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Research Article

Effects of Pyriproxyfen on Life Table Indices of *Plutella xylostella* in Multigenerations

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The diamondback moth (DBM), *Plutella xylostella* (L.) (Lepidoptera: Plutellidae), is a major pest of Brassicaceae family in Iran. This study investigated the sublethal effects of pyriproxyfen, a juvenile hormone analogue, on DBM, for two subsequent generations. The leaf dip bioassay method was adopted in conducting this experiment. Sublethal concentrations resulted in a significant decrease in fecundity, oviposition period, and pupal weight of parents and offspring generations. Also, the development time of DBM was prolonged after exposure to pyriproxyfen. The biological parameters such as net reproductive rate (R_0) and intrinsic (r_m) and finite (λ) rate of increase were lower than control in treatment groups, significantly. From our investigations, pyriproxyfen is a good choice for control of the diamondback moth population through continuous generations.

1. Introduction

The diamondback moth (DBM), *Plutella xylostella* (L.) (Lepidoptera: Plutellidae), is one of the most destructive insect pests of Brassicaceae worldwide. Its annual cost for control is estimated to be US $1 billion [1, 2]. It is ranked among the most resistant species [3]. DBM feeds only on members of the Brassicaceae such as radish, turnips, kohlrabi cabbage, broccoli, Brussels sprouts, cabbage, mustard, Chinese cabbage, and rape. These plants are the most common vegetables in Asian diet [1, 4]. The high reproductive rate, rapid resistance development to insecticides, and absence of effective natural enemies, especially parasitoids, are majorly responsible for the increasing pest status of DBM in most counties [5, 6].

Over the last two decades, DBM has been a major pest of cruciferous crops in Tehran province and other areas of Iran [7]. Owing to its ability to develop resistance to many conventional insecticides, the use of new insecticides which have low effects on other nontarget organisms can be effective and helpful. The use of very low doses of insecticides with strong sublethal effects offers a promising and environmentally friendly component to improve integrated pest management strategies [8].

Pesticides at sublethal concentrations have a strong impact on insects physiologically and behaviorally [9]. The study of the life table parameters of an organism (demographic toxicology) can be a good indicator for background toxicology [10]. Fenoxycarb and pyriproxyfen are aromatic nonterpenoid insecticides which can mimic the action of JHs in a number of physiological processes [11]. Pyriproxyfen with a low mammalian toxicity was first registered in Japan in 1991 for control of public health pest [12]. The sublethal concentrations of IGRs and other groups of insecticides have been shown to affect reproductive parameters. For example, according to Sial and Brunner [8], the adult weight of Obliquebanded leafroller, *Choristoneura rosaceana* (Harris) (Lepidoptera: Tortricidae), was lowered upon application of pyriproxyfen. Also, fluctuations (increasing and decreasing) in the developmental times of various insects have been reported after exposure to the insecticides [13–17]. In addition, the chemical and natural compounds may affect the insects' larval weight [17–20] and other reproductive parameters such as the pupal weight [21], hatchability [19],

Table 1: Toxicity of pyriproxyfen on the 3rd instar larvae of diamondback moth, *Plutella xylostella*.

	n^a	df	LC_{10} ($g\,L^{-1}$)[b]	LC_{25} ($g\,L^{-1}$)[b]	LC_{50} ($g\,L^{-1}$)[b]	Slope ± SE	χ^2
Pyriproxyfen	259	5	0.610 (0.394–0.764)	0.848 (0.643–0.988)	1.223 (1.070–1.362)	4.24 ± 0.74	7.30

a: number of subjects.
b: 95% confidence limits in parenthesis.

fecundity [17, 22], preoviposition and postoviposition periods [23], and other reproductive parameters such as net reproductive rate (R_0) and intrinsic rate of increase (r_m) [24, 25].

In a previous report, contact toxicity (topical) of pyriproxyfen on DBM was studied by Alizadeh et al. [26]. In the current study, leaf dip method which is a combination of contact and oral toxicity has been adopted. This combined method of pyriproxyfen application is similar to its recorded application in field. Therefore, the current results can be more functional for DBM control. This study was conducted to evaluate the sublethal effects and toxic activity of pyriproxyfen on the demographic parameters of DBM, such as fecundity and pupal weight, developmental time, preoviposition, oviposition, and postovipostion periods, adult longevity, and total life span. The oviposition parameters included gross reproductive rate (GRR), net reproductive rate (R_0), intrinsic rate of increase (r_m), finite rate of increase (λ), mean generation time (T), doubling time (Dt), birth rate (b), and death rate (d).

2. Materials and Methods

2.1. Insect Rearing. The *P. xylostella* larva was collected from an insecticides-free field at Faculty of Agriculture at Tarbiat Modares University, Tehran, Iran, during the 2013 growing season. Leaves of cauliflower, *Brassica oleracea* (Brassicaceae), were used in rearing the larva. A 10% sugar solution was used in feeding the adult. Insect colonies was maintained at 25 ± 1°C and 65 ± 5% relative humidity (RH) under a 16L:8D cycle in a growth chamber. The bioassays were started after three generations.

2.2. Dose-Mortality Response and Sublethal Effects on Parent Generation. The bioassay tests were performed through leaf dip method [27]. This was performed by dipping circular cabbage leaf disks into various concentrations of insecticide (pyriproxyfen, Admiral 10 EC, Sumitomo Chemical, Japan) prepared with water containing 0.02% Tween-20 for 10 s, under laboratory condition. Water and Tween-20 were used for control. After drying at room temperature, the leaf disks were placed in plastic cups. Thereafter, 10 randomly selected 3rd instar larvae were placed on each leaf disk. The test was repeated in 4 cycles. The mortality counts were recorded and analyzed 96 h after treatment using probit analysis SAS version 9.1 [28].

To determine the effect of sublethal doses on biological parameters of parent generation, the cabbage leaf disks were dipped in sublethal solutions for 10 s. Whenever the leaves had dried, twenty-five 3rd instar larvae were put on the treated leaf disks, kept in plastic cups, and allowed to feed for 96 h. Each treatment was replicated eight times. The circular leaf disks were treated as explained in the previous section while 0.02% Tween-20 in water was used as a control. To measure the fecundity and other demographic parameters, the surviving larvae were transferred onto fresh cabbage leaves and allowed to continue their development to pupation. On the 2nd day of pupal period, the pupae in both the parent and offspring generations were individually weighed. To determine the oviposition parameters, fifteen pairs (male and female) from each treatment were set up and introduced into a plastic cage (8.5 × 6.5 × 4 cm) containing fresh leaf disks necessary for mating and oviposition. The adults were fed on a 10% sugar solution. Daily collection and replacement of leaves by new ones were necessary to prevent starvation of larvae.

2.3. Effects of Sublethal Doses on Offspring Generation. To evaluate the effect of pyriproxyfen on the next generation, 100 eggs obtained from the parent adults of each treatment were individually placed in plastic cages. The larvae were fed on cabbage leaves. The developmental time and survival rates of various stages were recorded daily until death of all individuals. Oviposition parameters were recorded as above.

2.4. Data Analysis. To test for the sublethal effects of treatments on the demographic parameters of *P. xylostella*, a one-way analysis of variance was performed. A significant difference was necessitated for the mean to be separated using Tukey's Studentized Range Test (at $P < 0.05$). All statistical tests were performed in SAS version 9.1 [28]. Jackknife technique [29] which is similar to bootstrapping was used to estimate the sample mean and standard error of biological parameters.

3. Results

3.1. Toxicity of Tests. Treatment with pyriproxyfen caused a high level of toxicity on *P. xylostella* (Table 1). The calculated LC_{50} of leaf dip bioassay on the third instar larvae of *P. xylostella* was 1.223 $g\,L^{-1}$. The values of LC_{10} and LC_{25} measured 96 h after treatments were 0.610 and 0.848 $g\,L^{-1}$, respectively.

3.2. Pupal Weight and Fecundity. Sublethal concentrations of pyriproxyfen had determined effects on pupal weight and fecundity of parent and offspring generations as shown in Table 2. A significant decrease in the fecundity of both parent and offspring generations (ANOVA; parent, F (2, 42) = 44.27, $P < 0.0001$; offspring, F (2, 46) = 9.10; $P = 0.0005$) was observed when pyriproxyfen treatment was applied. Also, the pupal weight was significantly affected by pyriproxyfen in

Table 2: Comparison of fecundity of *P. xylostella* treated with sublethal doses of pyriproxyfen and control (untreated group) in the parent and offspring (*F*1 generation).

Entries	Fecundity (egg/female)	
	Parent	Offspring
	Mean ± SE#	Mean ± SE#
Control	169.40 ± 12.84[a]	148.00 ± 12.22[a]
LC_{10}	57.40 ± 10.13[b]	79.54 ± 13.49[b]
LC_{25}	32.86 ± 9.55[b]	55.55 ± 27.29[b]
F	44.27	9.10
P	<0.0001	0.0005
$df_{t,e}$	2, 42	2, 46

#: means marked with the same letters within a column are not significantly different (Tukey's test; $P < 0.05$).

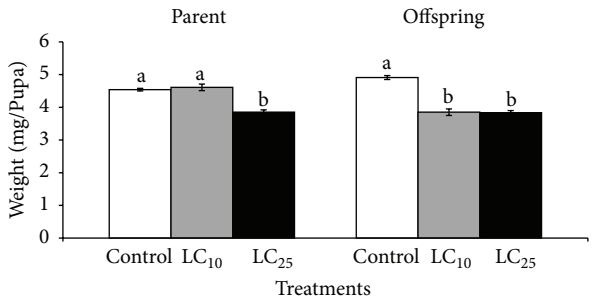

Figure 1: The effects of sublethal doses of pyriproxyfen on the pupal weight of *P. xylostella* in subsequent generations (parent: F (2, 72) = 10.65, $P < 0.0001$; offspring: F (2, 72) = 10.67, $P < 0.0001$).

parent and offspring generations (Figure 1) (ANOVA; parent, F (2, 72) = 10.65, $P < 0.0001$; offspring, F (2, 72) = 10.67, $P < 0.0001$).

3.3. Developmental Time and Adult Life Span. Pyriproxyfen significantly affected the developmental times of *P. xylostella* (Table 3). There was a significant extension in the development time of eggs in the treated groups compared to control (ANOVA; F (2, 281) = 313.34, $P < 0.0001$). Furthermore, the developmental time of 1st instar larvae was lower than control in LC_{25} level (ANOVA; F (2, 151) = 7.01, $P = 0.0012$). Moreover, the developmental time of 2nd (ANOVA; F (2, 122) = 3.83, $P = 0.0244$), 3rd (ANOVA; F (2, 114) = 6.03, $P = 0.0032$), and 4th (ANOVA; F (2, 101) = 37.65, $P < 0.0001$) instar larvae were significantly shortened compared to control (Table 3).

The total developmental times were significantly lower at LC_{10} and LC_{25} levels than in the control group (ANOVA; F (2, 99) = 22.29, $P < 0.0001$). Unlike in the prepupal stage, the pyriproxyfen treatment caused a significant decrease in the pupal developmental time (ANOVA; prepupa, F (2, 99) = 1.04, $P = 0.3559$; pupa, F (2, 94) = 6.69, $P = 0.0019$). Preadult developmental time was significantly increased in the sublethal groups (ANOVA; F (2, 94) = 52.37, $P < 0.0001$). The male life span diminished at LC_{25} level (ANOVA; F (2, 48) = 4.94, $P = 0.0114$) but the female life span at LC_{10} and LC_{25} level was similar to the offspring (ANOVA; F (2, 48) = 1.72, $P = 0.1910$).

3.4. Oviposition Period in Parent and Offspring. Table 4 presents the adult longevity and preoviposition, oviposition, and postoviposition period of treated insects. In the parent generation, treatment with the LC_{10} and LC_{25} values of pyriproxyfen had no significant effect on adult preoviposition and postoviposition period as well as the male and female adult longevity (ANOVA; APOP, F (2, 42) = 1.94, $P = 0.1558$; postoviposition, F (2, 42) = 0.92, $P = 0.4057$; male adult longevity, F (2, 42) = 1.87, $P = 0.1662$; female adult longevity, F (2, 42) = 0.40, $P = 0.6759$). Also, there was a significant decrease in the oviposition period in the parent generation by sublethal doses (ANOVA; F (2, 42) = 14.14, $P < 0.0001$). Pyriproxyfen had no effect on the APOP (ANOVA; F (2, 48) = 1.26, $P = 0.2926$) and postoviposition period in the next generation (ANOVA; F (2, 48) = 0.41, $P = 0.6636$). The male longevity was significantly extended only by the LC_{25} in offspring generation (ANOVA; F (2, 48) = 2.48, $P = 0.0421$). The female longevity at LC_{25} level was lower than in the control in the parent generation (ANOVA; F (2, 48) = 4.97, $P = 0.0111$). Pyriproxyfen significantly enhanced the total preoviposition period in a dose-dependent manner (ANOVA; F (2, 48) = 48.78, $P < 0.0001$). Unlike the LC_{10} dose, LC_{25} decreased preoviposition period in the offspring generation (ANOVA; F (2, 48) = 5.48, $P = 0.0074$).

3.5. Sublethal Effects on Population Growth Parameters. Table 5 shows the effects of pyriproxyfen on population growth parameters of the DBM. Pyriproxyfen had no significant effect on the gross reproductive rate (GRR) (ANOVA; F (2, 48) = 1.68, $P = 0.1973$). The net reproductive rate (R_0) differed significantly between control and sublethal treatments (ANOVA; F (2, 48) = 21.98, $P < 0.0001$). Also, the intrinsic rate of increase (r_m) and finite rate of increase (λ) diminished by both concentrations (ANOVA; r_m, F (2, 48) = 20.63, $P < 0.0001$; λ, F (2, 48) = 21.27, $P < 0.0001$). Generation time (T) and doubling time (Dt) were significantly increased only at LC_{10} compared to the control (ANOVA; generation time (T), F (2, 48) = 8.90, $P = 0.0005$; doubling time (Dt), F (2, 48) = 4.47, $P = 0.0166$). In addition, a significant difference was observed in birth rate (b) between control and LC_{10} value. At LC_{25}, this was similar to control (ANOVA; F (2, 48) = 7.94, $P = 0.0010$). Death rate (d) was significantly decreased by LC_{25} compared to the control; however, there was no observed significant difference in death rate between LC_{10} and LC_{25} (ANOVA; F (2, 48) = 16.56, $P < 0.0001$). Also Figures 2–4 show the life expectancy (e_x) (Figure 2), Age-specific survival rate (l_x) (Figure 3) and age-specifi fecundity (m_x) (Figure 4) of DBM in control and treatment groups.

4. Discussion

The present proved that application of pyriproxyfen in leaf dip method has an effective way of suppressing the population of larval stages of the DBM. Topical effect of pyriproxyfen

Table 3: The effects of pyriproxyfen on the developmental period of 3rd instar larvae of *P. xylostella* in two subsequent generations.

Treatments	Developmental time (mean ± SE) (day)[#]			F	P	$df_{t,e}$
	Control	LC_{10}	LC_{25}			
Egg	2.18 ± 0.03^{c}	3.31 ± 0.04^{b}	3.54 ± 0.05^{a}	313.34	<0.0001	2, 281
Larva 1	2.98 ± 0.05^{a}	2.84 ± 0.14^{ab}	$2.48. \pm 0.14^{b}$	7.01	0.0012	2, 151
Larva 2	1.61 ± 0.08^{b}	2.18 ± 0.19^{a}	2.00 ± 0.20^{ab}	3.83	0.0244	2, 122
Larva 3	1.25 ± 0.07^{b}	1.88 ± 0.24^{a}	1.85 ± 0.25^{a}	6.03	0.0032	2, 114
Larva 4	1.51 ± 0.06^{c}	3.25 ± 0.20^{a}	2.25 ± 0.37^{b}	37.65	<0.0001	2, 101
All larvae	7.44 ± 0.23^{b}	9.88 ± 0.28^{a}	8.31 ± 0.53^{a}	22.29	<0.0001	2, 99
Prepupa	0.40 ± 0.06^{a}	0.26 ± 0.08^{a}	0.25 ± 0.11^{a}	1.04	0.3559	2, 99
Pupa	3.70 ± 0.10^{b}	4.42 ± 0.17^{a}	4.46 ± 0.40^{a}	6.69	0.0019	2, 94
Pre adult stages	13.61 ± 0.19^{c}	18.11 ± 0.42^{a}	16.60 ± 0.77^{b}	52.37	<0.0001	2, 94
Total life span (male)	30.78 ± 1.26^{a}	31.78 ± 1.09^{a}	23.71 ± 1.92^{b}	4.94	0.0114	2, 48
Total life span (female)	31.30 ± 1.18^{a}	32.90 ± 2.15^{a}	27.44 ± 2.23^{a}	1.72	0.1910	2, 48

# indicates that means marked with the same letters within a row are not significantly different (Tukey's test; $P < 0.05$).

Table 4: The effects of sublethal concentrations of pyriproxyfen on preoviposition, ovipostion, and postoviposition periods and adult longevity of *P. xylostella* in parent and offspring generations.

Generations	Stages	Mean ± SE (day)[A]			F	P	$df_{t,e}$
		Control	LC_{10}	LC_{25}			
Parent	APOP[B]	2.13 ± 0.66^{a}	5.13 ± 1.11^{a}	7.73 ± 2.25^{a}	1.94	0.1558	2, 42
	Oviposition	11.26 ± 0.95^{a}	5.73 ± 1.13^{b}	4.06 ± 0.90^{b}	14.14	<0.0001	2, 42
	Postoviposition	0.86 ± 0.30^{a}	1.66 ± 0.39^{a}	1.73 ± 0.80^{a}	0.92	0.4057	2, 42
	Male adult longevity	20.07 ± 1.98^{a}	17.46 ± 1.14^{a}	15.73 ± 1.54^{a}	1.87	0.1662	2, 42
	Female adult longevity	14.26 ± 1.16^{a}	12.53 ± 1.05^{a}	13.53 ± 1.81^{a}	0.40	0.6759	2, 42
Offspring	APOP[B]	4.13 ± 0.78^{a}	6.45 ± 1.56^{a}	4.55 ± 1.67^{a}	1.26	0.2926	2, 48
	TPOP[C]	13.17 ± 0.26^{b}	22.63 ± 1.51^{a}	21.33 ± 2.04^{a}	48.78	<0.0001	2, 48
	Oviposition	10.65 ± 0.89^{a}	7.18 ± 2.00^{ab}	4.44 ± 1.49^{b}	5.48	0.0074	2, 48
	Postoviposition	2.06 ± 0.57^{a}	1.27 ± 0.35^{a}	1.33 ± 1.21^{a}	0.41	0.6636	2, 48
	Male adult longevity	16.60 ± 1.27^{b}	13.50 ± 1.18^{b}	20.71 ± 4.42^{a}	2.48	0.0421	2, 48
	Female adult longevity	16.62 ± 1.20^{a}	14.90 ± 1.87^{a}	10.33 ± 2.32^{b}	4.97	0.0111	2, 48

A: means marked with the same letters within a row are not significantly different (Tukey's test; $P < 0.05$).
B: adult preoviposition period, time between adult emergence and first oviposition.
C: total preoviposition period, time from birth to first reproduction in female.

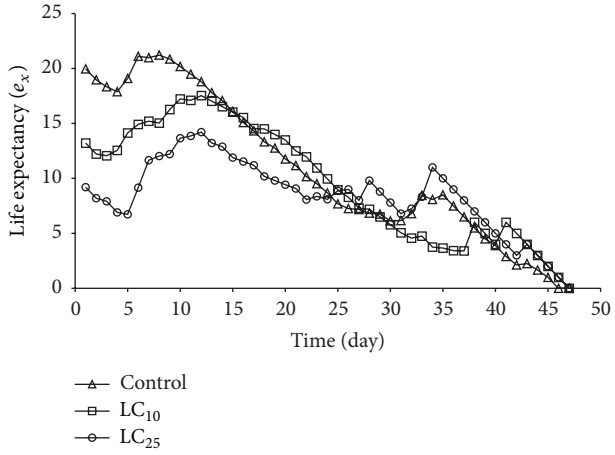

Figure 2: The life expectancy (e_x) of *P. xylostella* after treatment with sublethal doses of pyriproxyfen.

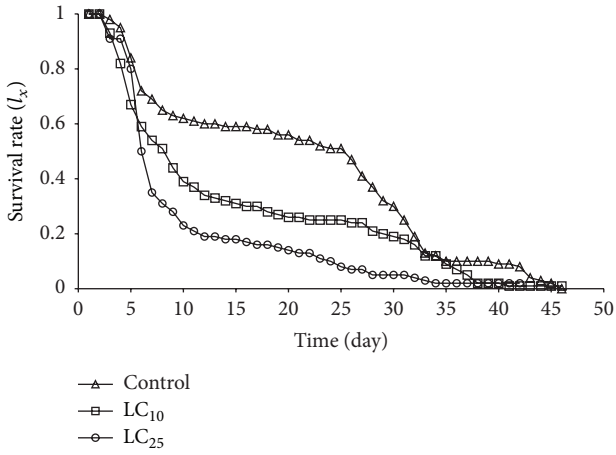

Figure 3: The survival rate (l_x) of *P. xylostella* treated with sublethal doses of pyriproxyfen.

Table 5: The effects of pyriproxyfen on the biological parameters of 3rd instar larvae of *P. xylostella* in the next generation.

Treatment	Mean ± SE[#]							
	GRR	R_0	r_m (day^{-1})	λ (day^{-1})	T (day)	Dt (day)	b (birth rate)	d (death rate)
Control	98.68 ± 12.02^a	50.76 ± 4.00^a	0.190 ± 0.008^a	1.21 ± 0.010^a	20.73 ± 0.71^b	3.61 ± 0.18^b	0.26 ± 0.01^a	0.07 ± 0.003^b
LC_{10}	76.14 ± 17.69^a	12.99 ± 1.85^b	0.099 ± 0.010^b	1.10 ± 0.011^b	26.44 ± 1.61^a	6.67 ± 1.04^a	0.17 ± 0.01^b	0.08 ± 0.003^b
LC_{25}	45.64 ± 18.24^a	8.16 ± 2.02^b	0.112 ± 0.021^b	1.11 ± 0.022^b	21.08 ± 1.33^b	3.98 ± 0.08^{ab}	0.21 ± 0.02^{ab}	0.10 ± 0.003^a
F	1.68	21.98	20.63	21.27	8.90	4.47	7.94	16.56
P	0.1973	<0.0001	<0.0001	<0.0001	0.0005	0.0166	0.0010	<0.0001
$df_{t,e}$	2, 48	2, 48	2, 48	2, 48	2, 48	2, 48	2, 48	2, 48

#: means marked with the same letters within a column are not significantly different (Tukey's test; $P < 0.05$).

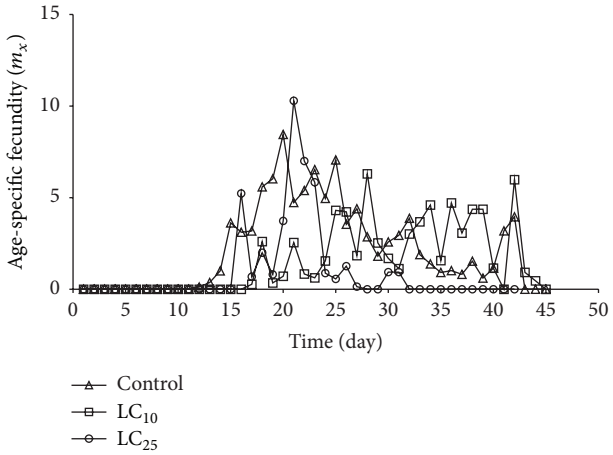

Figure 4: Age-specific fecundity (m_x) of *P. xylostella* treated with pyriproxyfen.

on DBM was evaluated in a previous study [26]. Toxicity of pyriproxyfen in leaf dip method in this study was 2-fold higher than in the topical method [26]. In leaf dip, the insecticide took effect orally and by contact, whereas its effect was by contact alone in topical method. This may be due to the increased toxicity in the leaf dip test.

The effects of pyriproxyfen were determined on fecundity in both generations in the current study. In previous studies, impact of pyriproxyfen on fecundity had various results [30, 31]. Steigenga et al. [30] reported an increase in fecundity when females of *Bicyclus anynana* (Butler) (Lepidoptera: Nymphalidae) were treated with sublethal doses of pyriproxyfen. On the contrary, pyriproxyfen at sublethal concentrations lowered the fecundity of the Asian citrus psyllid, *Diaphorina citri* Kuwayama (Hemiptera: Psyllidae) [31]. The current results are consistent with those of Boina et al. [31] on *D. citri* which indicated a decrease in the fecundity by pyriproxyfen. In contrast, Abo-Elghar et al. [32] indicated a decrease in egg hatchability of *Callosobruchus maculatus* F. (Coleoptera: Bruchidae) after treatment with sublethal doses of pyriproxyfen. However, in the current study, treatment with pyriproxyfen had no influence on egg hatchability of DBM. After treatment of the third instars with the LC_{10} and LC_{25} concentrations of pyriproxyfen, the surviving pupae showed a lower mean weight in treatment groups compared to control in both (parent and offspring) generations. This weight reduction may be as result of decrease in nutrition ability after treatment with pyriproxyfen. Contrary to the current research, the body weight of tobacco budworm, *Heliothis virescens* F. (Lepidoptera: Noctuidae) increased by another JH mimic, fenoxycarb, compared to control [33]. The results are similar to those of Sial and Brunner [8] on *Choristoneura rosaceana* (Harris) (Lepidoptera: Tortricidae) and cotton leaf worm *Spodoptera littoralis* (F.) (Lepidoptera: Noctuidae) treated with pyriproxyfen [33]. Contrary to our results, Mauchamp et al. [34] found an increase in the body weight of tobacco budworm, *Heliothis virescens* F. (Lepidoptera: Noctuidae) compared to control, after treatment with another JH mimic, fenoxycarb.

In addition, the current study showed an increase in the developmental time of eggs, larvae, and pupae of *P. xylostella* by sublethal concentrations of pyriproxyfen. A previous study reported that pyriproxyfen extended the larval developmental period of *Spodoptera littoralis* (Boisduval) (Lepidoptera: Noctuidae) [33]. Similarly, Ghasemi et al. [35] also showed that the growth duration of *P. interpunctella* was postponed by pyriproxyfen. In contrast, pyriproxyfen at 50 and 150 mg L^{-1} concentrations decreased the developmental times of 1st and 4th nymphal instars of soybean aphid, *Aphis glycines* Matsumura (Homoptera: Aphididae) [36].

From the results of the current study, sublethal doses did not change the adult longevity of parent generation. In the next generation, adult longevity increased in males and decreased in females. Application of pyriproxyfen on *Plodia interpunctella* (Hübner) (Lepidoptera: Pyralidae) decreased adult longevity [35]. Lee et al. [37] observed that treatment with pyriproxyfen significantly lowered the adult longevity of *Bemisia tabaci* (Homoptera: Aleyrodidae). Female longevity of *B. anynana* was similar to control after pyriproxyfen treatment [30]. Treatment with pyriproxyfen also affected other aspects of adult performance. In this study, the oviposition period of *P. xylostella* were shortened in both generations. Compared with the control, the total preoviposition period (TPOP) of offspring was increased upon application of pyriproxyfen treatment. According to the present results, pyriproxyfen delayed the maturation period of ovaries, resulting in postponement of mating by adults. Reduced oviposition period lead to a decrease in fecundity (number of eggs laid). Some of the biological parameters such as r_m, R_0, and λ are related to fecundity. Therefore, suppression of this

ability is an important factor in IPM strategies. The current finding is similar to those of Zhang et al. [38] indicating that metaflumizone at LC_{15} and LC_{25} doses significantly increased TPOP of DBM. In contrast, other studies have provided mixed results. In some cases, the sublethal doses of insecticide have been found to either have no effect [37] or extend [26, 39] the preoviposition period in many insect groups. For example, Lee et al. [37] reported that treatment of *B. tabaci* with pyriproxyfen did not change the preoviposition period when compared to control [36]. An extension of the preoviposition period of DBM was observed after treating the larvae with cantharidin. In this study, the oviposition period of DBM declined in parent and *F1* generations. Also postoviposition period reduced in treated groups compared to control. In current study, oviposition in the females began after 7 days at LC_{25}, in parent generation. On the other hand, a decrease of 82% was observed in the fecundity by LC_{25} when compared to the control. The observed preoviposition period and corresponding decrease in the fecundity in contact toxicity (LC_{25}) were 1.5 days and 56%, respectively [26].

Finally, pyriproxyfen at the sublethal concentrations had effect on biological parameters of DBM. Similar results have been found in previous studies [40, 41]. For example, Ahmad et al. [40] showed that Neemarin, at various concentrations, lowered finite rate of increase (λ), intrinsic rate of increase (r_m), and net reproductive rate (R_0) of DBM [40]. Also, Mahmoudvand and Moharramipour [41] observed that fenoxycarb increased Dt and declined R_0, λ, and r_m of the DBM females. Han et al. [22] reported the Dt and T of DBM increased when treated with sublethal concentrations of chlorantraniliprole.

Contrary to the current study data, Zanuncio et al. [25] reported that R_0, r_m, and λ of *Supputius cincticeps* (Stål) (Heteroptera: Pentatomidae) topically exposed to five doses of permethrin were raised compared to the untreated group.

In conclusion, from the results, it can be seen that pyriproxyfen, at sublethal doses, is effective in controlling the population of *P. xylostella*. However, the toxicity of JHAs was evaluated through topical method, and the current results showed that using the leaf dip can be a suitable method for this insecticide. Therefore sublethal doses of insecticides usage could be a good method for controlling insect pests that are resistant to insecticides after a few generations. Using high doses is the main cause of insect resistance.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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