# Sublethal effects of pymetrozine on the development, reproduction and insecticidal susceptibility of *Sogatella furcifera* (Hemiptera: Delphacidae)

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**Abstract**: 【Aim】 The white-backed planthopper, *Sogatella furcifera* (Horváth) (Hemiptera: Delphacidae) is an important insect pest of rice. The present study aims to determine the sublethal effects of pymetrozine on the development and reproduction of this insect and its susceptibility to other insecticides. 【Methods】 The life table method was used to evaluate the sublethal effects of pymetrozine ($LC_{10}$ and $LC_{25}$) on developmental duration, survival rate, emergence rate and longevity of $F_0$ and $F_1$ generations of *S. furcifera* and rice stem dipping method was adopted to determine its susceptibility to other insecticides after pymetrozine ($LC_{10}$ and $LC_{25}$) treatment. 【Results】 The developmental duration of the $F_0$ generations of *S. furcifera* treated with sublethal concentrations ($LC_{10}$ and $LC_{25}$) of pymetrozine for 48 h was increased by 1.98 d and 4.25 d, the longevities were shortened by 0.49 d and 1.73 d, the survival rates (85.00% and 68.50%, respectively) of the 3rd – 5th instar nymphs and the emergence rate (75.89% and 67.78%, respectively) decreased as compared with the control (92.00% and 85.90%, respectively), but significant difference was just observed in generation duration between the $LC_{25}$ treatment group and the control. Furthermore, the $F_1$ generation of *S. furcifera* exposed to sublethal concentrations ($LC_{10}$and $LC_{25}$) of pymetrozine for 48 h had decreased emergence rate (76.97% and 68.94%, respectively), copulation rates (77.79% and 66.44%, respectively), egg hatching rates (73.19% and 68.67%, respectively), fecundity (112.36 and 88.34 eggs laid per female, respectively), and relative fitness (0.41 and 0.20, respectively) as compared with the control (88.22%, 86.67%, 87.26%, 147.80 eggs laid per female and 1.00, respectively). The susceptibility of pymetrozine-treated *S. furcifera* to thiamethoxam, chlorpyrifos, and buprofezin showed that the $LC_{50}$ values of the three chemicals were 2.16, 40.87 and 3.12 mg/L in $LC_{10}$ treatment group, and 4.93, 17.96 and 8.39 mg/L in $LC_{25}$ treatment group, respectively. The relative toxicity index (RTI) of thiamethoxam, chlorpyrifos and buprofezin to *S. furcifera* indicated that the susceptibility of pymetrozine-treated *S. furcifera* to these three insecticides was reduced. 【Conclusion】 Pymetrozine at sublethal concentrations can reduce the fecundity and population growth of *S. furcifera* and make it less susceptible to thiamethoxam, chlorpyrifos and buprofezin.

**Key words**: *Sogatella furcifera*; pymetrozine; sublethal effect; fitness; population trend index; insecticide susceptibility

## 1 INTRODUCTION

The white-backed planthopper, *Sogatella furcifera* (Horváth) (Hemiptera: Delphacidae) is an important long-distance migratory rice pest (Kisimoto, 1976; Jiang *et al.*, 2015; Zhang *et al.*, 2016) that seriously threatens rice production in China by feeding on rice plant sap and transmitting southern rice black-streaked dwarf virus (Shen *et al.*, 2003; Zhou *et al.*, 2008). At present, application of insecticides remains the main strategy for suppressing *S. furcifera* populations and controlling transmission of the virus in China (Zhou *et al.*, 2008; Zheng *et al.*, 2014; Matsukura *et al.*, 2015; Kang *et al.*, 2016). However, the extensive use of pymetrozine, thiamethoxam, chlorpyrifos and other pesticides to control *S. furcifera* has led to its

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resistance to several conventional insecticides (Li *et al.*, 2015). Thus, identification and use of an alternative product could help control *S. furcifera* more effectively.

Pymetrozine is a new pyridine heterocyclic insecticide acting on the blood amine signaling pathway of the insect. It can cause neurotoxic-like reactions and regulate feeding behavior by inhibiting the central nervous system and interfering with normal feeding activity (Kaufmann *et al.*, 2004). Studies of pymetrozine that used electronic penetration graph technology showed that once an insect touches the insecticide, it immediately stops feeding and eventually starves to death due to irreversible physical effects (He *et al.*, 2011; Wang *et al.*, 2011). The toxic effects of pymetrozine on the insects occur by surface contact as well as feeding on the inner tissues of treated plants. Furthermore, because it acts via an idiographic mechanism, pymetrozine has very low mammalian toxicity, which makes exposure safe for most non-target arthropods, birds, fish, predatory mites and other animals (Jansen *et al.*, 2011; Xing and Xu, 2011). Pymetrozine is therefore a promising and environmentally friendly alternative insecticide against *S. furcifera* (Chen *et al.*, 2010; Cui *et al.*, 2010; Xu *et al.*, 2010; Zhang *et al.*, 2014).

When evaluating the efficacy of an insecticide, its lethal effect on target pests is usually the first parameter to be examined. However, its sublethal effect should also be considered. To date, pymetrozine has demonstrated good performance in controlling rice planthoppers, *Bemisia tabaci* and other pests with piercing-sucking mouthparts. Its sublethal concentration also had an inhibitory effect on brown planthoppers (Liu and Han, 2006; Liu *et al.*, 2012; Nauen *et al.*, 2013). However, the effect of the sublethal concentrations of pymetrozine on *S. furcifera* has not yet been reported.

After application in the field, insecticide residuals inevitably exert a sublethal effect on the pest population (Boina *et al.*, 2009; Cutler *et al.*, 2009; Han *et al.*, 2011). For instance, the presence of sublethal concentrations of insecticides could stimulate the fertility of pests and lead to resurgence of the population (He, 2010; Li *et al.*, 2014; Wang *et al.*, 2014; Xie *et al.*, 2014; Duan *et al.*, 2015; Liu *et al.*, 2016), or it could continue to reduce pest survival rate and fecundity and thereby inhibit the growth of pest populations (Xu *et al.*, 2011; Yang *et al.*, 2013; Tu *et al.*, 2016). Therefore, studying the effects of sublethal concentrations of insecticides on pests' survival, development, reproduction and population growth could help inform the use of insecticides in the field. Smarter insecticide use in turn could slow the development of insecticide resistance in pests, decrease the insecticide stress on ecosystems, and reduce the environmental pollution.

Herein, the life table method (Liu and Han, 2006) was used to understand the effect of pymetrozine on *S. furcifera*. The aim of the study is to evaluate the effect of application of sublethal concentrations of pymetrozine on the biological fitness of *S. furcifera* under laboratory conditions, and to understand how sublethal concentrations of pymetrozine affect the sensitivity of *S. furcifera* to other commonly used insecticides. Results of this study could provide insights for the use of pymetrozine to control *S. furcifera*.

## 2 MATERIALS AND METHODS

### 2.1 Test insects and insecticides

Test insects: *S. furcifera* adults were collected from a rice field in Huaxi, Guiyang, Guizhou, China in 2013. They were then maintained as laboratory population for use without any exposure to insecticides on rice seedlings at 25 ± 1℃ and 70% ± 10% relative humidity with a 16L : 8D photoperiod. The 3rd instar nymphs were selected from the laboratory population for the test.

Test insecticides: 95.25% pymetrozine was obtained from Shangyu Yinbang Chemical Co., Ltd. (Zhejiang, China); 96% thiamethoxam from Nanjing Panfeng Chemical Co., Ltd. (Jiangsu, China); 95.6% chlorpyrifos from Guangxi Tianyuan Biochemical Co., Ltd. (Guangxi, China); and 97% buprofezin from Guangxi Pingle Pesticide Factory (Guangxi, China).

### 2.2 Effects of sublethal concentrations of pymetrozine on the relative fitness of $F_0$ and $F_1$ generations of *S. furcifera*

The toxicity of pymetrozine to *S. furcifera* was determined previously by our research team using a modified version of the rice stem dipping method (Zhuang *et al.*, 2000). The sublethal concentrations of pymetrozine are 1.96 mg/L ($LC_{10}$) and 4.65 mg/L ($LC_{25}$), respectively (Liu *et al.*, 2016). The 3rd instar nymphs of *S. furcifera* were collected at the same age and in the same physiological condition. They were treated with the $LC_{10}$ and $LC_{25}$ of pymetrozine for 48 h. Control insects were fed with rice stems treated with water only (Cui *et al.*, 2010; Wang *et al.*, 2011; Su *et al.*, 2013). The surviving nymphs were moved into clean two-pass glass tubes containing fresh rice (10 nymphs per tube, 10 tubes

per treatment, and five replicates for each treatment). Old rice was replaced with fresh rice every 2 days. Culture conditions were as follows: temperature 25 ± 1℃, relative humidity 70% ± 10%, and photoperiod 14L∶10D. One hundred neonates representing the $F_1$ generation were collected from female adults of the $F_0$ generation treated with different concentrations of pymetrozine and then reared in the control conditions previously described. The insects were transferred to fresh rearing tubes, with 10 neonates per tube. The survival rates from the neonate to the 3rd instar nymphal stage (*Sr*1) and from the 3rd to 5th instar nymphal stage (*Sr*2) were recorded daily.

After *S. furcifera* molted to the 5th instar nymphal stage, males and females were collected every day, and their emergence rate (*Er*) and percentage of females (*Fr*) were recorded. A single male-female pair was placed in an individual tube containing fresh rice, which was replaced every 2 days. From the first appearance of the $F_1$ generation, the tubes were checked every 2 days to record the number of eggs and newly hatched nymphs present, which were then removed, and this continued until the adults died. The copulation rate (*Cr*) and fecundity (*Fd*, regarded as single female fecundity) were calculated. Egg hatching rate (*Ehr*) was determined as the number of all neonates divided by the number of all neonates and unhatched eggs. The experiments were carried out with five replicates.

The population trend index (*I*) and relative fitness were calculated as follows:

$$N_t = N_0 \times Sr1 \times Sr2 \times Er \times Fr \times Cr \times Fd \times Ehr;$$

$$I = N_t / N_0;$$

$$\text{Relative fitness} = I_T / I_C.$$

where $N_0$ is the number of individuals in the initial population, $N_t$ is the number of individuals in the population of the next generation, $I_T$ is the population growth index in the pymetrozine treatments, and $I_C$ is the population growth index of the control.

### 2.3 Effects of pymetrozine stress on susceptibility of *S. furcifera* to other insecticides

The 3rd instar nymphs of *S. furcifera* were collected and fed with rice stems treated with sublethal concentrations ($LC_{10}$ and $LC_{25}$) of pymetrozine; any insects surviving after 48 h were then collected. The control insects were fed rice stems treated with water only. The nymphs were exposed to thiamethoxam, chlorpyrifos and buprofezin by using the rice stem dipping method previously described (Zhuang *et al.*, 2000)

For the toxicity tests, the test insecticides were accurately weighed on 1/10 000 electronic load cell scales, dissolved to the appropriate concentration in acetone, and diluted to five equal-ratio gradients with plain water. Tiller stage rice cultivar Taichung Native 1 with strong and consistent roots were pulled, cleaned, and put in the shade to dry until the surface was free of water; next, they were cut into 15-cm strips that contained roots. The treated rice stems were soaked in the solution containing thiamethoxam, chlorpyrifos and buprofezin in the order of low to high concentration for 30 s, and the controls were soaked in water. Plant roots were surrounded by absorbent cotton, and the lengths of rice were placed in double-pass glass tubes. The surviving nymphs after exposure to sublethal concentrations of pymetrozine were placed on the treated rice, with 20 nymphs per tube and 5 replicates for each treatment. The mortality was recorded every 24 h. The treated insects were maintained under the conditions of 25 ± 1℃, 70% ± 10% relative humidity and a 16L∶8D photoperiod in an artificial climate box.

### 2.4 Statistical analysis

The data were analyzed using Statistical Product and Service Solutions 16.0 (SPSS 16.0, IBM, New York, USA). Differences between the pymetrozine treatment groups and the control group were tested using Duncan's multiple range test when the variance was homogeneous. When the variance was not homogeneous, Tamhane's $T^2$ multiple comparison test was used. Based on the following formula, the relative toxicity index of the tested insecticides to different populations of *S. furcifera* was calculated:

$$\text{Relative toxicity index (RTI)} = \frac{LC_{50}\text{ value of the untreated population}}{LC_{50}\text{ value of a }LC_{10}\text{ or }LC_{25}\text{ treated population}} \times 100.$$

## 3 RESULTS AND ANALYSIS

### 3.1 Effects of pymetrozine stress on the $F_0$ generation of *S. furcifera*

Exposure to sublethal concentrations ($LC_{10}$ and $LC_{25}$) of pymetrozine affected the $F_0$ generation of *S. furcifera* in a number of ways (Table 1). The developmental duration of the 3rd – 5th instar nymphs in the $LC_{10}$ and $LC_{25}$ pymetrozine treatment groups was 1.98 and 4.25 d longer than that of the control group, respectively, and statistically significant difference existed among all the three groups ($P < 0.05$). The adult longevities in the $LC_{10}$ and $LC_{25}$ groups were 0.49 d and 1.73 d shorter than that of the control group, respectively, but their differences were not statistically significant ($P >$

0.05). The survival rates (85.00% and 68.50%, respectively) of the 3rd – 5th instar nymphs were significantly lower in both the $LC_{10}$ and $LC_{25}$ pymetrozine treatment groups as compared with that of the control group (92.00%). The emergence rates (75.89% and 67.78%, respectively) of the $F_0$ generation groups treated with pymetrozine was reduced as compared with that of the control group (85.90%), and the difference was statistically significant between the $LC_{25}$ group and the control group ($P < 0.05$).

**Table 1 Effects of sublethal concentrations of pymetrozine on the development of the $F_0$ generation of *Sogatella furcifera***

| Treatment dose of pymetrozine | Nymphal duration (d) | | | | Survival rate of the 3rd to 5th instar nymph (%) | Emergence rate (%) | Adult longevity (d) |
|---|---|---|---|---|---|---|---|
| | 3rd instar | 4th instar | 5th instar | 3rd – 5th instar | | | |
| 0 (Control) | 2.50 ± 0.25 a | 2.41 ± 0.23 a | 3.33 ± 0.32 a | 8.25 ± 0.43 a | 92.00 ± 2.55 a | 85.90 ± 2.25 a | 14.54 ± 0.41 a |
| $LC_{10}$ | 2.85 ± 0.18 a | 3.34 ± 0.33 ab | 4.04 ± 0.36 ab | 10.23 ± 0.63 b | 85.00 ± 3.06 b | 75.89 ± 2.00 ab | 14.05 ± 0.52 a |
| $LC_{25}$ | 3.85 ± 0.26 b | 4.12 ± 0.47 b | 4.53 ± 0.22 b | 12.50 ± 0.43 c | 68.50 ± 5.62 b | 67.78 ± 5.76 b | 12.81 ± 0.67 a |

Water was applied as the control. Different lowercase letters following the data (mean ± *SE*) within a column indicate significant difference between the pymetrozine treatment groups and the control group ($\alpha = 0.05$) by Duncan's multiple range test. The same for Tables 2 and 3.

### 3.2 Effects of pymetrozine stress on the developmental duration of the $F_1$ generation of *S. furcifera*

Sublethal concentrations of pymetrozine generally increased the developmental duration of the $F_1$ generation of *S. furcifera* (Table 2). The duration of the 1st instar nymph under $LC_{25}$ stress was extended by 0.92 d as compared with that of the control group ($P < 0.05$). The duration of the 2nd, 3rd, 4th and 5th instar nymphs was longer in the pymetrozine-treated groups as compared with that of the control group, but their differences were not statistically significant ($P > 0.05$). The total nymphal duration in the $LC_{25}$ group was significantly longer (2.23 d) than that of the control group ($P < 0.05$).

**Table 2 Nymphal duration of the $F_1$ generation of *Sogatella furcifera* treated with pymetrozine**

| Treatment dose of pymetrozine | Nymphal duration (d) | | | | | |
|---|---|---|---|---|---|---|
| | 1st instar | 2nd instar | 3rd instar | 4th instar | 5th instar | 1st to 5th instar |
| 0 (Control) | 3.35 ± 0.26 a | 2.54 ± 0.29 a | 2.58 ± 0.30 a | 3.13 ± 0.13 a | 3.46 ± 0.11 a | 15.07 ± 0.58 a |
| $LC_{10}$ | 3.77 ± 0.34 ab | 3.01 ± 0.25 a | 2.92 ± 0.07 a | 2.85 ± 0.12 a | 3.69 ± 0.30 a | 16.25 ± 0.64 ab |
| $LC_{25}$ | 4.27 ± 0.18 b | 3.08 ± 0.10 a | 2.89 ± 0.24 a | 3.27 ± 0.37 a | 4.07 ± 0.37 a | 17.30 ± 0.67 b |

### 3.3 Effects of pymetrozine treatment on the survival rate, emergence rate, copulation rate, female rate, fecundity and egg hatching rates of the $F_1$ generation of *S. furcifera*

The life tables were established to evaluate the susceptibility of the $F_1$ generation of *S. furcifera* to pymetrozine ($LC_{10}$ and $LC_{25}$). As shown in Table 3, the population trend indexes of *S. furcifera* treated with the $LC_{10}$ and $LC_{25}$ of pymetrozine were 16.62 and 7.92, respectively, whereas that of the control group was 40.16. The survival rates of *Sr*1 and *Sr*2 decreased in the $LC_{10}$ and $LC_{25}$ groups as compared with the control group, but only the survival rates of *Sr*1 between the $LC_{25}$ group and the control group had statistically significant difference ($P < 0.05$). The *Er* values of both treated groups were lower than that of the control, but the difference was significant only between the $LC_{25}$ group and the control group ($P < 0.05$). The egg hatching rates of both treated groups were significantly lower than that of the control group, and the same was true for the copulation rate ($P < 0.05$). The proportions of females in the treatment groups ($LC_{10}$ and $LC_{25}$) did not differ significantly from that in the control ($P > 0.05$). The fecundities of females in the $LC_{10}$ and $LC_{25}$ groups were significantly lower (112.36 and 88.34 eggs laid per female, respectively) than that of the control group (147.80 eggs laid per female), indicating that the $LC_{10}$ and $LC_{25}$ concentrations of pymetrozine inhibited the fecundity of *S. furcifera*. The fecundity of *S. furcifera* stressed by the $LC_{25}$ and $LC_{10}$ of pymetrozine was significantly different from that of the control group. The relative fitness values of *S. furcifera* exposed to the $LC_{10}$ and $LC_{25}$ of pymetrozine were 0.41 and 0.20, respectively, while that in the control was 1.00.

### 3.4 Sensitivity of *S. furcifera* to other insecticides after treatment with sublethal concentrations of pymetrozine

As shown in Table 4, the $LC_{50}$ values of thiamethoxam to the 3rd instar nymphs of *S. furcifera* after exposed to $LC_{10}$ and $LC_{25}$ of pymetrozine were 2.16 and 4.93 mg/L, respectively, while those of chlorpyrifos were 40.87 and 17.96 mg/L, and those of buprofezin were 3.12 and 8.39 mg/L, respectively. The highest RTI of thiamethoxam, chlorpyrifos and buprofezin to *S. furcifera* was found in the control group, and the moderate RTI in the $LC_{10}$ group and the least RTI in the $LC_{25}$ group, indicating that the susceptibility of pymetrozine-treated *S. furcifera* to other insecticides was reduced.

**Table 3 Effects of sublethal concentrations of pymetrozine on the life table parameters of the $F_1$ generation of *Sogatella furcifera***

| Treatment dose of pymetrozine | $N_0$ | *Sr*1 (%) | *Sr*2 (%) | *Er* (%) | *Fr* (%) |
|---|---|---|---|---|---|
| 0 (Control) | 100 | 88.20 ± 2.33 a | 90.28 ± 2.78 a | 88.22 ± 3.37 a | 51.15 ± 1.44 a |
| $LC_{10}$ | 100 | 83.00 ± 3.39 a | 81.22 ± 3.65 a | 76.97 ± 4.32 ab | 50.07 ± 1.34 a |
| $LC_{25}$ | 100 | 73.40 ± 2.80 b | 80.94 ± 4.55 a | 68.94 ± 5.61 b | 47.98 ± 2.38 a |

| Treatment dose of pymetrozine | *Cr* (%) | *Fd* | *Ehr* (%) | $N_t$ | *I* | Relative fitness |
|---|---|---|---|---|---|---|
| 0 (Control) | 86.67 ± 3.50 a | 147.80 ± 13.54 a | 87.26 ± 2.54 a | 4 016.35 | 40.16 | 1.00 |
| $LC_{10}$ | 77.79 ± 3.72 b | 112.36 ± 8.06 b | 73.19 ± 4.36 b | 1 661.99 | 16.62 | 0.41 |
| $LC_{25}$ | 66.44 ± 3.27 b | 88.34 ± 8.51 b | 68.67 ± 5.20 b | 792.04 | 7.92 | 0.20 |

*Sr*1: Survival rate from neonate to the 3rd instar nymph; *Sr*2: Survival rate from the 3rd to 5th instar nymph; *Er*: Emergence rate; *Fr*: Percentage of females; *Cr*: Copulation rate; *Fd*: Fecundity (number of eggs laid per female); *Ehr*: Egg hatching rate; $N_0$: Number of individuals in the initial population; $N_t$: Number of individuals in the population of the next generation; *I*: Population trend index.

**Table 4 Susceptibility of pymetrozine-treated *Sogatella furcifera* to three insecticides**

| Insecticide | Population | Regression equation | $LC_{50}$ (mg/L) (95% CL) | Relative toxicity index (RTI) |
|---|---|---|---|---|
| Thiamethoxam | Control | $Y = 0.96X + 0.16$ | 0.72 (0.52 – 1.00) | 100 |
| | $LC_{10}$ treated | $Y = 2.18X - 0.73$ | 2.16 (1.86 – 2.50) | 33.34 |
| | $LC_{25}$ treated | $Y = 2.55X - 1.77$ | 4.93 (4.30 – 5.62) | 14.65 |
| Chlorpyrifos | Control | $Y = 2.14X - 1.68$ | 6.07 (5.22 – 7.10) | 100 |
| | $LC_{10}$ treated | $Y = 2.12X - 3.42$ | 40.87 (35.14 – 48.00) | 14.85 |
| | $LC_{25}$ treated | $Y = 2.56X - 3.21$ | 17.96 (15.69 – 20.49) | 33.79 |
| Buprofezin | Control | $Y = 1.30X - 0.08$ | 1.15 (0.88 – 1.49) | 100 |
| | $LC_{10}$ treated | $Y = 1.86X - 0.92$ | 3.12 (2.65 – 3.68) | 36.85 |
| | $LC_{25}$ treated | $Y = 2.05X - 1.90$ | 8.39 (7.17 – 9.73) | 13.70 |

## 4 DISCUSSION

Pymetrozine is a new pesticide that is safe to humans and livestock but has high efficiency for eradicating pests. As time elapses, the concentration of insecticide sprayed on the plants decreases to a value that cannot kill insects but is still high enough to stress the remaining insects, and this is referred to as the sublethal concentration (Han *et al.*, 2011). Thus, beyond direct killing of pests, the sublethal concentration of pymetrozine will have a collective influence biologically on the surviving population in the field. In this study, the developmental duration of the $F_0$ generation of *S. furcifera* was prolonged and the survival rate and emergence rate decreased under both sublethal pymetrozine treatments ($LC_{10}$ and $LC_{25}$). This is similar to the result reported for *Nilaparvata lugens* treated with pymetrozine ($LC_{30}$) (Liu *et al.*, 2012). In addition, *Rhopalosiphum padi* treated with pymetrozine ($LC_{10}$ and $LC_{15}$) exhibited an extended developmental duration and decreased survival rate and fecundity (Cui *et al.*, 2010; Nauen *et al.*, 2013). In the current study, oviposition of the $F_1$ generation of *S. furcifera* was significantly lower in the pymetrozine-treated groups than in the control group, indicating that the developmental rate and fecundity of the population were inhibited after treatment with sublethal concentrations of pymetrozine. This effect may be related to the action mechanism of pymetrozine.

Once a pest touches pymetrozine, feeding is inhibited and "blockage of the stylet penetration" occurs (Harrewijn and Kayser, 1997). Electronic penetration graphs of the feeding behavior of *N. lugens* revealed that pymetrozine treatment of rice could significantly decrease the feeding of this pest within the phloem of rice (He *et al.*, 2011). Similar results were reported in *B. tabaci* (Wang *et al.*, 2011). Therefore, the current results suggest that *S. furcifera* treated with sublethal concentrations of pymetrozine experience changes in feeding behavior that inhibit nutritional status, normal development and reproduction.

Relative fitness can be used to evaluate the adaptability of pests to insecticide treatment (Liu and Lu, 2016). Studying the change of relative fitness under treatment with sublethal concentrations of pymetrozine in *S. furcifera* could provide a reference for the application of the insecticide in the field. Yang *et al.* (2012) reported that treatment with sublethal concentrations of chlorantraniliprole could significantly shorten the oviposition period and reduce the oviposition amount and the fecundity of the next generation of *S. furcifera*. The relative fitness of *S. furcifera* treatment with sublethal concentrations of triazophos (Liu *et al.*, 2016) and bromothyrinamide (Zhou *et al.*, 2016) was reduced as compared with that of the control group. In the current study, the mating rate, egg hatching rate, fecundity per female and the population fitness in the $F_1$ generation of *S. furcifera* treated with sublethal concentrations of pymetrozine were lower than those of the control group. Liu *et al.* (2012) reported similar effects of treatment with sublethal concentrations of pymetrozine on the mating rate, fecundity, egg hatching rate, emergence rate and population fitness of the brown planthopper (Liu *et al.*, 2012). These results indicated that the fecundity and relative fitness of *S. furcifera* decreased after exposure to sublethal concentrations of pymetrozine, which illustrates that pymetrozine could effectively control the population growth of *S. furcifera*. When *S. furcifera* was treated with a sublethal concentration of triazophos, its relative fitness was also reduced. The difference between treatments with sublethal concentrations of pymetrozine and triazophos was that the reproduction of *S. furcifera* was significantly stimulated under treatment with triazophos (Liu *et al.*, 2016). Li (2012) found that triazophos treatment could stimulate the reproduction of female *N. lugens*, as the expression of reproduction-related genes (*e. g.*, vitellogenin genes) was significantly up-regulated. Thus, the response mechanism of *S. furcifera* to insecticides appears to be different from one to the other, and pymetrozine treatment may down-regulate the expression of reproduction-related genes in *S. furcifera*.

The sensitivity of pests to insecticides is an important reference for the chemcals' application in the field. In this study, the susceptibility of pymetrozine-stressed *S. furcifera* to thiamethoxam, chlorpyrifos and buprofezin was lower as compared with the control. The same result was reported for the susceptibility of the Western flower thrips to other insecticides under the stress of $LC_{25}$ of spinosas (Gong *et al.*, 2010). When *Bemisia tabaci* were treated with pymetrozine, the product encoded by CYP6CM1 gene, which was the first hemipteran cytochrome P450 gene identified, could metabolised structurally different insecticides belonging to two different action modes: functionally expressed nicotinic acetylcholine receptor agonists (neonicotinoids) and selective homopteran feeding blockers (Nauen *et al.*, 2013). Therefore, we propose that the same mechanism was activated in *S. furcifera* and consequently its susceptibility to other insecticides decreased. These may be related to the mechanism of stress resistance that occurs after exposure to the stress.

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# 吡蚜酮对白背飞虱的发育、繁殖和药剂敏感性的亚致死效应

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**摘要：**【目的】白背飞虱 *Sogatella furcifera*（Horváth）是我国重要的水稻害虫。本研究旨在确定亚致死浓度吡蚜酮对白背飞虱发育和繁殖及亚致死浓度处理后白背飞虱对其他药剂的敏感性变化的影响。【方法】用生命表法研究了亚致死浓度吡蚜酮处理对白背飞虱 $F_0$ 及 $F_1$ 代发育历期、存活率、羽化率和寿命的亚致死效应；采用稻茎浸渍法，测定了亚致死浓度吡蚜酮处理后白背飞虱对其他药剂的敏感性。【结果】经 $LC_{10}$ 和 $LC_{25}$ 吡蚜酮处理后，白背飞虱 $F_0$ 代 3－5 龄若虫历期比对照（8.25 d）分别延长了 1.98 d 和 4.25 d，寿命分别比对照（14.54 d）缩短了 0.49 和 1.73 d，3－5 龄若虫存活率（分别为 85.00% 和 68.50%）和羽化率（分别为 75.89% 和 67.78%）比对照（分别为 92.00% 和 85.90%）下降，其中 $LC_{25}$ 处理组与对照比差异显著。$LC_{10}$ 和 $LC_{25}$ 吡蚜酮处理的白背飞虱 $F_1$ 代羽化率（分别为 76.97% 和 68.94%）、交尾率（分别为 77.79% 和 66.44%）和卵孵化率（分别为 73.19% 和 68.67%）比对照（分别为 88.22%，86.67% 和 87.26%）显著降低，但只有 $LC_{25}$ 处理组的 $F_1$ 代发育历期与对照组有显著差异；$LC_{10}$ 和 $LC_{25}$ 吡蚜酮处理后的 $F_1$ 代单雌产卵量比对照（147.80 粒/雌）显著下降（分别为 112.36 和 88.34 粒/雌），种群相对适合度比对照（1.00）也明显下降（分别为 0.41 和 0.20）。经吡蚜酮 $LC_{10}$ 和 $LC_{25}$ 处理后，测定白背飞虱对噻虫嗪，毒死蜱和噻嗪酮的敏感性结果显示，这 3 种杀虫剂的 $LC_{50}$ 在 $LC_{10}$ 处理组中分别为 2.16，40.87 和 3.12 mg/L，在 $LC_{25}$ 处理组中分别为 4.93，17.96 和 8.39 mg/L。噻虫嗪、毒死蜱、噻嗪酮的相对毒力指数（RTI）结果显示，$LC_{10}$ 和 $LC_{25}$ 处理后的白背飞虱对这 3 种杀虫剂的敏感性均降低。【结论】吡蚜酮处理后，白背飞虱对其他药剂的敏感性均降低。吡蚜酮亚致死浓度处理能降低白背飞虱的繁殖力，抑制种群增长，亚致死浓度处理后的白背飞虱种群对噻虫嗪、毒死蜱和噻嗪酮的敏感性均降低。

**关键词：**白背飞虱；吡蚜酮；亚致死效应；适合度；种群趋势指数；药剂敏感性

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