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Sublethal effects of fenpropathrin on the oxalis spider mite, *Tetranychina harti* (Ewing) (Acari: Tetranychidae)

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ABSTRACT

The sublethal effects of fenpropathrin on the oxalis spider mite, *Tetranychina harti* (Tetranychidae) were investigated. The results showed that, relative to the control group, sublethal doses of fenpropathrin significantly shortened the developmental duration of immature offspring in the LC_{15} group ($P < 0.05$) but significantly prolonged it in the LC_{30} group ($P < 0.05$). Furthermore, these sublethal exposures shortened the pre-oviposition period while prolonging the oviposition period of F_1 female adult mites. Notably, a significant reduction in mean fecundity per female was observed only in the LC_{15} group compared to the control ($P < 0.05$). The cumulative survival rate curves and age-specific fecundity curves indicated that sublethal concentrations (LC_{15} and LC_{30}) of fenpropathrin did not exert a clearly adverse effect on the survival or fecundity of *Tetranychina harti*. Both treatment groups exhibited higher net reproductive rates (R_0) than the control. Similarly, the intrinsic rates of increase (r_m) in the LC_{15} and LC_{30} groups exceeded that of the control, and the finite rates of increase (λ) in both treatment groups were also higher. In addition, the population doubling time (DT) was shorter in the treatment groups than in the control. These findings suggest that sublethal exposure to fenpropathrin may compromise its efficacy in controlling this mite population.

KEYWORDS

Fecundity, life-table parameters, *Petrobia harti*, pyrethroids, survival

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INTRODUCTION

When applied in the fields, insecticides not only directly kill pests but also exert sublethal effects on some individuals due to variations in exposure dose among individuals and over time. These effects include alterations in pest biology and ecological behavior, changes in reproductive capacity, and the development of pesticide resistance (Wang 2004). Pyrethroids are widely used globally. As a type II pyrethroid, fenpropathrin is extensively applied in agricultural production for controlling a broad spectrum of crop pests and mites (Parashar and Shahani 2024). However, studies have shown that sublethal doses of such insecticides may enhance pest or mite reproduction, potentially leading to pest resurgence (Gerson and Cohen 1989; Zanardi *et al.* 2018; Pan *et al.* 2024).

Spider mites are a group of harmful arthropods with a wide host range, primarily infesting grain crops, vegetables, fruit trees, and ornamental plants. Due to their small size, short generation time, high fecundity, and rapid population growth, these pest mites easily develop pesticide resistance, causing significant losses in agricultural production. Many researchers have investigated the sublethal effects of common acaricides on spider mites. For instance, when the *Panonychus citri* (McGregor) was exposed to sublethal doses (LC_{20}) of fenpropathrin and abamectin, fenpropathrin stimulated population growth in both the exposed generation and their offspring, whereas abamectin suppressed the exposed generation

but promoted offspring population growth (He *et al.* 2016). Cheng *et al.* (2021) found that sublethal doses (LC_{10} and LC_{30}) of both cyetpyrafen and cyenopyrafen significantly increased the intrinsic rate of increase (r_m) of *Panoychus citri* populations, thereby promoting population increase. These results demonstrated that sublethal doses of several acaricides, including fenpropathrin, abamectin, cyetpyrafen, and cyenopyrafen, can all stimulate population growth in spider mites. Bifenazate and pyridaben not only directly kill *Tetranychus urticae* Koch, but their residual activity can also provide sustained control of mite population growth, which indicates that sublethal doses of these two acaricides can effectively suppress the growth of *Tetranychus urticae* populations (Kim *et al.* 2006). The effects of clofentezine treatment on the population development of *Tetranychus urticae* varied significantly across different developmental stages. When early-stage eggs (0–24 h) were treated, the population's intrinsic rate of increase (r_m) was higher than that of the control group. In contrast, treatment of other developmental stages, including late-stage eggs (72–96 h), larvae, and nymphs resulted in r_m lower than the control. These findings demonstrated that the sublethal effects of acaricides exhibit stage-specific variations in their impact on mite populations (Marcic 2003). Treatment with fenpropathrin at LC_{10} and LC_{20} concentrations on either eggs or adult mites of *Tetranychus urticae* resulted in shortened developmental duration of offspring, increased r_m, and stimulated population growth. In contrast, treatment with spirodiclofen at LC_{10} and LC_{20} concentrations showed opposite effects: prolonged developmental duration, decreased r_m, and consequently suppressed population growth (Zhang *et al.* 2012). Under sublethal doses of cyhalothrin and fenpropathrin, the *Tetranychus urticae* showed significantly enhanced biological parameters compared to the control group: increased oviposition in adult females, extended longevity, and higher egg hatch rate (Shen and Zhang 2002). These findings demonstrated that sublethal exposures to both insecticides (cyhalothrin and fenpropathrin) stimulate population increase of *Tetranychus urticae*. While Li (2019) demonstrated that fenpropathrin exposure exerted inhibitory effects on both susceptible and resistant populations of the *Tetranychus urticae* red form. Sublethal doses of tebufenpyrad and pyridaben, when applied to adult mites and eggs of *Tetranychus truncatus* Ehara, significantly prolonged the developmental duration of immature stages in offspring and reduced reproductive capacity. These results demonstrated that neither acaricide (tebufenpyrad or pyridaben) stimulated reproduction in *Tetranychus truncatus*, and effectively suppressed population growth (Guo *et al.* 2014). When eggs or female adult mites of *Tetranychus turkestani* Ugarov & Nikolski were treated with sublethal doses (LC_{10} and LC_{20}) of abamectin or pyridaben (Gu *et al.* 2010), the durations of the egg stage, larval stage, nymphal stage, and pre-oviposition period were prolonged; additionally, the adult lifespan and fecundity decreased compared to the control group, then the r_m, net reproductive rate (R_0), and finite rate of increase (λ) declined, and conversely, the generation time and population doubling time (DT) were extended. These results indicated that sublethal doses of abamectin and pyridaben have an inhibitory effect on the experimental population growth of *Tetranychus turkestani*. Sublethal doses (LC_{10}, LC_{25}, and LC_{50}) of clofentezine, abamectin, and azocyclotin all exhibited inhibitory effects on the population of *Amphitetranychus viennensis* (Zacher), while sublethal effects of fenpropathrin on *A. viennensis* varied with the dose of fenpropathrin: fenpropathrin LC_{25} inhibited the population of *A. viennensis*, but fenpropathrin LC_{10} significantly stimulated the reproduction of *A. viennensis* (Li *et al.* 2006). Sublethal dose of pyridaben significantly suppressed the population development of *Oligonychus litchii* Lo & Ho and *Acaphylla theae* Watt (Xu *et al.* 2014; Hu *et al.* 2016).

Existing research findings indicate that the sublethal effects of common pesticides on spider mites, particularly their impact on population development, varies significantly. This necessitates further studies to provide foundational data and insights into the mechanisms of the pest outbreaks. The *Tetranychina harti* primarily feeds on plants of the *Oxalis* genus (Oxalidaceae). During outbreaks, this pest mite often causes leaves to turn yellow and wither, even leading to complete defoliation, significantly impairing the ornamental value of affected plants (Zheng and Hong 2007). Research on this mite remains relatively limited, probably because the economic damage it causes has not yet attracted sufficient attention (Dubitzki and Gerson 1987). However, with the increasing use of *Oxalis corymbosa* DC. and *O. triangularis* A. St. Hil. as landscaping plants, coupled with the mite's relatively large size, which makes it suitable for experimental studies, research on this species has been receiving growing interest (Zheng and Hong 2007; Roy *et al.* 2011; Qin *et al.* 2013; Yang *et al.* 2017; He 2020; Ghosh *et al.* 2025). The sublethal effects of

pyridaben at LC_{10} and LC_{30} concentrations on this pest mite were investigated (He 2020), but no other studies have examined the sublethal effects of other insecticides on *Tetranychina harti*. Studying the sublethal effects of fenpropathrin on the oxalis spider mites not only provides valuable insights for its control but also helps further elucidate the impact of sublethal pyrethroid exposure on pest (mite) population growth.

MATERIAL AND METHODS

Mites and chemicals

Tetranychina harti mites were collected in May 2014 from infested plants, *O. corymbosa*, in Mianyang City, Sichuan Province, China. They were reared on *O. corymbosa* in an artificial climate chamber for multiple generations and were not exposed to any pesticides.

Fenpropathrin (20% EC, Anhui Tianchengji Agricultural Science Research Institute) was used as the acaricide in this study.

Bioassay

The above-mentioned fenpropathrin in section "Mites and chemicals" was diluted with distilled water into five concentration gradients (60 mg/L, 300 mg/L, 600 mg/L, 900 mg/L, 1200 mg/L, distilled water as the control). Bioassay methods include the slide-dip (SD) method, the leaf-dip (LD) method, the Potter spray tower (PST) method, and the residual contact vial (RCV) method. However, the SD method is time-consuming, labor-intensive, and requires high technical skills. The LD method, while more time-efficient, labor-saving, and easier to perform, suffers from mite escape, which leads to high variability in results. The PST method requires specialized equipment and still cannot prevent mite escape. Although the RCV method avoids mite escape, it only evaluates contact toxicity and does not account for stomach toxicity. While the vial-leaf dip (VLD) method combines the advantages of the above approaches and can be used for mite bioassays (Wang *et al.* 2015). According to the VLD bioassay method (Wang *et al.* 2015), pesticide-treated vials were prepared by pipetting 1.5 mL of test solution into 2.0 mL centrifuge tubes, which were then capped and gently rotated to ensure uniform inner-wall coating. Then the excess solution was poured off, and the coated tubes were air-dried for 24 h in a ventilated area. Fresh *O. corymbosa* leaves were immersed in test solutions for 10 s and air-dried for 1–2 h. The treated leave was placed into the corresponding tube, and each concentration was replicated five times, with distilled water as the control.

After the treated tubes were air-dried naturally, thirty adult female mites were transferred into each tube with the corresponding treated leaf. The tubes were maintained at 25 °C. Mortality was evaluated after 24 h by stereomicroscopic examination.

Mortality was corrected using Abbott's formula: corrected mortality = (treated group mortality − control group mortality) / (1 − control group mortality). Based on the corrected mortality at each concentration, the virulence regression equation was derived using SPSS 25.0, the procedure as follows: analyze, regression, probit. Then, based on the regression equation, the concentrations corresponding to LC_{15} and LC_{30} were calculated.

Treatment with sublethal doses of fenpropathrin on F_0 female adults

The LC_{15} and LC_{30} medicated membrane tubes and treated leaves were prepared using the method described in the section "Bioassay". Then, thirty adult females (F_0) were transferred into each tube with a treated leaf, and each concentration was replicated five times, with distilled water as the control. After 24 h, surviving mites were used in the section.

Effects of sublethal doses of fenpropathrin on developmental stages of the F_1 generation

The surviving female adults (F_0) in the section "Treatment with sublethal doses of fenpropathrin on F_0 female adults" were individually reared. The condition was as follows: A water-saturated cotton pad with filter paper on it was placed into a 90 mm Petri dish, with detached leaves of *O. corymbosa* on the filter paper. The female mite was transferred to the leaves, and a male adult mite was placed with each female adult. The leaves were replaced every two days. These mites were reared at a temperature of 25 ±

1 °C, relative humidity of 70 ± 10%, and a photoperiod of 14-hour light and 10-hour dark cycle (14 L: 10 D).

When the F_0 generation female adult mites reached their peak egg-laying period, not fewer than 100 eggs were collected to form the F_1 generation. After the eggs hatched, the young mites were transferred to the *O. corymbosa* fresh leaves and reared separately in the same conditions as above. They were observed every 12 hours until the F_1 generation developed into adult mites, and each developmental stage was recorded.

In this study, female adults of the F_0 generation were treated with LC_{15} and LC_{30}, respectively, using distilled water as the control. Eggs laid by the treated mites were collected to form the F_1 generation, and changes in the developmental duration of the offspring were observed, aiming to clarify the impact of sublethal stress on the offspring development duration.

Effects of sublethal doses of fenpropathrin on survival and reproduction of F_1 female adults

A male adult mite was introduced to each newly emerged female adult in F_1 generation in the section "Effects of sublethal doses of fenpropathrin on developmental stages of F_1 generation". The cumulative survival rate, pre-oviposition period, oviposition duration, daily eggs, and lifespan of each female adult mite were recorded every 12 hours until death.

***Effects of sublethal doses of fenpropathrin on the population growth of* Tetranychina harti**

To investigate the effects of sublethal doses of fenpropathrin on the population growth of *Tetranychina harti*, a life table assessment was conducted. According to the method described in the section "Treatment with sublethal doses of fenpropathrin on F_0 female adults", no fewer than 30 F_0 female adults were treated with LC_{15} and LC_{30}, respectively, and distilled water served as the control. After F_0 female adults were treated, no fewer than 100 eggs from each treatment were collected as the F_1 generation.

The rearing method was the same as "Effects of sublethal doses of fenpropathrin on developmental stages of F_1 generation". Daily observations were made to record the survival rate (l_x), which means the survival divided by the initial total. Once they develop into adult mites, they must be reared in male-female pairs. Not only the l_x, but also the daily egg production and the number of female mites were recorded until all individuals died. During this process, no fewer than 200 eggs (F_2 generation) laid by F_1 female adults from each treatment were collected and continued to be reared (method referring to the section "Effects of sublethal doses of fenpropathrin on developmental stages of F_1 generation") until the F_2 generation developed into adult mites. Then the female ratio was calculated. The m_x value, which represents the average female offspring (F_2) laid by each female adult (F_1), was calculated based on the daily egg production divided by the number of females on that day, multiplied by the female ratio.

The life table was constructed according to the method of Ding (1994) with the following demographic parameters calculated: net reproductive rate $R_0 = \sum l_x m_x$, mean generation time $T = \sum x l_x m_x / \sum l_x m_x$; intrinsic rate of increase $r_m = \ln R_0 / T$, finite rate of increase $\lambda = \exp(r_m)$, and population doubling time $DT = \ln 2 / r_m$, where x represents the time interval, l_x indicates the age-specific survival rate, and m_x denotes the average female offspring laid by each female during the x period.

Data analysis

Software SPSS 25.0 was used to calculate virulence regression equation, then according to the equation, LC_{15} and LC_{30} were calculated. Also, F_1 generation developmental duration (egg stage, larval stage, nymphal stage and immature stage), longevity, pre-oviposition period, oviposition period and egg production of F_1 female adult were analyzed by one-way ANOVA, followed by Duncan's multiple range test (DMRT, $P < 0.05$) for multiple comparisons of means among different treated groups (LC_{15}, LC_{30} and control). In addition, the cumulative survival rate of F_1 female adults was analyzed by Kaplan-Meier based on Log-Rank (Mantel-Cox) using software SPSS 25.0. Graphs were plotted using Excel software.

RESULTS

***Toxicity of fenpropathrin to* Tetranychina harti**

The regression equation of fenpropathrin to *Tetranychina harti* was y = −4.028 + 1.38X, the chi-

square χ^2 value 17.684, test for Pearson's goodness-of-fit showed significance level (heterogeneity) 0.774 ($P > 0.15$), indicating that the equation fitted the data well. Based on the equation, the value of LC_{50} was 354.954 mg/L (95% confidence intervals 303.892 mg/L ~ 410.000 mg/L). Finally, concentration of LC_{15} and LC_{30} were obtained as 78.354 mg/L and 165.273 mg/L, respectively.

Effects of sublethal doses of fenpropathrin on the development duration of Tetranychina harti

Treatment of F_0 adult female mites with sublethal doses (LC_{15} and LC_{30}) of fenpropathrin significantly influenced the development stages of F_1 generation (Table 1). Compared with the control, LC_{15} treatment significantly shortened the F_1 egg stage (7.72 d), larval stage (2.28 d), and total immature stage duration (14.77 d) ($P < 0.05$). In contrast, LC_{30} treatment markedly prolonged both the nymphal stage (6.06 d) and total immature stage (16.14 d) in comparison with the control ($P < 0.05$). The results revealed that LC_{30} caused significantly longer nymphal stage and total immature stage than LC_{15} ($P < 0.05$), whereas no significant differences were detected in egg or larval stages ($P > 0.05$). These results demonstrated that LC_{15} fenpropathrin accelerated the development of immature stages in *Tetranychina harti* offspring, while LC_{30} exhibited the opposite effect by delaying development.

Table 1. Effects on *Tetranychina harti* F_1 generation developmental stages after F_0 female adults treated with sublethal dose of fenpropathrin.

F_0 females treated	Egg duration/d	Larva duration/d	Nymph duration/d	Immature duration/d
Control	8.26 ± 0.92 a	2.59 ± 0.45 a	4.62 ± 0.83 b	15.47 ± 1.04 b
LC_{15}	7.72 ± 1.34 b	2.28 ± 0.58 b	4.77 ± 0.70 b	14.77 ± 1.42 c
LC_{30}	7.64 ± 0.97 b	2.43 ± 0.45 ab	6.06 ± 0.51 a	16.14 ± 1.10 a

Note: Data in the table represented mean ± standard deviation. Different lowercase letters within the same column indicated significant differences ($P < 0.05$).

Effects of sublethal doses of fenpropathrin on the reproduction of Tetranychina harti

As shown in Table 2, after treatment of F_0 adult female mites with sublethal doses (LC_{15} and LC_{30}) of fenpropathrin, no significant differences were observed in the longevity of F_1 adult females compared to the control ($P > 0.05$). The pre-oviposition period of F_1 females was shortened to 1.71 d and 1.09 d in the LC_{15} and LC_{30} treatment groups, respectively. However, the LC_{15} group showed no significant difference from the control ($P > 0.05$), while the LC_{30} group differed significantly from both the control and the LC_{15} group ($P < 0.05$). The oviposition duration was extended to 23.41 d and 25.03 d in the LC_{15} and LC_{30} groups, respectively. However, only the oviposition duration of the LC_{30} group was significantly longer than that of the control group ($P < 0.05$); there was no significant difference not only between the LC_{15} and control but also between the LC_{15} and LC_{30} ($P > 0.05$). Average egg production (108.76 eggs) per female in the control group was significantly higher than that in the LC_{15} group (75.15 eggs) ($P < 0.05$), while no significant differences were found between the LC_{30} group (97.25 eggs) and the control ($P > 0.05$). These results demonstrated that sublethal doses of fenpropathrin can shorten the pre-oviposition period while prolonging the oviposition duration in offspring generations compared to the control.

Table 2. Effects of sublethal doses of fenpropathrin on reproduction of *Tetranychina harti* F_1 female adults.

F_0 females treated	Longevity/d	Pre-oviposition/d	Oviposition/d	Eggs/female
Control	26.29 ± 1.45 a	2.21 ± 0.17 b	20.35 ± 1.42 a	108.76 ± 7.92 b
LC_{15}	26.47 ± 0.86 a	1.71 ± 0.12 b	23.41 ± 0.91 ab	75.15 ± 3.78 a
LC_{30}	27.18 ± 1.30 a	1.09 ± 0.09 a	25.03 ± 1.24 b	97.25 ± 5.45 b

Note: Data in the table represented mean ± standard deviation. Different lowercase letters within the same column indicated significant differences ($P < 0.05$).

Effects of sublethal doses of fenpropathrin on the survival of Tetranychina harti

After F_0 female adults were treated with fenpropathrin LC_{15} and LC_{30}, respectively, the sublethal effects on the cumulative survival rate of female adults were shown in Table 3. The results showed that

there was no significant difference between the control group and the LC_{15} group ($\chi^2 = 2.342$, $P = 0.126 > 0.05$), no significant difference between the control group and the LC_{30} group ($\chi^2 = 0.518$, $P = 0.472 > 0.05$), and no significant difference between the LC_{15} group and the LC_{30} group ($\chi^2 = 3.123$, $P = 0.077 > 0.05$).

Table 3. Pairwise comparison on the cumulative rate of F_1 female adults.

Log Rank (Mantel-Cox)	F_0 females treated	Control		LC_{15}		LC_{30}	
		χ^2	*P*	χ^2	*P*	χ^2	*P*
	Control	-	-	2.342	0.126	0.518	0.472
	LC_{15}	2.342	0.126	-	-	3.123	0.077
	LC_{30}	0.518	0.472	3.123	0.077	-	-

As shown in Figure 1, the cumulative survival rate curve showed that the survival rates of female adult mites in the control group, LC_{15} treatment group, and LC_{30} treatment group remained at 100% from day 0 to 12. From days 13 to 16, the survival rate of the LC_{15} treatment group remained at 100%, while female mites in the control group and the LC_{30} treatment group began to die from day 13, with the control group exhibiting a faster decline in survival rate. This trend continued until day 29. In other words, during days 0–29 of the female mites, the survival rates in both the LC_{15} and LC_{30} treatment groups were higher than those of the control group. However, from days 30 to 32, the survival rate of the control group exceeded that of the LC_{15} treatment group but remained lower than that of the LC_{30} treatment group. From day 33 onward, the survival rate of the control group was higher than that of both the LC_{15} and LC_{30} treatment groups.

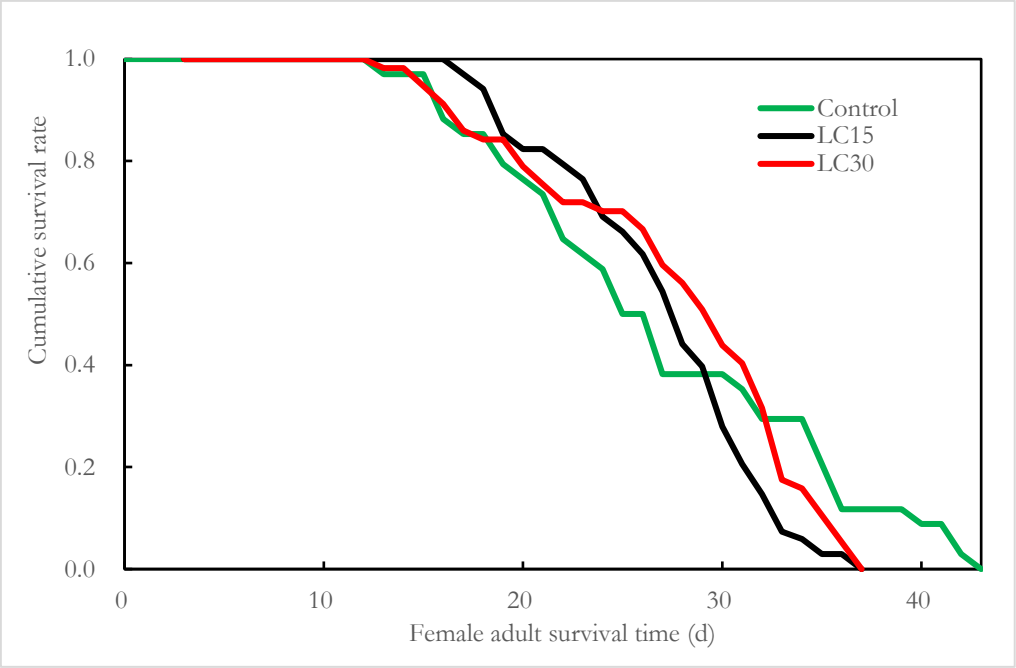

Figure 1. The Kaplan-Meier survival graphs of *Tetranychina harti* female adult mites.

Effects of sublethal doses of fenpropathrin on age-specific fecundity of Tetranychina harti *F_1 female adults*

The age-specific fecundity curve of F_1 female adult mites (Fig. 2) revealed that the daily average number of female offspring produced by per female adult in the control group exceeded 1 from days 2 to 27, while in the LC_{15} treatment group, it exceeded 1 from days 2 to 24, and in the LC_{30} treatment group, it exceeded 1 from days 1 to 29. Further analysis showed that although the control group had a higher daily average number of female offspring than both the LC_{15} and LC_{30} treatment groups during

days 3–17, the LC_{30} treatment group surpassed the control group during days 18–34. Overall, the decline in the age-specific fecundity curve of the LC_{30} treatment group was relatively gradual, maintaining a higher level of reproductive output over a longer period.

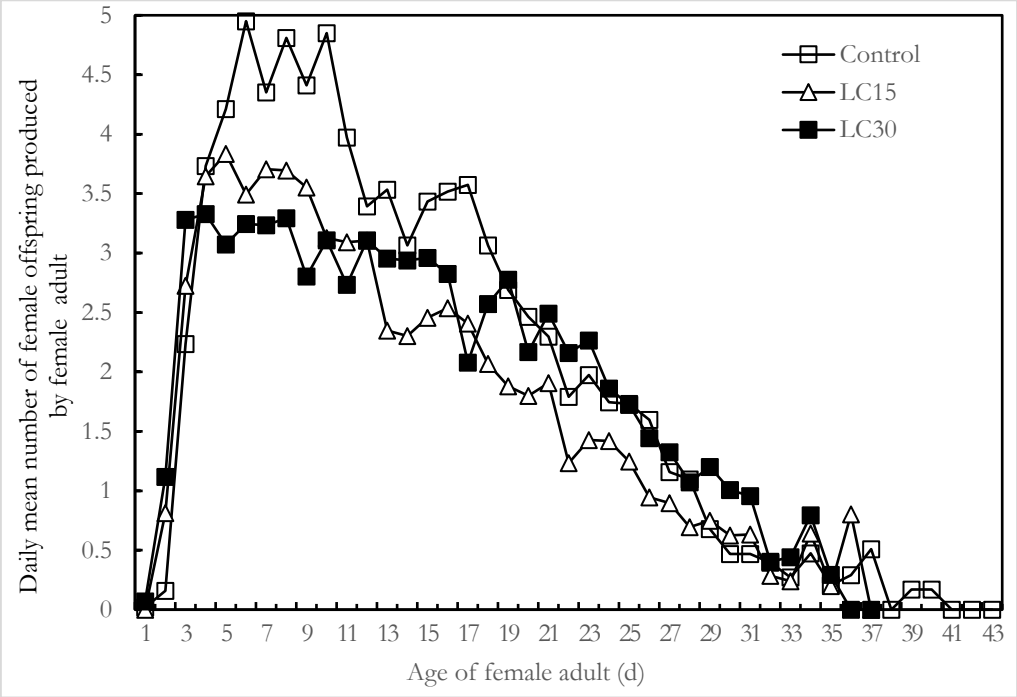

Figure 2. Age-specific fecundity rate curve of *Tetranychina harti* female adult mites.

Effects of sublethal doses of fenpropathrin on life table parameters of Tetranychina harti

As shown in Table 4, the net reproductive rate (R_0), intrinsic growth rate (r_m), and finite rate of increase (λ) of the offspring in the treatment groups LC_{15} and LC_{30} were all higher than those in the control group, with LC_{30} exhibiting a greater degree of increase. Also, the offspring female ratio in the LC_{15} group was greater than that of the control group. Following LC_{15} treatment, the mean generation time (T) was shortened by 1.82 days compared to the control, and the population doubling time (DT) was reduced by 0.51 days. In contrast, after LC_{30} treatment, the mean generation time (T) slightly increased compared to the control, but the population doubling time (DT) was shortened by 3.31 days, less than half that of the control. These results indicated that sublethal doses of fenpropathrin had a stimulatory effect on the population proliferation of *Tetranychina harti*.

Table 4. Effects of sublethal doses of fenpropathrin on the life table parameters of the F_1 generation of *Tetranychina harti*.

F_0 females treated	R_0	r_m	λ	T/d	DT/d	Female ratio
Control	29.02	0.12	1.13	28.27	5.82	0.6787
LC_{15}	31.50	0.13	1.14	26.45	5.31	0.8026
LC_{30}	34.75	0.33	1.38	28.93	2.15	0.6632

DISCUSSION

Effects of sublethal doses of fenpropathrin on the developmental duration of Tetranychina harti

In this study, the sublethal doses of fenpropathrin LC_{15} significantly shortened the developmental duration of the immature stages of *Tetranychina harti*, which aligned with previous findings showing that sublethal doses (LC_{10} and LC_{20}) of fenpropathrin significantly reduced the developmental duration of immature *Tetranychus urticae* compared to the control group (Zhang *et al.* 2012). However, the LC_{30} dose of fenpropathrin prolonged the developmental duration of the immature stages of *Tetranychina harti*, consistent with the results of He *et al.* (2016), who reported that a sublethal dose (LC_{20}) of fenpropathrin

extended the egg and nymphal stages of *P. citri*. These variations may be attributed to differences in pesticide doses and target species. When *Tetranychina harti* mites were treated with sublethal doses (LC_{10} and LC_{20}) of pyridaben, the developmental duration of the F_1 generation did not differ significantly from the control group (He 2020), which is inconsistent with these findings. This suggested that different acaricides may have distinct effects on the developmental duration of *Tetranychina harti*. Similar phenomena have been observed in other studies. For instance, when eggs of *P. citri* were exposed to sublethal doses of cyetpyrafen and cyenopyrafen, their developmental durations varied significantly depending on the acaricide used (Cheng *et al.* 2021): cyetpyrafen (LC_{10} and LC_{30}) had no significant effect on the developmental duration of immature *P. citri*, whereas cyenopyrafen (LC_{10} and LC_{30}) significantly shortened the developmental duration. Conversely, when *P. citri* adult females were treated with the same sublethal doses, cyetpyrafen (LC_{10} and LC_{30}) significantly shortened the developmental duration of the F_1 generation, while cyenopyrafen (LC_{10} and LC_{30}) had no significant effect. These results suggested that the impact of sublethal pesticide doses on developmental duration varied depending on the target species, life stage, type of pesticide, and pesticide dose.

***Effects of sublethal doses of fenpropathrin on the reproduction of* Tetranychina harti**

The impact of sublethal doses of insecticides/acaricides on arthropod reproduction remains controversial, with some studies reporting inhibitory effects while others suggest stimulatory effects. Our results demonstrated that sublethal doses of fenpropathrin shortened the pre-oviposition period and extended the oviposition duration of *Tetranychina harti*, with these effects becoming more noticeable at higher concentrations. While only the LC_{15} treatment significantly reduced total fecundity compared to control, the LC_{30} treatment showed no significant effect on egg production, suggesting potential reproductive stimulation by fenpropathrin. This stimulatory effect was further confirmed by increased intrinsic rate of increase (r_m), net reproductive rate (R_0), and finite rate of increase (λ), along with decreased population doubling time (DT) in treated groups. Similar reproductive stimulation by sublethal pyrethroids has been reported for other mite species: fenpropathrin LC_{10} enhanced reproduction in *A. viennensis* (Li *et al.* 2006); treatment with fenpropathrin LC_{10} and LC_{20} increased the r_m from 0.1919 (control group) to 0.1934 (LC_{10} treated group) and 0.2059 (LC_{20} treated group) in subsequent generations (Zhang *et al.* 2012); and various pyrethroids (deltamethrin, esfenvalerate, λ-cyhalothrin) significantly improved reproductive parameters (R_0, r_m, λ) in *P. citri* (Zanardi *et al.* 2018). Notably, fenpropathrin LC_{20} treatment of *P. citri* nymphs increased fecundity in the parental generation, shortened pre-oviposition periods in F_1 and F_2 generations, elevated female ratios, improved r_m and λ values, while reducing generation time (T) and population doubling time (DT) (He *et al.* 2016).

However, inconsistent reports exist regarding the sublethal effects of pyrethroids on the reproduction of mites. Some studies found either inhibitory or neutral effects: while fenpropathrin LC_{15} stimulated *A. viennensis* reproduction, LC_{25} showed no significant impact on net reproductive rate or population growth (Li *et al.* 2006); sublethal fenpropathrin suppressed both susceptible and resistant strains of *Tetranychus urticae* red form (Li 2019); and for *Cydia pomonella* L., fenpropathrin LC_{10} and LC_{20} decreased fecundity, hatch rate, adult longevity, and reproductive parameters, with prolonging generation time (T) and population doubling time (DT) (Liu 2016). Studies have shown that sublethal doses of acaricides can alter the proportion of female offspring in spider mites (Gu *et al.* 2010; He *et al.* 2016; He 2020), consistent with the findings of the present study. These contradictory findings highlight that sublethal effects of pyrethroids on the reproduction of mites depend on multiple factors, including species, developmental stage, and acaricide dose.

In summary, when female adult mites *Tetranychina harti* were exposed to sublethal doses of fenpropathrin, the F_1 generation exhibited shortened developmental duration of immature stages and pre-oviposition period, while showing increased intrinsic rate of increase (r_m), net reproductive rate (R_0), and finite rate of increase (λ). Additionally, the population doubling time (DT) was shorter than that of the control group. These findings collectively indicated that sublethal doses of fenpropathrin have a stimulatory effect on the population growth of *Tetranychina harti*.

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اثرهای زیرکشندهٔ فنپروپاترین بر هرنای تارتن ترشک، *Tetranychina harti* (Ewing) (Acari: Tetranychidae)

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چکیده

اثرات زیرکشنده فنپروپاترین بر هرنای تارتن ترشک، *Tetranychina harti* (Tetranychidae) بررسی شد. نتایج نشان داد که نسبت به گروه شاهد، دُزهای زیرکشنده فنپروپاترین به مقدار زیادی طول دورهٔ رشد فرزندان نابالغ را در گروه LC_{15} کوتاه کرد ($P < ۰/۰۵$) اما در گروه LC_{30} به میزان بسیاری آن را طولانی کرد ($P < ۰/۰۵$). افزون بر این، این دُزهای زیرکشنده دورهٔ پیش از تخمگذاری را کوتاه کردند در حالی که دورهٔ تخمگذاری کنه‌های بالغ ماده F_1 را طولانی‌تر کردند. نکته قابل توجه این است که کاهش فراوانی در میانگین باروری به ازای هر ماده فقط در گروه LC_{15} در مقایسه با گروه شاهد مشاهده شد ($P < ۰/۰۵$). منحنی‌های میزان زنده‌مانی تجمعی و منحنی‌های باروری وابسته به سن نشان دادند که غلظت‌های زیرکشنده (LC_{15} و LC_{30}) فنپروپاترین تأثیر نامطلوبی بر زنده‌مانی یا باروری کنهٔ *Tetranychina harti* نداشتند. هر دو گروه تیمار، میزان خالص تولید مثل (R_0) بیشتری نسبت به گروه شاهد نشان دادند. به طور مشابه، میزان ذاتی افزایش (r_m) در گروه‌های LC_{15} و LC_{30} از گروه شاهد بیشتر بود و میزان متناهی افزایش (λ) در هر دو گروه تیمار نیز بیشتر بود. افزون بر این، زمان دو برابر شدن جمعیت (DT) در گروه‌های تیمار کوتاه‌تر از گروه کنترل بود. این یافته‌ها نشان می‌دهد که قرار گرفتن در معرض فنپروپاترین در غلظت‌های زیرکشنده ممکن است اثربخشی آن را در کنترل جمعیت این کنه به خطر بیندازد.

واژگان کلیدی: باروری، پراسنجه‌های جدول زندگی، *Petrobia harti*، پایروتروئیدها، زنده‌مانی

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