IJIRR

International Journal of Information Research and Review
Vol. 04, Issue, 06, pp.4228-4240, June, 2017

RESEARCH ARTICLE

DERANGED ADULT PERFORMANCE AND REPRODUCTIVE POTENTIAL OF THE OLIVE LEAF MOTH *PALPITA UNIONALIS* (HÜBNER) (LEPIDOPTERA: PYRALIDAE) BY THE NON-STEROIDAL ECDYSONE AGONIST, METHOXYFENOZIDE

[1]Khalid Hamadah, [1*]Karem Ghoneim, [2]Amany Mansour and [1]Ahmed Abo Elsoud

[1]Department of Zoology and Entomology, Faculty of Science, Al-Azhar University, Cairo, Egypt
[2] Desert Research Center, Cairo, Egypt

ARTICLE INFO

Article History:

Received 02nd March, 2017
Received in revised form
27th April, 2017
Accepted 09th May, 2017
Published online 30th June, 2017

Keywords:

Emergence, Fecundity, Fertility, Incubation, Longevity, Morphogenesis, Oviposition.

ABSTRACT

The olive leaf moth *Palpita unionalis* (Lepidoptera: Pyralidae) is an economic pest of the olive groves in Egypt and other olive producing countries in the world. The present study was conducted aiming to assess the effects of Methoxyfenozide, on adult performance and reproductive potential after treatment of newly moulted last (6th) instar larvae with sublethal concentrations (0.001, 0.01, 0.10, 1.00 and 10.0 ppm) of the tested ecdysteroid agonist.Methoxyfenozide could not affect the adult morphogenesis but displayed adulticidal effects (10% mortality) only at 0.10 and 1.00 ppm and arrested the adult emergence, especially at the higher four concentrations. The total adult longevity, pre-oviposition period andpost-oviposition period had been pronouncedly prolonged, in a dose-dependent course, but the oviposition period was slightly shortened. Oviposition efficiency of the successfully emerged females was pronouncedly inhibited, in a dose-dependent trend. Fecundity and fertility were tremendously reduced, in a dose-dependent course. The embryonic development was drastically retarded, since the incubation period was significantly prolonged, proportional to the concentration.

INTRODUCTION

Olive (*Olea europaea* L.) is one of the economically important crops in the Mediterranean Basin.Olive tree is subjected to attack by several insect pests causing considerable yield losses in quality and quantity (Spooner-Hart *et al*., 2007). The olive leaf moth *Palpita unionalis* (Hübner) (Lepidoptera: Pyralidae) is one of the most dangerous pests of olives in Egypt and other Mediterranean countries (Broumas *et al*., 2002; Shehata *et al*., 2003; Yilmaz and Genc, 2012). The most important damage of the pest occurs on young trees, nurseries and shoots of old trees (Pinto and Salemo, 1995; Grossley, 2000). The control of *P. unionalis* on olive trees has relied upon the use of traditional insecticides (Foda*et al*., 1976). Different pesticides exhibited a good control when applied on the early larval instars (Fodale and Mule, 1990). Insecticide residues have been detected in olive oil and in the environment where olives are grown (Montiel and Jones, 2002). In addition, the intensive and discriminate uses of many broad-spectrum conventional insecticides led to several drastic problems, such as the environmental hazards, destruction of the natural enemies, like parasites, predators, birds, fishes and mammals, serious toxicological problems to humans, as well as the development of insect resistance toward different insecticides (Rose, 2001; Davies *et al*., 2007; Costa *et al*., 2008; Mosallanejad and Smagghe, 2009). Therefore, alternative control agents have been searched recently to minimize the pesticide hazards.As a result, scientists have looked for new target sites beyond the nervous system on which the conventional insecticides have act. During the last few decades, a new class of comparatively safe compounds have been developed and known as insect growth regulators (IGRs) (Dhadialla *et al*., 1998; Khan and Qamar, 2012). In contrast to the classical chemical (neurotoxic) insecticides, IGRs are not directly toxic, but act selectively on the development, metamorphosis and/or reproduction of the target insect pests (Biddinger and Hull, 1995; Hoffmann and Lorenz, 1998; Nicholas *et al*., 1999; Martins and Silva, 2004) owing to their disruptive effects on the normal activity of endocrine system of insects (Wang and Liu, 2016). On the basis of the mode of action, IGRs had been grouped in three categories: (i) Juvenile hormone analogues (JHAs) (also called as Juvenoids), (ii) Ecdysteroids or ecdysone agonists and (iii) Chitin synthesis inhibitors (CSIs) or moult inhibitors (Wing and Aller, 1990; Dhadialla *et al*., 1998; Oberlander and Silhacek, 2000**)**. Latter, Tunaz and Uygun (2004) classified IGRs into CSIs and substances that interfere with the action of insect hormones (i.e. JHAs, and ecdysteroids).

****Corresponding author: Karem Ghoneim,***
Department of Zoology and Entomology, Faculty of Science, Al-Azhar University, Cairo, Egypt.

Ecdysone agonists are harmless to vertebrates (Carlson *et al*., 2001) with little or no adverse effects on the beneficial insects (Retnakaran *et al*., 2003). They have narrow spectrum of activity, positive ecotoxicological profile, and short persistence in the environment (Sundaram *et al*., 2002, Osorio *et al*., 2008).Like other IGRs, these compounds act more slowly than neurotoxic insecticides disrupting the hormonal regulation or the physiological development of insects rather than directly killing them (Biddinger *et al*., 2006). In some detail, uses of ecdysone agonists lead to a premature and lethal larval molt by binding directly to the ecdysteroid receptors (Smagghe *et al*., 2004), delayed or accelerated developmental rates (Biddinger *et al*., 2006), weight loss of immature stages (Pineda *et al*., 2007), pupal deformations (Pineda *et al*., 2004), adult deformities (Sundaram *et al*., 2002), disturbed diapause (Eizaguirre *et al*., 2007), impaired reproductive parameters (Palli and Retnakaran, 2001;Yanagi *et al*., 2006; Pineda *et al*., 2009) and changes in the adult sex ratio (Biddinger *et al*., 2006). Although these compounds are used for controlling lepidopterous and coleopterous pests (Ishaaya*et al*., 2001; Palli and Retnakaran, 2001; Yanagi *et al*., 2006) and orthopterous pests (Al-Dali *et al*, 2008), they are highly selective against lepidopterous larvae (Schneider *et al*., 2008). Nowadays, ecdysone agonists are being commercialized as selective bio-rational insecticides to be used in combinations with other control strategies to develop integrated pest management programs in agricultural ecosystems.

Several substituted dibenzoyl hydrazines that act as non-steroidal ecdysone agonists have been synthesized, such as RH-5849 (the prototype compound), Tebufenozide(RH-5992), Methoxyfenozide (RH-2485) and Halofenozide (RH-0345) and Chromafenozide (ANS-118).Methoxyfenozide is a potent synthetic non-steroidal ecdysteroid agonist discovered by Rohm and Haas (Spring House, PA, USA)(Dhadialla *et al*., 2005). It has an excellent margin of safety to non-target organisms, including a wide range of beneficial insects (Medina *et al*., 2004; Schneider *et al*., 2008). Its high efficacy against lepidopterous larvae (including many species in families Pyralidae, Pieridae, Tortricidae and Noctuidae) has been widely recognized (Saenz-de-Cabezon *et al*., 2005; Pineda *et al*., 2007). For some detail, toxic effects of Methoxyfenozide had been reported on some insect species, such as *Choristoneura fumiferana* (Sundaram *et al*., 2002) and *Pectinophora gossypiella* (Sabry and Abdou, 2016). It caused some morphological aberrations during moulting/ metamorphosis of *Leptinotarsa decemlineata* (Smagghe and Degheele, 1994), *Spodoptera littoralis* (Gobbi *et al*., 2000, Pineda *et al*., 2004), *Lymantria dispar* (Ouakid *et al*., 2016) and *Culex pipiens* (Hamaidia and Soltani, 2016). After larval treatment with Methoxyfenozide, fecundity and fertilityin several insects were inhibited, such as *S. littoralis* (Pineda *et al*., 2009), *Choristoneura rosaceana* (Sun *et al*., 2000), *Tribolium castaneum* (Ali *et al*., 2016), *Culex pipiens* (Hamaidia and Soltani, 2016), *P. gossypiella* (Sabry and Abdou, 2016) and *L. dispar* (Ouakid *et al*., 2016). In addition, Methoxyfenozide interfered with the ability of *Argyrotaenia velutinana* and *Choristoneura rosaceana* adult males to respond to the pheromonesof sexually mature females (Hoelscher and Barret, 2003). Objective of the current study was to determine the effects of the ecdysteroid agonist, Methoxyfenozide, on the most important parameters of adult performance and reproduction of *P. unionalis*.

MATERIALS AND METHODS

Experimental insect

A sample of olive leaf moth *Palpita unionalis* (Hubner) (Lepidoptera: Pyralidae) larvae was kindly obtained from the culture of susceptible strain maintained for several generations in Desert Research Center, Cairo, Egypt.A new culture was maintained in Department of Zoology and Entomology, Faculty of Science, Al-Azhar University, Cairo, Egypt, under laboratory controlled conditions (27±2^{o}C, 65±5% R.H., photoperiod 14 and 10 h L:D) according to the procedure described byMansour(2012). Larvae were daily provided with fresh olive leaves *Olea europaea* L, as a food. After the larval stage, the developed pupae were collected and transferred to Petri dishes (5.5×1.4cm). The emerged adults were daily collected and released in plastic jars (3L) provided with cotton pieces, soaked in 10% sugar solution, for feeding, as well as olive twigs (20 cm in length) as an oviposition site. After egg deposition, adult males and females were transferred into new plastic jars. The jars of eggs were provided with fresh tender olive twigs fixed in a small bottle containing water, so as to keep the leaves flat and fresh, for feeding of the newly hatched larvae. The fresh tender olive leaves were renewed daily until pupation.

Methoxyfenozide and larval treatment

The ecdysone agonist, Methoxyfenozide:3-methoxy-2-methylbenzoic acid 2-(3,5-dimethylbenzoyl)-2-(1,1-dimethylethyl) hydrazide has the molecular formula: $C_{22}H_{28}N_2O_3$. It was kindly obtained from Plant Protection Research Institute, Agricultural Research Center, Doqqi, Giza, Egypt. A series of sublethal concentrations of Methoxyfenozide was prepared by diluting with distilled water in volumetric flasks as follows: 0.001, 0.01, 0.10, 1.00 and 10.0 ppm). Fresh olive leaves were dipped in each concentration for 5 minutes and air dried before introducing to the newly moulted last instar (6th) larvae of *P. unionalis* for feeding. Control larvae were provided with water-treated olive leaves. Ten replicates of treated and control larvae (one larva/replicate) were kept separately in glass vials. The larvae were allowed to feed on treated leaves for 24 hrs. Then, they provided with fresh untreated olive leaves.Just after the adult emergence, all parameters of adult performance and reproductive potential were recorded.

Adult performance parameters

Adult emergence: Number of successfully metamorphosed adults was expressed in % according to Jimenez-Peydro *et al*. (1995) as follows:

[No. of completely emerged adults / No. of pupae] × 100

Adulticidal activity: The adulticidal activity of the IGR was determined by observing the adult mortality.

***Morphogenic efficiency*:** It was determined by the impaired adult morphogenesis as appearedin deformed adult females and recorded in %. It was calculated in percentage as follows:

[No. of deformed adults / No. of emerged adults] ×100

***Adult longevity*:** Total longevity of adult females and its major compartments were measured in mean days±SD: pre-oviposition (ovarian maturation) period, oviposition period (reproductive life-time) and post-oviposition period.

Criteria of the reproductive potential

The emerged adults of *P. unionalis* were daily collected and released in plastic jars (3L) provided with sterilized cotton pieces, soaked in 10% sugar solution, for feeding, as well as olive twigs (20 cm in length) as an oviposition site. The treated adult females were coupled with normal adult males (1:2) of the same age obtained from the main culture. The eggs were collected daily, and carefully transferred to Petri dishes to count eggs.

Oviposition efficiency

Oviposition efficiency could be detected by the oviposition rate which was calculated as follows:

Number of laid eggs per ♀/reproductive lifetime (in days).

Reproductive capacity

***Fecundity*:** The laid eggs were counted for calculating the number of eggs per female.

***Fertility*:** Thehatchability was usually expressed in hatching percentage of laid eggs.

***Sterility index*:** It was calculated according to Toppozada *et al.*(1966) as follows:

$$\text{Sterility Index} = 100 - [(a\, b / A\, B) \times 100]$$

Where: a: mean number of eggs laid per female in the treatment. b: percentage of hatching in the treatment. A: mean number of eggs laid per female in the controls. B: percentage of hatching in the controls.

Incubation period

The laid eggs were kept in Petri dishes under the same controlled laboratory conditions, as previously mentioned. Just after the oviposition, eggs were observed until hatching elapsing an incubation period (in days).

Statistical analysis of data

Data obtained were analyzed by the Student's *t*-distribution, and refined by Bessel correction (Moroney,1956) for the test significance of difference between means.

RESULTS

Effects of Methoxyfenozide on adult performance of *P. unionalis*

Data of the most important parameters of the adult performance of *P. unionalis*, after treatment of newly moulted last (6^{th}) instar larvae with sublethal concentrations of Methoxyfenozide (0.001, 0.01, 0.10, 1.00 and 10.0 ppm), were distributed in Table (1). As clearly shown in this table, Methoxyfenozide could not exhibit morphogenic efficiency on the emerged moths, since no adult malformation was observed. On the other hand, it displayed an adulticidal effect (10% mortality) only at 0.10 and 1.00 ppm. Moreover, the tested ecdysteroid agonist considerably arrested the adult emergence, especially at the higher four concentrations, in a dose-dependent manner (70, 50, 40 and 10% adult emergence, at 0.01, 0.10, 1.00 and 10.0 ppm, respectively, *vs*. 100% emergence of control adults). In respect of the adult longevity, data assorted in the aforementioned table obviously demonstrated that only one adult female could reproduce after larval treatment with the highest concentration level of Methoxyfenozide. Its total longevity and major compartments had been remarkably prolonged. At other concentrations, the total adult longevity was significantly prolonged, in a dose-dependent course (10.60±1.14, 11.25±0.95, 12.33±0.57 and 13.50±2.12 days, at 0.001, 0.01, 0.10 and 1.00 ppm, respectively, *vs*. 10.00±1.41 days of control females). In addition, the larval treatment with Methoxyfenozide resulted in pronouncedly prolonged pre-oviposition period, indicating a serious retarding action of the tested compound on the ovarian maturation rate (3.2±0.83, 4.2±1.25, 4.6±0.57 and 5.5±0.70 days, respectively, *vs*. 3.0±0.89 days of control females). Not only the pre-oviposition period was prolonged but the post-oviposition period was, also, considerably prolonged. In contrast, the oviposition period (reproductive life-time) was insignificantly shortened, in no certain trend, indicating a slight promoting action of Methoxyfenozide on the ovipositing females to lay eggs quickly (4.40±0.54, 4.00±0.01, 3.66±0.57 and 3.50±0.70 days, at 0.001, 0.01, 0.10 and 1.00 ppm, respectively, *vs*. 4.5±0.83 days of control females).

Effects of Methoxyfenozide on reproductive potential of *P. unionalis*

After treatment of the newly moulted last instar larvae of *P. unionalis* with Methoxyfenozide, data of the most important reproductive criteria were summarized in Table (2). On the basis of these data, only one adult female could reproduce at the highest concentration level, therefore the statistical analysis could not be applied. The oviposition efficiency of females was pronouncedly prohibited, since the oviposition rate was seriously regressed, in a dose-dependent trend (36.06±4.63, 32.68±4.30, 28.04±1.00, 27.97±7.52 and 10 eggs/♀/day, at 0.001, 0.01, 0.10, 1.00 and 10.0 ppm, respectively, *vs*. 48.48±10.13 eggs/control ♀/day). Dealing with the reproductive capacity, data arranged in the previously mentioned table exiguously revealed that fecundity (mean number of eggs/♀) was tremendously reduced, in a dose-dependent course (157.8±19.95, 130.7±17.21, 99.6±8.96, 98.5±23.33 and 30 eggs/♀, at 0.001, 0.01, 0.10, 1.00 and 10.0 ppm, respectively, *vs*. 213.1±29.7 eggs/control ♀). Another major parameter of the reproductive capacity is fertility (hatching % of laid eggs, or egg viability) which was considerably inhibited, proportional to the ascending concentration (51.1, 27.5, 26.4, 21.6 and 6.66%, at 0.001, 0.01, 0.10, 1.00 and 10.0 ppm, respectively, *vs*. 71.6% of eggs laid by control females). Sterility was increasingly induced by increasing concentration level of Methoxyfenozide. Incubation period of the laid eggs is good indicator of the embryonic developmental rate in insects. As evidently shown in the same table, the embryonic development was drastically retarded by Methoxyfenozide, since the incubation period was significantly prolonged in accordance with the concentration (3.6±0.89, 5.0±0.81, 6.0±1.00, 6.5±0.70 and 7.0±0.72 days, at 0.001, 0.01, 0.10, 1.00 and 10.0 ppm, respectively, *vs*. 3.2±0.83 days of eggs laid by control females).

Table 1. Adult performance of *P. unionalis* as affected by treatment of newly moulted last instar larvae with sublethal concentrations of Methoxyfenozide

Conc. (ppm)	Adult emergence (%)	Adultmortality (%)	Adultdeformities (%)	Longevity (mean days±SD)			
				Ovarian maturation period	Reproductive lifetime	Post-oviposition period	Total Longevity
10.00	10	00	00	6*	5*	5*	16*
1.000	40	10	00	5.5±0.70b	3.50±0.70a	4.50±0.70b	13.50±2.12b
0.100	50	10	00	4.6±0.57b	3.66±0.57a	4.00±1.0 b	12.33±0.57b
0.010	70	00	00	4.2±1.25b	4.00±0.01a	3.20±0.50b	11.25±0.95b
0.001	100	00	00	3.2±0.83a	4.40±0.54a	3.00±0.70a	10.60±1.14a
Control	100	00	00	3.0±0.89	4.50±0.83	2.33±1.03	10.00±1.41

Conc.: concentration level. Mean ± SD followed with the letter a: not significantly different (p>0.05), b: significantly different (p<0.05).
*: Only one adult female.

Table 2. Affected reproductive potential of *P. unionalis* adults after treatment of the newly moulted last instar larvae with sublethal concentrations of Methoxyfenozide

Conc. (ppm)	Oviposition rate (Mean±SD)	Fecundity (Mean no. of eggs/♀)	Fertility (%)	Sterility index	Incubation period (Mean days±SD)
10.00	10*	30*	6.66	99.81	7.00±0.72 d
1.00	27.97±7.52 b	098.5±23.33 c	21.6	93.50	6.50±0.70 c
0.10	28.04±1.00 b	099.6±8.96 d	26.4	91.97	6.00±1.00 c
0.01	32.68±4.30 b	130.7±17.21 c	27.5	85.57	5.00±0.81 c
0.001	36.06±4.63 b	157.8±19.95 c	51.1	58.88	3.60±0.89 a
Control	48.48±10.13	213.1±29.7	71.6	---	3.20±0.83

Conc.: See footnote of Table (1). Mean±SD followed by letter a: not significantly different (P>0.05), b: significantly different (P<0.05), c: highly significantly different (P<0.01), d: very highly significantly different (P<0.001). *: only one adult female.

DISCUSSION

Influenced adult life parameters of *P. unionalis* by Methoxyfenozide

Blocked adult emergence

As reported in the available literature, the adult emergence of many insect species was significantly blocked after larval treatment with various IGRs, such as *Plutella xylostella* after larval treatment with Hexaflumuron (Mahmoudvand *et al*., 2012), *Drosophila melanogaster* after topical application of 3rd instar larvae with Pyriproxyfen (Benseba *et al*., 2015), *Spodoptera littoralis* after treatment of penultimate or last instar larvae with Novaluron (Ghoneim *et al*., 2015) or Cyromazine (Tanani *et al*., 2015), *Glyphodes pyloalis* after treatment of the 4th instar larvae with LC_{30} of Lufenuron (Aliabadi *et al*., 2016), *Culex quinquefasciatus* and *Aedes albopictus* after larval treatments with Pyriproxyfenand Methoprene (Khan *et al*., 2016) and *Pectinophora gossypiella* after treatment of newly hatched or full grown larvae with Novaluron (Hassan *et al*., 2017). Pupal treatment of *Encarsia formosa* with Pyriproxyfen resulted in prohibited adult emergence (Wang and Liu, 2016). Moreover, adult emergence was completely blocked in *Corcyra cephalonica* after treatment of 4th instar larvae with Fenoxycarb (Singh and Tiwari, 2016). In agreement with those reported results, adult emergence of *P. unionalis*, in the present study, was drastically blocked after treatment of newly moulted last (6th) instar larvae with Methoxyfenozide, in a dose-dependent course. The present result of blocked adult emergence can be interpreted by the interference of Methoxyfenozide with some aspects of the hormonal regulation such as disturbance of adult eclosion hormonerelease and/or inhibition of the neurosecretion (prothoracicotropic hormone, PTTH)(Al-Sharook *et al*., 1991; Josephrajkumar *et al*., 1999).

Reduced adult survival

In the current study, Methoxyfenozide exhibited an adulticidal effect (10% mortality) on *P. unionalis*, after treatment of newly moulted last instar larvae with only 0.10 and 1.00 ppm. This result of the extended toxic action of Methoxyfenozide on adults of *P. unionalis* was, to some extent, in accordance with those very scarcely reported toxicities of some IGRs (including CSIs) on adults of some insect species, such as *S. littoralis* after treatment of larvae with Novaluron, especially at the higher concentrations (Hamadah *et al*., 2015) and *Delia antique* after larval treatment with Pyriproxyfen (Zhou *et al*., 2016). Also, reduced adult survival was reported for *P. gossypiella* after treatment of larvae, especially the newly hatched larvae, with Novaluron (Hassan *et al*., 2017). The reduced adult survival of *P. unionalis* by Methoxyfenozide (at some concentrations), in the present study, can be explained by the retention and distribution of this compound in the insect body as a result of rapid transport from the gut of treated larvae into other tissues, and then into different tissues of the successfully emerged adults, and/or may be due to a lower detoxification capacity of adults against the tested IGR (Osman *et al*., 1984; Smagghe and Degheele, 1992). Also, a latent lethal effect of Methoxyfenozide may be due to the disturbance of enzymatic pattern and hormonal hierarchy in adults of *P. unionalis* (Kartal *et al*., 2003). However, the adult life in insects depends on healthy immature stages. Digestive disorders such as starvation, metabolism disturbance, degeneration of peritrophic membranes and accumulation of faecal materials at the hind gut may be the cause of untimely adult mortality, as a result of IGR treatment (Soltani, 1984).

Affected adult morphogenesis

Impaired adult morphogenesis, as expressed in the production of deformed adults, was widely reported in the available literature, after treatment of various insects with different IGRs (or CSIs), such as *S. littoralis* after treatment with Tebufenozide and Methoxyfenozide (Pineda *et al*., 2004), Flufenoxuron (Bakr *et al*., 2010) or Novaluron (Hamadah *et al*., 2015); *Rhynchophorus ferrugineus* after treatment with Diofenolan (Tanani, 2001); *Choristoneura fumiferana* after treatment with Tebufenozide and Methoxyfenozide (Sundaram *et al*., 2002); *Tribolium castaneum* and *Tribolium confusum* after treatment with Cyromazine (Kamaruzzaman *et al*.,2006); *Eurygaster integriceps* after treatment with Pyriproxyfen (Mojaver and Bandani, 2010); *Dysdercus koenigii* after treatment with Flucycloxuron (Khan and Qamar, 2011); *Spodoptera frugiperda* after treatment with Methoxyfenozide (Zarate *et al*., 2011); *Anagasta kuehniella* after treatment with Diflubenzuron and hexaflumuron (Ashouri*et al*., 2014); *Helicoverpa armigera*after treatment with Hexaflumuron (Taleh *et al*., 2015); *C. cephalonica*after treatment with Fenoxycarb (Begum and Qamar, 2016); *etc*. Results of the present study on *P. unionalis* disagreed with the previously reported results because Methoxyfenozide had no morphogenic efficiency on adults, since no adult deformities had been caused after treatment of the newly moulted last instar larvae with different concentrations of this ecdysone agonist. On the other hand, the present result coincided with the result of failure of Novaluron to affect the adult morphogenesis of *P. gossypiella* (Hassan *et al*., 2017).

Disturbed adult longevity

Total adult longevity

After the attainment of sexual maturity, insects often show degenerative changes in some tissues and organs which can be called 'senility' or 'aging'. In insects, the affected adult longevity can be considered an informative indicator for the adult aging, i.e., prolongation of longevity may denote a delay of aging and *vice versa*, although the death is usually the destiny of all creatures. In the current investigation, the total adult longevity of *P. unionalis* was remarkably prolonged, in a dose-dependent course, after treatment of newly moulted last instar larvae with Methoxyfenozide, indicating a delaying effect of this compound on the adult aging. The present result was in agreement with those reported results of prolonged adult longevity in some insects by delaying action of different IGRs, such as *P. gossypiella* by Lufenuron, Chlorfluazuron and Chromafenozide(Kandil *et al*., 2012), Hexaflumuron (Kandil*et al*., 2013), Pyriproxyfen(Sabry and Abdou, 2016) and the lowest concentration of Novaluron (Hassan *et al*., 2017); as well as *Lipaphis erysimi* by pyriproxyfen (Liu and Chen, 2001).

On the contrary, the present result is inconsistent with those reported results of shortened adult longevity of other insects by various IGRs, such as *Spodoptera litura* by the ecdysone agonist RH-5849 (Seth *et al*., 2004); *S. littoralis* by Lufenuron (Sammour *et al*., 2008), Methoxyfenozide (Pineda *et al*., 2009) and Novaluron (Hamadah *et al*., 2015); *Agrotis ipsilon* by Flufenoxuron (El-Sheikh, 2002); *Grapholita molesta* (Reinke and Barrett, 2007) and *Spodoptera exigua* (Luna *et al*., 2011) by Methoxyfenozide; *G. pyloalis* by Lufenuron (Aliabadi *et al*., 2016); *P. gossypiella* by Diflubenzuron and Chlorfluazuron (Kandil et al., 2005; Salem, 2015); *etc*. Furthermore, no effect was exhibited by some IGRs on the adult longevity of a number of insects, such as Diofenolan against *Musca domestica* (Hamadah, 2003), Tebufenozide or methoxyfenozide against *Cydia pomonella* (Saenz-de-Cabezon *et al*., 2005), Buprofezin against *S. littoralis* (Ragaei and Sabry, 2011), Methoxyfenozide against *S. frugiperda* (Zarate *et al*., 2011) and Novaluron against *Lygus lineolaris* (Portilla *et al*., 2012). In the current study, the prolongation of female adult longevity of *P. unionalis*, after treatment of newly moulted last instar larvae with Methoxyfenozide, may be attributed to its interference with the hormonal regulation of adult longevity because a close relation between certain hormones and adult longevity was reported in other insects, such as *Drosophila*(Broughton *et al*., 2005; Clancy *et al*., 2001; Simon *et al*., 2003; Carbone *et al*., 2006). At least one of the *Drosophila* insulin-linked peptides expressed in the median neurosecretory cells (which produce PTTH) is likely to contribute to the endocrine regulation of longevity (Toivonen and Partridge, 2009). However, the exact mode of action of the tested IGR on the biochemical sites in adults of *P. unionalis* is unknown until now. Also, more information on the adult endocrine system of *P. unionalis*is required to clarify the mechanism by which ecdysone agonists can affect the adult longevity.

Pre-oviposition period

In most insects, the pre-oviposition period can be called 'ovarian maturation period' and it may be an informative indicator for the ovarian maturation rate, i.e., the shorter period indicates faster rate and *vice versa*. In the present study, the pre-oviposition period was considerably prolonged, indicating drastically retarding effect of Methoxyfenozide on the ovarian maturation rate. The present result corroborated with those reported results of prolonged period after treatment of newly hatched larvae of *P. gossypiella* with Diflubenzuron, Hexaflumuron or Chlorfluazuron (Kandil *et al*., 2005, 2013), LC_{50} values of Chromafenozideand Diflubenzuron (Salem, 2015), LC_{50} of Teflubenzuron (El-Khayat *et al*., 2015) and after treatment of newly hatched or full grown larvae with Novaluron (Hassan *et al*., 2017). It was in agreement, also, with those reported prolongation of the pre-oviposition period in other insects, such as *S. littoralis*, after larval treatment with Diflubenzuron (Aref *et al*., 2010) and *Ephestia kuehniella*, after larval treatment with Tebufenozide (Bouzera and Soltani-Mazouni, 2014). On the other hand, the present result of prolonged pre-oviposition period in *P. unionalis* contradictory to those reported results of shortened period in *P. gossypiella*, after treatment of newly hatched larvae with Diflubenzuron (Rashad*et al*., 2006) and *D. antique*, after larval treatment with a dose of 100 mg kg^{-1} of Pyriproxyfen (Zhou *et al*., 2016). Moreover, this period was unaffected in *S. litura*, after larval treatment with Chlorfluazuron and Methoxyfenozide (Shahout *et al*., 2011) and in *D. antique*, after larval treatment with high doses of Pyriproxyfen (Zhou *et al*., 2016). The retarding effect of Methoxyfenozide on the ovarian maturation rate (prolonged pre-oviposition period) in *P. unionalis* may be understood by influenced germ band or the number of germ cells formed in the embryo (Hodin and Riddiford, 1998). However, the exact mode of retarding action of the tested IGR on pre-oviposition period is unfortunately available right now but its interference with the hormonal regulation needs further investigation in the foreseeable future.

Oviposition period

In respect of the oviposition period (reproductive life-time), scarcely reported results have been seen in the available literature. For instances, the oviposition period in *S. litura* was significantly shortened after treatment of 2nd instar larvae with LC_{30} of Methoxyfenozide (Shahout *et al.*, 2011). The oviposition period in *P. gossypiella* had been shortened after treatment of newly hatched larvae with Chlorfluazuron (Kandil *et al.*, 2005), Diflubenzuron (Rashad*et al.*, 2006), Hexaflumuron and Chlorfluazuron (Kandil*et al.*, 2013) and LC_{50} of Methomyl(El-Khayat *et al.*, 2015) as well as after treatment of newly hatched or full grown larvae with Novaluron (Hassan *et al.*, 2017). The oviposition period in *Plutella xylostella* was significantly shortened by Pyriproxyfen (Mahmoudvand *et al.*, 2015). Result of the present study on *P. unionalis* was, to a great extent, concomitant to those reported results, since the oviposition period was conspicuously shortenedafter treatment of newly moulted last instar larvae with Methoxyfenozide. On the contrary, this result disagreed with the reported considerable prolongation of oviposition period in *P. gossypiella*, after treatment of newly hatched larvae with LC_{50} of Chromafenozide or Diflubenzuron (Salem, 2015) and Teflubenzuron (El-Khayat *et al.*, 2015).In the current study, Methoxyfenozide exhibited an enforcing effect on the adult females of *P. unionalis* to quickly lay eggs during a very short time interval. The exact mechanism of this enforcing action of Methoxyfenozide on *P. unionalis* adult females is still unknown. However, these females may be enforced to lay their eggs quickly to avoid this toxic xenobiotic factor.

Post- oviposition period

Depending on the currently available literature, very scarce studies have examined the effects of IGRs on post-oviposition period. After treatment of newly moulted last instar larvae of *P. unionalis* with Methoxyfenozide, in the present study, the post-oviposition period was remarkably prolonged. This result was in accordance with those reported results of prolonged post-oviposition period of *P. gossypiella* after larval treatment with Hexaflumuron or Chlorfluazuron (Kandil*et al.*, 2013) but diversely affected by Novaluron, depending on the concentration (Hassan *et al.*, 2017). Unfortunately, we have no acceptable interpretation for this prolongation right now!!

Disrupted reproductive potential of *P. unionalis* by Methoxyfenozide

Reproduction in insects is mainly controlled by the juvenile hormone (JH), which is also responsible for protein metabolism, and is specifically needed for egg maturation. The insect growth regulators (IGRs) have been reported to cause sterility of insects or prohibited their fecundity (Ghoneim *et al.*, 2014). However, effects of IGRs on the insect reproduction can be grouped into: i) reproductive behaviour, ii) oviposition, iii) egg hatchability (ovicidal and embryocidal), and iv) sterilization of adults (Mondal and Parween, 2000). On the other hand, ecdysteroids have essential functions in controlling the processes involved in insect reproduction, i.e., vitellogenesis, ovulation of matured eggs and spermatocyte growth (Wigglesworth, 1984; Hagedorn, 1985).

Inhibited oviposition efficiency of *P. unionalis* by Methoxyfenozide

In insects, the oviposition rate can be used as an informative indicator for the oviposition efficiency (Ghoneim *et al.*,2014). In the present study on *P. unionalis*, treatment of the newly moulted last instar larvae with Methoxyfenozide resulted in drastically prohibited oviposition efficiency, since the oviposition rate was conspicuously regressed, in a dose-dependent manner. This result was in conformity with the reported results of inhibited oviposition efficiency of some insects by various IGRs, such as *S. littoralis* by Tebufenozide (Bakr *et al.*, 2005), Flufenoxuron (Bakr *et al.*, 2010) and Novaluron (Ghoneim *et al.*, 2014); *Schistocerca gregaria* by Flufenoxuron and lufenuron (Soltani-Mazouni and Soltani, 1994) or Tebufenozide (Al-Dali *et al.*, 2008); *Plodiainterpunctella* by the ecdysteroid agonist RH-5849 (Smagghe and Degheele, 1994); *Callosobruchas maculates* by Cyromazine (Al-Mekhlafi *et al.*, 2011) and *P. gossypiella* by Novaluron (Hassan *et al.*, 2017). In contrast, the present result disagreed with the stimulated oviposition of *Gryllus bimaculatus* by some ecdysteroid agonists (Behrens and Hoffmann, 1983). The prohibited oviposition efficiency, in the current study, may be explained as a result of the inhibition of ovarian DNA synthesis or the interference of Methoxyfenozide with vitellogenesis in *P. unionalisvia* certain biochemical processes. However, the tested compound may exert a reverse action to those exerted by the ecdysteroid agonists which stimulate the neurosecretory cells to release a myotropic ovulation hormone (Parween *et al.*, 2001).

Perturbation of the reproductive capacity of *P. unionalis* by Methoxyfenozide

Prohibited fecundity

The available literature contains many reported results of prohibited fecundity (mean number of eggs/female) of several insects after treatment of their larvae with various IGRs, such as *S. littoralis* after treatment with Diflubenzuron (Aref *et al.*, 2010), Lufenuron (Gaaboub *et al.*, 2012), Methoxyfenozide (Pineda *et al.*, 2009) and Novaluron (Ghoneim *et al.*, 2014). Also, fecundity of other insect species was reduced by various IGRs, such as *E. kuehniella* by Tebufenozide (Khebbeb *et al.*, 2008); *Choristoneura rosaceana* (Sun *et al.*, 2000), *Lobesia botrana*(Saenz-de-Cabezon *et al.*, 2005) and *S. litura* (Shahout *et al.*, 2011) by Methoxyfenozide; *Leptinotarsa decemlineata* (Farinos *et al.*, 1999) and *Tenebrio molitor*(Taibi *et al.*, 2003) by Halofenozide (RH-0345); *S. litura* by Chlorfluazuron (Perveen and Miyata, 2000); *Argyrotaenia velutinana* (Sun *et al.*, 2000), *T. castaneum* (Ali *et al.*, 2016) and *Lymantria dispar* (Ouakid*et al.*,2016) by Methoxyfenozide; *M. domestica* by Lufenuron (Hamadah, 2003), *D. koenigi* by Flufenoxuron (Khan and Qamar, 2011); *A. kuehniella* by Diflubenzuron and Hexaflumuron (Ashouri *et al.*. 2014); *P. xylostella* by Pyriproxyfen (Mahmoudvand *et al.*, 2015); *Callosobruchus chinensis* by some terpene compounds (Chaubey, 2015); *T. castaneum* (Gado *et al*, 2015) and *D. antique* (Zhou *et al.*, 2016) by Lufenuron and *C. cephalonica* by Fenoxycarb(Begum and Qamar, 2016); *etc*. In the present study on *P. unionalis*, our result corroborated with the previously reported results, since treatment of newly moulted last instar larvae with Methoxyfenozide resulted in tremendously reduced fecundity, in a dose-dependent manner.

This result was, also, in agreement with some of the reported results of considerably reduced fecundity in some insects, such as *P. gossypiella* after treatment of newly hatched larvae with Tebufenozide(Zidan *et al*., 1998; El-Khayat *et al*., 2015), Diflubenzuron (Kandil *et al*., 2005; Rashad*et al*., 2006; Salem, 2015), Chlorfluazuron (Kandil *et al*., 2005), Buprofezin (Al-Kazafy, 2013), Hexaflumuron and Chlorfluazuron (Kandil*et al*., 2013), Chromafenozide (Salem, 2015), as well as Pyriproxyfen, Methoxyfenozide and Lufenuron (Sabry and Abdou, 2016) and Novaluron (Hassan *et al*., 2017). On the contrary, recorded result in the current investigation disagree with some reported results of failure of some IGRs to affect the fecundity in various insects, such as Fenoxycarb against *Apis mellifera* (Thompson *et al*., 2005), Methoxyfenozide against *S. exigua* (Christian-Lius and Pineda, 2010) as well as Novaluron and Diflubenzuron against *Halyomorpha halys* (Kamminga *et al*., 2012). Moreover, feeding of larvae on leaves treated with Methoxyfenozide enhanced the fecundity of *S. littoralis* (Ishaaya *et al*., 1995).

However, these diverse effects can be attributed to the different modes of action of IGRs, different susceptibilities of the insect species, time of treatment and other factors. The drastically prohibited fecundity of *P. unionalis*, after treatment of the newly moulted last instar larvae with Methoxyfenozide, in the present study, may be due to the interference of this compound with one or more processes, from the ovarian follicle development to egg maturation. In some detail, this can be explained by some reasons, as follows. (1) The tested IGR may cause some disorders in the ovaries, including cell death in the germarium, resorption of oocytes in the pre-vitellarium and vitellarium, formation of vitellin envelops and undue proliferation of follicle cells sometimes resulting in malformation of the whole ovary (Lucantoni *et al*., 2006; Khan *et al*., 2007). (2) The tested IGR may inhibit the development of some ovarioles and/or synthesis and metabolism of proteinaceous constituents during the oogenesis (Salem *et al*., 1997). (3)

The tested IGR exerted an inhibitory action on the ecdysone activity, threshold of which is essential for the normal oogenesis (Terashima *et al*., 2005). (4) On the basis of hormonal regulation of insect reproduction, the present IGRmay disturb the production and/or function of the gonadotropic hormone (juvenile hormone, JH) responsible for the synthesis of vitellogenins (yolk precursors) and vitellogenesis (Di Ilio *et al*., 1999). (5) Eggs may develop normally in ovaries, but they could not be lay, owing to the adversely deformed ovipositor of adult females or to the reduced mechanical strength (Moreno *et al*., 1994) or their rebsorpion before oviposition (Zhou *et al*., 2016). (6) It may be acceptable to suggest that the prohibited fecundity of *P. unionalis*, in the current work, may be due to inhibitory effects of the tested IGR on synthesis of both DNA and RNA, suboptimal nutrition owing to reduced feeding, altered mating behaviour as a result of sublethal intoxication, or a combination of factors.

Reduced fertility

Fertility (egg hatching % or egg viability) is another informative parameter of the reproductive capacity in insects. In the present study, fertility of the eggs laid by *P. unionalis* had been drastically reduced after treatment of newly moulted last instar larvae with Methoxyfenozide, in a dose-dependent course. This result was in accordance with those reported results of reduced fertility in *P. gossypiella* after treatment of newly hatched larvae with some IGRs, such as Lufenuron, methoxyfenozide, Chromafenozide and Chlorfluazuron (Kandil *et al*., 2012) and Novaluron (Hassan *et al*., 2017); as well as some of other insects, such as *S. littoralis* by Chlorfluazuron (Sammour *et al*., 2008), Methoxyfenozide (Pineda *et al*., 2009), Diflubenzuron (Aref *et al*., 2010), Lufenuron (Adel, 2012; Gaaboub *et al*., 2012), Triflumuron (El-Naggar, 2013) and Novaluron (Ghoneim *et al*., 2014); *S. litura* by Diofenolan (Perveen and Miyata, 2000) and Chromafenozide (Shahout *et al*., 2011); *T. molitor*by Halofenozide (Taibi *et al*., 2003); *M. domestica* by Diofenolan (Hamadah, 2003), *T. castaneum* by Novaluron (Kostyukovsky and Trostanelsky, 2004); *E. kuehniella*by Tebufenozide (Khebbeb *et al*., 2008); *D. koenigi* by Flufenoxuron (Khan and Qamar, 2011), *C. maculates* by Cyromazine (Al-Mekhlafi *et al*., 2011), *A. kuehniella* by Diflubenzuron and Hexaflumuron (Ashouri *et al*., 2014); *A. velutinana* and *Ch. rosaceana* (Sun *et al*., 2000), *T. castaneum* (Ali *et al*., 2016), *P. gossypiella* (Sabry and Abdou, 2016), *Culex pipiens* (Hamaidia and Soltani, 2016) and *L. dispar* (Ouakid*et al*.,2016) by Methoxyfenozide;*etc*.

For explicating the fertility reduction in *P. unionalis* by Methoxyfenozide, in the present study, some suggestions can be provided herein. (1) Maturation of the insect eggs depends basically on the vitellogenins, precursor materials of vitellins including proteins, lipids and carbohydrates, all of which are necessarily required for the embryonic development (Soltani and Mazouni, 1992; Chapman, 1998). These materials are synthesized primarily by fat body during the immature stages (Telfer, 2009) or by the ovary *in situ* (Indrasith *et al*., 1988). Wherever the site of synthesis of these materials, the tested IGR may disturb their production and/or accumulation in adult females of *P. unionalis* leading to the reduction of fertility. (2) The tested IGR may indirectly affect the fertility *via* its disruptive effect on opening of the intracellular spaces in follicular epithelium or generally inhibited the role of JH (gonadotropic hormone) responsible for the regulation of vitellogenin deposition into oocytes (Davey and Gordon, 1996). (3) The reduction in fertility may be due to the penetration of residual amounts of Methoxyfenozide in *P. unionalis* mothers into their eggs and disturbance of embryonic cuticle synthesis. So, the fully mature embryos had weakened chitinous mouth parts that were insufficiently rigid to perforate the surrounding vitellin membrane and free from the eggs (Sallam, 1999; Sammour *et al*., 2008). (4) The reduced fertility of *P. unionalis*, in the current study, may be due to serious effect of the tested IGR on survival of the developing embryos at certain stages as recorded in decreasing hatching percentage. (5) Because some molecular studies revealed the effects of some IGRs on insect reproduction owing to the perturbation of gene expression in the hierarchy cascade of vitellogenesis and/or choriogenesis (Sun *et al*., 2003), Methoxyfenozide may interfere with the gene expression resulting in a reduction of the developed embryos in *P. unionalis*, in the present study.

Retarded embryonic development of *P. unionalis* by Methoxyfenozide

In insects, incubation period can be used as a valuable indicator of the embryonic developmental rate, i.e., longer period usually denotes slower rate and *vice versa*. In the present study, the embryonic development of *P. unionalis* was considerably retarded, since the incubation period of laid eggs was significantly prolonged, in a dose-dependent manner, after treatment of newly moulted last instar larvae with Methoxyfenozide. The present result corroborated with the scarcely reported results, in the available literature, concerning a similar retarding action of some IGRs on the embryonic development of *P. gossypiella*, after larval treatment with LC_{50} of lufenuron, chlorfluazuron or chromafenozide (Kandil *et al*., 2012) and after larval treatment with different concentrations of Novaluron (Hassan *et al*., 2017), as well as *C. maculates* after treatment with Cyromazine (Al-Mekhlafi *et al*., 2011) and *S. littoralis* after treatment with Novaluron (Ghoneim *et al*., 2014). The delayed embryonic development in *P. unionalis* after treatment of larvae with Methoxyfenozide, in the present study, may be due to its disturbing effect on the ecdysteroid level responsible for the regulation of embryogenesis at certain stages, especially those originating from the ovary *in situ* (Chapman, 1998).

Conclusion

Depending on results of the present study, Methoxyfenozide disruptively affected the adult emergence, survival, ovarian maturation rate, reproductive life-time and longevity of the olive leaf moth*P. unionalis*, as well as it drastically prohibited the oviposition efficiency, reproductive capacity and impaired the embryonic development leading to a reduction of the pest population. Therefore, Methoxyfenozide may be a potential IGR being involved in the integrated control program against this worldwide insect which was reported as an economic pest of the olive groves in Egypt and other olive producing countries in the world.

Acknowledgement

The authors thank Plant Protection Research Institute, Agricultural Research Center, Doqqi, Giza, Egypt for kindly providing the tested IGR, Methoxyfenozide.

REFERENCES

Adel, M.M. 2012. Lufenuron impair the chitin synthesis and development of *Spodoptera littoralis* Bosid. (Lepidoptera: Noctuidae). *J. App. Sci. Res*., 8(5): 27-66.

Al-Dali, A.G., Ghoneim, K.S., Bakr, R.F., Bream, A.S. and Tanani, M.A. 2008. Egg productivity of *Schistocerca gregaria* (Orthoptera: Acrididae) as affected by the non-steroidal ecdysone agonist Tebufenozide (RH- 5992). *J. Egypt. Acad. Soc. Environ. Develop*., 9(10): 27-38.

Ali, Q ,ul Hasan, M., Mason, L.J., Sagheer, M. and Javed, N. 2016. Biological activity of insect growth regulators, Pyriproxyfen, Lufenuron and Methoxyfenozide against *Tribolium castaneum* (Herbst).*Pakistan J. Zool*., 48(5): 1337-1342.

Aliabadi, F.P., Sahragard, A. and Ghadamyari, M. 2016. Lethal and sublethal effects of a chitin synthesis inhibitor, lufenuron, against *Glyphodes pyloalis* Walker (Lepidoptera: Pyralidae). *J. Crop Prot*., 5(2): 203□214.

Al-Kazafy, H.S. 2013. Effect of some pesticides with different target sites on the pink bollworm, *Pectinophora gossypiella* (Saunders). *Archives of Phytopathology and Plant Protection*, 46(8): 942-951.

Al-Mekhlafi, F., Mashaly, A.M., Abdel, Mageed, A., Wadaan, M.A. and Al-Mallah, N.M. 2011. Overlap effects of Cyromazine concentration, treatment method and rearing temperature on the Southern cowpea weevil (*Callosobruchus maculatus* F.) reared on cowpea. *Afr. J. Microbio. Res*., 5(32): 5848-5853.

Al-Sharook, Z., Balan, K., Jiang, Y. and Rembold, H. 1991. Insect growth inhibitors from two tropical Meliaceae: Effects of crude seed extracts on mosquito larvae. *J. App. Entomol*. 111: 425-430.

Aref, S.A., Bayoumi, O.C.h and Soliman, H.A.B. 2010. Effect of certain insecticides on the biotic potential of the cotton leafworm, *Spodoptera littoralis* (Boisd.).*Egypt. J. Agric. Res*., 88(1): 31-40.

Ashouri, S., Pourabad, R.F. and Ebadollahi, A. 2014. The effect of diflubenzuron and hexaflumuron on the last larval instars of the Mediterranean flour moth *Anagasta kuehniella* (Zeller) (Lepidoptera: Pyralidae) under laboratory conditions. *Archives of Phytopathology and Plant Protection*, 47(1):75-81.

Bakr, R.F.A., El-barky, N.M., Abd, Elaziz, M.F., Awad, M.H. and Abd El-Halim, H.M.E. 2010. Effect of chitin synthesis inhibitors (flufenoxuron) on some biological and biochemical aspects of the cotton leaf worm *Spodoptera littoralis* Bosid. (Lepidoptera: Noctuidae). *Egypt. Acad. J. Biolog. Sci.*, 2(2): 43-56.

Bakr, R.F.A., Guneidy, N.A.M. and El-Bermawy S.M. 2005. Toxicological and biological activities of three IGRs against fourth larval instar of the cotton leafworm *Spodoptera littoralis* (Boisd.). *J. Egypt. Acad. Environ. Develop*., 6(4): 103-132.

Begum, R. and Qamar, A. 2016. Fenoxycarb- a potent inhibitor of metamorphosis and reproduction in Rice Moth, *Corcyra cephalonica* (Stainton). *J. Entomol. Zool. Studies*, 4(4): 572-577.

Behrens, W. and Hoffman, K.H.1983. Effects of exogenous ecdysteroids on reproduction in cricket *Gryllus bimaculatus*. *Int. Invertr. Reprod. Develop*., 6: 149-159.

Benseba, F., Kilani-Morakchi, S., Aribi, N. and Solatani, N. 2015. Evaluation of pyriproxyfen, a juvenile hormone analog, on *Drosophila melanogaster* (Diptera: Drosophilidae): Insecticidal activity, ecdysteroid contents and cuticle formation. *Eur. J. Entomol*., 112(4): 625–631. doi: 10.14411/eje.2015.084

Biddinger, D., Hull, L., Huang, H., McPheron, B. and Loyer, M. 2006. Sublethal effects of chronic exposure to tebufenozide on the development, survival, and reproduction of the tufted apple bud moth (Lepidoptera: Tortricidae). *J. Econ. Entomol*., 99: 834-842.

Biddinger, D.J. and Hull, L.A.1995. Effect of several types of insecticides on the mite predator *Stethorus punctum* (Coleoptera: Coccinellidae), including insect growth regulators and abamectin. *J. Econ. Entomol*., 88: 358-366.

Bouzera, H. and Soltani-Mazouni, N. 2014. Comparative effects of two moulting hormone agonists (Methoxyfenozide and Tebufenozide) on the Mediterranean flour moth *Ephestia kuehniella* Zeller (Lepidoptera:

Pyralidae): ecdysteroids amounts of testes and reproductive events. *World App. Sci. J*., 31 (11): 1903-1910.

Broughton, S.J., Piper, M.D., Ikeya, T., Bass, T.M., Jacobson, J., Driege, Y., Martinez, P., Hafen, E., Withers, D.J., Leevers, S.J. and Partridge, L. 2005. Longer lifespan, altered metabolism, and stress resistance in *Drosophila* from ablation of cells making insulin-like ligands. *Proc. Natl. Acad. Sci. U.S.A* 102: 3105-3110.

Broumas, T., Haniotakis, G., Liaropoulos, C., Tomazou, T. and Ragoussis, N. 2002. The efficacy of an improved form of the mass-trapping method, for the control of the olive fruit fly, *Bactrocera oleae* (Gmelin) (Dipt., Tephritidae), pilot-scale feasibility studies. *J.App. Entomol*., 126(5): 217–223.

Carbone, M.A., Jordan, K.W., Lyman, R.F., Harbison, S.T., Leips, J., Morgan, T.J., DeLuca, M., Awadalla, P. and Mackay, T.F. 2006. Phenotypic variation and natural selection at catsup, a pleiotropic quantitative trait gene in *Drosophila*. *Curr. Biol*., 16: 912-919.

Carlson, G.R., Dhadialla, T.S., Hunter, R., Jansson, R.K., Jany, C.S., Lidert, Z. and Slawecki, R.A. 2001. The chemical and biological properties of methoxyfenozide, a new insecticidal ecdysteroid agonist. Pest Manag. Sci., 57:115-119.

Chapman, R.F. 1998. The insects: structure and function. 4th ed. Cambridge: Cambridge University Press, pp: 116-118.

Chaubey, M.K. 2015. Biological activities of terpenes against pulse beetle, *Callosobruchus chinensis* (Coleoptera: Bruchidae). Entomol.App. Sci. Letters, 2(1): 50-61.

Christian-Luis, R. and Pineda, S. 2010. Toxicity and sublethal effects of methoxyfenozide on *Spodoptera exigua* (Lepidoptera: Noctuidae). *J. Econ. Entomol*., 103: 662-667.

Clancy, D.J., Gems, D., Harshman, L.G., Oldham, S., Stocker, H., Hafen, E., Leevers, S.J. and Partridge, L. 2001. Extension of life-span by loss of CHICO, a *Drosophila* insulin receptor substrate protein. *Sci*., 292: 104-106.

Costa, L.G., Giordano, G., Guizzetti, M. and Vitalone, A. 2008. Neurotoxicity of pesticides: a brief review. *Frontiers BioSci*., 13: 1240-1249.

Davey, K.G. and Gordon, D.R.B. 1996. Fenoxycarb and thyroid hormones have JH-like effects on the follicle cells of *Locosta migratoria in vitro*. *Arch. Insect Biochem.Physiol*., 32: 613- 626.

Davies, T.G.E., Field, L.M., Usherwood, P.N.R. and Williamson, M.S. 2007. DDT, pyrethrins and insect sodium channels.*IUBMB Life*, 59: 151-162.

Dhadialla, T.S., Carlson, G.R. and Le, D.P. 1998. New insecticides with ecdysteroidal and juvenile hormone activity. *Annu. Rev. Entomol*. 43: 545-569.

Dhadialla, T.S., Retnakaran, A. and Smagghe, G. 2005. Insect growth and development disrupting insecticides. In: "Comprehensive Insect Molecular Science" (Gilbert LI, Kostas I and Gill S., eds.). vol. 6. Pergamon Press, New York, NY. pp. 55-116.

Di Ilio, V., Cristofaro, M., Marchini, D., Nobili, P. and Dallai, R. 1999. Effects of a neem compound on the fecundity and longevity of *Ceratitis capitata* (Diptera: Tephritidae). *J. Econ.Entomol*., 92:76-82.

Eizaguirre, M., López, C., Schafellner, C.H. and Sehnal, F. 2007. Effects of ecdysteroid agonist RH-2485 reveal interactions between ecdysteroids and juvenile hormones in the development of *Sesamia nonagrioides*. *Arch. Insect Biochem. Physiol*., 65: 74-84.

El-Khayat, E.F., Rashad, A.M., Abd-El Zaher, T.R., Shams, El-Din, A.M. and Salim, H.S. 2015. Toxicoloical and biological studies of some pesticidal formulations against *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae). *American-Eurasian J. Toxicol. Sci*., 7(1): 01-06.

El-Naggar, J.B.A. 2013. Sublethal effect of certain insecticides on biological and physiological aspects of *Spodoptera littoralis* (Boisd.). *Nature and Science*, 11(7): 19-25.

El-Sheikh, T.A.A. 2002. Effects of application of selected insect growth regulators and plant extracts on some physiological aspects of the black cutworm, *Agrotis ipsilon* (HUF.). Ph. D. Thesis, Fac. Sci., Ain Shams Univ., Egypt.

Farinos, G.P., Smagghe, G., Tirry, L. and Castañera, P. 1999. Action and pharmacokinetics of a novel insect growth regulator, halofenozide, in adult beetles of *Aubeonymus mariaefranciscae* and *Leptinotarsa decemlineata*. *Arch. Insect Biochem. Physiol*., 41: 201-213.

Foda, S.M., Awadallah, A.M. and Abou-El-Ghar, M.R. 1976. Chemical control of the olive moth *Palpita unionalis* Hb. *Agric. Res. Rev.*, 54 (1): 153-159.

Fodale, A.S. and Mule, R. 1990. Bioethological observations on *Palpita unionalis* Hb. in Sicily and trials of defence.*Acta Horticul*., 286: 351-353.

Gaaboub, I., Halawa, S. and Rabiha, A. 2012. Toxicity and biological effects of some insecticides, IGRs and Jojoba oil on cotton leafworm *Spodoptera littoralis* (Boisd.). *J. App. Sci. Res*., 2: 131-139.

Gado, P., Salokhe, S.G. and Deshpande, S.G. 2015. Impact of Lufenuron (5.4% EC) on reproductive end points of *Tribolium castaneum*. *World J. Pharmaceut. Res*., 4(3): 1593-1599.

Ghoneim, K., Tanani, M., Hamadah, K.h, Basiouny, A. and Waheeb, H. 2015. Bioefficacy of Novaluron, a chitin synthesis inhibitor, on survival and development of *Spodoptera littoralis* (Boisd.)(Lepidoptera: Noctuidae). *J. Adv. Zool*., 1(1): 24-35.

Ghoneim, K., Tanani, M., Hamadah, Kh, Basiouny, A. and Waheeb, H. 2014. Inhibited reproductive capacity of Egyptian cotton leaf worm *Spodoptera littoralis* (Boisd.) (Lepidoptera: Noctuidae) by the chitin synthesis inhibitor Novaluron. *Egypt. Acad. J. Biolog. Sci*., 7(2): 105-118.

Gobbi, A., Budia, F., Schneider, M., Estal, P. del, Pineda, S. and Viñuela, E. 2000. Tebufenozide effects on *Spodoptera littoralis* (Boisduval), *Mythimna unipuncta* (Haworth) and *Spodoptera exigua* (Hübner). *Boletín de Sanidad Vegetal, Plagas*, 26(1): 119-127.

Grossley S. 2000. *Palpita unionalis*. Retrived April, 2001. Available from http://www.nysaes. cornell.edu/fst/faculty/ acree/pheromet/ ins/ palpiunion.html

Hagedorn, H.H. 1985. The role of ecdysteroids in reproduction. In: "Comprehensive Insect Physiology, Biochemistry and Pharmacology"(Kerkut GA and Gilbert LI., eds.), vol. 8. Pergamon, Oxford, pp. 205-262.

Hamadah, Kh, Tanani, M., Ghoneim, K., Basiouny, A. and Waheeb, H. 2015. Effectiveness of Novaluron, chitin synthesis inhibitor, on the adult performance of Egyptian cotton leafworm, *Spodoptera littoralis* (Boisd.) (Lepidoptera: Noctuidae). *Int. J. Res. Studies Zool.*, 1(2): 45-55.

Hamadah, Kh Sh. 2003. Physiological and Biochemical Effects of IGRs and plant extracts on the house fly *Musca* *domestica*.M.Sc. *Thesis, Fac. Sci., Al-Azhar Univ., Cairo*, Egypt.

Hamaidia, K. and Soltani, N. 2016. Ovicidal activity of an insect growth disruptor (methoxyfenozide) against *Culex pipiens* L. and delayed effect on development. *J. Entomol. Zool. Studies*, 4(4): 1202-1207.

Hassan, H.A., Ghoneim, K., Tanani, M.A. and Bakr, N.A. 2017. Impairing effectiveness of the chitin synthesis inhibitor, Novaluron, on adult performance and reproductive potential of the pink bollworm *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae). *J. Entomol. Zool. Studies*, 5(2): 581-592.

Hodin, J. and Riddiford, L.M. 1998. The ecdysone receptor and ultraspiracle regulate the timing and progression of ovarian morphogenesis during *Drosophila metamorphosis*. *Devel. Genes Evol.*, 208: 304-317.

Hoelscher, A.J. and Barret, A.B. 2003. Effects of methoxyfenozide-treated surfaces on the attractiveness and responsiveness of adult leafrollers. *Entomol. Exp. App*., 107: 133-140.

Hoffmann, K.H. and Lorenz, M.W. 1998. Recent advances in hormones in insect pest control. *Phytoparasitica*, 26(4): 323-330.

Indrasith, L., Sasaki, S.T., Yaginuma, T., Yamashita, O. 1988. The occurrence of premature form of egg-specific protein in vitellogenic follicles of *Bombyx mori*.*J.Comp. Physiol*., 158: 1-7.

Ishaaya, I., Kontsedalov, S., Masirov, D. and Horowitz, A.R. 2001. Bio-rational agents-mechanism, selectivity and importance in IPM programs for controlling agricultural pests. *Med. Landbouww Rijksuniv Gent*, 66: 363-374.

Ishaaya, I., Yablonski, S. and Horowitz, A.R. 1995. Comparative toxicity of two ecdysteroid agonists, RH-2485 and RH-5992, on susceptible and pyrethroid-resistant strains of the Egyptian cotton leafworm, *Spodoptera littoralis*. *Phytoparasitica*, 23:139-145.

Jimenez-Peydro, R., Gimeno-Martos, C., Lopez-Ferror, J., Serrano-Delgado, C. and Moreno-Mari, J. 1995. Effects of the insect growth regulator, cyromazine, on the fecundity, fertility and offspring development of Mediterranean fruit fly, *Ceratitis capitata* Wied (Diptera, Tephritidae).*J. App. Entomol*., 119: 435-438.

Josephrajkumar, A., Subrahmanyam, B. and Srinivasan, S. 1999. Plumbagin and azadirachtin deplete haemolymph ecdysteroid levels and alter the activity profiles of two lysosomal enzymes in the fat body of *Helicoverpa armigera* (Lepidoptera: Noctuidae). *Eur. J. Entomol*., 96: 347-353.

Kamaruzzaman, A., Reza, A., Mondal, K. and Parween, S. 2006. Morphological abnormalities in *Tribolium castaneum* (Herbst) and *Tribolium confusum* Jacquelin du Val Duval due to cyromazine and pirimiphos-methyl treatments alone or in combination.*Invertebrate Survival J*., 3:97-102.

Kamminga, K.L., Kuhar, T.P., Wimer, A. and Herbert, D.A. 2012. Effects of the insect growth regulators novaluron and diflubenzuron on the brown marmorated stink bug. *Plant Health Progress Online* doi:10.1094/PHP-2012-1212-01-RS.

Kandil, A.A.M., Abd El-Zhar,T.R. and Rashad, A.M. 2005. Some biological and biochemical effects of chitin synthesis inhibitor on pink bollworm *Pectinophora gossypiella*. *Ann. Agric. Sc. Moshtohor (Egypt),* 43(4): 1991-2002.

Kandil, M.A., Ahmed, A.F. and Moustafa, H.Z. 2012. Toxicological and biochemical studies of lufenuron, chlorfluazuron and chromafenozide against *Pectinophora gossypiella* (Saunders). *Egypt. Acad. J. Biolog. Sci*., 4(1): 37- 47.

Kandil, M.A.A., Salem, M.S. and Adly, A.M. 2013. Biological and biochemical changes in pink bollworm, *Pectinophora gossypiella* after treatment with Hexaflumuron and Chlorfluazuron. *Ann. Agric. Sci., Moshtohor (Egypt)*, 51(4): 472-437.

Kartal, M., Altun, M.L. and Kurucu, S. 2003. HPLC method for the analysis of harmol, harmalol, harmine and harmaline in the seeds of *Peganum harmala* L. *J. Pharmaceut.Biomed. Analysis*, 31: 263-269.

Khan, G.Z., Khan, I., Khan, I.A., Alamzeb, Salman M and Kalim Ullah. 2016. Evaluation of different formulations of IGRs against *Aedes albopictus* and *Culex quinquefasciatus* (Diptera: Culicidae). *Asian Pacific J. Trop. Biomedicine*, 6(6): 485-491.

Khan, I. and Qamar, A. 2011. Biological activity of andalin (flucycloxuron), a novel chitin synthesis inhibitor, on red cotton stainer *Dysdercus koenigii* (Fabricius).*Frontiers in Life Sciences: Basic and Applied, Biology and Medicine*, 3(2): 324-335.

Khan, I. and Qamar, A. 2012. Andalin, an insect growth regulator, as reproductive inhibitor for the red cotton stainer, *Dysdercus koenigii* (F.) (Hemiptera: Pyrrhocoridae). *Acad. J. Entomol*., 5(2): 113-121.

Khan, M., Hossain, M.A. and Islam, M.S. 2007. Effects of neem leaf dust and a commercial formulation of a neem compound on the longevity, fecundity and ovarian development of the melon fly, *Bactocera cucurbitae* (Coquillett) and the oriental fruit fly, *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae). *Pak. J. Biol. Sci.*, 10: 3656-3661.

Khebbeb, M.E.H, Gaouaoui, R. and Bendjeddou, F. 2008. Tebufenozide effects on the reproductive potentials of the Mediterranean flour moth, *Ephestia kuehniella*. *Afr. J. Biotech*., 7(8): 1166-1170.

Kostyukovsky, M. and Trostanetsky, A. 2004. The effect of a new chitin synthesis inhibitor, Novaluron, on various developmental stages of *Tribolium castaneum* (Herbst).*J. stored Prod. Res*., 42(2): 136-148.

Liu, T.X. and Chen, T.Y. 2001. Effects of the insect growth regulator fenoxycarb on immature *Chrysoperla rufilabris* (Neuroptera: Chyrsopidae). *Fl. Entomol*., 84(4): 628-633.

Lucantoni, L., Giusti, F., Cristofaro, M., Pasqualini, L., Esposito, F., Lupetti, P. and Habluetzel, A. 2006. Effects of a neem extract on blood feeding, oviposition and oocyte ultrastructure in *Anopheles stephensi* Liston (Diptera: Culicidae). *Tissue Cell*, 38: 361-371.

Luna, J.C., Robinson, V.A., Martinez, A.M., Schneider, M.I., Figueroa, J.I., Smagghe, G., Vinuela, E., Budia, F. and Pineda, S. 2011. Long-term effects of methoxyfenozide on the adult reproductive processes and longevity of *Spodoptera exigua* (Lepidoptera: Noctuidae). *J. Econ. Entomol*., 104(4): 1229-1235.

Mahmoudvand, M., Abbasipour, H., SheikhiGarjan, A. and Bandani, A.R. 2012. Decrease in pupation and adult emergence of *Plutella xylostella* (L.) treated with hexaflumuron. *Chilean J. Agric. Res*. 72(2):206-211.

Mahmoudvand, M., Moharramipour, S. and Iranshahi, M. 2015. Effects of pyriproxyfen on life table indices of

Plutella xylostella in multigenerations. *Psyche*, Article ID 453701, 7 pp. http://dx.doi.org/10.1155/2015/453701

Mansour, A.N. 2012. Biocontrol studies on using *Bracon* sp. (Hymenoptera: Braconidae) to control lepidopterous pests infesting Egyptian olive. Ph. D. Thesis, Fac. Sci., Al-Azhar Univ., Egypt, 176 pp.

Martins, F. and Silva, I.G. 2004. Avaliação da atividade inibidora do di-flubenzuron na ecdise das larvas de *Aedes aegypti* (Linnaeus, 1762) (Diptera, Culicidae). *Rev. Soc. Bras. Med. Trop*., 37: 135-138.

Medina, P., Budia, F., Del Estal P and Vinuela, E. 2004. Influence of azadirachtin, a botanical insecticide, on *Chrysoperla carnea* (Stephens) reproduction: toxicity and ultrastructural approach. *J. Econ. Entomol.*, 97: 43-50.

Mojaver, M. and Bandani, A.R. 2010. Effects of the insect growth regulator pyriproxyfen on immature stages of sunn pest, *Eurygaster integriceps* Puton (Heteroptera: Scutelleridae). *Munis Entomol. Zool*., 5(1): 187-197.

Mondal, K. and Parween, S. 2000. Insect growth regulators and their potential in the management of stored-product insect pests. *Integr. Pest Manage. Rev*., 5: 255-295.

Montiel, B.A. and Jones, O. 2002. Alternative methods for controlling the olive fly, *Bactrocera oleae*, involving semiochemicals. *Proceedings of Pheromones and Other Biological Techniques for Insect Control in Orchards and Vineyards. IOBC/ WPRS Bull*., 25(9): 147-156.

Moreno, D.S., Martinez, A.J. and Riviello, M.S. 1994. Cyromazine effects on the reproduction of *Anastrepha ludens* (Diptera: Tephritidae) in the laboratory and in the field. *J. Econ. Entomol*., 87: 202-211.

Moroney, M.J. 1956. Facts from figures (3rded.). Penguin Books Ltd., Harmondsworth. Middle Sex.

Mosallanejad, H and Smagghe, G. 2009. Biochemical mechanisms of methoxyfenozide resistance in the cotton leafworm *Spodoptera littoralis*.*Pest Manage. Sci*., 65: 732-736.

Nicholas AH,Thwaite WG and Spooner-Hart RN.1999. Arthropod abundance in a disruption and supplementary insecticide treatments for codling moth, *Cydia pomonella* (L) (Lepidoptera: Torticidae).*Austral. J.Entomol*., 38: 23-29.

Oberlander, H. and Silhacek, D. 2000.Insect growth regulators. In: "Alternatives to pesticides in stored-product IPM" (Subramanyam B and Hagstrum DW., eds.). Kluwer Academic Publishers, Boston, pp. 147-163.

Osman, E.E., Rarwash, I. and El- Samadisi, M.M. 1984. Effect of the anti-moulting agent "Dimilin" on the blood picture and cuticle formation in *Spodopterea littoralis* (Boisd.) larvae.*Bull. Entomol.Soc. Egypt (Econ.Ser.)*, 14: 3-46.

Osorio, A., Martínez, A.M., Schneider, M.I., Díaz, O., Corrales, J.L., Avilés, M.C., Smagghe, G., and Pineda, S. 2008. Monitoring of beet armyworm resistance to spinosad and methoxyfenozide in Mexico.*Pest Manage. Sci.*, 64: 1001-1007.

Ouakid, M.L., Adjami, Y., Habbachi, W., Ghanem, R., Daas, H. and Tahraoui, A. 2016. Insecticidal effect of halofenozide and methoxyfenozide in different stages of *Lymantria dispar*, an important cork oak defoliator. *Turk. J. Forestry*, 17: doi: http://dx.doi.org/10.18182/tjf.97406

Palli, R. and Retnakaran, A. 2001. Ecdysteroid and juvenile hormone receptors: properties and importance in developing novel insecticides, In: "Biochemical sites of insecticides action and resistance". (Ishaaya I., ed), pp.:107-132, Berlin, Springer, 343pp.

Parween, S., Faruki, S.I. and Begum, M. 2001. Impairment of reproduction in the red flour beetle, *Tribolium castaneum* (Herbst.)(Coleoptera: Tenebrionidae) due to larval feeding on triflumuron-treated diet. *J.App.Entomol*., 125: 1-4.

Perveen, F. and Miyata, T. 2000. Effects of sublethal dose of Chlorfluazuron on ovarian development and oogenesis in the common cutworm *Spodoptera litura* (Lepidoptera: Noctuidae). *Ann. Entomol. Soc. Amer*., 93(5): 1131-1137.

Pineda, S., Budia, F., Schneider M.I., Gobbi, A., Vinuela, E., Valle, J. and del Estal, P. 2004. Effects of two biorational insecticides, spinosad and methoxyfenozide, on *Spodoptera littoralis* (Lepidoptera: Noctuidae) under laboratory conditions. *J. Econ. Entomol*., 97: 1906-1911.

Pineda, S., Martinez, A.M., Figueroa, J.I., Schneider, M.I., del Estal, P., Vinuela, E., Gomez, B., Smagghe, G. and Budia, F. 2009. Influence of azadirachtin and methoxyfenozide on life parameters of *Spodoptera littoralis*. *J. Econ. Entomol*., 102(4): 1490-1496.

Pineda, S., Schneider, M.I., Smagghe, G., Martinez, A.M., del Estal, P., Vinuela, E., Valle, J. and Budia, F. 2007. Lethal and sublethal effects of methoxyfenozide and spinosad on *Spodoptera littoralis* (Lepidoptera: Noctuidae). *J. Econ. Entomol*., 100(3): 773-780.

Pinto, M. and Salemo, G. 1995. The olive pyralid.*Informator, Agrio*., 51 (43): 77-81.

Portilla, M., Snodgrass, G. and Luttrell, R. 2012. A Novel bioassay using a non-autoclaved solid *Lygus* diet to evaluate the effect of *Beauveria bassiana* and the insect growth regulator novaluron on tarnished plant bug, *Lygus lineolaris*.The 3rd international *Lygus* symposium, Scottsdale, Arizona, USA.

Ragaei, M. and Sabry, K.H. 2011. Impact of spinosad and buprofezin alone and in combination against the cotton leafworm, *Spodoptera littoralis* under laboratory conditions. *J.Biopestic*., 4(2): 156-160.

Rashad AM, Hewady MAA and Kandil MAA. 2006. Effect of Neemazal, Spinosad and Dimilin on some biological and physiological activities of pink bollworm *Pectinophora gossypiella* (Saund.). *Ann. Agric. Sci., Moshtohor (Egypt)*, 44(1): 304-319.

Reinke, M.D. and Barrett, B.A. 2007. Fecundity, fertility and longevity reductions in adult oriental fruit moth (Lepidoptera: Tortricidae) exposed to surfaces treated with the ecdysteroid agonists tebufenozide and methoxyfenozide. *J. Entomol. Sci*., 42: 457-466.

Retnakaran, A., Krell, P., Feng, Q. and Arif, B. 2003. Ecdysone agonists: mechanism and importance in controlling insect pests of agriculture and forestry. *Arch. Insect Biochem. Physiol*., 54: 187-199.

Rose, R.I. 2001. Pesticides and public health: integrated methods of mosquito management. *Emerg. Infect. Dis*., 7(1): 17-23.

Sabry, K.H. and Abdou, G.Y. 2016. Biochemical and toxic characterization of some insect growth regulators to the pink bollworm, *Pectinophora gossypiella* (Saunders). *American-Eurasian J. Sustain. Agric*., 10(1): 8-14.

Saenz-de-Cabezon, I.F.J., Marco, V., Salmo, F.G. and Perez-Moreno, I. 2005. Effects of methoxyfenozide on *Lobesia botrana* Den and Schiff (Lepidoptera: Tortricidae) egg, larval and adult stages. *Pest Manage. Sci*., 11: 1133-1137.

Salem, H., Smagghe, G. and Degheele, D. 1997. Effects of tebufenozide on oocyte growth in *Plodia interpunctella*. *Medical. Faculty. Landbouww. Gent University*, 62(1): 9-13.

Salem, M.S.M. 2015. Latent effect of different compounds on *Pectinophora gossypiella* (Saunders). *J. Plant Prot. and Pathol, Mansoura Univ., Egypt*, 6(2): 269-279.

Sallam, M.H. 1999. Effect of Diflubenzuron on embryonic development of the acridid, *Heteracris littoralis*. *J. Egypt. Ger. Soc. Zool*., 30(E): 17-26.

Sammour, E.A., Kandil, M.A. and Abdel-Aziz, N.F. 2008. The reproductive potential and fat of clorfluazuron and lufenuron against cotton leafworm, *Spodoptera littoralis* (Boisd). *American-Eurasian J. Agric. Environ. Sci.*, 4(1): 62-67.

Seth, R.K., Kaur, J.J., Rad, D.K. and Reynolds, S.E. 2004. Effect of larval exposure to sublethal concentrations of the ecdysteroid agonists RH-5849 and Tebufenozide (RH-5992) on male reproductive physiology in *Spodoptera litura*.*J.Insect Physiol*., 50(6): 505- 517.

Shahout, H.A., Xu, J.X., Qiao, J., Jia, Q.D. 2011. Sublethal effects of methoxyfenozide, in comparison to chlorfluazuron and beta-cypermethrin, on the reproductive characteristics of common cutworm *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae). *J. Entomol. Res. Soc.*, 13(3): 53-63.

Shehata,W.A.,Abou-Elkhair, S.S., Youssef, A.A. and Nasr, F.N. 2003. Biological studies on the olive leaf moth, *Palpita unionalis* Hübner (Lepid., Pyralidae), and the olive moth, *Prays oleae* Bernard (Lepid., Yponomeutidae). *J. Pest Sci*., 76(6): 155-158.

Simon, A.F., Shih, C., Mack, A. and Benzer, S. 2003. Steroid control of longevity in *Drosophila melanogaster*. *Sci*. 299: 1407-1410.

Singh, A. and Tiwari, S.K. 2016. Role of Fenoxycarb, a juvenile hormone analogue, on the developmental stages of rice-moth, *Corcyra cephalonica* Staint. (Lepidoptera: Pyralidae). *Int. J. Zool. Investigat*., 2(2): 267-280.

Smagghe, G. and Degheele, D. 1994. The significance of pharmacokinetics and metabolism to the biological activity of RH-5992 (tebufenozide) in *Spodoptera exempta*, *Spodoptera exigua* and *Leptinotarsa decemlineata*. *Pest.Biochem. Physiol*., 49: 224-234.

Smagghe, G., Bylemans, D., Medina, P., Budia, F., Avilla, J. and Viñuela, E. 2004. Tebufenozide distorted codling moth larval growth and reproduction, and controlled field populations. *Ann. App. Biol*., 145: 291-298.

Smagghe, G. and Degheele, D. 1992. Effects of the non-steroidal ecdysteroid agonist, RH-5849 on production of *Spodoptera littoralis* (Boisd.) (Lepidoptera: Noctuidae). *Phytoparasitica*, 48: 23-29.

Soltani, N. 1984. Effects of ingested Diflubenzuron on the longevity and peritrophic membrane of adult mealworms (*Tenebrio molitor* L.).*Pestic. Sci*., 15: 221-225.

Soltani-Mazouni, N. and Soltani, N. 1994. Diflubenzuron affected DNA synthesis in the ovaries of *Tenebrio molitor*. *J. Invert. Reprod. Devel*., 25: 19-21.

Soltani, N. and Mazouni, A. 1992. Diflubenzuron and oogenesis in the codling moth, *Cydia pomonella*.*Pesti. Sci*., 34: 257-261.

Spooner-Hart R, TesoriİeroL and Hall B. 2007. Field Guide to Olive Pests, Diseases and Disorders in Australia. ISSN 1440-6845.65 pp.

Sundaram, M., Palli, S.R., Smagghe, G., Ishaaya, I., Feng, Q.L., Primavera, M., Tomkins, W.L., Krell, P.J. and Retnakaran, A. 2002. Effect of RH-5992 on adult development in spruce budworm, *Choristoneura fumiferana*. *Insect Biochem. Mol. Biol*., 32: 225-231.

Sun, X., Barett, B.A. and Biddinger, D.J. 2000. Fecundity and fertility reductions in adult leafrollers exposed to surfaces treated with the ecdysteroid agonist tebufenozide and methoxyfenoside. *Entomol. Exp. App*., 94: 75-83.

Sun, X., Song, Q. and Barrett, B. 2003. Effect of ecdysone agonists on vitellogenesis and the expression of EcR and USP in codling moth (*Cydia pomonella*).*Arch.Insect Biochem.Physiol*., 52:115-129.

Taibi F, Smagghe G, AmraniL and Soltani-Mazouni N.2003.Effect of ecdysone agonist RH-0345 on reproduction of mealworm, *Tenebrio molitor*.*Comp. Biochem. Physiol*., 135: 257-267.

Taleh, M., Pourabad, R.F., Geranmaye, J. and Ebadollahi, A. 2015. Toxicity of Hexaflumuron, as an insect growth regulator (IGR), against *Helicoverpa armigera* Hubner (Lepidoptera: Noctuidae). *J. Entomol.Zool. Studies*, 3(2): 274-277.

Tanani, A.M. 2001. Study the effects of certain IGRs and plant extracts on some physiological aspect of the *Rhyncophorus ferrugenius*(Curculionidae: Coleoptera). M.Sc. Thesis, Fac. Sci., Al-AzharUniv., Egypt.

Tanani, M., Hamadah, Kh, Ghoneim, K., Basiouny, A. and Waheeb, H. 2015. Toxicity and bioefficacy of Cyromazine on growth and development of the cotton leafworm *Spodoptera littoralis* (Lepidoptera: Noctuidae). *Int. J. Res. Studies Zool*., 1(3):1-15.

Telfer, W.H. 2009. Egg formation in Lepidoptera. J. Insect Sci., 9: 50. (insectscience.org/9.50).

Terashima, J., Takaki, K., Sakurai, S. and Bownes, M. 2005. Nutritional status affects 20-hydroxyecdysone concentration and progression of oogenesis in *Drosophila melanogaster*. *J. Endocrinol*., 187: 69-79.

Thompson, H.M., Wilkins, S., Battersby, A.H., Waite, R.J. and Wilkinson, D. 2005. The effects of four insect growth-regulating (IGR) insecticides on honeybee (*Apis mellifera* L.) colony development, queen rearing and drone sperm production, *Ecotoxicol*., 14: 757-769.

Toivonen, J.M. and Partridge, L. 2009. Endocrine regulation of aging and reproduction in *Drosophila*. *Molec. Cell. Endocrinol*. 299: 39-50.

Toppozada, A. Abd-allah, S. and El-Defrawi, M.E. 1966. Chemosterilization of larvae and adults of the Egyptian cotton leafworm, *Prodenia litura* by apholate, metepa and hempa. *J. Econ. Entomol*., 59: 1125-1128.

Tunaz, H. and Uygun, N. 2004. Insect growth regulators for insect pest control. *Turk. J. Agric.Forestry*, 28: 337-387.

Wang, Q.L. and Liu, T.X. 2016. Effects of three insect growth regulators on *Encarsia formosa* (Hymenoptera: Aphelinidae), an endoparasitoid of *Bemisia tabaci* (Hemiptera: Aleyrodidae). *J. Econ. Entomol*., 0(0): 1-8. doi: 10.1093/jee/tow216

Wigglesworth, V.B. 1984. Insect Physiology. 8th ed., Chapman & Hall, London, 191 pp.

Wing, H.D. and Aller, H.E. 1990. Ecdysteroid agonists as novel insect regulators. In: "Pesticides and alternatives" (Casida JE., ed.). Elsevier Science Publishers B.V., Amsterdam, pp. 251-257.

Yanagi, M., Tsukamoto, Y., Watanabe, T. and Kawagishi, A. 2006. Development of a novel lepidopteran insect control agent, chromafenozide. *J. Pestic. Sci*., 31: 163-164.

Yilmaz, Ç. and Genç, H. 2012. Determination of the life cycle of the olive fruit leaf moth, *Palpita unionalis* (Lepidoptera: Pyralidae) in the Laboratory. *Fl. Entomol*., 95(1):162-170.

Zarate, N., Diaz, O., Martinez, A.M., Figueroa, J.I., Schneider, M.I., Smagghe, G., Vinuela, E., Budia, F. and Pineda, S. 2011. Lethal and sublethal effects of Methoxyfenozide on the development, survival and reproduction of the fall armyworm, *Spodoptera frugiperda*(J.E. Smith) (Lepidoptera: Noctuidae). *Neotrop. Entomol.*, 40(1): 129-137.

Zhou, F., Zhu, G., Zhao, H., Wang, Z., Xue, M., Li, X., Xu, H., Ma, X. and Liu, Y. 2016. Sterilization effects of adult-targeted baits containing insect growth regulators on *Delia antiqua*. *Sci. Rep*. 6, 32855; 9pp. doi: 10.1038/srep32855.

Zidan, Z.H., Abdel-Megeed, M.I., Abd El-Hafez, A., Hussein, N.M., El-Gemeiy, H.M. and Shalaby, M.M. 1998. Toxicological and histological studies of *Bacillus thuringiensis*, MVP II against larvae of pink and spiny bollworms. The 7th Conf. Agric. Dev. Res., Fac. Agric., Ain-Shams Univ., Cairo, Egypt, Dec., pp. 319-332.

****