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Lethal Effects of Pyriproxyfen, Spinosad, and Indoxacarb and Sublethal Effects of Pyriproxyfen on the 1st Instars Larvae of Beet Armyworm, *Spodoptera exigua* Hübner (Lepidoptera: Noctuidae) in the Laboratory

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ABSTRACT

The beet armyworm (*Spodoptera exigua* Hübner) is an important pest of many agricultural crops all over the world. Most of the sugar beet growing regions in Iran are infested. In this study, the acute lethal effects of Pyriproxyfen, Spinosad, and Indoxacarb as well as sublethal effects of Pyriproxyfen on the 1st instar *S. exigua* were assessed by leaf dip bioassay method. Mortality was recorded 48 hours after treatment. LC_{50} and LC_{90} values for Spinosad were 0.096 and 0.252 mg ai l^{-1}, respectively, and for Indoxacarb, they were 2.510 and 38.828 mg ai l^{-1}, respectively. The LC_{50} value for Spinosad was 26 times lower than that of Indoxacarb. Preliminary experiments revealed that Pyriproxyfen did not cause acutely lethal effects on the beet armyworm larvae even following exposure at recommended doses. Pyriproxyfen, however, did show considerable delayed effects against this pest. Significant differences in biological, reproductive, and population growth parameters were found in Pyriproxyfen treated insects in comparison with the control insects. Population growth parameters including net reproduction rate (R_0), gross reproduction rate (GRR), intrinsic rate of population increase (r_m), and finite rate of population increase (λ) were reduced by 14.7-, 6.63-, 2.33-, and 1.09-fold, respectively, following Pyriproxyfen exposure. Additionally, mean generation time (T) and doubling time (DT) of the population were increased by 1.12- and 2.3-fold, respectively.

Keywords: Insecticides, Lethal effects, Life table, Spodoptera exigua, Sublethal effects.

INTRODUCTION

The beet armyworm *Spodoptera exigua* Hübner (Lepidoptera: Noctuidae), is a polyphagous tropical insect that is found around the world, but not in South America. This insect is a serious pest of vegetable, field and flower crops. Larvae feed on both foliage and fruit. Young larvae feed gregariously and skeletonize foliage. As they mature, they become solitary and eat large irregular holes in foliage (Capinera, 2001). In Iran, this pest has a very high population density. In most years, it causes considerable yield losses in many sugar beet growing regions. The beet armyworm is not effectively controlled by most commercially available insecticides because of wide spread resistance (Moulton *et al*., 2000; Cook *et al*., 2004; Jung and Kim, 2006; Naghdi and Bandani, 2012). In order to reduce the emergence of resistant biotypes and to reach sustainable agricultural productivity, the agrochemical industry has recently introduced new chemistries with novel modes of action that are unrelated to

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previous chemical classes (Ahmad *et al*., 2003). These novel compounds are generally safer, yet highly effective and show minimal side effects on natural enemies and the environment.

Spinosad and Indoxacarb are novel compounds that have demonstrated efficacy against noctuids (Moulton *et al*., 2000; Ahmad *et al*., 2003). Indoxacarb is a member of the new oxidiazine family of pro-insecticides that has good field efficacy against a number of lepidopteran pests. Activation of the parent oxadiazines to the S-enantiomers of the *N*-decarbomethoxyllated metabolites, which are powerful sodium channel blockers. Mechanistically, the metabolite acts by inhibiting sodium ion entry into nerve cells by bioactivation in target insects (Wing *et al*., 2000). Insects exposed to this compound stop feeding, become less mobile, undergo paralysis, and eventually die. The major mode of entry into the target pest is through ingestion (Wing *et al*., 2000; Bostanian *et al*., 2004). Spinosad, is a naturally occurring mixture of two active components, Spinosyn A and Spinosyn D, produced by the soil actinomycete *Saccharopolyspora spinosa*. During poisoning, Spinosyn A reaches a concentration inside the insect that is sufficient to directly excite the central nervous system (Salgado *et al*., 1998). Modern pest management programs emphasize application of the so-called "soft" pesticides, with a view toward decreasing the high mortality usually inflicted on natural enemies by environmental toxicants. These biorational pesticides, including insect growth regulators, usually cause lower initial natural enemy mortality in comparison to conventional synthetic insecticides. Because of the impact of pesticides on biological control agents in agroecosystems, many recent researchers have emphasized the need to develop standardized tests for measuring sublethal effects. Studies in which insecticide exposure results in < 30% mortality are classified as sublethal experiments, indicating a probable induction effect (Croft, 1990). Long-term sublethal exposure to pesticides, as well as physiological and biochemical characteristics of populations that survive the stress, may be crucial for planning pesticide application strategies and for estimating environmental side effects of the used chemical (Adamski *et al*., 2003). Pyriproxyfen is a juvenile hormone analogue and is considered an environmentally-friendly compound among insect growth regulators. It is a broad-spectrum insect growth regulator with insecticidal activity against agricultural, horticultural, and public health insect pests (WHO, 2008). In this study, we report the toxicity of Pyriproxyfen, Spinosad, and Indoxacarb to *S. exigua* and investigate the larvicidal activity of Spinosad and Indoxacarb against the 1st instar larvae of this pest**.** These data will support insecticide use recommendations and provide reference dose-mortality data for future insecticide resistance monitoring programs. Since information regarding life fecundity tables of this pest in the laboratory was not available, the present study investigated lethal and sublethal effects of Pyriproxyfen against the laboratory population of *S. exigua*. This study was carried out to evaluate the long-term exposure of the first instar larvae of beet armyworm to Pyriproxyfen in Iran.

MATERIALS AND METHODS

Insects

Larvae of *S. exigua* were obtained from sugar beet farms in Mian-doab of West Azarbaijan Province in July 2007. These larvae were used to establish the colony of this insect in the greenhouse. Larvae were reared (26±2°C, 50±10% RH and 16:8 (L:D) hour photoperiod) on artificial diet containing 106 g of soaked mungbean, 16 g of brewers' yeast, 1.6 g of ascorbic acid, 1.0 g of methyl-4-hydroxybenzoate, 6.4 g of agar, 1.0 ml of formaldehyde solution 37% and 320 ml water to complete development

(Singh, 1977). Groups of 10-15 larvae were placed into plastic boxes (18 cm in diameter and 8 cm in height). Pupae were collected from these boxes and placed into one film cup 3 cm in diameter and 5 cm in height for adult emergence. Adults were kept in plastic containers (17 cm in diameter and 25 cm in height) and provided with a 15% (w:v) sucrose solution diet and wax paper sheets on which to oviposit. Eggs, which were laid on the wax sheets or stuck on the walls of the rearing containers, were collected daily, washed in 10% formalin for 10 minutes, and rinsed in tap water.

Insecticide

The insecticides tested were Pyriproxyfen (Admiral® 10 EC, Sumitomo Chemical company, Japan), Spinosad (Tracer, 240 SC, Dow Agrosciences Company, England), and Indoxacarb (Avaunt, 150 SC, DuPont Company, France).

Lethal Effect Bioassays for Spinosad and Indoxacarb

The toxicity of the insecticides was assessed on the 1st instar larvae of *S. exigua* by a leaf dip bioassay. Serial dilutions as ppm of the active ingredient of each test compound were prepared using distilled water. The appropriate concentration range for each compound was based on preliminary experiments. After these experiments, the upper limit of 80% and lower limit of 25% were obtained. The concentration ranges for Spinodad and Indoxacarb were 0.06-0.19 and 0.6-18 mg ai l^{-1}, respectively. Specifically, the insecticide solutions were 0.06, 0.07, 0.10, 0.14, and 0.19 mg ai l^{-1} for Spinosad; and 0.6, 1.5, 3, 7.5, and 18 mg ai l^{-1} for Indoxacarb. All of the solutions contained Triton X-100 as a surfactant (approximately one drop equivalent to 555 ppm). Sugar beet leaf discs (5 cm-diameter) of fully expanded leaves were cut and dipped into the insecticide solutions for 5 seconds with gentle agitation, then allowed to dry between two layers of paper towels at ambient temperature on the laboratory bench. After drying, one leaf disc, adaxial side up, was placed in a ventilated plastic petri dish (6 cm-diameter) containing solidified 2% agar solution. The agar layer was placed beneath leaf disc to avoid desiccation. Fifteen 1st instar larvae (< 12 hours old) were transferred to each leaf disc. The same number of leaf discs per treatment was dipped into distilled water as control treatment. At least five replicates were performed for each of the five concentrations tested, plus control treatments (water and surfactant). Mortality was assessed 48 hours after treatment. The larvae were scored as "affected" if noticeable paralysis was present and no movement was observed after being prodded with a brush or if they were dead. The toxicity of the insecticides was compared based on a comparison of the 95% confidence limits of the LC_{50} value. If the 95% confidence ratio was > 1, then the difference between LC_{50}s was considered significant (Robertson *et al*., 2007). The data were statistically analyzed by SAS 6.1 software using probit method (SAS, 1996).

Sublethal Effect Bioassay for Pyriproxyfen

In this study, the sublethal effects of Pyriproxyfen were assessed on 1st instar larvae of *S. exigua*. Neonates (< 12 hours old) were exposed to the insecticide by the leaf dip method described above. Recommended field rate of Pyriproxyfen (1,000 ppm) was applied. One hundred and fifty 1st instar larvae were treated plus a control (150 larva). The 1st instar larvae from the initial cohort were transferred onto each petri dish, individually. The treated larvae were monitored at 24 hours intervals until adults appeared. The insecticide treated leaf discs (or control leaf discs) were removed after 5 days, and replaced with

untreated leaf discs. The emerged adults from the surviving larvae, were collected and were placed in ventilated plastic boxes (8 cm in diameter by 9.5 cm in height) in pairs (one male and one female) and allowed to mate. Eggs were collected and counted daily. The cumulative number of eggs that were laid per female per day and the percentage of eggs that hatched were determined and used to evaluate fecundity and fertility, respectively. The construction, description, and analysis of the life table parameters were carried out using Carey's method (Carey, 1993; Maia *et al*., 2000) using the following equations:

$$\sum_{x=\alpha}^{\beta} e^{-rmx} L_x m_x = 1$$

Where, x is the age of cohort, L_x is the proportion of individuals that survive to age x, m_x is the number of females produced per female of age x, and r_m is the intrinsic rate of increase for the population.

Gross reproduction rate (GRR) $= \sum_{\alpha=x}^{\beta} m_x$

Net reproduction rate (R_0) $= \sum_{x=\alpha}^{\beta} L_x m_x$

Generation time (T)= $\frac{\ln R_0}{r}$

Doubling time (DT)= Ln 2/ r_m

Finite rate of increase (λ) $= e^{r_m}$

In order to compare life table parameters, a Jackknife technique was used (Meyer *et al.,* 1986).

Data Analysis

In order to construct the fertility life table**,** the data were analyzed by SPSS 15.1 software (SPSS, 2006). Analysis of mean comparisons for the life table parameters was also performed using SPSS 15.1. The means were compared by *T*- test.

RESULTS AND DISCUSSION

Acute lethal effects for Spinosad and Indoxacarb

The results of dose-response bioassays for Spinosad and Indoxacarb using 1st instar larvae of *S. exigua* are summarized in Table1 and Figure 1. Because Pyriproxyfen did not cause considerable mortality at concentrations as high as 2,500 mg ai l^{-1}, it was not possible to draw a dose-response line and estimate an LC_{50} value. LC_{50} values for Spinosad and Indoxacarb were 0.096 and 2.51 mg ai l^{-1}, respectively (Table 1 and Figure 1). Spinosad was 26 times more toxic than Indoxacarb against 1st instar larvae of *S. exigua* indicating that these larvae were more tolerant to Indoxacarb. Spinosad showed a relatively steep dose-response line. The steep slope suggested that the use of higher doses of Spiosad would lead not only to a substantial increase in mortality of the pest but also a potential increase in selection pressure leading to the development of

Table 1. LC_{50} [a] and LC_{90} values of Spinosad and Indoxacarb on the first instar larvae of *Spodoptera exigua* using Robertson *et al*. (2007) method.

Insecticide	Category	n	Slope±SE	LC_{50} (mg ai l^{-1}) (95% CL)	LC_{90} (mg ai l^{-1}) (95% CL)	χ^2	R^2
Spinosad	Spinosyn	305	3.07 ± 0.44	0.096 [a] (0.085 – 0.108)	0.252 (0.202-0.366)	1.932	0.9608
Indoxacarb	Triazine	305	1.07 ± 0.15	2.51 [b] (1.763 – 3.457)	38.828 (20.78-111.85)	0.299	0.9946

[a] LC_{50} within each row followed by different letters are significantly different (P> 0.01).

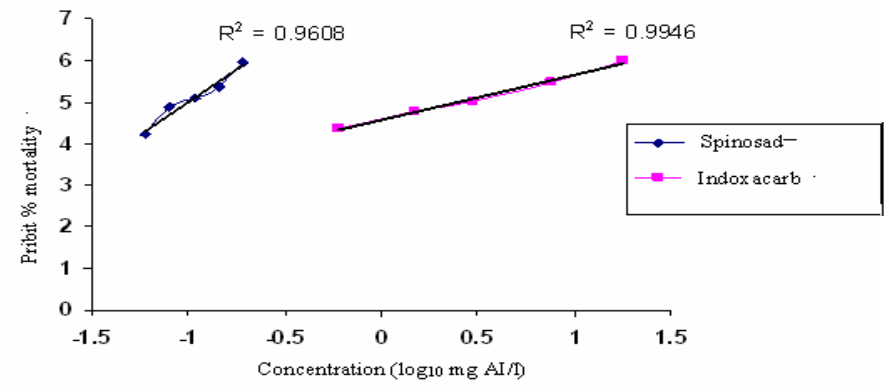

Figure 1. Dose-response lines for Spinosad and Indoxacarb.

resistance. Indoxacarb had a lower χ^2 than Spinosad (Table 1), indicating homogeneous population level response to continuous exposure to Indoxacarb. The coefficient of the determination of dose–response lines (R^2) also showed a high correlation between insecticide concentrations and response of the population (Table1), indicating that the test population was homogenized. This result is consistent with the fact that Spinosad and Indoxacarb have not been used on farms in Iran against the beet army worm.

Spinosad and Indoxacarb have been widely reported to be highly efficacious against lepidopteran pests especially noctuids (Ahmad *et al*., 2003; Cook *et al*., 2004; Pineda *et al*., 2007). Our LC_{50} values were similar to those reported by Pineda *et al*. (2007) against neonates of *S. littoralis* that were exposed to pepper leaves treated with Spinosad (after 96 h). Cook *et al*. (2004) and Ahmad *et al*. (2003) also reported that Spinosad was more toxic to adults of *S. exigua* and second instar larvae of *Helicoverpa armigera* (Hübner) in comparison to Indoxacarb. The LC_{50} values for second and third instars of *S. exigua* that fed on cotton leaves that were treated with Spinosad, were 0.279-6.14 and 0.589-14 mg ai l^{-1}, respectively (Moulton *et al*., 2000). Wang *et al*. (2013) determinated lethal effects of Spinosad against late second-instar larvae of *S. exigua* by oral exposure. Considering the methods of application and life stage of pest, the LC_{50} values of Spinosad were 0.317 and 0.293 mg kg^{-1} after 48 and 72 hours, respectively. Ramasubramanian and Regupathy (2004) reported that Indoxacarb provided excellent control of persistent *H. armigera* infestations. Although the results of Ramasubramanian and Regupathy (2004) are somewhat similar to what we found for *S. exigua*, their results used different methods of application, insect species, and life stages. The results obtained in this study indicated that Spinosad and Indoxacarb were potent compounds for controlling the beet armyworm. The high activity of both compounds along with their low environmental toxicity and different modes of action, indicate that these insecticides are potentially important components in IPM programs of sugar beet and the application of these compounds can be a part of management programs against this pest. Spinosad, however, should be used carefully because it shows a steep dose-response curve to Spinosad and some natural enemies, especially parasitoids, show susceptibility (Williams *et al*., 2003).

In conclusion, we found that Spinosad and Indoxacarb showed high acute toxicity against 1st instars of *S. exigua*. If similar results are obtained in the field, these insecticides might be suitable candidates for use in integrated pest management programs.

Sublethal Effects for Pyriproxyfen

Because Pyriproxyfen did not cause sufficient mortality at concentrations as high as 2,500 mg ai l^{-1}, it was impossible to generate a dose-response line and estimate an LC_{50} value. Thus, the recommended field rate (100 mg ai l^{-1}) of Pyriproxyfen was used in order to study the delayed effects of this compound. Significant differences in the biology, reproduction, and population growth parameters were found in the Pyriproxyfen-treated insects (Tables 2, 3, and 4).

Pyriproxyfen prolonged the feeding period and growth due to delays in larval development. Under the conditions in this study, the mean generation time (T) was higher in Pyriproxyfen-treated insects in comparison to control insects. When

Table 2. Mean comparison of biological parameters of the 1st instar larvae of *S. exigua* using *t*-test.[a]

Treatment parameter	Developing days (Mean±SE)		df	t
	Control	Pyriproxyfen		
Female longevity	9.28 ± 0.19 a	9.25 ± 0.49 a	38	0.082
Male longevity	9.75 ± 0.29 a	9.75 ± 0.64 a	38	0.000
Pre-oviposition	2.39 ± 0.12 a	3.50 ± 0.26 b	38	- 4.248
Oviposition	6.5 ± 0.19 a	3.9 ± 0.31 b	38	7.230
Post-oviposition	1.42 ± 0.22 a	3 ± 0.32 b	38	- 3.937

[a] Means within each row followed by the similar letter are not significantly different (P> 0.01).

Table 3. Mean comparison of population growth parameters of the 1st instar larvae treatment of *S. exigua* using *t*-test.[a]

Treatment parameter[b]	Mean±SE		df	t
	Control	pyriproxyfen		
GRR*	405 ± 22 a	61 ± 7 b	81	14.272
R_0	147 ± 24 a	10 ± 3 b	81	5.504
r_m	0.152 ± 0.005 a	0.065 ± 0.008 b	81	8.348
T	32.8 ± 0.43 a	36.7 ± 0.60 b	81	- 5.204
DT	4.53 ± 0.16 a	10.44 ± 1.55 b	81	- 3.775
λ	1.164 ± 0.006 a	1.067± .009 b	81	8.532

[a] Means within each row followed by a similar letter are not significantly different (P> 0.01).
[b] *GRR*= Gross Reproductive Rate; R_0= Net reproduction rate; r_m= Intrinsic rate of natural increase; *DT*= Doubling Time, *T*= Mean generation time, and λ= Finite rate of increase.

Table 4. Mean comparison of reproduction parameters of the 1st instar larvae of *S. exigua* using *t*-test.[a]

Treatment parameter	Mean±SE		df	t
	Control	Pyriproxyfen		
Gross fecundity rate	810 ± 45 a	135 ± 14 b	66	14.185
Gross fertility rate	494 ± 27 a	2.15 ± 0.347 b	66	17.640
Gross hatch rate	0.609 ± 0.001 a	0.016 ± 0.001 b	66	251.303
Net fecundity rate	310 ± 46 a	21 ± 6 b	66	6.102
Net fertility rate	189 ± 28 a	0.358 ± 0.117 b	66	6.590
Eggs/female/day	12.22 ± 1.31 a	1.47 ± 0.21 b	66	8.06
Fertile eggs/female/day	7.45 ± 0.80 a	0.024 ± 0.004 b	66	9.23

[a] Means within each row followed by a similar letter are not significantly different (P> 0.01).

allowed to feed on sugar beet, the durations of the egg, larval, pre pupal, pupal, male adult and female adult stages were 3, 16, 1.5, 7.2, 9.75 and 9.28 days in the control larvae and 3, 20, 1.4, 7.7, 9.75 and 9.25 days in those exposed to Pyriproxyfen. In particular, the developmental time of 1st instar larvae was significantly affected by Pyriproxyfen exposure in comparison to control larvae. The longevity of female and male adults was not different following Pyriproxyfen exposure, although the times of pre oviposition, oviposition, and post oviposition did show significant differences (Table 2). Pyriproxyfen exposure decreased the oviposition period, and increased the pre-oviposition and post-oviposition periods. The mortality rates during the larval and pupal stages were 36 and 16% in the control insects, and 64 and 14% in Pyriproxyfen treated insects, respectively.

Growth population parameters including net reproduction rate (R_0), gross reproduction rate (GRR), intrinsic rate of population increase (r_m) and finite rate of population increase (λ) showed decreases in neonate *S. exigua* that were exposed to Pyriproxyfen. In contrast, mean generation time (T) and doubling times (DT) of the population increased. The net reproduction rate and other reproduction parameters were also affected by Pyriproxyfen treatment (Tables 2 and 3). The gross fecundity rate showed a 6-fold decrease in insects that were exposed to Pyriproxyfen. The gross fertility rate, net fecundity rate, net fertility rate, gross hatch rate, eggs/female/day, and fertile eggs/female/day values were reduced following Pyriproxyfen exposure as neonates. Decreases in lifetime and daily reproductive rates were also found. The intrinsic rates of increase (r_m) for the control and Pyriproxyfen exposed insects were 0.152 and 0.065, respectively.

The sex ratio and pupal weight were not affected by Pyriproxyfen treatment significantly. However, there was some change in sex ratio toward males. The eggs

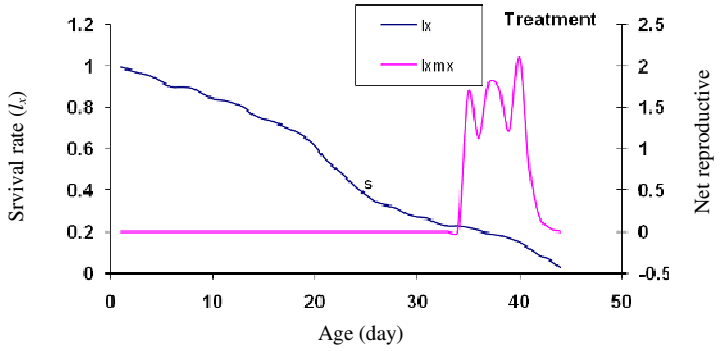

Figure 2. Survival and net reproductive rate curves of the 1st instar *S. exigua* following exposure to Pyriproxyfen (1,000 ppm).

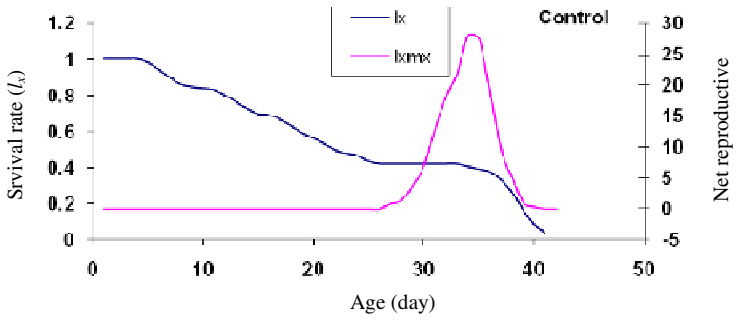

Figure 3. Survival and net reproductive rate curves of the 1st instar *S. exigua* following control treatment.

that were laid by females from the Pyriproxyfen treated insects were smaller than those from control females. Survival and net reproductive rate curves of *S. exigua* that were treated with Pyriproxyfen or control insects are shown in Figures 2 and 3. These curves showed an exponential decrease in survival similar to that represented by a type II survivorship curve, which suggested that mortality at all stages of development was equal.

Fertility life table analysis is an appropriate way to study the dynamics of animal populations, especially arthropods, as an intermediate process for estimating parameters related to the population growth potential, which are also called demographic parameters (Maia *et al*., 2000). Life table analysis may be one of the most effective means of evaluating changes in population density. Longevity, fecundity, sex ratios, and generation time can be examined as they relate to the intrinsic rate of increase.

Three types of effects of IGRs were recognized: (1) inhibition of ecdysis and metamorphosis; (2) inhibition of adult emergence, and (3) inhibition of embryogenesis. IGRs have been shown to cause numerous sublethal effects, including increase/decrease in fecundity, increase/decrease in developmental rate as well as changes in sex ratio, diapause, and morphology (Croft, 1990). In our study, the toxic effects of Pyriproxyfen exposure

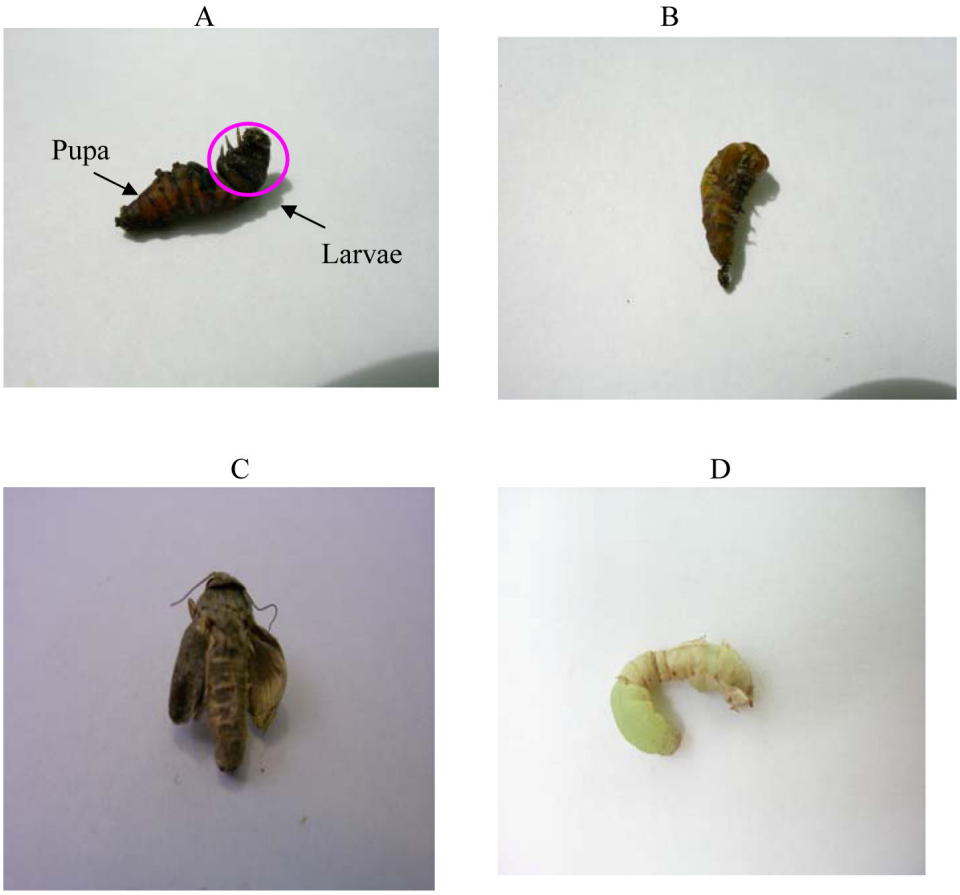

Figure 4. Abnormal stages of larvae treated with Pyriproxyfen: (A) Larvae–pupa intermediate; (B) Deformed pupa; (C) Deformed moth, and (D) Disruption in metamorphosis

included the formation of larval-pupal intermediates (Figure 4-A), deformed pupae (Figure 4-B), deformed moths (Figure 4-C), and the disruption of metamorphosis (Figure 4-D) have been observed.

All of the intermediates were non-viable. A few of the Pyriproxyfen exposed larvae molted into malformed pupae. Treated individuals failed to emerge from larval skin or resembled pupae, with slightly tanned skin at the ventral part of the body. Adult body, wings and antennae were deformed, or adults emerged partially from the pupal skin or developments of the wings was not complete, but were able to mate and produce fertile eggs which developed into normal healthy adults.

Malformation following pyriproxyfen exposure has been reported in several studies. For example, female adults of S. *litura* that were treated with 0.3 ng of Pyriproxyfen showed wing abnormalities (Nomura and Miyata, 2000). *S. exigua* generally show up to 6 larval instars, but in this study, 7 larval instars were observed. The length of the larval stage was longer and adults showed abnormal reproductive capability. This was certainly the case in *S. litura* as reported by Nomura and Miyata (2000). In lepidopterous insects, reduction of egg viability by treatment with Pyriproxyfen is not well documented (Oouchi, 2005). Horowitz and Ishaaya (1992) reported that Pyriproxyfen had two modes of action on *Bemisia tabaci*: suppression of egg hatch (ovicidal and transovarial activities) and failure of adult emergence (pupal mortality). Nomura and Miyata (2000) also reported that Pyriproxyfen caused reduction in the total number of eggs oviposited (reduced fecundity) and hatchability of oviposited eggs (reduced fertility) in *S. litura*. Ovarian development was inhibited and about 40% of females showed morphological ovarian abnormalities. Female adults with no morphological ovarian abnormality, oviposited fewer eggs than untreated females and the hatchability of oviposited eggs was lower. Reduction in egg hatch rate of *Trialeurodes vaporariorum*, either directly (ovicidal) or indirectly (transovarial and suppression of adult formation upon treatment of larvae) has been reported by Ishaaya *et al*. (1994). Pyriproxyfen, caused a 90% reduction in egg hatch rate of *Plutella xylostella.* Third instar larvae treated with Pyriproxyfen failed to pupate (Oouchi, 2005). Similar results have been obtained with *Choristoneura rosaceana* (Sial and Brunner, 2010).

In conclusion, Pyriproxyfen exposure dramatically interfered with the life cycle of *S. exigua*. The effects of Pyriproxyfen exposure were observed during embryonic development of eggs and metamorphosis; and dramatically impacted the life table parameters of the beet armyworm. If similar results are obtained in the field, Pyriproxyfen might be a suitable candidate for use in integrated pest management programs. Furthermore, application of Pyriproxyfen as a pre-infestation (prophylactic) technique may be suitable in IPM program.

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تعیین اثرهای کشندگی پایری پروکسی فن، اسپینوسد و ایندوکساکارب و غیرکشندگی پایری پروکسی فن روی لارو سن اول کرم برگخوار چغندرقند - *Spodoptera exigua* (Lepidoptera: Noctuidae) در شرایط آزمایشگاهی

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چکیده

کرم برگخوار چغندرقند *Spodoptera exigua* (Hübner) یک آفت مهم بسیاری از محصولات کشاورزی در سراسر جهان می‌باشد. در ایران بیشتر مناطق کاشت چغندرقند آلوده به این آفت است. در این تحقیق، اثرهای کشندگی پایری پروکسی فن، اسپینوسد و ایندوکساکارب و اثرهای غیرکشندگی پایری پروکسی فن روی لاروهای سن اول برگخوار چغندرقند با روش غوطه وری برگ مورد بررسی قرار گرفتند. میزان مرگ و میر ۴۸ ساعت پس از تیمار ثبت شد. مقادیر LC_{50} و LC_{90} برآورد شده برای اسپینوسد به ترتیب ۰/۹۶ و۰/۲۵۲ mgai/l و برای ایندوکساکارب این مقادیر به ترتیب ۲/۵۱۰ و ۳۸/۸۳۸mgai/l بودند. مقادیر LC_{50} برای اسپینوسد ۲۶ برابر نسبت به ایندوکساکارب برای لاروهای سن ۱ برگخوار چغندرقند، سمی‌تر بود. آزمایشات اولیه نشان دادند اگرچه حتی در دوز توصیه شده، پایری‌پروکسی‌فن اثرات کشندگی حادی روی کرم برگخوار ندارد ولی باعث اثرات تأخیری قابل توجه بر روی این آفت می‌شود. فراسنجه‌های رشد جمعیت از قبیل نرخ خالص تولیدمثل (R_0)، نرخ ناخالص تولیدمثل (GRR)، نرخ ذاتی افزایش جمعیت (r_m) و نرخ متناهی افزایش جمعیت (λ) به ترتیب ۱۴.۷، ۶.۶۳، ۲.۳۳ و ۱.۰۹ بار کاهش نشان دادند. میانگین زمان تولید یک نسل (T) و زمان دوبرابر شدن جمعیت (DT) به ترتیب ۱.۱۲ و ۲.۳ بار افزایش یافتند.