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CHANGE IN LIFE EXPECTANCY AND STABLE AGE DISTRIBUTION OF THE DIAMONDBACK MOTH, *PLUTELLA XYLOSTELLA* (L.) AFTER INDOXACARB TREATMENT

Mohammad Mahmoudvand[1,2], Habib Abbasipour[1], Aziz Sheikhi Garjan[3], Ali Reza Bandani[4]*

[1] Department of Plant Protection, Faculty of Agricultural Sciences, Shahed University, Tehran, 33191-18651 Iran

[2] Department of Entomology, Faculty of Agriculture, Tarbiat Modares University, Tehran, Iran

[3] Iranian Research Institute of Plant Protection, Tehran, 14115-336 Iran

[4] Department of Plant Protection, College of Agriculture and Natural Resources, University of Tehran, Karaj, 31587-77871 Iran

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Abstract: Using high doses of insecticides is very dangerous for the environments and for humans. Decreased concentrations are necessary. Insecticides have lethal and sublethal effects. The aim of the present study was to determine the behavior of *Plutella xylostella* when exposed to sublethal doses of indoxacarb in terms of the age-specific fecundity (m_x), life expectancy (e_x) and stable age distribution (C_x). Also, the effects of sublethals on the pre-oviposition, oviposition and post-oviposition period of this insect were investigated. The results show that exposure to this insecticide decreased the age-specific fecundity (m_x) and life expectancy (e_x) of the insect. Although the pre-oviposition period was delayed in the treated groups, the post-oviposition period significantly decreased when exposed to LC_{10} and LC_{25} doses (the dose concentrations killed 10 and 25% of the populations) of indoxacarb. The oviposition period did not change. Furthermore, sublethal concentrations of the applied insecticide caused changes in the exposed structure.

Key words: *Plutella xylostella*, sublethal doses, indoxacarb, life expectancy, stable age distribution, oviposition period

INTRODUCTION

The stable age distribution is defined as the schedule of fractions each age class represents in the ultimate population. Life expectancy at age x (e_x) gives the average remaining lifetime for an individual (Carey 1993). Insecticides at sublethal doses can affect the physiological and behavioral characteristics of insects (Haynes 1988). The developmental time (Wang *et al.* 2008), weight of pupae and survivorship (Mahmoudvand *et al.* 2011a), adult longevity (Ergin *et al.* 2007), fecundity (Haseeb and Amano 2002) and reproduction parameters such as the net reproductive rate (R_0), intrinsic rate of increase (r_m), finite rate of increase (λ), and doubling time (Dt) (Mahmoudvand *et al.* 2011b; Rezaei *et al.* 2007) can also be affected by sublethal concentrations. In demographic toxicology, the subjects are treated with a pesticide and the life table parameters of the population are compared with untreated populations (Stark and Wennergren 1995).

The diamondback moth (DBM), *Plutella xylostella* (L.) (Lepidoptera: Yponomeutidae), is the most destructive pest of brassica crops such as broccoli, Brussels sprouts, cabbage, Chinese cabbage, cauliflower, kale, mustard and many others worldwide (Caperina 2001; Sarfraz *et al.* 2006). The pest annually occurs throughout Tehran province, wherever brassica crops are grown and causes substantial crop losses especially during outbreak years. The global importance of *P. xylostella* is reflected in the cost of its control, estimated at almost 1 billion US$ annually (Talekar and Shelton 1993). Most of the control options by growers targeting this pest have been the use of synthetic insecticides (quote source). Indoxacarb is an effective insecticide against several lepidopteran pests and it is safe for numerous non-target insects (Wing *et al.* 1998). It is easily metabolized to a decarbomethoxylated form in larva midgut of Lepidoptera (Wing *et al.* 2000).

Effects of indoxacarb at sublethal doses, on developmental time and reproduction parameters (Golmohammadi *et al.* 2009) and hatchability and fecundity (Galvan *et al.* 2005) in different insects have been investigated.

Using insecticides has various harmful effects on the environment and beneficial organisms. So, applying methods which will decrease the concentration values of these compounds is necessary. This study is part of a project investigating the effects of sublethal doses of indoxacarb on the biological parameters of the diamondback moth. Some data, such as pupal weight, pupal rate, adult emergence and reproduction parameters (r_m, R_0, λ and Dt) were reported by Mahmoudvand *et al.* (2011b). The present report was designed to assess the effects of sublethal doses of indoxacarb on life expectancy, pre-

*Corresponding address:
msco1381@gmail.com

oviposition, oviposition and post-oviposition period, and stable age distribution of *P. xylostella*.

MATERIALS AND METHODS

Insect Rearing

The initial *P. xylostella* colony was collected in August, 2008 from cauliflower fields at Shahre-Rey, south of Tehran, Iran. For egg laying, about 500 adults of *P. xylostella* were placed in a plastic cage (50x30x30 cm) and the eggs were transferred to cauliflower leaves, *Brassica oleracea* var. *botrytis* as food material to continue their development. The insect stock was maintained at 25±1°C and 65±5% relative humidity (RH) under a 16:8 (L:D) photoperiod in the growth chamber.

Bioassay tests

For bioassay experiments, a leaf dip method was used (Tabashnik and Cushing 1987). Cabbage leaf discs (3 cm in diameter) were dipped in different concentrations (0.75, 2.25, 4.5, 7.5, 15 and 22.5 mg/l) of indoxacarb (Avaunt® 150 SC, DuPont) solutions containing 0.02% Tween-80 for 30 sec. In the control, the leaf discs were dipped in water with 0.02% Tween-80. The treated leaf discs were permitted to dry at room temperature for 2 h. Then, the dry-treated leaf discs were placed in a plastic cup (3 cm in depth and 5.5 cm in diameter). The third larval instars which had been starved for 2 h (n = 10) were released on the leaf discs. These tests were replicated 4 times and at least 60 third larval instars were used for each concentration. Mortality was recorded 48 h after treatment. The d*ata were analyzed* by linear regression fitted to a *probit* model using SAS software (SAS Institute 1997). Estimated LC_{10} and LC_{25} of leaf dip bioassay on the third instars of *P. xylostella* at 48 h were 0.66 (mg/l) and 1.69 (mg/l), respectively.

Treatment with sublethal doses of indoxacarb

Cabbage leaf discs were treated with LC_{10} and LC_{25} concentrations of indoxacarb and the control group was treated with 0.02% of Tween-80. After drying, the third larval instars which had been starved for 2 h (n = 25), were placed on treated leaves in a plastic cup (3 cm deep and 5.5 cm in diameter). For each treatment, 8 replicates were used. After 48 h, survivors were provided fresh cabbage leaves up to pupation. After emergence, 20 pairs of emerging adults from each treatment were selected and each pair was released in an independent plastic cage (14x11x5 cm). A sugar solution (10%) was used to feed the adults. Cabbage leaves were placed in each cage for ovipositon. Leaves were replaced with fresh ones and number of eggs laid was recorded daily. This process continued until the death of adults.

Data analysis

Since there are l_x individuals that survive to age x in the cohort and a total of T_x insect-days remaining to these l_x individuals, the life expectancy (e_x) was obtained by this equation: $e_x = T_x/l_x$ (Carey 1993). The age-specific fecundity (m_x) was calculated through M_x (gross maternity) x number of female/all. The stable age distribution (C_x) was assessed by this formula:

$$\frac{e^{-rx} L_x}{\sum_{x=0}^{\omega} e^{-rx} L_x}$$

where:
r – intrinsic rate of increase,
x – age,
e^{-rx} – the expotential of intrinsic rate of increase and age,
w – the last day of female life,
Lx – survival rate.

One way ANOVA was used for statistical analysis and $p < 0.05$ was accepted as the significance level. Means were compared by Tukey's Studentized Range Test. For all the analyses, SAS software was used (SAS Institute 1997).

RESULTS

Changes in age-specific fecundity (m_x) after indoxacarb treatment

Figure 1 shows the age-specific fecundity (m_x) of *P. xylostella* in the control and treated groups with indoxacarb at the sublethal doses. Egg laying started on the 21st day of life (along with adult emergence) in the control. However, in treated groups with sublethal concentrations (LC_{10} and LC_{25}) of applied insecticide, egg laying occurred at day 22 and 23, respectively (Fig. 1).

Effects of sublethal indoxacarb concentrations on life expectancy

Sublethal concentrations of indoxacarb decreased the life expectancy (e_x) of *P. xylostella*, although life expectancy in both the control and treatment groups increased for a short time at the beginning (days 4–9) (Fig. 2). Values of life expectancy in the first day of life of the untreated group were 28.56 and in LC_{10} and LC_{25} doses of indoxacarb at the beginning of life were 24.53 and 21.73. In the first day after adult emergence, life expectancy values of the control, LC_{10} and LC_{25} of indoxacarb were 20.15, 19.20 and 17.33 days, respectively.

Effects of indoxacarb on stable age distribution (C_x) of the offspring generation

Sublethal doses of indoxacarb changed the stable age distribution (C_x) of the offspring generation of *P. xylostella* (Table 1). The highest rate of population in all groups was in the larva stage. On the other hand, the lowest rate of population was observed in the adult stage. Total percentage of egg, larval and pupal stage in the control was 97.6% and percentage of adult stage was 1.8%. Percentage of the adult stage was 3 and 3.1% in LC_{10} and LC_{25} of indoxacarb treated groups. These results indicated that sublethal doses of indoxacarb decreased the trend of pre-adult stages and increased the rate of the adult stage in treated populations.

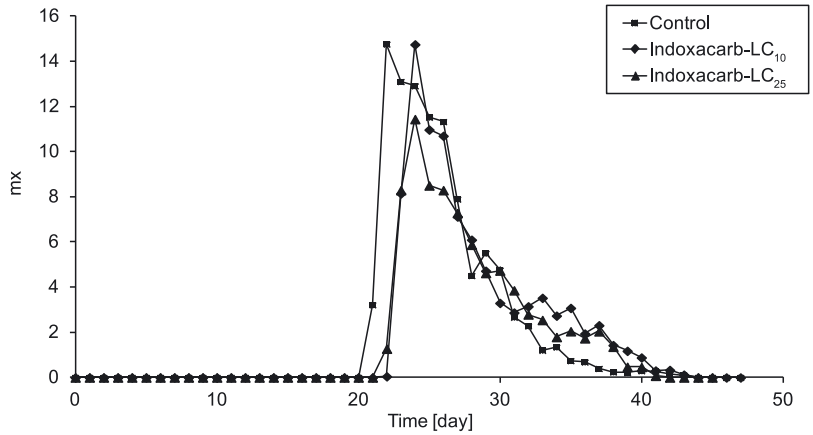

Fig. 1. Effects of sublethal concentrations (LC_{10} and LC_{25}) of indoxacarb on age-specific fecundity (m_x) of *P. xylostella* during their lifetime

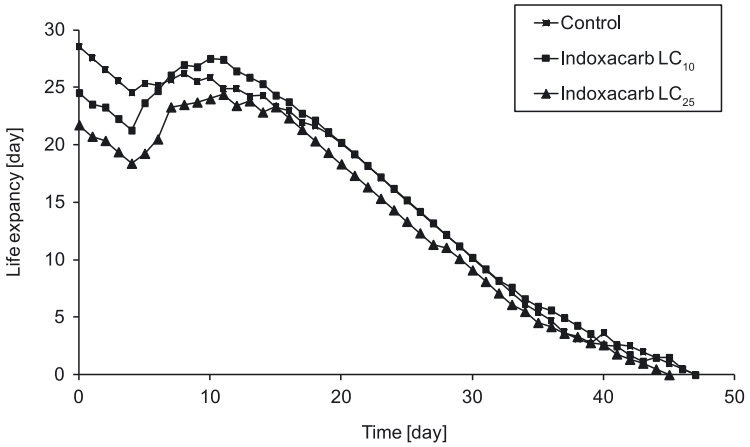

Fig. 2. Effects of sublethal doses (LC_{10} and LC_{25}) of indoxacarb on life expectancy (e_x) of *P. xylostella* throughout their life

Table 1. Effect of sublethal concentrations of indoxacarb on stable age distribution (C_x) of *P. xylostella*

Treatment	Egg	Larva	Pupa	Adult
The control	45.5	47	5.1	1.8
LC_{10}	42.9	43	10.9	3
LC_{25}	42	42	12.9	3.1

Oviposition period

It can be seen in figure 3 that sublethal effects of indoxacarb on the pre-oviposition (the time between adult emergence and first oviposition), oviposition and post-oviposition period of *P. xylostella*. Indoxacarb in sublethal doses, significantly increased the pre-oviposition period of *P. xylostella* (F = 6.15, P = 0.0038, df = 2, 57) (Fig. 3a), However, indoxacarb had no effect on the ovipositon period (F = 1.92, P = 0.1566, df = 2, 57) (Fig. 3b). The post-oviposition period was significantly decreased by both concentrations compared to the control (F = 5.33, P = 0.0076, df = 2, 57) (Fig. 3c).

DISCUSSION AND CONCLUSIONS

Sublethal concentrations of indoxacarb had a decreasing effect on the age-specific fecundity (m_x), and life expectancy (e_x) of the diamondback moth. In addition, this insecticide could change the stable age distribution (C_x) of the treated population compared to the control. The impact of indoxacarb on the oviposition parameters was also obvious. Clearly, the influence of LC_{25} specimens was stronger than that of LC_{10} concentration.

The highest values of age-specific fecundity (m_x) in the control and LC_{10} concentration of insecticide were seen in the initial days of adult emergence. Galvan *et al.* (2005) found that indoxacarb significantly decreased fecundity of *Harmonia axyridis* Pallas (Col.: Coccinelidae).

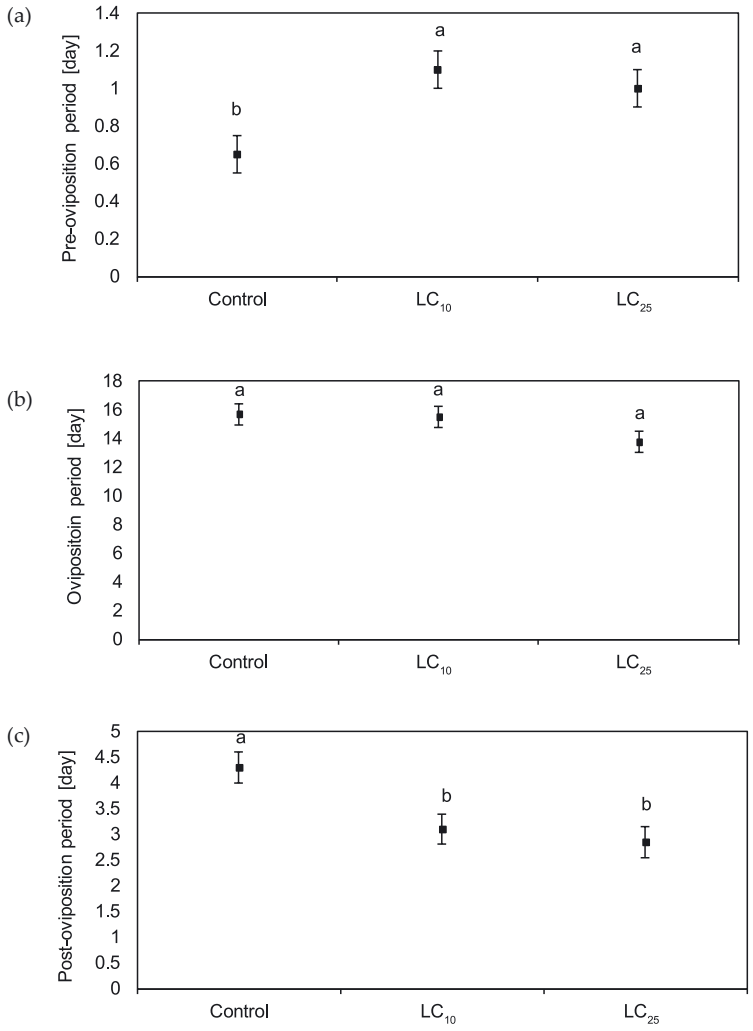

Fig. 3. Effect of sublethal doses of indoxacarb on the pre-oviposition (a), oviposition (b) and post-oviposition period (c) of females of *P. xylostella* (pre-oviposition: F = 6.15, P = 0.0038, df = 2, 57; oviposition: F = 1.92, P = 0.1566, df = 2, 57; post-oviposition; F = 5.33, P = 0.0076, df = 2, 57)

In our current study, the life expectancy of the diamondback moth was lower in indoxacarb groups in comparison with the control, in the beginning days of the treatment. After four days of exposure, the life expectancy intensified both in the control and treated groups and then 5 days after (day 9) exposure, it declined. This diminishing effect continued to the last day of insects' life in all groups. Increasing the life expectancy in the mentioned time, may be due to decreasing the mortality of insects after a period of high death. The highest mortality was observed in the first and second larval instars of the next generation. In a stable population, the trend of the pre-adult stages is higher than that in the adult stage. Thus, if a factor can increase the rate of the adult stage of a pest, it may be considered as a good factor for the movement of the population to instability. In this study, age distribution of *P. xylostella* changed after exposure to indoxacarb. Similarly, Acheampong and Stark (2004) reported that in treating *Diaeretiella rapae McIntosh* (Hym.: Aphidiidae) using a mixture of pymetrozine and Sylgard 309 (adjuvant), the adult trend increased compared with the control. Similar to this study, Mahmoudvand *et al.* (2011c) stated that sublethal concentrations of an Insect Growth Regulators (IGR), hexaflumuron had affected e_x and m_x of *P. xylostella*. Also, hexaflumuron at sublethals decreased fertile eggs per day in *P. xylostella*. Yin *et al.* (2008) reported that the pre-oviposition period of *P. xylostella* exposed to spinosad, increased. In contrast with our study, Josan and Singh (2000) found that the oviposition period of *P. xylostella* treated with lufenuron, significantly decreased. In our study, the ovipositon period did not change. A decrease in the post-oviposition period was shown in those moths from the treated groups, which were seen to die after oviposition sooner than those from the control.

In conclusion, the present results demonstrated that sublethal doses of indoxacarb can profoundly affect the survival and reproduction parameters of *P. xylostella*. This insecticide can also reduce the number of fertile eggs per day and fertile eggs per female per day in this pest. Furthermore, exposure to sublethal concentrations of indoxacarb can alter the stable age distribution of the next generation. Further studies, however, are needed to assess the effect of these sublethal doses of indoxacarb on *P. xylostella* in the next generations.

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