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Sublethal effects of Proteus on the demographic characteristics of *Tetranychus urticae* Koch 1836

Mohammad Nasir Shaterian Mohammadi[1], Ayad Kadhim Alsendi[1], Hayder Abdulhasan Ali [2] and Ali A. Kareem[2]

[1] Dept. of Plant Protection, Faculty of Agriculture and natural resources, University of Tehran, Karaj, Iran.

[2] Dept. of Plant Protection, Faculty of Agriculture, University of Kerbala, Karbala, Iraq.

Email: ali.kareem@uokerbala.edu.iq; haider.abid@uokerbala.edu.iq

ABSTRACT

Tetranychus urticae Koch (Trombidiformes: Tetranychidae) constitutes a significant member of the agricultural product family. Applying sublethal concentrations minimizes the requirement for pesticides while also curbing the issue of resistance in pests. This constitutes an integral part of Integrated Pest Management (IPM) and effective control over the pest population. The infectious effects (LC_{10}, LC_{20}, LC_{30}) belonging to Proteus within demographic factors associated with *T. urticae* age-wise, theory of two-sex life table got tested in a controlled laboratory environment [25 ± 2C, 60 ± 5% R.H, 16:8 (L:D) h]. The results showed that *T. urticae* adults exposed to LC_{10}, LC_{20}, LC_{30} belonging to Proteus; a sharp decrease was noted in fecundity and oviposition period compared against control settings. Subjecting to infectious Proteus concentrations did not affect the progeny of APOP's treated mites. The intrinsic increase rate (*r*) ranged from 0.233 day^{-1} for the mites exposed to distilled water to 0.197 per day for LC_{30} treatments of Proteus. The acaricide concentration affected the finite increase rate (λ) (low value at LC_{30} conc.: 1.1217 day^{-1}). Due to the obtained data, comparing the effect Proteus casts on *T. urticae's* population growth, this pesticide has been shown to effectively control both spider mites with spotted skin in the form of integrated pest management.

Keywords: Life table parameters, Sub-lethal effects, *Tetranychus urticae*, Proteus

Introduction

Tetranychus urticae Koch (Trombidiformes: Tetranychidae), commonly called two-spotted spider mite, is a worldwide invasive phytophagous mite (Helle and Sabelis, 1985). It infests various plant families, including flowers, crops and vegetables, causing significant damage to various production (Grbić et al. 2011). This species has short life history and high reproductive rates, develops quickly in highly dense populations, and can drive crop destruction in host plants when timely management does not take place (Hoyt et al. 1985; Kim et al. 2006; Sangak Sani et al. 2019; Havasi et al. 2020; Al-Fatlawi et al. 2021). Synthetic acaricides are the prime control mean pertinent to this pest (Alinejad et al., 2014; Havasi et al., 2019; Bozhgani et al., 2019; Ayad Alsendi et al., 2022)

However, biological control exerted on spider mites, and insects pest has been effective in a few glass-house plants, multitude of products are related to chemical control (Sanderson and Zhang, 1995; Van Leeuwen et al. 2015; Mohammed et al. 2022). Acaricides/pesticides have been applied anxiously in the back 70 years to manage *T. urticae* and exhibited resulted in extensive resistance to many chemical compounds with opposing modes of action (Van Leeuwen and Dermauw, 2016). Screening for novel and effective products having unique mode of action is crucial for resistance management in *T. urticae*.

Proteus® offers an amalgamation of systemic insecticide belonging to chloro-nicotinyl group along with synthetic pyrethroid, providing contact and systemic action for controlling tuber moth, thrips in addition to psyllids (Bayer Crop Science, 2012). This insecticide combines two different modes of action; the sodium channel modulator is exemplified by deltamethrin (Group 25 of IRAC classification), while thiacloprid signifies the agonist of nicotinic acetylcholine receptor (Haug et al. 1990; Elbert et al. 2001; Almasi et al. 2016)

To efficacy forestall an acaricide/pesticide in action, life table answer experiences prove superior to lethal concentration assessment. The scope of such experiments is not only limited to the effect pesticides cast upon society's growth rate (Marcic, 2005). As a result, comprehension of infectious effects is categorical to figure out the potency and danger regarding the use of pesticides (Desneux et al. 2007; Wang et al. 2016;). Currently, several studies on the toxic properties of various pesticides on demographic characteristics of *T. urticae* emerged (Marcic 2007; Wang et al. 2014; Mohammadi et al. 2016; Li et al. 2017; Međo et al. 2017; Mohammadi et al. 2022), and a study was also conducted on pervasive implications of Proteus® on biological characteristics of *T. urticae*.

This investigation aimed to assess the pervasive effects of Proteus® on *T. urticae*'s demographic characteristics employing the latest technique, the status of age and two-sex life table theory. This new knowledge could be used to improve IPM programs for *T. urticae*.

Materials and Procedures

Host Plant and mites

The cucumber plants, *Cucumis sativus* L. cv. Veolla F1 (Cucurbitaceae) were allowed to grow in plastic pots (diameter of15 cm) within controlled conditions (25 ± 5°C, 60 ± 10% R.H. as well as a photoperiod lasting 16: 8 (L:D) hours. The primary stock of *T. urticae* was prepared from contaminated Pakdasht greenhouses (the South-Eastern sector of Tehran, Iran), which had never been subjected to pesticides.

Chemical tested

Proteus OD 110, an insecticide containing a mixture of thiacloprid in a quantity of 100 g active substance (a.s.)/l and deltamethrin in the quantity of 10 g a.s./l (Bayer Agricultural Products, Germany), was employed in this investigation.

Bioassay experiments

Employing a leaf-dipping method, Concentration-response bioassay was carried out (Helle and Overmeer 1985; Ibrahim and Yee 2000) (the mortal character expression ranges from 10%–90%).

The cucumber leaf discs (diameter of 4 cm) got submerged for 15 seconds in Proteus® solutions. Those leaf discs were made to dry under room conditions for a period of 3 hours and dispensed in Petri dishes (total diameter of 6 cm, height of 1.5 cm). Afterwards, each concentration placed twenty adult mites, all with the same age of twenty-four hours, categorized as female and male in a ratio of 10:10 on the leaf discs which had been treated. On four occasions, bioassay replication took place, and five different concentrations were tested against the control. Mite fatality of the mites got numbered following a period of 24 hours. The mites were considered dead when they did not motion after incitement. All investigations were conducted under Lab conditions of 25±2°C, 60±5% RH, and photoperiod lasting 16:8 (L:D) h.

Life-Table Assessment

To analyze the toxic consequences of Proteus® upon *T. urticae*, cucumber leaf discs were subjected to infectious concentrations, including LC_{10}, LC_{20}, $LC_{30.}$ At the same time, distilled water was established as a control and given three hours to dry.

In the next stage, after treating the cucumber leaf discs holding a concentration above Proteus®, females aged twenty-four hours were positioned on the leaf discs. Following the period of twenty four hours, the females surviving every treatment got positioned individually on leaf discs which had not been treated. In every experiment, just a single egg could be saved after a period of twenty-four hours. Females who had emerged recently were allowed to mate with males. Males were used from the stocked colony when their quantity could not match the females. Daily monitoring of experimental units was carried out. Female fecundity (replication of a hundred at every concentration value) was recorded on a daily basis, parameters of both male and female populations were calibrated, and only the demise of the last mite marked the end of the recording of changes.

Statistical analysis

The LC_{10}, $LC_{20,}$, LC_{30} values along with 95% fiducially limitations were calibrated utilizing the procedure of Probit through IBM-SPSS statistics (SPSS version 19.0). theoretical model was considered the basis for analyzing original information relevant to all the individuals (Chi and Liu, 1985; Chi, 1988). The program TWOSEX-MS Chartwas employed for raw data analysis and establishing population parameters (Chi 2019). Several growth parameters of the population, including net reproductive rate, gross rate of reproduction, intrinsic increase rate and finite increase rate, average time of generation (Fathipour and Maleknia, 2016), standard and average values of conventional error were determined utilizing the method of paired bootstrap, accompanying 100,000 replications (Efron and Tibshirani, 1993; Huang and Chi, 2012, Akkopru et al. 2015).

Results

Concentration-response bioassay

Due to the current data, the LC_{50} values for females and males of *T. urticae* were 327.4 and 338.1 ppm (Table 1).

Table 1. . Probit evaluation for the conc.-mortality effect carried out by Proteus upon adult life periods of *Tetranychus urticae*

	*N	*df*	aLC10 (ppm)	aLC20 (ppm)	aLC30 (ppm)	aLC50 (ppm)	*P*-value	X^2
Proteus	480	4	118.7	170.0	220.3	338.1	0.183	4.84

*20 members per replicate, 4 replicates per conc.,6 concentrations in every assay
[a] LC values recorded in the form of ppm along 95% confidence

Developmental parameters

The current data indicated that the sublethal effects of the Proteus upon progeny development arising from females who have been treated, adult longevity, and total lifetime of two-spotted spider mites and males reduced at LC_{30} concentration, in Proteus contrast by control (Tables 2 and 3). The longevity of both sexes of TSSM was divested from 8.26 to 10.56 days and from 9.11 to 13.01 days for Proteus. An analysis of longevity values related to both TSSM genders revealed that concentration growth had a significant reduction. It is noteworthy that the longevity value was determined by calibrating the average days spent from adulthood to demise. Proteus LC_{30} demarcated the minimum life duration of *T. urticae*.

Table 2. Average developmental time period measured in days (mean ± SE), length of adult stage in addition to complete life span for *T. urticae* exposed to Proteus® toxicity and standardization of distilled water as control.

Parameter	**Treatment**			
	Control	**LC_{10}**	**LC_{20}**	**LC_{30}**
Preadult				
Male	10.51±0.21 a	10.46±0.22 a	10.53±0.17 a	9.78±0.49 a
Female	10.68±0.08 a	10.71±0.09 a	10.65±0.09 a	9.81±0.11 a
Adult longevity				
Male	10.56±0.18a	9.83±0.15b	9.21±0.18b	8.26±0.23c
Female	13.01±0.02a	11.68±0.13b	10.68±0.13c	9.11±0.08d
Total life span				
Male	21.12±0.22a	20.26±0.23b	19.51±0.15b	18.52±0.33c
Female	23.73±0.09a	22.31±0.19b	21.15±0.16c	19.11±0.12d

Bootstrap method employed along 100,000 samples to calculate standard errors. With the level of significance as low as 5%, various letters belonging to the same row reflected varying average values upon implementation of tpaired bootsrap method.

Table 3. Average (±SE) period of reproductive condition and complete fecundity of progeny from female *T. urticae* exposed to infectious Proteus® conc. and standardization of distilled water as control.

Parameter	Treatment			
	Control	LC_{10}	LC_{20}	LC_{30}
Oviposition day (day)	10.89±0.04a	9.72±0.13b	8.67±0.13c	7.06±0.08d
APOP[1] (day)	1.09±0.03a	1.07±0.05a	1.06±0.06a	1.11±0.06a
TPOP[2] (day)	11.81±0.10a	11.61±0.14a	11.47±0.12a	11.02±0.12a
Total fecundity values (offspring or individual)	60.24±0.30a	45.93±0.71b	36.14±0.82c	27.39±0.51d

[1]APOP: adult pre-ovipositinal period. [2]TPOP: total pre-oviposition period.
at 5% significance level.
Bootstrap method employed along 100,000 samples to calculate standard errors. With the level of significance as low as 5%, various letters belonging to the same row reflected varying average values upon implementation of tpaired bootsrap method.

Reproductive Periods

Table 3 displays the effects of the treatments on the adult pre-oviposition period (APOP). No significant differences were scored for APOP at different concentrations for mites treated by Proteus. The TPOP of TSSM subjected to LC_{30} was significantly shorter than the control.

Growth parameters of the population

Tables 4 show collation s of population demographics of progeny relevant to the two-spotted spider mites females who have been treated with pilot dosses of Proteus, contrasted with the control. The assessed GRR and R_0 for *T. urticae* impressed by sublethal concentrations ranged from 52.96 (offspring or individual) in those untreated to 21.36 (offspring or individual) among the LC_{30} concentration for Proteus. The r and λ of two-spotted spider mites were remarkable when treated by Proteus compared to the control treatment. The shortest time for completing a generation of *T. urticae* was 14.46 days, which was related to the LC_{30} concentration of Proteus.

Table 4.

Parameters of life (average ±SE) of progeny from female *T. urticae* exposed to infectious Proteus® conc.

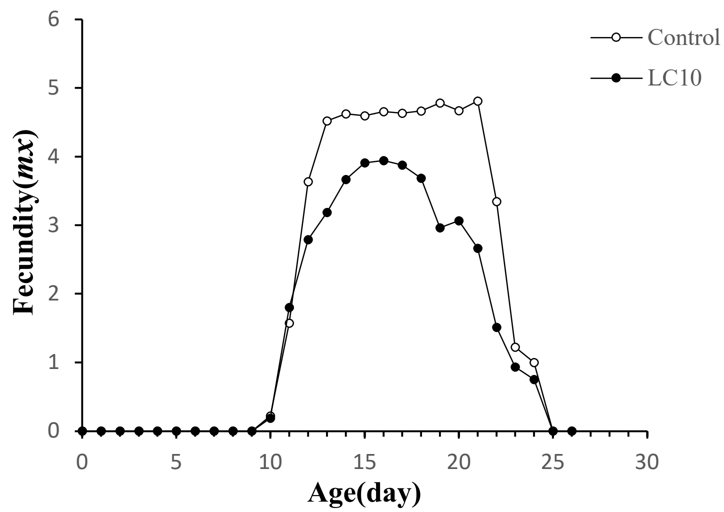
Parameter	Treatment			
	Control	LC_{10}	LC_{20}	LC_{30}
GRR (offspring/individual)	52.96±2.20a	38.93 ± 2.20b	29.46 ±0.82c	21.36±1.35d

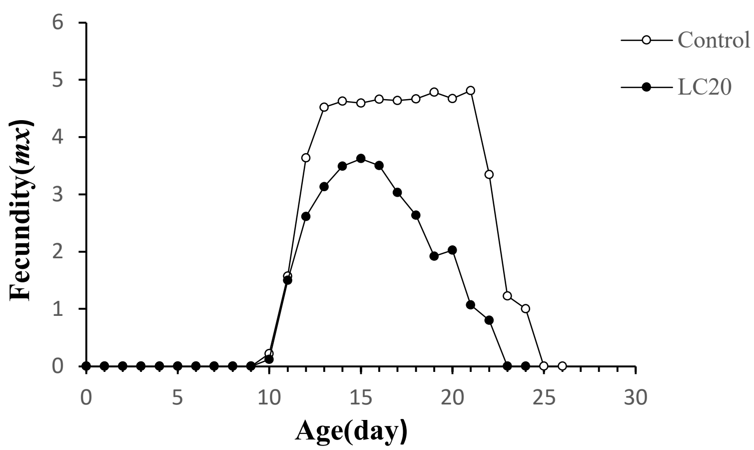
R_0 (offspring/individual)	48.19 ± 2.41a	30.77 ± 2.21b	23.84±1.79c	18.08±1.33d
r (day^{-1})	0.233±0.003a	0.212±0.004b	0.202±0.005b	0.197±0.005c
λ (day^{-1})	1.262±0.004a	1.237± 0.006b	1.224±0.006b	1.217±0.006c
T (day)	16.60±0.10a	16.09± 0.12b	15.63±0.10c	14.66±0.102d

No significant difference was observed in average values held by same letters belonging to the same row. 100,000 bootstraps were employed to estimate SE values utilizing method of paired bootstraps. The level of significance was consistent at 5%.

Survival and Fecundity Curves

The fecundity and survivorship of two-spotted spider mites, specific to their age at various concentrations of Proteus are shown in Figures 1 and 2, respectively. The total lifetime of the original *T. urticae* cohort was 26 days. In contrast, it was 26, 24, 23 days for LC_{10}, LC_{20} ,LC_{30} concentration of Proteus (Fig. 2). The m_x value in Proteus was 4.81, 3.94, 3.62, and 3.38 eggs per individual per day for the control and mites treated with LC_{10}, LC_{20} ,LC_{30}, respectively, which occurred on the days 21, 16, 15 ,14 of a lifetime, respectively (Fig. 1).





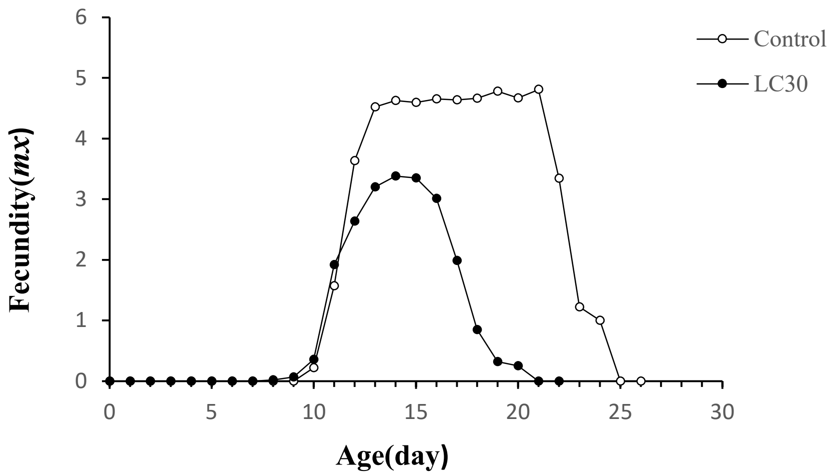
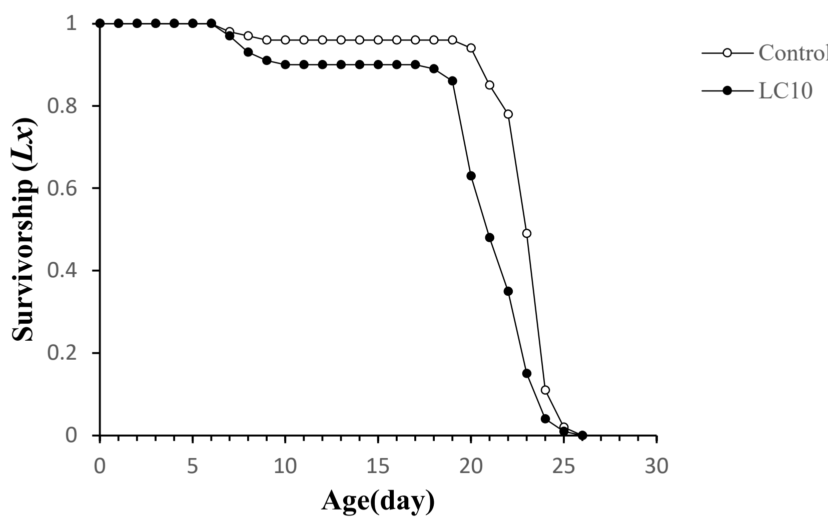
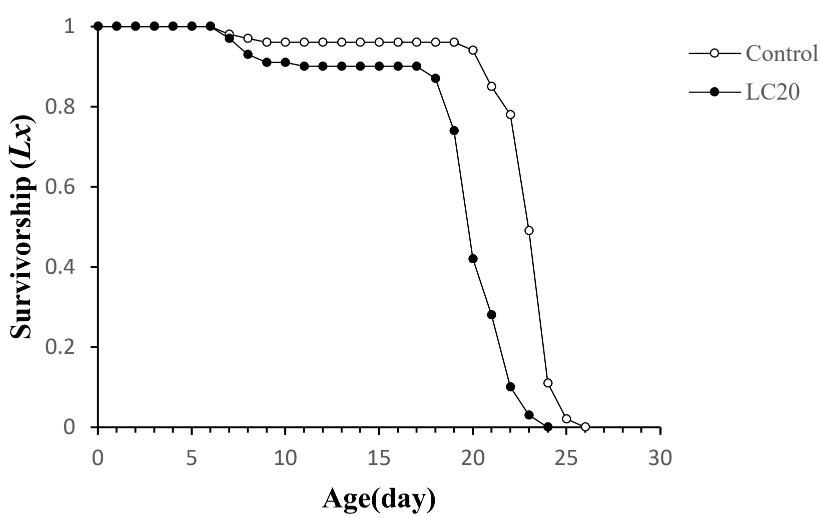


Figure 1. Age-related fecundity (m_x) values for the progeny of the exposed and original *T. urticae* mites by Proteus





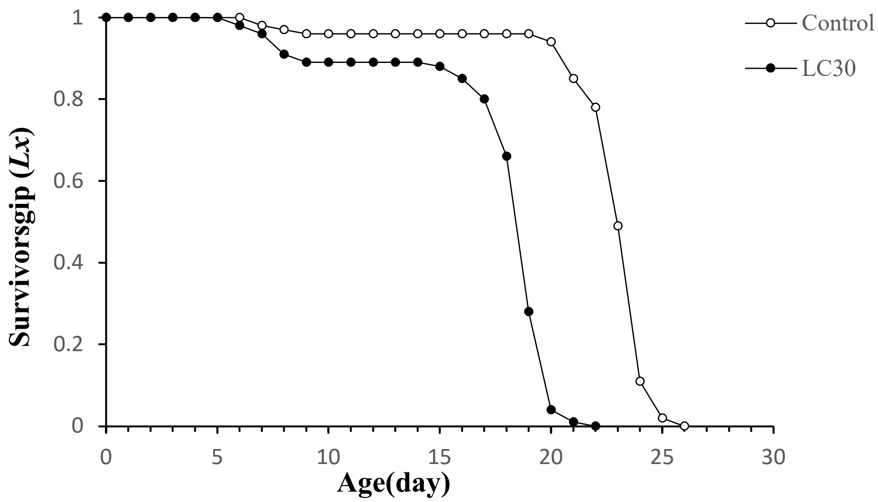


Figure. 2. Age-related survivorship (*lx*) values for the progeny of the exposed and original *T. urticae* mites by Proteus

Discussion

The recommended field rates of application of Proteus® for *T. urticae* control are 1L/hectare for Proteus®, according to the producers' instructions. While the concentrations applied in this research were less than recommended, some experimental dosages influenced the development of two-spotted spider mites. The current investigation marks the pioneer in research over infectious concentration of Proteus® on demographic characteristics of offspring of *T. urticae*. The longevity along with the length of total life for both genders of *T. urticae* had a sharp decrease when a rise in concentration took place from LC_{10} to LC_{30} for Proteus, compared to the that of mites which had not been treated. Our results follow the outcomes of Marcic (2005), Alinejad et al. (2015) and Saber et al. (2018) when examining sublethal concentrations of tebufenpyrad, fenazaquin, pyridaben and abamectin on *T. urticae*.

Vice versa, clofentezine (a tetrazine compound and growth inhibitor) did not affect the developmental time of *T. urticae* at 27.5 ± 1.5 °C and 65-85% RH Marcic (2003). Results of the current study indicated that Proteus® considerably affected the total fecundity and oviposition day of *T. urticae* females, which unified with the findings of was in alignment with studies of Saber et al. (2018) and Sangak Sani et al. (2019) that evidence of the damaging effect of pyridaben, abamectin and spirodiclofen on the reproduction of two-spotted spider mites. The lowest total fecundity and oviposition day belonged to the concentrations (LC_{30}) of Proteus, reflecting slow potential among population of mites that have been treated to demonstrate recovery. This outcome aligned with the judgement of Ako et al. (2004), who treated *T. urticae* adult females with thiacloprid and thiamethoxam. Similar trends of implications on fecundity and longevity of adults were recorded by Martinez-Villar et al. (2005), who indicated significantly decreased at 64 and 128 ppm of azadirachtin. This data was considered via Saenz-de-Cabzon et al. (2006) that discussed experimental dosages of triflumuron as an inhibitor of the chitin synthesis, which had no effect on *T. urticae* fecundity.

Our results show GRR and R_0 presentation of a decreasing tendency for females treated with experimental dosages of Proteus compared to control females. Our results are in compromise with the readings of Marcic (2003), Alinejad et al. (2015), and Bozhgani et al. (2018), who reported that *T. urticae* treated with clofentezine, fenazaquin and chlorfenapyr demonstrated a significant decrease in *GRR* and $R_{0.}$

In a separate investigation, the significance of GRR for *T. urticae* exposed to LC_{20} of diflovidazin was less (36.99) (Havasi et al. 2018). The outcomes reflected higher concentrations of Proteus caused a significant decline trend for key factor (*r*) of demographic parameters, which opposes the outcomes of Wang et al. (2016) reported that the r value was remarkably enhanced for LC10 and LC20 of spinoterom in collation by control females. This diversity can be due to the efficacy of pesticides' formulation and the mites' sensitivity. Based on the present study's obtained results, a decreasing *r*-value for mites treated with the LC_{30} concentration of all concentrations (LC_{10}, $LC_{20,}$ and LC_{30}) of Proteus® was shown.

The preconceived *r* value in the current investigation on mites exposed to LC_{30} was calculated to be 0.216 day^{-1} for Danisaraba®, which resembled the findings of Leviticus et al. (2019) for *T. urticae* exposed to LC_{30} of fluralaner (0.25 day-1). Our outcomes aligned with the observations made by Li et al. (2017) that presented the r notably diminution for offspring of *T. uticae* treated with bifenazate. These data are mutual to the findings Havasi et al. (2018) showed. They reported that infectious concentrations of diflovidazin cast no considerable effect on parameters of *T. urticae* population (like *r*, λ) of It is possible for this diversity to be attributed to the pesticide (diflovidazin constitutes an elective acaricide and is a member of the tetrazine group).

The values of λ obtained in this study were lower than those in other studies. Barati and Hejazi et al. (2015) obtained a *λ* for the same mite species of 1.360 and 1.363 day^{-1} for thiamethoxam and thiacloprid, respectively. Also, the *T* value displayed a diminution sentiment by expanding the applied doses. The obtained data were in accord with what was the publication by Marcic (2005), Barati and Hejazi, (2015), and Bozhgani et al. (2019). They reported the sublethal effects of tebufenpyrad, acetamiprid, and spiromesifen on mean generation time of *T. urticae*.

The most and least areas beneath l_x curve were taken for untreated and LC_{30} concentration. The age-related fertility curve represented a considerable reduction for mites that had been treated. Similarly, Havasi et al. (2018) demonstrated a declining trend for the two mentioned curves (m_x, l_x). In conclusion, populations of *T. urticae* exposed to sublethal dosages provide favourable modifications in the population parameters accessed. The current data show that the growth rate of *T. urticae* population was influenced by LC_{30} of the tested compound (Proteus®) as a consequence of a minus impact on the reproductive time span, fecundity, and population characteristics. These chemical compounds can be used in IPM programs for T. urticae populations if consistent outcomes are derived from semi-filed and field trials.

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