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Sublethal Effects of Methoxyfenozide on Growth and Development of Common Cutworm *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae)

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Abstract: Methoxyfenozide is an ecdysone agonists, belonging to a novel group of Insect Growth Regulators (IGRs). In this study, the sublethal effects of methoxyfenozide on growth and development of common cutworm *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae) were evaluated. The (2nd and 5th) instars larvae of *S. litura* were fed on cabbage leaves, treated with sublethal concentration of methoxyfenozide (LC_{10}, LC_{30}) (which were estimated based on the laboratory preliminary experiments bioassay. After 48 h of the feeding on cabbage leaves treated with methoxyfenozide, larvae were moved and fed on cabbage leaves free of chemicals and allowed to them to grow and pupate until the adult emergence. The results revealed that when larvae 2nd instar were treated with methoxyfenozide the 3rd-6th larval instar duration was significantly ($p<0.05$) increased by both (LC_{10}, LC_{30}) of methoxyfenozide. Also pupation percent, pupal weight, adult emergence and adult longevity were significantly ($p<0.05$) reduced by both (LC_{10}, LC_{30}) of methoxyfenozide when both (2nd and 5th) instar larvae were treated. However, the pupal duration was significantly ($p<0.05$) prolonged when both (2nd and 5th) instar larvae were treated with (LC_{10}, LC_{30}) of methoxyfenozide compared to the control. The results also revealed that when *S. litura* larvae (2nd and 5th) instars 2nd and 5th were treated with sublethal doeses (LC_{10}, LC_{30}) of methoxyfenozide the adult duration (longevity) was significantly ($p<0.05$) reduced however, the reduction was more pronounced when the LC_{30} of methoxyfenozide was applied to larvae 5th instars. Researchers concluded that the sublethal effects of methoxyfenozide might exhibit significant ($p<0.05$) effects on the population dynamics of *S. litura* as well as it might play a vital role 2nd and 5th in Integrated Pest Management program (IPM).

Key words: *Spodoptera litura*, methoxyfenozide, sublethal effects, growth and development, sublethal, China

INTRODUCTION

The common cutworm, *Spodoptera litura* (*S. litura)* fabricius is among the most damaging insect pest of vegetables in Asia. It is known to feed on >120 host plants including crops, vegetables, weeds and ornamental plants (Ramana *et al*., 1988). It feeds gregariously on leaves leaving midrib veins only. Insect Growth Regulators (IGRs) are biorational insecticides with novel modes of action which disrupt the physiology and development of the target pest such compounds tend to be selective and generally less toxic to on-target organisms than conventional insecticides (Biddinger and Hull, 1999; Gurr *et al*., 1999). IGRs disrupt the molting process of insect larvae by inhibiting chitin deposition in their cuticles during growth and development (Retnakaran and Hackman, 1985). Ecdysone agonists are one of the most recent developed groups of IGR's that mimic the molting hormone, resulting in premature molting (Dhadialla *et al*., 1998), they are highly specific to lepidopterous larvae and their effectiveness in (both in laboratory and field trials) against many such economically important horticultural, agronomic, stored and forest pests have been reported (Chandler *et al*., 1992; Smagghe *et al*., 1996a, b; Cadogan *et al*., 1997). Tebufenozide (RH-5992) and methoxyfenozide (RH-2485) belong to a novel class of IGRs, bisacylhydrazine ecdysteroid agonists (Smagghe and Degheele, 1994a, b). Methoxyfenozide (RH-2485) is a newest IGR which is the most potent member of the Molt-Accelerating Compounds (MACs) against Lepidoptera (Smagghe *et al*., 2003). Due to its high specificity against Lepidoptera and low toxicity towards other insect orders, it is considered as an environmentally friendly compound (Dhadialla *et al*., 1998; Palli and Retnakaran, 2001). The sublethal effects of ecdysone agonists on growth and development have been evaluated on lepidopterons in many studies for example when injected into

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Choristoneura fumiferana pupae (Lepidoptera: Tortricidae, RH-5992 (tebufenozide) interfered with the normal developmental processes resulting in pupal mortality. At higher concentrations (>100 ng pupa^{-1}), there is a significant reduction in adult emergence due to pupal mortality. Thus, the interference of RH-5992 (an analogue of methoxyfenozide) in the developmental process is explicated (Sundaram *et al*., 1998). *S. litura* larvae are a major cosmopolitan pest of a wide range of crops (Skibbe *et al*., 1995). Because of its resistance to almost all kinds of chemicals, the searching for new chemicals to control this pest is a great challenge. In this study, researchers determined the sublethal effects of ecdysteroid agonists methoxyfenozide RH-2485 on growth development of *S. litura* to maintain the pest population 2nd and 5th below the economic loss level by applying the sub lethal doses (LC_{10}, LC_{30}) of methoxyfenozide orally on newly molted 2nd and 5th instars of *S. litura*.

MATERIALS AND METHODS

Insects and rearing: *S. litura* cultures used were from the Institute of Plant Protection (IPP), Chinese Academy of Agricultural Science (CAAS), cultures were routinely maintained on soybean-based artificial diet at standard conditions of 27±2°C temperature, 75±5% r.h. and 16:8 (L:D) photoperiods in growth chamber in the Laboratory of Plant Protection Department, Faculty of Horticulture and Plant Protection, Yangzhou University at the year of 2009. In the experiments reported here, insects were transferred to experimental diets immediately after moulting to 6th (final) instar then kept at standard condition and allowed to pupate. Pupae were then collected and placed in four walls square wooden emergence cage (40×40×40 cm) lined by thin gauze. In each cage (40~50) pupae were placed. As soon as the adult emerged, wax paper was used around the internal wall cage to let the adults copulate and oviposit freely. After the emergence, 10% honey water solution was provided when nutrition was needed. The egg masses oviposited on the paraffined wax paper were collected and sterilized with 2 or 4% formalin to avert microbial infection. After hatching larvae were reared and allowed to pupate and emerge and oviposit again freely.

Tested chemical: Pesticides used were methoxyfenozide (RH-2485, 24% SC) as one of moulting hormone agonists, purchased from Dow Agro Science Co. (China). Chlorfluazuron (5% EC) as another IGR of chitin synthesis inhibitor was brought from Ishihara Sangyo Kaisha, Ltd. (Japan). β-cypermethrin (4.5% EC) as a common traditional chemical against *S. litura* was from Jiangsu Yangnong Chemical Group Co., Ltd. In this research, zmethoxyfenozide was mainly the target of the investigation however, chlorfluazuron and β-cypermethrin were used for comparison.

Dose-response bioassays: Dose-response bioassays were conducted to determine the toxicity of methoxyfenozide to *S. litura* larvae. Leaf-drop method as described by was used in the bioassay. At least five concentrations per replicate of tested chemicals were prepared from serial dilutions by using tap water. Cabbage leaves were cut in suitable size then dropped in the solution for 10 sec and dried naturally for 4-6 h. The dried leaves were put individually into petri dish with 20 cm diameter and 10 (2nd or 5th) instar larvae were moved on the leaves. Three dishes per concentration were used for each replicate; distilled water was used as control. About 24 h later, the tested larvae were moved to fresh leaves free from chemicals and 48 h after treatment, larvae were checked and the number of dead and survival individuals were recorded. If no movement was observed larvae were recorded as dead. Probit analysis was conducted on the dose-response data using DPS. The sublethal effects associated with methoxyfenozide, chlorfluzuron and β-cypermethrin were already estimated in previous study by feeding (2nd and 5th) instars larvae via ingestion on treated cabbage leaves with concentrations corresponded to the (LC_{10} and LC_{30}) for the three insecticide until pupation and emergence. Larvae were allowed to feed on concentrations corresponded to the (LC_{10} and LC_{30}) for the three insecticides which already estimated from the larval toxicity bioassay.

Growth and development of *S. litura:* Second and 5th instars; larvae were used in the experiment, 40 larvae treatment^{-1} were moved on to cabbage leaf treated with tested chemicals at (LC_{10} and LC_{30}). During the test of different stages of the insect the following parameters were investigated; 3rd-6th Instars larval duration, pupal duration/day, pupation (%), pupal weight (mg) adult emergence (%) and longevity (adult duration)/day with respect to larva 2nd instar and pupal duration/day, pupation (%), pupal weight (mg) adult emergence (%) and longevity (adult duration)/day with respect to larva 5th instar.

RESULTS

The effect of toxicity of tested pesticides on different instar larva of *S. litura:* Presents probit-log concentration regression equations obtained for the 2nd and 5th instar larvae of *S. litura*. (LC_{10}, LC_{30}) values of the tested chemical were estimated for *S. litura* based on the

results of the preliminary experiments bioassay in the following experiments the concentrations values (LC_{10}, LC_{30}) to (2nd and 5th) instars larvae were as follow; for 2nd instar larvae when pesticides were tested found that (LC_{10} = 0.0173 ppm, LC_{30} = 0.2803 ppm), (LC_{10} = 0.0797 ppm, LC_{30} = 0.6246 ppm) and (LC_{10} = 0.6613, ppm, LC_{30} = 2.7256 ppm) with respect to methoxyfenozide, chlorfluzuron and β-cypermethrin, respectively. When 5th instar larvae when pesticides were tested researchers found that (LC_{10} = 4.0021 ppm, LC_{30} = 13.1594 ppm), (LC_{10} = 0.6878 ppm , LC_{30} = 1.8393 ppm) and (LC_{10} = 0.9904 ppm, LC_{30} = 2.4083 ppm) with the same pesticides, respectively (Table 1).

Sublethal concentrations of methoxyfenozide on the growth and development of *S. litura* when larvae 2nd instars were treated: When larvae 2nd instar were treated with LC_{10} of methoxyfenozide, chlorfluazuron and β-cypermethrin the 3rd instar duration was significantly ($p<0.05$) higher than the control with average (4.2±0.7), (4.1±1.0) and (3.8±0.7) days. Similarly, 4th instar duration was significantly ($p<0.05$) increased to (4.2±0.7), (3.8±0.7) and (3.3±0.9) days with respect to methoxyfenozide, chlorfluazuron and β-cypermethrin compare control value (3.3±0.9) days. As well as 5th instar duration was significantly ($p<0.05$) increased by methoxyfenozide to (3.8±0.7) days compared 2nd and 5th to the control however; the duration was significantly ($p<0.05$) the same of the control when chlorfluazuron and β-cypermethrin were used.

The 6th instar duration was also significantly ($p<0.05$) prolonged to (4.8±1.5), (4.4±1.0) and (3.9±0.9) days when methoxyfenozide, chlorfluazuron and β-cypermethrin were used compare to the control value which was (3.3±0.7) days (Table 2). When LC_{10} was applied to *S. litura* larvae 2nd instar pupation percent was significantly ($p<0.05$) reduced to 80, 80 and 85% with respect to methoxyfenozide, chlorfluazuron and β-cypermethrin respectively compared to the control value 90%. The result revealed that pupa duration was significantly ($p<0.05$) increased when LC_{10} of methoxyfenozide was applied compared to the control while the duration was not affected when chlorfluazuron and β-cypermethrin were applied. Pupa duration reached to (12.5±1.0^{a}) days in methoxyfenozide treatment while it was only (8.8±1.0), (8.5±1.3) and (8.6±1.2^{b}) at chlorfluazuron and β-cypermethrin and control, respectively.

The result also showed that the pupal weight was significantly ($p<0.05$) reduced to (336.1±65.6) g by methoxyfenozide compared to the control (379.6±28.1) g however, there was no significant difference observed when chlorfluazuron and β-cypermethrin were used. The results showed that the adult emergence decreased to 75, 80 and 85% compared 2nd and 5th to 90% which was found in the control. When LC_{10} of of methoxyfenozide was applied the adult duration (longevity) was significantly ($p<0.05$) reduced to (6.5±1.1) days compared to the control (9.7±1.1) days followed by significant ($p<0.05$) reduction of (8.2±2.2) days observed for chlorfluazuron however, the longevity was not affected when β-cypermethrin was used (Table 2).

Sublethal effects of LC_{30} methoxyfenozide on the development of *S. litura* when larvae 2nd instars were treated: When larvae 2nd instar were treated with LC_{30} of methoxyfenozide, chlorfluazuron and β-cypermethrin the 3rd instar duration was significantly ($p<0.05$) higher than the control with averages (4.6±0.5), (4.7±0.5) and (4.4±0.8) days. Also, 4th instar duration was significantly ($p<0.05$) increased to (4.6±0.5), (4.1±0.7) and (4.6±0.5) days with respect to methoxyfenozide, chlorfluazuron and

Table 1: The toxicity of tested pesticides to larvae of *Spodoptera litura*

Pesticides	Instar	Regression equation (Y = aX+b)	Correlation coefficient (r)	LC_{10} (ppm)	LC_{30} (ppm)
Methoxyfenozide	2nd	Y = 0.6259X+4.8212	0.9595	0.0173	0.2803
Chlorfluazuron		Y = 0.8467X+4.6487	0.9614	0.0797	0.6246
β-cypermethrin		Y = 0.2310X+3.9400	0.9213	0.6613	2.7256
Methoxyfenozide	5th	Y = 1.4646X+2.8363	0.9034	4.0021	13.1594
Chlorfluazuron		Y = 1.7724X+4.0066	0.9663	0.6878	1.8393
β-cypermethrin		Y = 1.9619X+3.7260	0.9767	0.9904	2.4083

Table 2: The effects of LC_{10} concentration on the growth and development of *S. litura* when larvae 2nd instar were treated

Development index	Methoxyfenozide	Chlorfluazuron	β-cypermethrin	Control
3rd instar duration (days)	4.2±0.7^{a}	4.1±1.0^{a}	3.8±0.7^{a}	3.0±0.8^{b}
4th instar duration (days)	4.5±0.7^{a}	3.8±0.7^{a}	3.3±0.9^{b}	3.3±0.9^{b}
5th instar duration (days)	3.8±0.7^{a}	3.3±0.5^{ab}	3.7±0.8^{ab}	3.2±1.0^{b}
6th instar duration (days)	4.8±1.5^{a}	4.4±1.0^{a}	3.9±0.9^{a}	3.3±0.7^{b}
Pupation (%)	80.0	80.0	85.0	90.0
Pupa duration (days)	12.5±1.0^{a}	8.8±1.0^{b}	8.5±1.3^{b}	8.6±1.2^{b}
Pupa (weight mg^{-1})	336.1±65.6^{b}	366.2±47.5^{ab}	364.5±29.2^{ab}	379.6±28.1^{a}
Adult emergence (%)	75.0	80.0	85.0	90.0
Adult duration (longevity) (days)	6.6±1.1^{c}	8.2±2.2^{b}	8.5±2.1^{ab}	9.7±1.1^{a}

The dates indicate means±SD and those with the same small letter are not significantly different ($p \leq 0.05$)

β-cypermethrin compared to the control value (3.0±0.8) days. The 5th instar duration was also significantly ($p<0.05$) increased by methoxyfenozide to (4.6±0.5) days followed by significant ($p<0.05$) increase of (4.6±0.5) and (4.5±0.5) days observed for chlorfluazuron and β-cypermethrin compared to the control value (2.6±0.5) days. Results disclosed that the 6th instar duration was also significantly ($p<0.05$) prolonged to (4.9±0.7), (4.7±0.8) and (5.3±0.8) days when methoxyfenozide, chlorfluazuron and β-cypermethrin were used compared to the control value which was (3.9±0.9) days (Table 3).

When LC_{30} was applied to *S. litura* larvae 2nd instar, the pupation percent was significantly ($p<0.05$) reduced to 60, 60 and 70% with respect to methoxyfenozide, chlorfluazuron and β-cypermethrin, respectively compared to the control value 85%. The result showed that pupa duration was significantly ($p<0.05$) increased to (12.9±1.9) and (11.5±0.5) when LC_{30} of methoxyfenozide and β-cypermethrin was applied compared to the control while the duration was not affected when chlorfluazuron was used. The data revealed that the pupal weight was significantly ($p<0.05$) reduced by methoxyfenozide to 174.6±17.0 g compared to the control 265.2±46.5 g followed by significant ($p<0.05$) reduction of 195.6±50.7 and 220.0±29.3 g observed for chlorfluazuron and β-cypermethrin, respectively. Moreover, the adult emergence was decreased from 80% in the control to 40, 50 and 60% with respect to the three pesticides, respectively. The adult duration (longevity) was significantly ($p<0.05$) reduced to (6.5±1.1) when LC_{30} of methoxyfenozide has been applied compared to the control followed by significant ($p<0.05$) reduction of (8.5±1.6) observed for chlorfluazuron while there was no significant ($p<0.05$) difference observed when β-cypermethrin was applied (Table 3).

Sublethal effects of LC_{10} methoxyfenozide on the development of *S. litura* when larvae 5th instars were treated: When larvae 5th instar was treated with LC_{10} of methoxyfenozide, pupation percent was significantly ($p<0.05$) reduced to 42.5% compared to the control 92.5% followed by significant ($p<0.05$) reduction of 75% observed for chlorfluazuron. The results also showed that the pupa duration was significantly ($p<0.05$) increased to 12.3±0.7 days with respect to methoxyfenozide while it was significantly ($p<0.05$) the same of the control with average of 11.1±1.3 and 10.4±0.5 days when chlorfluazuron and β-cypermethrin were used compared to the control value which was about 10.5±1.0 days. Pupal weight was significantly ($p<0.05$) reduced by methoxyfenozide to 239.9±8.8 g compared to the control value 336.6±28.1 g followed by significant ($p<0.05$) reduction of 282.7±12.9 and 283.1±30.6 g was observed for chlorfluazuron and β-cypermethrin, respectively. The results also showed that the adult emergence was significantly ($p<0.05$) reduced by methoxyfenozide to 20% followed by significant ($p<0.05$) reduction of 62.5 and 70% observed for chlorfluazuron and β-cypermethrin, respectively compared to the control 85%. When larvae 5th instar was treated with LC_{10} of methoxyfenozide adult duration was significantly ($p<0.05$) reduced to 6.9±2.4 days compared to the control however, it was significantly ($p<0.05$) the same of the control with average of 9.1±2.6 and 8.3±1.7 when chlorfluazuron and β-cypermethrin have been applied (Table 4).

Sublethal effects of LC_{30} methoxyfenozide on the development of *S. litura* when larvae 5th instars were treated: When larvae 5th instar was treated with LC_{30} of methoxyfenozide, pupation percent was significantly ($p<0.05$) reduced to 25.0% compared to the control 82.5%

Table 3: The effects of LC_{30} methoxyfenozide on the development of *S. litura* when larvae 2nd instars were treated

Development index	Methoxyfenozide	Chlorfluazuron	β-cypermethrin	Control
3rd instar duration (days)	4.6±0.5^{a}	4.7±0.5^{a}	4.4±0.8^{a}	2.6±0.8^{b}
4th instar duration (days)	4.6±0.5^{a}	4.1±0.7^{a}	4.6±0.5^{a}	3.0±0.8^{b}
5th instar duration (days)	4.6±0.5^{a}	4.6±0.5^{a}	4.5±0.5^{a}	2.6±0.5^{b}
6th instar duration (days)	4.9±0.7^{a}	4.7±0.8^{ab}	5.3±0.8^{a}	3.9±0.9^{b}
Pupation (%)	60.0	60.0	70.0	85.0
Pupa duration (days)	12.9±1.9^{a}	10.6±1.8^{bc}	11.5±0.5^{ab}	9.7±0.8^{c}
Pupa (weight mg^{-1})	174.6±17.0^{c}	195.6±50.7^{bc}	220.0±29.3^{b}	265.2±46.5^{a}
Adult emergence (%)	40.0	50.0	60.0	80.0
Adult duration (longevity) (days)	6.5±1.1^{b}	8.5±1.6^{b}	11.0±0.9^{a}	9.7±4.1^{a}

The dates indicate means±SD and those with the same small letter are not significantly different ($p \leq 0.05$)

Table 4: The effects of LC_{10} methoxyfenozide on the development of *S. litura* when larvae 5th instars were treated

Development index	Methoxyfenozide	Chlorfluazuron	β-cypermethrin	Control
Pupation (%)	42.5	75.0	92.5	92.5
Pupa duration (days)	12.3±0.7^{a}	11.1±1.3^{b}	10.4±0.5^{b}	10.5±1.0^{b}
Pupa (weight mg head^{-1})	239.9±8.8^{c}	282.7±12.9^{b}	283.1±30.6^{b}	336.6±28.1^{a}
Adult emergence (%)	20.0	62.5	70.0	85.0
Adult duration (longevity) (days)	6.9±2.4^{b}	9.1±2.6^{a}	8.3±1.7^{a}	9.4±2.4^{a}

The dates indicate means±SD and those with the same small letter are not significantly different ($p \leq 0.05$)

Table 5: The effects of LC_{30} methoxyfenozide on the development of *S. litura* when larvae 5th instars were treated

Development index	Methoxyfenozide	Chlorfluazuron	β-cypermethrin	Control
Pupation (%)	25.0	52.5	57.5	82.5
Pupa duration (days)	12.7±0.5^a	9.6±0.9^b	8.9±0.4^b	9.7±0.5^b
Pupa weight (mg head^{-1})	238.6±25.8^c	264.2±35.1^b	264.0±28.6^b	336.6±28.1^a
Adult emergence (%)	17.5	20.0	27.5	85.0
Adult duration (longevity) (days)	5.1±1.1^c	6.6±1.1^b	6.4±0.5^b	8.1±1.6^a

The dates indicate means±SD and those with the same small letter are not significantly different ($p \leq 0.05$)

followed by significant ($p<0.05$) reduction of 52.5 and 57.5% observed for chlorfluazuron and β-cypermethrin, respectively. The results also showed that the pupa duration was significantly ($p<0.05$) increased to 12.7±0.5 days with respect to methoxyfenozide while it was significantly ($p<0.05$) the same of the control with an average of 9.6±0.9 and 8.9±0.4 days when chlorfluazuron and β-cypermethrin were used compared to the control value which was about 9.7±0.5 days. Pupal weight was significantly ($p<0.05$) reduced by methoxyfenozide to 238.6±25.8 g compared to the control value 336.6±28.1 g followed by significant ($p<0.05$) reduction of 264.2±35.1 and 264.0±28.6 g observed for chlorfluazuron and β-cypermethrin, respectively. The result also showed that the adult emergence was significantly ($p<0.05$) reduced by methoxyfenozide to 17.5% followed by significant ($p<0.05$) reduction of 20.0 and 27.5% observed for chlorfluazuron and β-cypermethrin, respectively compared to the control value 85%. When larvae 5th instar was treated with LC_{30} of methoxyfenozide adult duration was significantly ($p<0.05$) reduced to 5.1±1.1 days compared to the control value 8.1±1.6 days followed by significant ($p<0.05$) reduction of 6.6±1.1 and 6.4±0.5 days observed when chlorfluazuron and β-cypermethrin have been applied (Table 5).

DISCUSSION

In the present study, the sublethal effects of methoxyfenozide on growth and development of *S. litura* was evaluated, the study confirmed that as an ecdysone agonist, methoxyfenozide has a significant sublethal effects on *S. litura*. The high effectiveness of methoxyfenozide against pest Lepidoptera has been widely recognized (Moulton *et al*., 2002; Smagghe *et al*., 2003; Pineda *et al*., 2004).

The sublethal effects of methoxyfenozide on growth and development of *S. litura* varied with different stage and treating concentration. Generally, larva duration was significantly ($p<0.05$) prolonged for both (LC_{10}, LC_{30}), pupal weight was significantly ($p<0.05$) reduced and adult emergence was significantly ($p<0.05$) decreased. Such observations are in accordance with Pineda *et al*. (2009) who reported that the incorporation of methoxyfenozide into the *Spodoptera frugiperda* diet had a significant effect on the timing of larval development 2nd and 5th. Both male and female treated larvae lived about 7 days longer than the controls for both concentrations (LC_{10}, LC_{25}) tested of methoxyfenozide also the treated larvae exhibited lower pupal weights, higher pupal mortality, presence of deformed pupae and more deformed adults than untreated larvae. Many other IGRs have been found to affect the development via lengthen the development time of insects. The incorporation of the LC_{25} of methoxyfenozide into *S. exigua* larvae diet resulted in reductions on the pupal weight in both sexes of between 5 and 8% (Emam *et al*., 1988; EL-Sayed *et al*., 1986; Christian-Luis and Pineda, 2010). Similarly, larvae of *Spodoptera littoralis* (Boisduval), *Spodoptera litura* (F.) (Lepidoptera: Noctuidae) and *Platynota idaeusalis* (Walker) (Lepidoptera: Tortricidae) fed on contaminated synthetic diet with tebufenozide or methoxyfenozide exhibited reductions in the pupal weight (Adel and Sehnal, 2000; Seth *et al*., 2004; Biddinger *et al*., 2006).

Christian-Luis and Pineda (2010) also determined that both male and female of *S. frugiperda* that had been treated with sublethal concentrations of methoxyfenozide in the 5th instar, secured less weight than untreated larvae. The results showed that when *S. litura* (2nd, 5th) instar treated with (LC_{10}, LC_{30}) of methoxyfenozide (larval and pupal) duration with respect to (larvae 2nd instar) and pupal duration with respect to (larvae 5th) were significantly ($p<0.05$) increased compared to the control. Similarly Christian-Luis and Pineda (2010) observed that a concentration of 0.018 (AI)/kg diet of methoxyfenozide caused an increase in both larval and pupal development times in *S. exigua*. Adel and Sehnal (2000) observed a delayed in *S. littoralis* larvae when they were exposed as (2nd and 4th) instars to methoxyfenozide, respectively. When 6th instars of *S. litura* were exposed to different concentrations of tebufenozide (an analogue of methoxyfenozide) ranging from 0.5-2 ppm, pupal developmental times increased by 14-18 h (Seth *et al*., 2004). Delayed development may be due to the induction of an additional larval molt after the application of ecdysone agonists as has been observed in *S. littoralis* (Adel and Sehnal, 2000). The results demonstrated that the pupation percent was significantly ($p<0.05$) reduced when both *S. litura* (2nd and 5th) instars

were treated with different dosages (LC_{10}, LC_{30}) of methoxyfenozide compared to the control however, the reduction was more pronounced when LC_{30} has been applied, the same result was also reported by Pineda *et al.* (2009) who demonstrated that the progeny from adults methoxyfenozide were only affected in percentage of pupation of eggs that successfully hatched. The data showed that when *S. litura* was treated with the concentrations (LC_{10}, LC_{30}) of methoxyfenozide; adult emergence was significantly ($p<0.05$) reduced. In contrast, Pineda *et al.* (2009) reported that when *S. littoralis* adult treated with different concentrations of methoxyfenozide through oral exposure, no effects were observed in adult emergence of individuals that successfully pupated such difference in results may be due to difference of insect used or the different of the stages that have been treated or the different of the route of treatment for example when the 6th (final) instar larvae of *S. litura* were fed on artificial diet containing varying concentrations of RH-5849 (an analogue of methoxyfenozide), the insects were exposed to higher concentrations of the insecticide, therebye experienced increasing disruption of moulting and metamorphosis so that the percentage successfully emerging as adults fell from 98.6% in the control group to only 33.3% at 5.0 ppm (Seth *et al*., 2004).

Little information is available about the effects of ecdysone agonists on the longevity of adults Lepidopteron. Here we observed that methoxyfenozide has reduced *S. litura* longevity when both (2nd and 5th) larva instar were treated for both doses. In contrast, Christian-Luis and Pineda (2010) reported that methoxyfenozide did not affect *S. exigua* longevity whereas when 5 and 6th instars of *S. litura* were treated with RH-5849 (an analogue of methoxyfenozide) a reduction of 50% in adult longevity was observed (Seth *et al.*, 2004). Moreover, Pineda *et al.* (2009) reported that methoxyfenozide significantly ($p<0.05$) reduced the longevity of *S. littoralis* adults only at the higher concentrations tested (10 and/or 100 mg [AI] L^{-1}).

The reason for such differences is unclear because the presence of biochemical target sites in lepidopteran adults for this compound is still unknown. The observed effects here suggests that Methoxyfenozide RH-2485 can likely disrupt the growth and ecdysteroid-dependent physiological on the embryonic development processe. However, more information on the adult endocrine system is required to clarify the mechanism by which ecdysone agonists can affect adult longevity. Results obtained in this study indicated that methoxyfenozide is potentially potent compound for controlling *S. litura*. The high activity of this compound to lepidopteron pests, along with their low toxicity to mammals (Dow Agrosciences LLC, 2002; Palli and Retnakaran, 2001) indicates that this insecticide potentially represent an important component in IPM programs in cotton, vegetables and ornamentals. However, methoxyfenzide should be used carefully because some natural enemies, especially hymenopteran parasitoids, seem to be susceptible to this insecticide (Schneider *et al*., 2003a, b; Williams *et al*., 2003).

CONCLUSION

In this study, the findings indicated that the sublethal effects of methoxyfenozide might exhibit significant ($p<0.05$) effects on the population dynamics of *S. litura* as well as it might play a vital role in Integrated Pest Management program (IPM).

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