% SC) in serial concentrations against *T. urticae.* Under laboratory conditions, their effects on the developmental stages and life table parameters of *T. urticae* were studied. In addition, the efficacy of abamectin, fenpyroximate, and chlorfenapyr was evaluated at the recommended rate against the moving stage of *Tetranychus urticae* under field conditions.

Toxicity to Females of *T. urticae* under Laboratory Conditions

Based on LC_{50} values, abamectin was significantly the most toxic pesticide against *T. urticae,* followed by fenpyroximate and chlorfenapyr with LC_{50} values of 0.01, 19.86, and 29.66 mg/L, respectively (Table 2). Abamectin had the highest toxicity index (100), while fenpyroximate and chlorfenapyr showed toxicity indices of 0.05 and 0.03 against *T. urticae,* respectively. Toxicity lines of abamectin (Vertimec 1.8% EC), fenpyroximate (Ortus 5% EC), and chlorfenapyr (Challenger 24% SC) against the moving stage of *Tetranychus urticae* are illustrated in Fig. 1. The obtained results agree with those of Mohamed et al. [21]; they tested abamectin (Vertimec 1.8 EC) acaricide's acaricidal efficacy at various concentrations, where the LC_{50} values were 1.02, 2.74, and 1.65 after 1 day, 2 days, and 3 days, respectively. Abdel Razik and Heikal [42] concluded that fenpyroximate was very toxic to *T. urticae*, whereas it was safer for *P. persimilis* for the spraying method. Rabbi et al. [43] stated that chlorfenapyr and abamectin can be used to manage *T. urticae* because of their high activity against *T. urticae* and low residual toxicity against *C. septempunctata*.

Toxicity to *T. urticae* under Field Conditions

Results presented in Table 3 indicate that abamectin, fenpyroximate, and chlorfenapyr, respectively, caused a significant difference ($F = 6.06$, $P = 0.036$) in the mean reduction percentage of *T. urticae* on *Phaseolus vulgaris* in 2020 (92.83, 86.57, and 80.43); nevertheless, in 2021 the differences were not significant ($F = 1.08$, $P = 0.41$), and the mean reduction percentages were (86.85, 80.38, and 76.13). The efficacy of abamectin, fenpyroximate, and chlorfenapyr against the moving stage of *Tetranychus urticae* under field conditions was illustrated in Fig. 2.

In this respect, the efficiency of the tested pesticides on *T. urticae* was estimated in several studies. Massoud et al. [44] showed that the order of acaricide efficacy against *T. urticae* was Milbemectin>Abamectin>Bi fenazate>Fenpyroximate>Hexythiazox >Ethoxazole after 72 h of treatment. Saleh et al. [45] found that

Table 2. The activity of abamectin, fenpyroximate, and chlorfenapyr on *Tetranychus urticae females* under laboratory conditions.

Pesticides	LC_{50} mg/L	95%Confidence limits		LC_{90} mg/L	95%Confidence limits		Slope ±SE	χ^2	Toxicity* index
		Lower	Upper		Lower	Upper			
Abamectin	0.01	0.004	0.026	3.5178	0.7826	43.99	0.51±0.07	0.62	100
Fenpyroximate	19.86	13.82	25.88	109.79	75.57	207.84	1.73±0.27	6.20	0.05
Chlorfenapyr	29.66	20.72	40.16	242.88	137.52	755.51	1.40±0.25	4.76	0.03

* The toxicity index was calculated with respect to abamectin as the most effective compound.

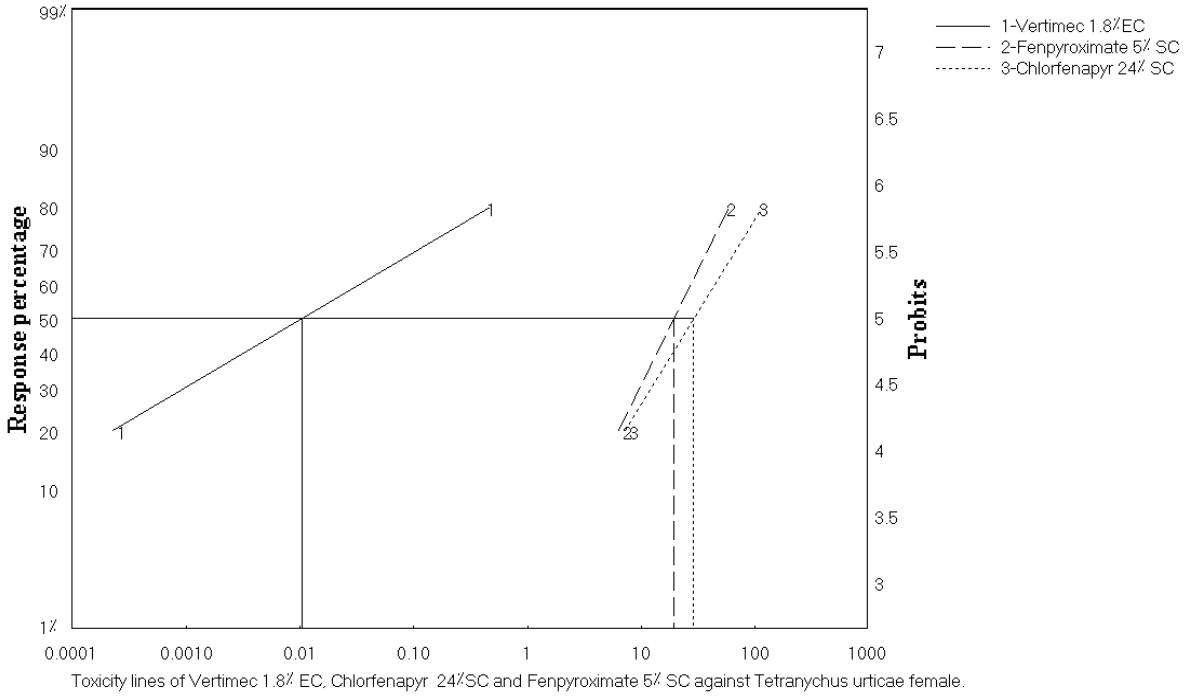

Fig. 1. Toxicity lines of abamectin (vertimec 1.8% EC), fenpyroximate (Ortus 5% EC), and chlorofenapyr (challenger 24% SC) against the moving stage of *Tetranychus urticae* under laboratory conditions.

the toxicity of acaricides could be arranged according to their potency against *T. urticae* as follows: abamectin 1.8% EC>buprofezin>abamectin 5%>chlorfenapyr> hexythiazox>fenpyroximate.

Regarding the safety of people and the environment, abamectin has demonstrated low toxicity to non-targeted beneficial arthropods, which aids in its inclusion in integrated pest management (IPM) programs [46]. Chlorfenapyr is thought to act as an uncoupler in mitochondrial oxidative phosphorylation. It obstructs the conversion of ADP to ATP, leading to an energy metabolism disorder that ultimately causes insect death. Thus, chlorfenapyr is considered an efficient, low-toxicity, target-specific, and environmentally friendly pesticide [47]. Recommended tested rates of fenpyroximate and thiacloprid negatively influenced the biological parameters of the predator *A. swirskii*. However, the combined treatment of the two pesticides

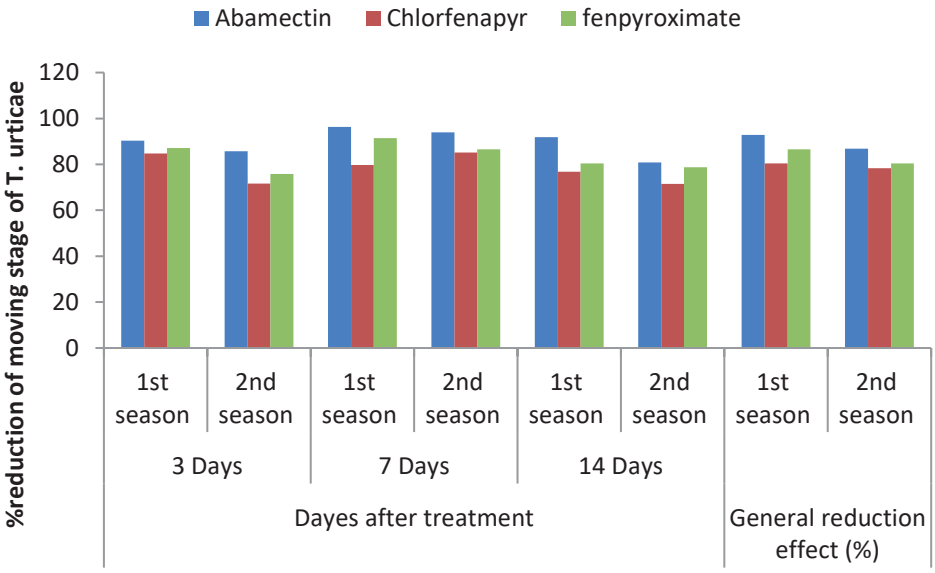

Fig. 2. Efficacy of abamectin, fenpyroximate, and chlorofenapyr against the moving stage of *Tetranychus urticae* under field conditions.

Table 3. The efficacy of abamectin, fenpyroximate, and chlorfenapyr against the moving stage of *Tetranychus urticae* under field conditions.

Treatments	% reduction of the moving stage of the two spotted spider mite in 2020 and 2021						General reduction effect (%)	
	3 days		7 days		14 days		2020	2021
	2020	2021	2020	2021	2020	2021		
Abamectin	90.28	85.76	96.36	93.92	91.86	80.87	92.83a	86.85 a
Chlorfenapyr	84.81	71.68	79.72	85.23	76.78	71.5	80.43 b	78.37 a
Fenpyroximate	87.08	75.88	91.46	86.51	80.46	78.75	86.57 ab	80.38 a
F							6.06	1.08
P							0.036	0.41
L.S.D							8.72	13.43
The degree of freedom in the numerator (df_1)							2	2
The degree of freedom in the denominator (df_2)							6	6

In the same column, the means followed by the same letters are not significantly different at the 5% level (95% confidence interval) by Duncan [41].

at reduced rates was less hazardous to *A. swirskii*. Our findings indicate that the combined use of these chemicals may be compatible with IPM programs utilizing *A. swirskii* as a biological control tool against phytophagous mites and other pests [48].

Influence on *T. urticae* Females' Developmental Stages

The results obtained in Table 4 showed that fenpyroximate resulted in the highest duration of eggs (5.63±0.13 days), total immature (11.61±0.24 days), and postoviposition (2.13±0.47 days) of *T. urticae*. Abamectin was the most effective on deutonymph duration (2.05±0.09 days) and preoviposition duration (1.63±0.18 days). However, chlorfenapyr showed the best result on oviposition duration (3.45±0.77 days), egg/female (9.45±3.6 eggs), and female longevity duration (6.09±0.94 days). *T. urticae* egg incubation periods were significantly affected longer on abamectin, fenpyroximate, and chlorfenapyr excised leaf discs (F = 97.75; LSD = 0.29; P =0 .0001), recording 5.31±0.06, 5.63±0.13, and 5.53±0.11 days, respectively. The development period of mite larvae was similar in abamectin, fenpyroximate, and chlorfenapyr treatments (F = 0.001; LSD = 0.10; P = 0.10), recording 2.03±0.37; 2.03±0.38; and 2.04±0.38 days, respectively. Protonymph developmental periods in abamectin, fenpyroximate, and chlorfenapyr treatments. (F = 0.03; LSD = 0.13; P = 0.10) were 2.04±0.43, 2.05±0.52, and 2.05±0.48 days, respectively. Furthermore, the deutonymph developmental period was significantly longer (F = 4.22; LSD = 0.26; P = 0.008) in abamectin (2.05±0.09 days) than in fenpyroximate (1.72±0.11 days) and chlorfenapyr (1.60±0.13 days). Moreover, the total development time was significantly longer (F = 3.19; LSD = 0.44; P = 0.03) in fenpyroximate (11.61±0.24 days) than in chlorfenapyr (11.30±0.18 days) and abamectin (11.26±0.13 days) treatments. Wakil et al. [49] reported that the development of *T. urticae* on both sides of tomato leaves was meaningfully prevented by applying entomopathogenic fungi treatments or abamectin compared to the control 21 days after infestation. However, a higher number of inhabited adults, immatures, and eggs were found on the abaxial surface of the leaves compared to the adaxial surface [50, 51].

The results obtained are in agreement with those obtained by Bozhgani [52]. He studied the sublethal effects of LC_{10}, LC_{20}, and LC_{30} of chlorfenapyr on demographic parameters of *T. urticae*. He stated that the egg incubation, protonymph, and deutonymph durations of both sexes were significantly reduced due to treatment with LC_{20} and LC_{30} of chlorfenapyr. In addition, the oviposition period in LC_{10} lasted 9.62 days, which was closer to the control (9.73 days), while it significantly decreased with increasing the concentration from LC_{20} to LC_{30}. Furthermore, LC_{20} and LC_{30} treatments decreased the fecundity of females by 55.5% and 61.6%, respectively.

Influence on *T. urticae* Life Table Parameters

Regarding the effect of the tested acaricides on the life table parameters of *T. urticae* females, data presented in Table 5 showed that the studied parameters were significantly acaricide-dependent. Mean generation time in days (T) was highly significantly different (F = 1194, P = 0.000); the shortest mean generation time (T) was 16.27 days on fenpyroximate, while the longest was 17.13 days on abamectin. Net reproductive rate (R_o) was highly significantly different (F = 5343.91, P = 0.000); the highest net reproductive rate (R_o) was

Table 4. The effect of acaricides on the development of *Tetranychus urticae* on *Phaseolus vulgaris* leaf discs under laboratory conditions.

Stages		Abamectin	Fenpyroximate	Chlorfenapyr	Control
Developmental duration in days (Mean±SE.)	Egg	(5.31±0.06) b N = 30	(5.63±0.13) a N = 30	(5.53±0.11) a N = 30	(3.43±0.09) c N = 30
	Larvae	(2.03±0.37) a N = 27	(2.03±0.38) a N = 26	(2.04±0.4) a N = 26	(2.03±0.36) a N = 28
	Protonymph	(2.04±0.43) a N = 23	(2.05±0.52) a N = 19	(2.05±0.48) a N = 21	(2.04±0.36) a N = 28
	Deutonymph	(2.05±0.09) a N = 19	(1.72±0.11) bc N = 18	(1.60±0.13) c N = 20	(1.92±0.05)b N = 26
	Total immature stages	(11.26±0.13) a N = 19	(11.61±0.24) a N = 18	(11.30±0.18) a N = 20	(9.38±0.09) b N = 26
	Preoviposition	(1.63±0.18) a N = 16	(1.25±0.11) b N = 16	(1.09±0.09) b N = 11	(1.2±0.09) b N = 20
	Oviposition	(6.00±0.44) b N = 16	(4.00±0.60) bc N = 16	(3.45±0.77) c N = 11	(9.65±0.97) a N = 20
	Postoviposition	(1.62±0.45) a N = 16	(2.13±0.47) a N = 16	(1.55±0.52) a N = 11	(1.65±0.15) a N = 20
	Female longevity	(9.25±0.76) b N = 16	(7.38±0.66) bc N = 16	(6.09±0.94) c N = 11	(12.5±0.03) a N = 20
	Eggs per Female	(24.19±3.07) a N = 16	(10.06±2.9) b N = 16	(9.45±3.6) b N = 11	(24.05±4.12) a N = 20

In the same row, figures followed by the same letters are not significantly different by Duncan [41].
df_1: the degree of freedom in the numerator,
df_2: the degree of freedom in the denominator.

Table 5. Life table parameters of *Tetranychus urticae* females reared on *Phasulus vulgaris* treated with different pesticides under laboratory conditions.

The Measured Parameters	Treatment					
	Abamectin	Fenpyroximate	Chlorofenapyr	Control	F	P
Mean generation time in days (T)	17.13 a	16.27 d	16.77 b	16.35 c	1194	0.000
Net reproductive rate (R_o)	12.90 b	4.97 c	3.47 d	15.80 a	5343.9	0.000
Intrinsic rate of natural increase (r_m) per day	0.15 a	0.15 a	0.07 b	0.17 a	14.75	0.001
Finite rate of increase (λ) per day	1.16 a	1.16 a	1.08 b	1.18 a	14.76	0.001
Sex ratio (female/total)	0.76 a	0.70 ab	0.52 b	0.77 a	3.91	0.05

15.80 female/female in the control, and the lowest rate was 3.47 female/female in chlorfenapyr. The intrinsic rate of natural increase (r_m) differed significantly (F = 14.75, P = 0.001) and was lowest, 0.07 female/female/day in chlorfenapyr, and highest, 0.17 female/female/day in the control. The finite rate of increase (λ) per day was significantly different (F = 14.76, P = 0.001), the lowest being 1.08 in chlorfenapyr and the highest in the control. The sex ratio (female/total) was not significantly different (F = 3.91, P = 0.05); it was recorded as the highest at 0.77 in the control and the lowest at 0.52 in chlorfenapyr.

Bartling et al. [53] reported that exposure to lethal or sublethal concentrations of pesticides can impact various physiological parameters of insects, including development and reproduction, through the effects on exposed tissues and the modification of behaviors that contribute to insect health and reproduction.

Bozhgani [46] studied the sublethal effects of chlorfenapyr on demographic parameters of *T. urticae* and concluded that the sublethal concentrations of chlorfenapyr profoundly reduced the population growth rate of *T. urticae*. Sublethal (LC_{25}) of Agnar 20% SC, penny 9% SC, and biomectin 5% EC significantly affected the *T. urticae* biological parameters such as longevity, total life span, net reproductive rate, intrinsic rate of natural increase, and finite rate of increase [54]. Our findings were in agreement with the previous results of Abu Arab et al. [55], Fadl et al. [56], and El-Shamy et al. [57]. Also, Rezaei et al. [58] found

that the application of Oberon Speed® for control of *T. urticae* in greenhouses at low concentrations led to an increase in the developmental time of progeny; both the LC_{20} and LC_{30} treatments decreased adult longevity, but the preoviposition period was increased with the LC_{30} treatment. Furthermore, the LC_{20} and LC_{30} treatments significantly decreased life table parameters and increased generation time. Consequently, reducing *T. urticae* populations in agricultural settings after applying abamectin may enhance crop protection and yield. Finally, three new reduced-risk acaricides, abamectin (Vertimec 1.8% EC), chlorfenapyr (Challenger 24% SC), and fenpyroximate (Ortus 5% SC), against T. urticae varied significantly under laboratory conditions in their toxicity and their effects on the developmental stages and life table parameters of T. urticae. These results are due to different modes of action in Tables 2, 4, and 5. Additionally, there was a significant difference in the field conditions in 2020.

Conclusions

From the results obtained, it could be concluded that abamectin was the most toxic acaricide against *T. urticae* females, followed by fenpyroximate and chlorfenapyr, either under laboratory or field conditions. Biological characteristics of *T. urticae* include developmental time, net reproductive rate (R_o), intrinsic rate of natural increase (r_m), finite rate of increase (λ), and sex ratio. Hence, the acaricides abamectin, fenpyroximate, and chlorfenapyr can effectively manage the two-spotted spider mite, *T. urticae.* The results of this study could be used as a guide for the rational use of abamectin, chlorfenapyr, and fenpyroximate in the field for better managing pest mites, which is done through the application of the rational and safe use of pesticides within the framework of integrated pest management to preserve the environment and beneficial insects.

Acknowledgments

This project was supported by Princess Nourah bint Abdulrahman University Researchers Supporting Project number (PNURSP2025R221), Princess Nourah bint Abdulrahman University, Riyadh, Saudi Arabia. Also, we acknowledge the Deanship of Scientific Research and Vice Presidency for Graduate Studies and Scientific Research, King Faisal University, Saudi Arabia.

Conflicts of Interest

The authors declare no conflict of interest.

References

1. MOORE PH., MING R. Genomics of tropical crop plants. Springer New York, NY. **2008**.
2. ABDOU A.H., ALKHATEEB O., MANSOUR H.H., GHAZZAWY H.S., ALBARDANI M.S., AL-HARBI N.A., AL-SHAMMARI W.B., ABDELAAL KH. Application of Plant Growth-Promoting Bacteria as an Eco-Friendly Strategy for Mitigating the Harmful Effects of Abiotic Stress on Plants. Phyton. **92** (12), **2023**.
3. AL-SHAMMARI W., ALSHAMMARY K., LOTFI S., ALTAMIMI H., ALSHAMMARI A., AL-HARBI N., JAKOVLJEVIC D., ALHARBI M., MOUSTAPHA M., ABD EL-MONEM D., ABDELAAL KH. Improvement of morphophysiological and anatomical attributes of plants under abiotic stress conditions using plant growth-promoting bacteria and safety treatments. PeerJ. **12**, e17286, **2024**.
4. RAZA HZ, SHAH AA, NOREEN Z, USMAN S, ZAFAR S, YASIN NA, SAYED SRM, AL-MANA FA, ELANSARY HO, AHMAD A, FARZANA HABIB, ASLAM M. Calcium oxide nanoparticles mitigate lead stress in Abelmoschus esculentus though improving the key antioxidative enzymes, nutritional content and modulation of stress markers. Plant Physiology and Biochemistry. **206**, 108171, **2024**.
5. ADIL M., SEHAR S., MA Z., TAHIRA K., ASKRI H., EL-SHEIKH M., AHMAD A., ZHOU F., ZHAO P., SHAMSI I.H. Insights into the alleviation of cadmium toxicity in rice by nano-zinc and *Serendipita indica*: Modulation of stress-responsive gene expression and antioxidant defense system activation. Environmental Pollution. **350**, 123952, **2024**.
6. YOUSAF W., SHAH A.A., AFZAL M., NISA Z., ALI N., ASHRAF M.A., ELANSARY H., AHMAD A. Supplementation of nano-biochar improved growth and physiological attributes in wheat seedlings exposed to salt stress through enhanced activity of hydrolysing and nitrogen metabolic enzymes and regulation of crucial metabolites. South African Journal of Botany. **167**, 500, **2024**.
7. ALKHATEEB O., GABALLAH M., EL-SAYED A., EL-NADY M., ABDELAAL KH., ABDOU A., METWALY M. Improving Water-Deficit Stress Tolerance in Rice (*Oryza sativa* L) by Paclobutrazol Exogenous Application. Polish Journal Environmental Studies. **33** (3), 3055, **2024**.
8. AL-SHAMMARI W.B., ALTAMIMI H.R., ABDELAAL K.H. Improvement in physiobiochemical and yield characteristics of pea plants with nano silica and melatonin under salinity stress conditions. Horticulturae. **9** (6), 711, **2023**.
9. ABDELAAL K.H., EL-MAGHRABY L.M., ELANSARY H., HAFEZ Y., IBRAHIM E.I., EL-BANNA M., EL-ESAWEI M., ELKELISH A. Treatment of Sweet Pepper with Stress Tolerance-Inducing Compounds Alleviates Salinity Stress Oxidative Damage by Mediating the Physio-Biochemical Activities and Antioxidant Systems. Agronomy. **10**, 26, **2020**.
10. OMARA R., ALKHATEEB O.A., ABDOU A.H., EL-KOT G.A., SHAHIN A., SAAD-EL-DIN H.I., ABGELGHANY R., AL- SHAMMARI W.B., ALBADRANI M., HAFEZ Y. How to Differentiate between Resistant and Susceptible Wheat Cultivars for Leaf Rust Fungi Using Antioxidant Enzymes and Histological and Molecular Studies? Cells. **12**, 2643, **2023**.

11. ALAFARI H., HAFEZ Y., OMARA R., MURAD R., ABDELAAL K., ATTIA K., KHEDR A. Physio-Biochemical, Anatomical, and Molecular Analysis of Resistant and Susceptible Wheat Cultivars Infected with TTKSK, TTKST, and TTTSK Novel Puccinia graminis Races. Plants. **13**, 1045, **2024**.
12. ALKILAYA O., HAMED K., SAYYED R., ABDELAAL KH., OMAR A. Characterization of Botrytis cinerea, the causal agent of tomato grey mould, and its biocontrol using Bacillus subtilis. Physiological and Molecular Plant Pathology. **133**, 102376, **2024**.
13. OMAR A.F., KHALIL F.M., ALOMRAN M.M., ISMAIL T., EL-TOKHY A., ABDELAAL KH., GHARSAN F.N., ALMOZINI R.N., ABOUELATTA A.M. Toxicity and enzymatic activity changes in rice weevil (*Sitophilus oryzae*) induced by basil (*Ocimum basilicum*) and cumin (*Cuminum cyminum*) essential oils. Scientific Reports. **14**, 28684, **2024**.
14. SHEASHA A., HOSNY A., KERATUM A., ABDELRAHMAN H., AL-HARBI NA., AL-QAHTANI, SM., ABDELAAL KH. Efficacy of Some Plant Essential Oils Against Two Spotted Spider Mite *Tetranychus urticae* under Laboratory Conditions. Polish Journal of Environmental Studies. **32** (4), 1, **2023**.
15. SEKI K. Leaf-morphology-assisted selection for resistance to two-spotted spider mite Tetranychus urticae Koch (Acari: Tetranychidae) in carnations (Dianthus caryophyllus L). Pest Management Science. **72**, 1926, **2016**.
16. MOSTAFIZ M.M., SHIM J.K., HWANG H.S., BUNCH H., LEE K.Y. Acaricidal effects of methyl benzoate against *Tetranychus urticae* Koch (Acari: Tetranychidae) on common crop plants. Pest Management Science. **76**, 2347, **2020**.
17. ABDELGALEIL S.M., BADAWY M.I., MAHMOUD N.F., MAREI A.E.M. Acaricidal activity, bio chemical effects and molecular docking of some mono- terpenes against two-spotted spider mite (*Tetranychus urticae* Koch). Pesticide Biochemistry and Physiology. **156**,105, **2019**.
18. ÇAĞATAY N.S., MENAULT P., RIGA M., VONTAS J., AY R. Identification and characterization of abamectin resistance in *Tetranychus urticae* Koch populations from greenhouses in Turkey. Crop Protection. **112**, 112, **2018**.
19. XUE W., MERMANS C., PAPAPOSTOLOU K.M., LAMPROUSI M., CHRISTOU I.K., INAK E., DOURIS V., VONTAS J., DERMAUW W., VAN LEEUWEN T. Untangling a Gordian knot: The role of a GluCl3 I321T mutation in abamectin resistance in *Tetranychus urticae*. Pest Management Science. **77**, 1581, **2021**.
20. DE ROUCK S., İNAK E., DERMAUW W., VAN LEEUWEN T. A review of the molecular mechanisms of acaricide resistance in mites and ticks. Insect Biochemistry and Molecular Biology. **159**, 103981, **2023**.
21. MOHAMED A.A., ABD EL-ALEEM D., FOUAD H., GAD M., AMIN N. Toxicological studies of *Thuja orientalis* plant extract and Vertimec 1.8 EC against two-spotted spider mite, *Tetranychus urticae* (Acari: Tetranychidae) under laboratory conditions. Journal of Sohag Agriscience. **8** (2), 33, **2023**.
22. BAKRY M., ABDELHAMID A., AL-HOSHANI N., MOHAMED R.A., GAD M. Green synthesis and bioefficacy screening of new insect growth regulators as eco-friendly insecticides against the cotton mealybug *Phenacoccus solenopsis*. Chemistry & Biodiversity. **21** (2), e202301390, **2024**.
23. MOUSA S.S., EL-QALIEI M., ATALLA A., HUSSIEN A., KHODAIRY A., ABDOU A., DRAR A., GAD M. Synthesis, Insecticide Evaluation & Molecular Docking Studies of Some New Functionalized Pyrazole Derivatives Against the Cotton Leafworm, Spodoptera littoralis. Chemistry & Biodiversity. **21** (10), e202400831, **2024**.
24. AHMAD A., KHAN T., SHAHZAD S., ULLAH S., SHAHZADI I., ALI A., AKRAM W., YASIN N., YUSUF M. BioClay nanosheets infused with GA3 ameliorate the combined stress of hexachlorobenzene and temperature extremes in *Brassica alboglabra* plants. Frontiers in Plant Science. **13**, 964041, **2022**. |
25. SAEED T., AHMAD A., KHAN M.T.A., SHAHZADI I. Glyphosate: Is Brassinosteroids Application a Remedy? In: Khan, M.T.A., Yusuf, M., Qazi, F., Ahmad, A. (eds) Brassinosteroids Signalling. Springer, Singapore. **2022**.
26. CERNA-CHÁVEZ E., RODRÍGUEZ-RODRÍGUEZ J.F., GARCÍA-CONDE K.B., OCHOA-FUENTES Y.M. Potential of *Streptomyces avermitilis*: A Review on Avermectin Production and Its Biocidal Effect. Metabolites. **14** (7), 374, **2024**.
27. ZHANG Y., XU D., WU Q., XIE W., GUO Z., WANG S. Frequencies and mechanisms of pesticide resistance in *Tetranychus urticae* field populations in China. Insect Science. **29**, 827, **2022**.
28. ZUO Y., HUANG J., WANG J., FENG Y., HAN T., WU Y., YANG Y. Knockout of a P-glycoprotein gene increases susceptibility to abamectin and emamectin benzoate in *Spodoptera exigua*. Insect Molecular Biology. **27**, 36, **2018**.
29. EL-MARZOKY A.M., ALI M.A., ELNAHAL A.S., ABULJADAYEL D.A., ALKHERB W.A., MOUSTAFA M., ALSHAHARNI M.O., ABD EL-AAL E.M. The Combination Effect of *Purpureocillium lilacinum* Strain (AUMC 10620) and Avermectin (B1a and B1b) on Control Citrus Nematode *Tylenchulus semipenetrans* (Cobb) Under Laboratory and Field Conditions. Biology. **14** (1), 60, **2025**.
30. HAMEDI N., FARAZMAND A., NAMVAR P., FARHANGI V. Efficacy of some acaricides against the two-spotted spider mite *Tetranychus urticae* on cucumber greenhouses. Journal of Crop Protection. **13** (3), 311, **2024**.
31. PAKYARI H., ZEMEK R. Evaluation of the lethal and sublethal effects of fenpyroximate on *Scolothrips longicornis*, a non-target predator of spider mites. Ecotoxicology. **7**, 1, **2024**.
32. ZHANG S., WANG X., YANG X., MA Z., LIU P., TANG S., ZHAO M., CHEN H., QIU Q., TANG M., PENG A. Toxicokinetics, in vivo metabolic profiling and tissue distribution of chlorfenapyr in mice. Archives of Toxicology. **98.**(11), 3763, **2024**.
33. IRAC (2019): Mode of Action Classification Scheme Issued, June 2019 Version 9.3 Prepared by: IRAC International MoA Working Group Approved by: IRAC Executive. Available online: https://higieneambiental.com/sites/default/files/images/control-plagas/moaclassification_v9.3_13june19.pdf, **2019**.
34. PREE D.L., COLE K.J., FISHER P.A. Comparison of leaf disc and Petri dish assays for the assessment of dicofol resistance in populations of European red mite (Acari:Tetranychidae) from southern Ontario. The Canadian Entomologist. **121** (9), 771, **1989**.
35. SUN Y.P. Toxicity index an improved method of comparing the relative toxicity of insecticides, Journal of Economic Entomology. **43**, 45, **1950**.
36. HENDERSON C.F., TELTON E.W. Test with acaricides against the brawn wheat mite. Journal of Economic Entomology. **48**, 157, **1955**.

37. BIRCH L.C. The intrinsic rate of natural increase of an insect population. Journal of Animal Ecology. **17**, 15, **1948**.
38. ABOU-SETTA M.M., SORRELL R.W., CHILDERS C.C. Life-48, a BASIC computer program to calculate life table parameters for an insect or mite species. Florida Entomologist. **69** (4), 690, **1986**.
39. ABBOTT W.S. A method of computing the effectiveness of an insecticide. Journal of Economic Entomology. **18**, 266, **1925**.
40. BAKR M.E. LDP line3. Available online: http://www.Ehab Soft. Com, **2000**.
41. DUNCAN D.B. Multiple Ranges and Multiple F test. Biometrics. **11**, 1, **1955**.
42. ABDEL RAZIK M.A., HEIKAL H.M. Toxicity of Some Pesticides and Plant Extracts on *Tetranychus urticae* and its Predator, *Phytoseiulus persimilis*. International Journal of Zoological Research. **15** (1), 28, **2019**.
43. RABBI A., NIZAM UDDIN M.D., ABDUL ALIM M.D., BACHCHU M.D., BHYAIN M.M., AKTERS S. Correction to: Efficacy of some pesticides against *Tetranychus urticae* Koch (Acari: Tetranychidae) and their residual effects on *Coccinella septempunctata* (L) (Coleoptera: Coccinellidae). International Journal of Tropical Insect Science. **42** (1), 615, **2021**.
44. MASSOUD M.A., MESBAH H.A., EBIEDA A.M., ABDEL-HANEED A.R., Comparative Field Evaluation of Certain Acaricides Against *Tetranychus urticae* on Strawberry. Journal of Advance Agricultural Research. **23** (2), 250, **2019**.
45. SALEH K.M., AIOUB A.A., SHALABY A., HENDAWY M.A. Efficiency of some acaricides on the two spotted spider mite *Tetranychus urticae* Koch, infesting eggplant and pepper under laboratory and field conditions. Zagazig Journal of Agricultural Research. **46** (5), 1377, **2019**.
46. PATHAK V.M., VERMA V.K., RAWAT B.S., KAUR B., BABU N., SHARMA A., DEWALI S., YADAV M., KUMARI R., SINGH S. Current status of pesticide effects on environment, human health and it's eco-friendly management as bioremediation: A comprehensive review. Frontiers in Microbiology. **13**, 962619, **2022**.
47. BLACK B.C., HOLLINGWORTH R.M., AHAMMADSAHIB K.I., KUKEL C.D., DONOVAN S. Insecticidal action and mitochondrial uncoupling activity of AC-303,630 and related halogenated pyrroles. Pesticide Biochemistry and Physiology. **50**, 115, **1994**.
48. GHASEMZADEH S., QURESHI J.A. Demographic analysis of fenpyroximate and thiacloprid exposed predatory mite Amblyseius swirskii (Acari: Phytoseiidae). PLoS One. **13** (11), e0206030, **2018**
49. WAKIL W., BOUKOUVALA M.C., KAVALLIERATOS N.G., RIASAT T., GHAZANFAR M.U., AVERY P.B. Acaricidal Efficacy of Abamectin against *Tetranychus urticae* Populations When Combined with Entomopathogenic Fungi. Horticulturae. **10** (10), 1019, **2024**.
50. CANASSA F., TALL S., MORAL R.A., DE LARA I.A., DELALIBERA I., MEYLING N.V. Effects of bean seed treatment by the entomopathogenic fungi *Metarhizium robertsii* and *Beauveria bassiana* on plant growth, spider mite populations and behaviour of predatory mites. Biological Control. **132**, 199, **2019**.
51. WU S., SARKAR S.C., LV J., XU X., LEI Z. Poor infectivity of Beauveria bassiana to eggs and immatures causes the failure of suppression on *Tetranychus urticae* population. BioControl. **65** (1), 61, **2020**.
52. BOZHGANI N.S.S., GHOBADIM H., RIAHI E. Sublethal effects of chlorfenapyr on the life table parameters of two-spotted spider mite, *Tetranychus urticae* (Acari: Tetranychidae). Systematic and Applied Acarology. **23** (7), **2018**.
53. BARTLING M.T., BRANDT A., HOLLERT H., VILCINSKAS A. Current Insights into Sublethal Effects of Pesticides on Insects. International Journal of Molecular Sciences. **25** (11), 6007, **2024**.
54. AHMED M.M., IBRAHIM E.S., FAHMY M.A. Integration of Certain Acaricides with *Phytoseiulus persimilis* to control *Tetranychus urticae* on Beans Plants, and Their Sub-Lethal Effect on Its Life-Table Parameters. Journal of Plant Protection and Pathology. **12** (10), 703, **2021**.
55. ABU ARAB H.R., KERATUM A., ABOUELATTA A.M., EL-TAWELAH N.M., HAFEZ Y., ABDELAAL KH. Fumigant and mixing with medium effect of Citrus reticulata and *Tagetes minuta* essential oil against adults of *Sitophilus oryzae* (L) and *Tribolium castaneum* (Herbst). Fresenius Environmental Bulletin. **31** (11), 10758, **2022**.
56. FADL H., BAYOUMI O., RAGAB A., ISMAIL A., HAFEZ Y., ABDELAAL KH. Monitoring of The Toxicity and Repellency of Some Essential Oils against *Solenopsis invicta* (Hymenoptera: Formicidae). Fresenius Environmental Bulletin. **31** (11), 10928, **2022**.
57. EL-SHAMY E.H., KERATUM A., HOSNY A., HAFEZ Y., ABDELAAL K.H. Studies on selection and resistance mechanism by some acaricides in *Tetranychus urticae* (Acari: Tetranychidae). Fresenius Environmental Bulletin. **31** (11), 10942, **2022**.
58. REZAEI E., ARAMIDEH S., MICHAUD J.P., MIRFAKHRAIE S., FOROUZAN M. Sublethal effects of a spiromesifen and abamectin combination on *Tetranychus urticae* (Acari: Tetranychidae) and its predators Phytoseiulus persimilis and Amblyseius swirskii (Acari: Phytoseiiidae). Experimental and Applied Acarology. **93** (3), 501, **2024**.