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Original Research Article

Ovicidal activities and developmental effects of the chitin synthesis inhibitors, Noviflumuron and Novaluron, on the pink bollworm *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae)

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Abstract: The pink bollworm *Pectinophora gossypiella* is one of the most destructive insects attacking cotton fields world-wide. The present study was conducted to evaluate the survival and developmental effects of the novel chitin synthesis inhibitors (CSIs), Noviflumuron and Novaluron**,** on this insect pest, after treatment of 1-day old eggs. These CSIs exhibited ovicidal activities on eggs, in a dose-dependent course. Complete (100%) mortality of larvae was recorded at the highest concentration (8.0 and 5.0 ppm, respectively) and various degrees of toxicity were recorded on larvae at other concentrations. Both CSIs failed to exhibit pupicidal or adulticidal effects. Noviflumuron exhibited stronger ovicidal activity than Novaluron (LC_{50} values: 0.188 and 0.274 ppm, respectively) and *vice versa* for larvicidal activity (LC_{50} values: 0.153 and 0.342 ppm of Novaluron and Noviflumuron, respectively). The larval and pupal durations were slightly or remarkably prolonged. The pupation rate was slightly reduced by Noviflumuron but conspicuously hindered by Novaluron. Noviflumuron and Novaluron could not affect the metamorphosis or morphogenesis of *P. gossypiella*.
Keywords: egg, larva, metamorphosis, morphogenesis, mortality, pupation.

INTRODUCTION

Worldwide, the pink bollworm *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae) is one of the most destructive insect pests that cause terrible damage to the cotton because it is difficult to be controlled by insecticides [1, 2]. Larvae damage the floral outgrowths, flowers, bolls, developing seeds within bolls and deteriorate the staple length and strength of lint. The termination of boll growth results in boll rotting and premature or partial boll opening [3]. In Egypt, this insect pest causes serious damage to cotton arising to one million kentar annually [4, 5]. Moreover, *P. gossypiella* has been reported to develop resistance against the transgenic cotton varieties in Arizona (USA) [6] and different districts of India [7]. In Egypt, also, this insect has recently developed resistance to several classes of insecticides currently used in cotton fields because of its ability to detoxify these chemicals [8].

As reported by many authors [9-15], the intensive and discriminate uses of many conventional pesticides lead to several drastic problems, such as the environmental pollution, hazards to human and animals like birds, fishes and mammals, destruction of the pollinators and other non-target insects as well as the natural enemies, like parasites and predators. Therefore, alternative materials have been initiated recently to minimize the environment hazards and the serious toxicological problems to humans and animals [16] as well as to delay the resistance development in *P. gossypiella* [17-20]. At present, using insect growth regulators (IGRs) is considered as the possible alternative way of synthetic insecticides for controlling this pest. In contrast to the classical chemical insecticides, IGRs are not directly toxic, but act selectively on the development, metamorphosis or reproduction of the target insect species [21, 22]. They are quite selective in their mode of action and potentially act only on the target species [23]. As reviewed by Tunaz and Uygun [24], chitin synthesis inhibitors (CSIs) are usually classified in IGRs interfering with chitin biosynthesis in insects and thus prevent moulting, or produce an imperfect cuticle.

Noviflumuron is a new chemical currently being developed by Dow Agro Sciences, Indianapolis, Indiana, USA, for the structural pest control market [25]. Noviflumuron is a benzoyl phenyl urea IGR that prevents the molting and development of some insects, such as fleas, ants, termites and houseflies [26, 27]. Its suspension concentrate, dust or gel bait can effectively

suppress *Blattella germanica* populations with a pattern of activity similar to that expected from a CSI [28-30]. Also, adult *B. germanica* exposed to Noviflumuron fail to produce viable eggs, hence their reproductive potential is reduced [31].

Novaluron is a relatively new benzoyl phenyl urea CSI with low mammalian toxicity [32, 33]. The compound has no appreciable effect on parasitoids and has probably a mild effect on the natural enemies [34, 35]. Its residues tend to dissipate with half-life of 2.08 days and the safe use of it on tomatoes, and possibly on other crops in Egypt was established [36]. Novaluron is a powerful suppressor of the pest populations, such as *Bemisia tabaci* and *Trialeurodes vaporariorum* [37]. It acts by ingestion and contact against several insect pests, such as *Spodoptera* spp., *Tuta absoluta*, *Helicoverpa armigera*, and *Liriomyza huidobrensis* [38]. It exhibited, also, a good activity against the Colorado potato beetle [39-42] and impaired the development [43] and adult performance [44] of *Spodoptera littoralis*. Recently, treatment of newly hatched and full grown larvae of *P. gossypiella* with Novaluron led to reduced survival, retarded development, impaired metamorphosis [45], disrupted adult performance, inhibited reproductive potential [46], declined main metabolites [47], and deteriorated larval haemogram [48]. Also, Novaluron adversely affected the survival and development of *Palpita unionalis* [49]. According to the available literature, few studies had been conducted on the ovicidal effects of insecticides and IGRs on eggs of lepidopterous pests but the majority focused on the treatment of larval stage [50]. Therefore, objectives of the present study were to evaluate the ovicidal action of Noviflumuron and Novaluron, novel CSIs, and to investigate their disruptive effects on the development on *P. gossypiella* after treatment of 1-day old eggs.

MATERIALS AND METHODS

Experimental insect

A culture of the pink bollworm *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae) was originated by a sample of newly hatched larvae from the susceptible culture maintained for several generations along some years in Plant Protection Research Institute, Doqqi, Giza, Egypt. It was reared under laboratory controlled conditions (27±2°C and 75±5% R.H.) at Department of Zoology and Entomology, Faculty of Science, Al-Azhar University, Cairo. Larvae were provided with an artificial diet as described by Abd El-Hafez *et al.;* [51]. For rearing details and manipulation of all developmental stages under the laboratory controlled conditions, see Ghoneim *et al.;* [45].

CSIs and preparation of concentrations

The tested Benzoyl phenyl urea compounds, in the present study, are Noviflumuron and Novaluron. Noviflumuron (Recruit III, and Recruit III AG) has the chemical name: N{[[3,5-dichloro-2-fluro-4-(1,1,2,3,3,3 hexa fuoro propoxy) phenyl] amino]carbonyl}-2,6-difluorobenzamide. Its molecular formula is $C_{17}H_7Cl_2F_9N_2O_3$. It was kindly obtained from Laboratory of Pesticides, Agricultural Research Center, Doqqi, and Giza, Egypt. Novaluron (Rimon) has the chemical name: [1-[chloro-4-(1, 1, 2-trifluoromethoxyethoxy) phenyl] -3- (2, 6-difluorobenzoyl) urea]. Its molecular formula is $C_{17}H_9ClF_8N_2O_4$. It was purchased from Sigma-Aldrich Chemicals. Five concentrations of each compound were prepared by diluting with distilled water in volumetric flasks as follows: Noviflumuron: 8.0, 4.0, 2.0, 1.0, 0.5 ppm. Novaluron: 5.0, 1.0, 0.5, 0.1, 0.05 ppm.

Egg treatment

Four groups of freshly emerged moths of *P. gossypiella*, each group 10 pairs (♂♂ X♀♀), were confined in a glass chimney cage (17 cm height and 7.12 cm in diameter), inside which a piece of cotton wool previously soaked in 20% sugar solution was suspended to be renewed 48 hr for moths' nutrition [52]. After deposition of eggs on plastic papers at the top and bottom of the cage, these papers had been divided into four pieces in order to obtain four replicates from 1-day old eggs (10 eggs/replicate). Then, each replicate was carefully sprayed with each concentration of each compound using an atomizer. All egg papers were left for 15 min. to allow evaporation of excess water under laboratory conditions. Similar replicates of control eggs were treated with distilled water using the same technique.

Each of the CSI-treated and control replicates was kept separately in a suitable plastic jar for hatching under the controlled conditions (27±2°C and 75±5% R.H.). After the incubation period, each newly hatched larva was transferred into a glass tube (6.0x1.5 cm) containing 2 g of artificial diet. Each larva of treated and control replicates was observed daily for recording all parameters of survival, development, and metamorphosis.

Criteria of study

Ovicidal and lethal effects

The ovicidal effect of each CSI was estimated by the recorded mortality of eggs (%). The successfully hatched larvae of treated and control replicates were observed every day for determining the mortalities of all stages and corrected according to Abbott's formula [53] as follows:

$$\% \text{ of corrected mortality} = \frac{\% \text{ of test mortality} - \% \text{ of control mortality}}{100 - \% \text{ of control mortality}} X100$$

The LC_{50} values were calculated for the general mortality by Microsoft® office Excel (2007), according to Finney [54].

Developmental and metamorphic parameters

***Developmental rate*:**

Dempster's equation [55] was applied for calculating the developmental duration, and Richard's equation [56] was used for calculating the developmental rate.

***Pupation rate*:** The pupation rate of the successfully developed pupae was calculated according to Jimenez-Peydro et al. [57] as follows:

P.R. = [No. pupae / No. treated larvae] × 100

Deranged metamorphosis: Deranged metamorphosis program was observed and calculated in larval-pupal or pupal-adult intermediates (%). Also, pupal deformation was calculated in %.

***Pupal water loss*:** Pupal water loss was calculated depending on the data of the initial and final weights of the pupae, as follows:

Water loss % = [initial weight – final weight /initial Weight] × 100

Statistical analysis of data

Data obtained were analyzed by the Student's *t*-distribution, and refined by Bessel correction [58] for the test significance of difference between means.

RESULTS

After treatment of 1-day old eggs of *P. gossypiella* with five concentrations of Noviflumuron, data of the ovicidal activity and lethal effects on larvae and pupae had been assorted in Table (1). On the basis of these data, Noviflumuron exhibited an ovicidal activity in a dose-dependent course (95.0, 87.5, 82.5, 75.0 and 65.0% of egg mortality, at 8.0, 4.0, 2.0, 1.0 and 0.5 ppm, respectively, *vs*. 12.5% mortality of control eggs). With regard to Novaluron, data distributed in Table (2) clearly reveal different egg mortalities after treatment of 1-day old eggs with five concentrations, proportional to the ascending concentration (92.5, 84.5, 55.0, 42.5 and 30.0% of egg mortality, at 5.0, 1.0, 0.5, 0.1 and 0.05 ppm, respectively, *vs*. 10.0% mortality of control eggs). Depending on data assorted in both tables, Noviflumuron exhibited stronger ovicidal activity than Novaluron (LC_{50} values: 0.188 and 0.274 ppm, respectively).

In the light of data included in Tables (1 and 2), treatment of 1-day old eggs with the highest concentration level of each compound resulted in complete (100%) mortality of larvae. At other concentrations of Noviflumuron, larvicidal effect was detected in various larval mortalities (66.7, 37.5, 39.6 and 06.3%, at 4.0, 2.0, 1.0 and 0.5 ppm, respectively, in comparison of 05.6% mortality of control larvae, Table 1). Also, Novaluron exhibited a larvicidal effect on the successfully hatched larvae (50.0, 30.0, 22.8 and 18.0% mortality of larvae, at 1.0, 0.5, 0.1 and 0.05 ppm, respectively, compared to 11.2% mortality of control larvae, Table 2). On the other hand, both compounds failed to display pupicidal or adulticidal effects, since no pupal or adult mortality could be observed. LC_{50} values of Noviflumuron and Novaluron for larvae were estimated in 0.342 and 0.153 ppm, respectively, indicating that Novaluron appeared to be more toxic than Noviflumuron.

After treatment of 1-day old eggs with Noviflumuron concentrations, data of the most important developmental criteria were assorted in Table (3). According to these data, larval duration was insignificantly prolonged, in almost dose-dependent course (15.5±0.71, 15.5±0.5, 15.4±0.75 and 15.4±0.50 days, at 4.0, 2.0, 1.0 and 0.5 ppm, respectively, *vs*. 15.1±0.48 days of control larvae). Also, the developmental rate was slightly regressed, in a similar trend. In respect of the inhibitory effect of Noviflumuron on pupation, the determined pupation percentage was remarkably reduced, in a dose-dependent fashion (33.3, 60.4, 62.5 and 93.7%, at 4.0, 2.0, 1.0 and 0.5 ppm, respectively, *vs*. 94.4% pupation of control insects). In addition, the pupation duration was slightly prolonged (for detail, see Table 3). Although Noviflumuron failed to exhibit a pupicidal effect, it induced the water loss of pupae, in a dose-dependent manner (21.40, 19.40, 19.27 and 18.16%, at 4.0, 2.0, 1.0 and 0.5 ppm, respectively, *vs*. 10.11% water loss of control pupae). Depending on data included in the aforementioned table, Noviflumuron failed to affect the metamorphosis and morphogenesis programs, since no deformed larvae, deformed pupae, larval-pupal or pupal-adult intermediates had been produced.

With regard to the inhibitory effects of Novaluron on the development of *P. gossypiella*, Table (4) contained data of the most important parameters. Depending on these data, the larval duration was considerably prolonged after treatment with the highest concentration (18.7±0.38 days, compared to 18.0±0.10 days of control larvae) but slightly prolonged after treatment with other concentrations (18.5±0.71, 18.5±0.69 and 18.0±0.17 days, at 0.5, 0.1 and 0.05 ppm, respectively, *vs*. 18.0±0.10 days of control congeners). Also, the developmental rate was slightly regressed, in no certain trend. In connection with the affected pupation process, treatment of 1-day old eggs with Novaluron resulted in conspicuously blocked pupation,

in a dose-dependent manner (50.0, 70.0, 77.2 and 82.0%, at 1.0, 0.5, 0.1 and 0.05 ppm, respectively, *vs*. 94.4% pupation on control insects). In addition, the pupal duration was slightly prolonged, in no certain trend (7.5±0.71, 7.6±0.43, 7.5±0.24 and 7.5±0.34 days, at 1.0, 0.5, 0.1 and 0.05 ppm, respectively, *vs*. 7.4±0.05 days of control pupae). Although Novaluron failed to exhibit a pupicidal action, pupae had been subjected to a powerful desiccation action of this compound, since water loss was estimated in greater percentage than of control pupae (26.20, 17.45, 18.72 and 20.23%, at 1.0, 0.5, 0.1 and 0.05 ppm, respectively, *vs*. 10.11% from control pupae). As clearly shown in the previously mentioned table, neither metamorphosis nor morphogenesis of *P. gossypiella* had been affected by Novaluron treatments.

Table 1: Ovicidal activity and lethal effect (%) of Noviflumuron after treatment of 1-day old eggs of *P. gossypiella*

Conc. (ppm)	Ovicidal activity			Larval mortality	Pupal mortality	Adult mortality	Total mortality	Corrected mortality	LC_{50}
	Mortality	Corrected mortality	LC_{50}						
8.0	95.0	94.3	0.188	100.0	*	*	100.0	100.0	0.342
4.0	87.5	85.7		66.7	00.0	00.0	95.0	93.93	
2.0	82.5	80.0		37.5	00.0	00.0	90.0	87.87	
1.0	75.0	71.4		39.6	00.0	00.0	82.5	78.78	
0.5	65.0	60		06.3	00.0	00.0	67.5	60.60	
Control	12.5	---		05.6	00.0	00.0	17.5	---	

Conc.: Concentration level. *: no developed pupae or adults.

Table 2: Ovicidal activity and lethal effect (%) of Novaluron after treatment of 1-day old eggs of *P. gossypiella*

Conc. (ppm)	Ovicidal activity			Larval mortality	Pupal mortality	Adult mortality	Total mortality	Corrected mortality	LC_{50}
	Mortality	Corrected mortality	LC_{50}						
5.0	92.5	91.7	0.274	100.0	*	*	100.0	100.0	0.153
1.0	84.5	82.8		50.0	00.0	00.0	95.0	93.75	
0.5	55.0	50.0		30.0	00.0	00.0	67.5	59.37	
0.1	42.5	36.1		22.8	00.0	00.0	55.0	43.75	
0.05	30.0	22.2		18.0	00.0	00.0	42.5	28.12	
Control	10.0	---		11.2	00.0	00.0	20.0	---	

Conc., *: see footnote of Table (1).

Table 3: Effect of Noviflumuron on the development of *P. gossypiella* after treatment of 1-day old eggs

Conc. (ppm)	Larval stage			Pupal stage			
	Duration(days) (mean ±SD)	Develop. Rate (%)	Larval-pupal Inter. (%)	Pupation (%)	Deformed pupae (%)	Duration (days) (mean ±SD)	Water loss (%)
4.0	15.5±0.71 a	6.45	00.0	33.3	00.0	7.5±0.71 a	21.40
2.0	15.5±0.50 a	6.45	00.0	60.4	00.0	7.2±0.28 a	19.40
1.0	15.4±0.75 a	6.49	00.0	62.5	00.0	7.2±0.17 a	19.27
0.5	15.4±0.50 a	6.49	00.0	93.7	00.0	7.3±0.46 a	18.16
Control	15.1±0.48	6.62	00.0	94.4	00.0	7.0±0.37	10.11

Conc.: see footnote of Table (1). Mean±SD followed with (a): not significantly different (P>0.05).
Develop: Developmental, Inter.: Intermediates

Table 4: Effects of Novaluron on the development of *P. gossypiella* after treatment of 1-day old eggs

Conc. (ppm)	Larval stage			Pupal stage			
	Duration (days) (mean ±SD)	Develop. Rate (%)	Larval-pupal Inter. (%)	Pupation (%)	Deformed pupae (%)	Duration (days) (mean ±SD)	Water loss (%)
1.0	18.7±0.38 b	5.35	00.0	50.0	00.0	7.5±0.71 a	26.20
0.5	18.5±0.71 a	5.41	00.0	70.0	00.0	7.6±0.43 a	17.45
0.1	18.5±0.69 a	5.41	00.0	77.2	00.0	7.5±0.24 a	18.72
0.05	18.0±0.17 a	5.56	00.0	82.0	00.0	7.5±0.34 a	20.23
Control	18.0±0.10	5.56	00.0	94.4	00.0	7.4±0.05	10.11

Conc. see footnote of Table (1). a, Develop., Inter.: see footnote of Table (3), Mean±SD followed with (b): significantly different ($P<0.05$).

DISCUSSION

Direct ovicidal activity of CSIs on *P. gossypiella*

On the basis of the available literature, some insecticides, insect growth regulators (IGRs) (including chitin synthesis inhibitors, CSIs) and botanicals had been reported to exhibit various ovicidal effects (egg mortality) on different ages of eggs of some insect species, such as Flufenoxuron and Hexaflumuron against *Lobesia botrana* [59]; LC_{50} values of abamectin and emamectin benzoate (Bacteria-based product) against *Spodoptera littoralis* [60]; Lufenuron against *Lobesia botrana* [61]; pyridalyl and hexaflumuron against *Plutella xylostella* [62]; Buprofezin and Diflubenzuron against *Diaphorina citri* [63]; emamectin benzoate and pyridalyl against *Tuta absoluta* [64]; piperine (extracted from the black pepper *Piper nigrum*) against *Spodoptera frugiperda* and *Diatraea saccharalis* [65] and thiodicarb against *Spodoptera litura* [66]. Recently, treatment of *Corcyra cephalonica* eggs, of different ages, with Fenoxycarb resulted in considerable egg mortality [67]. After treatment of *Tribolium castaneum* eggs with Pyriproxyfen, Methoxyfenozide and Lufenuron, the highest ovicidal effect (100% egg mortality) was exhibited by Pyriproxyfen, followed by Methoxyfenozide and Lufenuron, respectively [68]. After treatment of 1- and 3-day old egg masses of *S. littoralis* with LC_{50} of the sesame oil, the 1-day-old egg masses are more susceptible than 3-day-old eggs [69]. Ovicidal effect of *Prunus mahaleb* kernels oil (containing basic fatty acids, heneicosane and β-sitosterol) on *S. littoralis* eggs depended on the age of treated eggs and the method of treatment [70]. With regard to *Pectinophora gossypiella*, Amer *et al.;* [64] found that emamectin benzoate was more effective than pyridalyl for the ovicidal action on 1-day old eggs.

Results of the present study were, to a great extent, in agreement with those reported results, since Noviflumuron and Novaluron exhibited ovicidal activities on the treated 1-day old eggs of *P. gossypiella*, in a dose-dependent course. Noviflumuron possesses stronger ovicidal property than Novaluron. To explicate the ovicidal effect (egg mortality) of Noviflumuron and Novaluron on *P. gossypiella*, in the present study, some suggestions can be conceivable. Egg mortality may be due to the adverse effects of these CSIs on the chorion of eggs before hatching [71]. The present CSIs penetrated into eggs and might interfere with the embryonic cuticle synthesis and subsequently the malformed muscles could not enable the developed embryos to hatch from the egg wall [72].

Latent toxicity of CSIs on *P. gossypiella*

The available literature contains many reported results of toxic effects of several insect growth regulators (IGRs)(Juvenoids, ecdysteroids and chitin synthesis inhibitors, CSIs) on various insect species, such as *Spodoptera littoralis* by Diflubenzuron [73], Triflumuron [74], Flufenoxuron [75], Lufenuron [76,77], Buprofezin [78], Cyromazine [79]; *Papilio demoleus* by Diofenolan [80]; *Eurygaster integriceps* by Pyriproxyfen [81]; *Dysdercus koenigii* by Flufenoxuron [82]; *Halyomorpha halys* by Diflubenzuron [83]; *S. litura* by Chlorfluazuron [84]; *Culex pipiens* by Kinoprene [85]; *Agrotis ipsilon* by Flufenoxuron and Methoprene[86] and *Tribolium castaneum* by Lufenuron [87]. Recently, IGRs of different categories exhibited varying degrees of toxicity against some insects, such as Pyriproxyfen against *Spodoptera mauritia* [88]; Lufenuron and Methoxyfenozide against *T. castaneum* [68]; Methoxyfenozide against *C. pipiens* [89]; RH-5849 and Tebufenozide (RH-5992) against *Ephestia kuehniella* [90]; Lufenuron against *Glyphodes pyloalis* [91] and *Helicoverpa armigera* [92]; Fenoxycarb against *Corcyra cephalonica* [93, 67]; Buprofezin against *Paracoccus marginatus* [94]; Chlorfluazuron, Cyromazine, Lufenuron, and Precocene I against *Ctenocephalides felis* [95]; Methoprene and Pyriproxyfen against *Culex quinquefasciatus* and *Aedes albopictus* [96]; Cyromazine against *Musca domestica* [97] and Novaluron against *P. gossypiella* [45].

Results of the current study on *P. gossypiella*, to some extent, are in accordance with those reported

results, since treatment of 1-day old eggs of *P. gossypiella* with Noviflumuron or Novaluron resulted in complete (100%) larval mortality at the highest concentration level (8.0 and 5.0 ppm, respectively) and various degrees of toxicity on larvae at other concentrations. In contrast, both CSIs failed to exhibit pupicidal or adulticidal effects, since no pupal or adult mortality was observed. The larval deaths of *P. gossypiella* by Noviflumuron and Novaluron, in the current investigation, may be attributed to the failure of larvae to moult owing to the inhibition of chitin formation [98], to the inability to shed their exocuticle [99], or to swallow volumes if air for splitting the old cuticle and expand the new one during ecdysis [100]. Also, these larval deaths may be due to a prohibition of feeding and continuous starvation of the present insect [101].

According to the available literature, a great variation in the LC_{50} values of different IGRs had been reported against various insect species, such as 350.45 and 453.78 ppm of Novaluron and lufenuron, respectively, against *Spodoptera litura* [102]; 8.47 mg /L of Hexaflumuron against *H. armigera* [103]; 0.05 and 0.005 µg/insect of the ecdysone agonists RH-5849 and RH-5992 (Tebufenozide), respectively, against *Ephestia kuehniella* [90]; 24.54 µg/L of Methoxyfenozide against *C. pipiens* [89]; 19 ppm of Lufenuron against *G. pyloalis* [91]; *etc*. These reported LC_{50} values were determined depending on the larval treatment with IGRs.

In addition, treatment of eggs with IGRs or other compounds resulted in various LC_{50} values as reported for the present experimental insect, *P. gossypiella*, since LC_{50} values of Hexaflumuron were found 3.754, 2.863 and 2.004 ppm after treatment of 1-, 2- and pre-hatching day-old eggs [52]. After treatment of 4-day old eggs with Lufenuron, El-Shennawy [104] estimated LC_{50} in 2.276 ppm. Depending on the LC_{50} values of soluble liquid formulations of tar oil, 1-day old eggs were the most susceptible (highest egg mortality%) among other ages of eggs [105]. After treatment of 1-day old eggs, LC_{50} values of Lufenuron, Chlorfluazuron and Chromafenozide were calculated in 3.471, 4.189 and 122.703 ppm, respectively [5]. After treatment of 1-day old eggs, LC_{50} values of Radiant (Spintoram) and Profenofos were found 3.94 and 0.031 ppm, respectively [106]. In the current investigation on *P. gossypiella*, Noviflumuron exhibited stronger ovicidal activity than Novaluron (LC_{50} values: 0.188 and 0.274 ppm, respectively) and *vice versa* for larvicidal activity (LC_{50} values: 0.153 and 0.342 ppm of Novaluron and Noviflumuron, respectively). In the light of the present results on *P. gossypiella* and other reported results of larval or egg treatment with IGRs or other compounds, the estimated LC_{50} values depend on several factors, such as susceptibility of the insect and its treated stage or instar, ovicidal or lethal potency of the tested compound and its concentration levels, age of the treated eggs, method and time of treatment, as well as the experimental conditions.

Effects of CSIs on the development of *P. gossypiella*

Depending on the currently available literature, development of various insects had been retarded (as expressed in prolonged larval and pupal durations) after treatment of larvae with different IGRs, as reported for *S. littoralis* by Diflubenzuron [73], Methoprene and Fenoxycarb [107], Lufenuron [108], Novaluron [43], Cyromazine [79]; *P. demoleus* by Diofenolan [80]; *S. litura* by Chlorfluazuron [84]; *A. aegypti* [109] and *C. pipiens* [110,111] by Novaluron; *C. pipiens* by Kinoprene [85] and *A. ipsilon* by Methoprene and Flufenoxuron [86]; *Plutella xylostella* by Pyriproxyfen [112]; *G. pyloalis* by Lufenuron [91]; *C. pipiens* by Methoxyfenozide [89]; *Corcyra cephalonica* by Fenoxycarb [67]; *etc*. Also, the development of some insects was retarded after treatment of eggs with different IGRs, as reported for *S. littoralis* after treatment of 1- and 3-day old egg masses with LC_{50} of the sesame oil [69] and for *P. gossypiella* after treatment of 1-, 2- and 3-day old eggs with Hexaflumuron [52] as well as after treatment of 1-day old eggs with LC_{50} values of Lufenuron, Chlorfluazuron and Chromafenozide [5].

The retarded development of *P. gossypiella* were found in corroboration with those reported results, since treatment of 1-day old eggs with different concentrations of Noviflumuron and Novaluron, in the present study, resulted in an insignificantly or remarkably prolonged larval and pupal durations, in a dose-dependent course by Noviflumuron but in no certain trend by Novaluron. In a similar course, the developmental rate was slightly regressed. In addition, the present results are in accordance with those reported results of retarded development of the same lepidopterous insect after treatment of newly hatched larvae with Hexaflumuron [113]; Diflubenzuron and Chlorfluazuron [114]; Buprofezin [115]; Teflubenzuron [116]; and Chromafenozide and Diflubenzuron [117]; Lufenuron and Pyriproxyfen [23] and Novaluron [45].

In the current study, retarded development of *P. gossypiella* by egg treatments with Noviflumuron and Novaluron (as expressed in prolonged larval and pupal durations) may be attributed to the indirect interference of these CSIs with neuroendocrine organs responsible for the synthesis and release of tropic hormones, like prothoracicotropic hormone (PTTH) [118]. Also, the tested CSIs may affect the tissues and cells undergoing mitosis [119] or exhibit a delaying effect on the ecdysis and transformation [100]. In particular, the final step of chitin biosynthesis pathway was inhibited by the present CSIs and the precursor was

not converted into chitin leading to a prolongation of larval life [111].

Disrupted metamorphosis of *P. gossypiella* by CSIs

Depending on the available literature, the major symptoms and features of the impaired metamorphosis of an insect after treatment with various IGRs (including CSIs) had been described as reduction of pupation and adult emergence, production of larval-pupal and/or pupal-adult intermediates, deformed larvae and/or pupae and the production of supernumerary larval instars (superlarvae). However, all or some of these disrupted features were recorded in various insects by some IGRs, such as *Chrysoperla rufilabris* by Fenoxycarb [120]; *H. armigera* [121], *Phlebotomus papatasi* [122], *A. aegypti* [123], *M. domestica* and *Stomoxys calcitrans* [124] by Novaluron; *S. littoralis* by Chlorfluazuron [125], Triflumuron [75], Lufenuron [76], Flufenoxuron [75], Methoprene and Fenoxycarb [107], Novaluron [43] and Cyromazine [79]; *T. castaneum* [126], *Liriomyza trifolii* [127] and *Callosobruchus maculates* [128] by Cyromazine; *Rhynchophorus ferrugineus* [129] and *P. demoleus* [80] by Diofenolan; *Lobesia botrana* by Lufenuron [130]; *C. pipiens* by Kinoprene [85]; *etc*.

In the present study, our results disagree with the previously reported results, because Noviflumuron and Novaluron could not affect the metamorphosis or morphogenesis of *P. gossypiella* after treatment of 1-day old eggs, *viz*. no deformed larvae, deformed pupae, larval-pupal or pupal-adult intermediates had been produced. The inconsistency of the present results with those reported results may be due to the feeble potency of tested CSIs, different responsiveness of our experimental insect, stage under treatment or other factors. Moreover, few authors reported various disruptive effects of other CSIs on metamorphosis and/or morphogenesis of the same lepidopterous insect after treatment of eggs of different ages with Hexaflumuron [52] or Lufenuron, Chlorfluazuron and Chromafenozide [5].

However, it is important to point out that treatment of 1-day old eggs of *P. gossypiella*, in the current investigation, with Noviflumuron led to a slight reduction of pupation but it was conspicuously hindered after treatment with Novaluron, in a dose-dependent manner. These results are, to a great extent, consistent with those reported results of reduced pupation rate of some insects by various IGRs, such as *P. xylostella* by Hexaflumuron [131]; *S. littoralis* by Novaluron [43] and Cyromazine [79]; *G. pyloalis* by Lufenuron [91] and Fenoxycarb [93]; *Encarsia formosa* by Pyriproxyfen and Fenoxycarb [132]; *etc*. To understand the hindered pupation process of *P. gossypiella*, after treatment of 1-day old eggs with Noviflumuron and Novaluron in the present study, these compounds may interfere with the hormonal regulation of the pupation program by prohibiting the ecdysteroid synthesis or release [133]. Also, these CSIs might block such program *via* the disturbance of chitin synthase which is necessary for the pupal cuticle formation [134].

CONCLUSION

Although Noviflumuron and Novaluron failed to affect the survival of pupae and adults of *P gossypiella*, they exhibited high toxicities on eggs and larvae as well as retarded development and blocked pupation had been recorded after treatment of 1-day old eggs. From the practical point of view, these compounds appeared to be effective for controlling this pest which has developed resistance against the majority of conventional pesticides.

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REFERENCES

1. Patil SB. Studies on the Management of Cotton Pink Bollworm Pectinophora Gossypiella (saunders)(Lepideptera: Gelechiidae). University of Agricultural Sciences; 2003.
2. Lykouressis D, Perdikis D, Samartzis D, Fantinou A, Toutouzas S. Management of the pink bollworm Pectinophora gossypiella (Saunders)(Lepidoptera: Gelechiidae) by mating disruption in cotton fields. Crop protection. 2005 Feb 28; 24(2):177-83.
3. Abbas G, Farhan M, Haq I, Ghouse G. Accelerating Infestation Of Pink Bollworm Pectinophora Gossypiella (Saunders)(Lepidoptera: Gelechiidae) On Bt–Varieties Of Cotton In Pakistan.
4. El-Aswad AF, Aly MI. Screening of some insecticides against the cotton bollworms, *Pectinophora gossypiella* (Saund.) and *Earias insulana* (Boisd). J. Pest Cont. Environ. Sci., 2007; 15(2): 63-74.
5. Kandil MA, Ahmed AF, Moustafa HZ. Toxicological and biochemical studies of lufenuron, chlorfluazuron and chromafenozide against Pectinophora gossypiella (Saunders). Egypt. Acad. J. Biolog. Sci. 2012; 4(1):37-47.
6. Fabrick JA, Tabashnik BE. Similar genetic basis of resistance to Bt toxin Cry1Ac in boll-selected and diet-selected strains of pink bollworm. PLoS One. 2012 Apr 18; 7(4):e35658.
7. Akhtar ZR, Arif MJ, Mansoor-ul-Hassan BS, Irshad U, Majid M, Gong Y. Resistance Evaluation In Pink Bollworm Against Transgenic Cotton Under Laboratory And Field Conditions In Pakistan.

8. Abd-Elhady HK, El-Aal AA. Insecticides resistance detection in fieldcollected populations of Pectinophora gossypiella (Saunders). American J. Biochem. Molec. Biol. 2011; 1:337-48.
9. Miles M, Lysandrou M. Evidence for negative cross resistance to insecticides in field collected Spodoptera littoralis (Boisd.) from Lebanon in laboratory bioassays. Mededelingen (Rijksuniversiteit te Gent. Fakulteit van de Landbouwkundige en Toegepaste Biologische Wetenschappen). 2001 Dec; 67(3):665-9.
10. Abo El-Ghar GE, Elbermawy ZA, Yousef AG, Abd-Elhady HK. 2005. Monitoring and characterization of insecticide resistance in the cotton leafworm, *Spodoptera littoralis* (Boisd.) (Lepidoptera: Noctuidae). J. Asia-Pacific Entomol., 8(4); 397-410.
11. Aydin H, Gürkan MO. The efficacy of spinosad on different strains of Spodoptera littoralis (Boisduval)(Lepidoptera: Noctuidae). Turkish Journal of Biology. 2006 May 29; 30(1):5-9.
12. Davies TG, Field LM, Usherwood PN, Williamson MS. DDT, pyrethrins, pyrethroids and insect sodium channels. IUBMB life. 2007 Jan 1; 59(3):151-62.
13. Costa LG, Giordano G, Guizzetti M, Vitalone A. Neurotoxicity of pesticides: a brief review. Front Biosci. 2008 Jan 1; 13(4):1240-9.
14. Relyea RA. A cocktail of contaminants: how mixtures of pesticides at low concentrations affect aquatic communities. Oecologia. 2009 Mar 1; 159(2):363-76.
15. Mosallanejad H, Smagghe G. Biochemical mechanisms of methoxyfenozide resistance in the cotton leafworm Spodoptera littoralis. Pest management science. 2009 Jul 1; 65(7):732-6.
16. Derbalah AS, Khidr AA, Moustafa HZ, Taman A. Laboratory Evaluation of some Non-conventional Pest Control Agents against the Pink Bollworm Pectinophora gossypiella (Saunders). Egyptian Journal of Biological Pest Control. 2014 Jul 1; 24(2):363.
17. Dahi HF, El-Sayed YA, El-Barkey NM, Abd-El Aziz MF. Toxicological and biochemical studies of methylamine avermactin, a new type of bioinsecticide against the cotton leaf worm, Spodoptera littoralis (Biosd). Egypt. Acad. J. Biol. Sci. 2009; 2(1):103-16.
18. Hussain A. The effect of non-host plant volatiles on the reproductive behaviour of the Egyptian cotton leafworm, *Spodoptera littoralis*. M.Sc. Thesis Swedish Univ Agric Sci., 2012: 40.
19. Salama M, El-Baki Ma, El-Naggar Jb, El-Nagar Ey. Efficiency Of Some Insecticides Sequence On Cotton Bollworms And Histopathological Effects Of Some Biocides On Pink Bollworm Larvae.
20. Sabry KH, Abdel-Aziz NF. Resistance And Enzyme Assesment Of The Pink Bollworm, Pectinophora Gossypiella (Saunders) To Spinosad. Japs, Journal of Animal and Plant Sciences. 2013 Jan 1; 23(1):136-42.
21. Hoffmann KH, Lorenz MW. Recent advances in hormones in insect pest control. Phytoparasitica. 1998 Dec 1; 26(4):323-30.
22. Martins F, Silva IG. Avaliação da atividade inibidora do diflubenzuron na ecdise das larvas de Aedes aegypti (Linnaeus, 1762)(Diptera, Culicidae). Rev Soc Bras Med Trop. 2004:135-8.
23. Sabry KH, Abdou GY. Biochemical and toxic characterization of some insect growth regulators to the pink bollworm, Pectinophora gossypiella (Saunders). American-Eurasian Journal of Sustainable Agriculture. 2016 Jan 1; 10(1):8-15.
24. Tunaz H, Uygun N. Insect growth regulators for insect pest control. Turkish Journal of Agriculture and Forestry. 2004 Dec 29; 28(6):377-87.
25. Ameen A, Kaakeh W, Wang Ch, Bennett G. Laboratory and field efficacy of Noviflumuron formulations against the German cockroach. In: "Proceedings of 4th International Conference on Urban Pests" (Jones SC, Zhai J, Robinson WH. eds.). Pocahontas Press, Charleston, SC., 2002: 147–153.
26. Sheets J, Karr L. Kinetics of uptake, clearance, transfer, and metabolism of noviflumuron in termites (Reticulitermesflavipes). InThe Annual Meeting of the Entomological Society of America, San Diego, California 2001 Dec 9.
27. Karr LL, Sheets JJ, King JE, Dripps JE. Laboratory performance and pharmacokinetics of the benzoylphenylurea noviflumuron in eastern subterranean termites (Isoptera: Rhinotermitidae). Journal of economic entomology. 2004 Apr; 97(2):593-600.
28. Ameen A, Wang C, Kaakeh W, Bennett GW, King JE, Karr LL, Xie J. Residual activity and population effects of noviflumuron for German cockroach (Dictyoptera: Blattellidae) control. Journal of economic entomology. 2005; 98(3):899-905.
29. Smith MS, Karr LL, King JE, Kline WN, Sbragia RJ, Sheets JJ, Tolley M. Noviflumuron activity in household and structural insect pests. In: "Proceedings of 4th International Conference on Urban Pests" (Jones SC, Zhai J, Robinson WH. eds.). Pocahontas Press, Charleston, SC., 2002: 345-354.
30. Wang C, Bennett GW. Efficacy of noviflumuron gel bait for control of the German cockroach, Blattella germanica (Dictyoptera: Blattellidae)—laboratory studies. Pest management science. 2006 May 1; 62(5):434-9.
31. King JE. Ovicidal activity of noviflumuron when fed to adult German cockroaches (Dictyoptera: Blattellidae). Journal of economic entomology. 2005 Jun; 98(3):930-2.

32. Barazani A. Rimon, an IGR insecticide. Phytoparasitica. 2001; 29:59-60.
33. Ishaaya I, Horowitz AR. Novaluron (Rimon) a novel IGR: its biological activity and importance in IPM programs. Phytoparasitica. 2002; 30:203.
34. Ishaaya I, Horowitz AR, Tirry L, Barazani A. Novaluron (Rimon), a novel IGR--mechanism, selectivity and importance in IPM programs. Mededelingen (Rijksuniversiteit te Gent. Fakulteit van de Landbouwkundige en Toegepaste Biologische Wetenschappen). 2001 Dec; 67(3):617-26.
35. Ishaaya I, Horowitz AR, Tirry L, Barazani A. Novaluron (Rimon), a novel IGR--mechanism, selectivity and importance in IPM programs. Mededelingen (Rijksuniversiteit te Gent. Fakulteit van de Landbouwkundige en Toegepaste Biologische Wetenschappen). 2001 Dec; 67(3):617-26.
36. Malhat FM, Loutfy NM, Ahmed MT. Dissipation kinetics of novaluron in tomato, an arid ecosystem pilot study. Toxicological & Environmental Chemistry. 2014 Jan 2; 96(1):41-7.
37. Ishaaya I, Kontsedalov S, Horowitz AR. Novaluron (Rimon), a novel IGR: Potency and cross-resistance. Archives of insect biochemistry and physiology. 2003 Dec 1;54(4):157-64.
38. Kim KS, Chung BJ, Kim HK. DBI-3204: a new benzoylphenyl urea insecticide with a particular activity against whitefly. InThe BCPC Conference: Pests and diseases, Volume 1. Proceedings of an international conference held at the Brighton Hilton Metropole Hotel, Brighton, UK, 13-16 November 2000 2000 (pp. 41-46). British Crop Protection Council.
39. Christopher Cutler G, Scott-Dupree CD, Tolman JH, Ronald Harris C. Acute and sublethal toxicity of novaluron, a novel chitin synthesis inhibitor, to Leptinotarsa decemlineata (Coleoptera: Chrysomelidae). Pest management science. 2005 Nov 1; 61(11):1060-8.
40. Cutler GC, Tolman JH, Scott-Dupree CD, Harris CR. Resistance potential of Colorado potato beetle (Coleoptera: Chrysomelidae) to novaluron. Journal of economic entomology. 2005 Oct; 98(5):1685-93.
41. Cutler GC, Scott-Dupree CD, Tolman JH, Harris CR. Field efficacy of novaluron for control of Colorado potato beetle (Coleoptera: Chrysomelidae) on potato. Crop Protection. 2007 May 31; 26(5):760-7.
42. Alyokhin A, Guillemette R, Choban R. Stimulatory and suppressive effects of novaluron on the Colorado potato beetle reproduction. Journal of economic entomology. 2009 Nov 25; 102(6):2078-83.
43. Ghoneim K, Tanani M, Hamadah K, Basiouny A, Waheeb H. Bioefficacy of Novaluron, a chitin synthesis inhibitor, on survival and development of Spodoptera littoralis (Boisd.)(Lepidoptera: Noctuidae). Journal: Journal of Advances in Zoology. 2015; 1(1).
44. Hamadah KH, Tanani M, Ghoneim K, Basiouny A, Waheeb H. Effectiveness of Novaluron, chitin synthesis inhibitor, on the adult performance of Egyptian cotton leafworm, *Spodoptera littoralis* (Boisd.)(Lepidoptera: Noctuidae). Int. J. Res. Studies Zool., 2015; 1(2): 45-55.
45. Ghoneim K. Toxicity and Disruptive Impacts of Novaluron, A Chitin Synthesis Inhibitor, on Development and Metamorphosis of The Olive Leaf Moth Palpita unionalis. International Journal of Trend in Scientific Research and Development. 2017 May 16(International Journal of Trend in Scientific Research and Development).
46. Hassan HA, Ghoneim K, Tanani MA, Bakr NA. 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, 2017; 5(2): 581-592.
47. Tanani MA, Ghoneim K, Hassan HA, Bakr NA. Perturbation of main body metabolites in the pink bollworm *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae) by the chitin synthesis inhibitors Novaluron and Diofenolan. BioBull., 2017; 3(2): (In press).
48. Ghoneim K. Toxicity and Disruptive Impacts of Novaluron, A Chitin Synthesis Inhibitor, on Development and Metamorphosis of The Olive Leaf Moth Palpita unionalis. International Journal of Trend in Scientific Research and Development. 2017 May 16(International Journal of Trend in Scientific Research and Development).
49. Ghoneim K. Toxicity and Disruptive Impacts of Novaluron, A Chitin Synthesis Inhibitor, on Development and Metamorphosis of The Olive Leaf Moth Palpita unionalis. International Journal of Trend in Scientific Research and Development. 2017 May 16(International Journal of Trend in Scientific Research and Development).
50. Hanan SA, Samya ZS. Effects of certain insecticides on eggs of Spodoptera Littoralis. Egypt J. Agric. Res. 2014; 92:875-83.
51. ABD EL-HAFEZ A, Metwally AG, SALEH M. Rearing pink bollworm Pectinophora gossypiella (Saund.) on kidney bean diet in Egypt.(Lepidoptera-Gelechiidae). Res. Bull. Fac. of Agrie, Zagazig Univ., April. 1982.
52. Nehad M. Ovicidal Activity and Biological Effects of Radiant and Hexaflumuron against Eggs of Pink Bollworm, Pectinophora gossypiella (Saunders) (Lepidoptera: Gelechiidae) Nehad M. El-Barkey1; Amer AE 2 and Mervet A. Kandeel. 2.

53. Abbott WS. A method of computing the effectiveness of an insecticide. J. econ. Entomol. 1925 Apr 1; 18(2):265-7.
54. Finney DJ. Probit analysis. 3rd ed. Cambridge, England: Cambridge University Press, 1971: 318.
55. Dempster C. The population dynamic of Moroccan locust *Dociostarus murcocamus* in Cyprus. Anti-Locust Bull., 1957: 27.
56. Richards AG. Cumulative effects of optimum and suboptimum temperatures on insect development. Influence of temperatures on biological systems. American Physiological Society. 1957:57-65.
57. Jimenez-Peydro R, Gimeno-Martos C, Lopez-Ferrer J, Serrano-Delgado C, Moreno-Marí J. Effects of the insect growth regulator cyromazine on the fecundity, fertility and offspring development of Mediterranean fruit fly, Ceratitis capitata Wied.(Dipt., Tephritidae). Journal of Applied Entomology. 1995 Jan 12; 119(1-5):435-8.
58. Moroney MJ. Facts from figures (3rd ed.). Penguin Books Ltd., Harmondsworth. Middle Sex, 1956.
59. IORIATTI C, DELAITI M, DELAITI L. Studio dell'attività e della persistenza d'azione di alcuni regolatori di crescita degli insetti su Lobesia botrana (Den. et Schif.). Giornate fitopatologiche: Copanello (CZ), 21-24 aprile 1992: atti. 1992.
60. Venkateswari G, Krishnayya PV, Rao PA, Murthy KK. Bioefficacy of abamectin and emamectin benzoate against Spodoptera litura (Fab.). Pesticide Research Journal. 2008 Dec; 20(2):229-33.
61. Sáenz-de-Cabezón FJ, Pérez-Moreno I, Zalom FG, Marco V. Effects of lufenuron on Lobesia botrana (Lepidoptera: Tortricidae) egg, larval, and adult stages. Journal of economic entomology. 2006 Apr; 99(2):427-31.
62. Mahmoudvand M, Garjan AS, Abbasipour H. Ovicidal effect of some insecticides on the diamondback moth, Plutella xylostella (L.)(Lepidoptera: Yponomeutidae). Chilean Journal of Agricultural Research. 2011 Apr 1; 71(2):226.
63. Tiwari S, Clayson PJ, Kuhns EH, Stelinski LL. Effects of buprofezin and diflubenzuron on various developmental stages of Asian citrus psyllid, Diaphorina citri. Pest management science. 2012 Oct 1; 68(10):1405-12.
64. Hanan SA, Samya ZS. Effects of certain insecticides on eggs of Spodoptera Littoralis. Egypt J. Agric. Res. 2014; 92:875-83.
65. Tavares WS, Cruz I, Petacci F, Freitas SS, Serratilde JE, Zanuncio JC. Insecticide activity of piperine: Toxicity to eggs of Spodoptera frugiperda (Lepidoptera: Noctuidae) and Diatraea saccharalis (Lepidoptera: Pyralidae) and phytotoxicity on several vegetables. Journal of medicinal plants research. 2011 Oct 9; 5(21):5301-6.
66. Natikar PK, Balikai RA. Ovicidal action of newer insecticide molecules against the eggs of tobacco caterpillar, Spodoptera litura (Fabricius). J. Exp. Zool. 2015; 18(2):993-5.
67. Begum R, Qamar A. Fenoxycarb-a potent inhibitor of metamorphosis and reproduction in Rice Moth, Corcyra cephalonica (Stainton).
68. Ali A, Shah ZU, Saleem M, Hafeez F, Abbas M, Farooq M, Ghaffar A. Influence Of Weather Factors On The Trapped Population Of Spotted Bollworm (E. Vittella F And E. Insulana B) Under Bahawalpur Agroecosystem. Journal of Agricultural Research. 2016 Jul 1; 54(3).
69. Khedr MA. Ovicidal activity of Sesamum indicum (L.) oil against Spodoptera littoralis (Boisd.). Archives of Phytopathology and Plant Protection. 2016 Apr 2; 49(5-6):95-110.
70. Mead HM, El-Shafiey SN, Sabry HM. Chemical constituents and ovicidal effects of mahlab, Prunus mahaleb L. kernels oil on cotton leafworm, Spodoptera littoralis (Boisd.) eggs. Journal of Plant Protection Research. 2016 Jul 1; 56(3):279-90.
71. Nolting SP, Huckaba RM, Nead BA, Peterson LG, Porteous DJ, Borth PW. Insect control in cotton with tracer. Down to Earth. 1997; 52(1):21-7.
72. Marco V, Viñuela E. Effects of hexaflumuron on fecundity, fertility and longevity of Ephestia kuehniella Zeller and Spodoptera exigua (Hübner). Mededelingen-Faculteit Landbouwkundige en Toegepaste Biologische Wetenschappen Universiteit Gent (Belgium). 1994.
73. Aref SA, Bayoumi OC, Soliman HA. Effect of certain insecticides on the biotic potential of the cotton leafworm, Spodoptera littoralis (Boisd.). Egypt. J. Agric. Res. 2010; 88(1):31-40.
74. Bakr RF, El-Barky NM, Abd Elaziz MF, Awad MH, Abd El-Halim HM. Effect of Chitin synthesis inhibitors (flufenoxuron) on some biological and biochemical aspects of the cotton leaf worm Spodoptera littoralis Bosid.(Lepidoptera: Noctuidae). J. biolog. Sci. 2010; 2(2):43-56.
75. El-Naggar JB, Jehan BA. Sublethal effect of certain insecticides on biological and physiological aspects of Spodoptera littoralis (Boisd.). Nature and Science. 2013; 11(7):19-25.
76. Adel MM. Lufenuron impair the chitin synthesis and development of Spodoptera littoralis Bosid (Lepidoptera: Noctuidae). Journal of Applied Sciences Research, Jordan. 2012; 8(5):2766-75.
77. Bakr RF, Abd Elaziz MF, El-barky NM, Awad MH, Abd El-Halim HM. The Activity of Some Detoxification Enzymes in Spodoptera Littoralis (Boisd.) Larvae (Lepidoptera–Noctuidae) Treated With Two Different Insect Growth Regulators. Egypt. Acad. J. Biolog. Sci. 2013; 5(2):19-27.
78. Ragaei M, Sabry KH. Impact of spinosad and buprofezin alone and in combination against the cotton leafworm, Spodoptera littoralis under laboratory conditions. Journal of Biopesticides. 2011 Dec 1; 4(2):156-60.

79. Ghoneim K, Tanani M, Hamadah K, Basiouny A, Waheeb H. Bioefficacy of Novaluron, a chitin synthesis inhibitor, on survival and development of Spodoptera littoralis (Boisd.)(Lepidoptera: Noctuidae). Journal: Journal of Advances in Zoology. 2015; 1(1).
80. Singh S, Kumar K. Diofenolan: a novel insect growth regulator in common citrus butterfly, Papilio demoleus. Phytoparasitica. 2011 Jul 1; 39(3):205-13.
81. Mojaver M, Bandani AR. Effects of the insect growth regulator pyriproxyfen on immature stages of sunn pest, Eurygaster integriceps Puton (Heteroptera: Scutelleridae). Munis Entomol Zool. 2010; 5(1):187-97.
82. Khan I, Qamar A. Biological activity of andalin (flucycloxuron), a novel chitin synthesis inhibitor, on red cotton stainer Dysdercus koenigii (Fabricius). Biol. Med. 2011; 3:324-35.
83. Kamminga KL, Kuhar TP, Wimer A, Herbert DA. Effects of the insect growth regulators novaluron and diflubenzuron on the brown marmorated stink bug. Plant Health Prog. Doi. 2012; 10.
84. Perveen F. Biochemical analyses of action of chlorfluazuron as reproductive inhibitor in *Spodoptera litura*. Adv. Integ. Pest Manage, 2012; 293-326.
85. Hamaidia K, Soltani N. Laboratory evaluation of a biorational insecticide, kinoprene, against Culex pipiens larvae: Effects on growth and development. Annu. Res. Rev. Biol. 2014 Jul 15;4:2263-73.
86. Khatter NA. Effect of two insect growth regulators on the development of *Agrotis ipsilon* Hufn. (Lepidoptera: Noctuidae). J Harmonized Res. App. Sci., 2014; 2(1): 20-28.
87. Gado P, Salokhe SG, Deshpande SG. Impact of Lufenuron (5.4% EC) on reproductive end points of Tribolium castaneum. World J. Pharmaceut. Res. 2015; 4(3):1593-9.
88. Resmitha C, Meethal KV. Toxicity of Insect Growth Regulator, Pyriproxyfen, on larvae of Spodoptera mauritia Boisd (Lepidoptera: Noctuidae). Int. J. Agric. Innov. Res. 2016; 5(1):173-6.
89. Hamaidia K, Soltani N. Ovicidal activity of an insect growth disruptor (methoxyfenozide) against Culex pipiens L. and delayed effect on development.
90. Tazir A, Kirane-Amrani L, Soltani N. Impact of two bisacylhydrazines on development of Ephestia kuehniella Zeller, 1879 (Lepidoptera: Pyralidae) with respect to cuticular thickness and protein.
91. Piri Aliabadi F, Sahragard A, Ghadamyari M. Lethal and sublethal effects of a chitin synthesis inhibitor, lufenuron, against Glyphodes pyloalis Walker (Lepidoptera: Pyralidae). Journal of Crop Protection. 2016 Jul 1; 5(2):203-14.
92. Vivan LM, Torres JB, Fernandes PL. Activity of Selected Formulated Biorational and Synthetic Insecticides against Larvae of Helicoverpa armigera (Lepidoptera: Noctuidae). Journal of Economic Entomology. 2016 Dec 8:tow244.
93. Singh A, Tiwari SK. Role of Fenoxycarb, a juvenile hormone analogue, on the developmental stages of rice-moth, *Corcyra cephalonica* Staint. (Lepidoptera: Pyralidae). Int. J. Zool. Investig., 2016; 2(2): 267-280.
94. Ghoneim K. Toxicity and Disruptive Impacts of Novaluron, A Chitin Synthesis Inhibitor, on Development and Metamorphosis of The Olive Leaf Moth Palpita unionalis. International Journal of Trend in Scientific Research and Development. 2017 May 16(International Journal of Trend in Scientific Research and Development).
95. Rust MK, Hemsarth WL. Intrinsic Activity of IGRs against Larval Cat Fleas. Journal of medical entomology. 2017 Mar 1; 54(2):418-21.
96. Khan GZ, Khan I, Khan IA, Salman M, Ullah K. Evaluation of different formulations of IGRs against Aedes albopictus and Culex quinquefasciatus (Diptera: Culicidae). Asian Pacific Journal of Tropical Biomedicine. 2016 Jun 30; 6(6):485-91.
97. Donahue Jr WA, Showler AT, Donahue MW, Vinson BE, Osbrink WL. Lethal Effects of the Insect Growth Regulator Cyromazine against Three Species of Filth Flies, Musca domestica, Stomoxys calcitrans, and Fannia canicularis (Diptera: Muscidae) in Cattle, Swine, and Chicken Manure. Journal of Economic Entomology. 2017 Jan 25; 110(2):776-82.
98. Abdel Rahman SM, Hegazy EM, Elwey AE. Direct and latent effects of two chitin synthesis inhibitors to Spodoptera littoralis larvae (Boisd), American-Eurasian J. Agric. & Environ. Sci. 2007; 2:457-642.
99. Zorzetti J, Constanski K, Santoro PH, Fonseca IC, Neves PM. Growth regulator insecticides for the control of the lesser mealworm beetle Alphitobius diaperinus (Coleoptera: Tenebrionidae). Revista Colombiana de Entomología. 2015 Jun; 41(1):24-32.
100. Linton YM, Nisbet AJ, Mordue AJ. The effects of azadirachtin on the testes of the desert locust, Schistocerca gregaria (Forskål). Journal of Insect Physiology. 1997 Oct 31; 43(11):1077-84.
101. Ghoneim KS, Mohamed HA, Bream AS. Efficacy of the neem seed extract, neemazal, on growth and development of the Egyptian cotton leafworm, Spodoptera littoralis Boisd (Lepidoptera: Noctuidae). Journal-Egyptian German Society Of Zoology. 2000; 33(E):161-80.
102. Sharma SC, Pathania A. Susceptibility of tobacco caterpillar, Spodoptera litura (Fabricius) to some

insecticides and biopesticides. Indian J Sci Res Technol. 2014; 2:24-30.
103. Taleh M, Pourabad RF, Geranmaye J, Ebadollahi A. Toxicity of Hexaflumuron as an insect growth regulator (IGR) against Helicoverpa armigera Hubner (Lepidoptera: Noctuidae).
104. El-Shennawy AMR. Evaluation of some pesticides against pink bollworm *Pectinophora gossypiella* (Saunders). M.Sc. Thesis, Faculty of Science, Al-Azhar University, Egypt, 2009: 166.
105. Amer RA, EL–SISI AG. Insecticidal Activity Of Locally Formulated Tar Oil As Soluble Liquid On The Pink Bollworm, Pectinophora Gossypiella (Saunders). Egyptian Journal of Agricultural Research. 2011.
106. Salem MS, Adly AM, Ahmed AF. Effect of two insecticides on eggs and larvae of pink bollworm, Pectinophora gossypiella (Saunders)(Lepidoptera: Gelechiidae).
107. Hussein KT. Toxicity and some aspects of the action of Igr's and botanical essential oils on the cotton leafworm Spodoptera littoralis (Boisd.)(Lepidoptera-Noctuidae). Journal-Egyptian German Society Of Zoology. 2000; 33(E):81-92.
108. Gaaboub I, Halawa S, Rabiha A. Toxicity and biological effects of some insecticides, IGRs and Jojoba oil on cotton leafworm Spodoptera littoralis (Boisd.). J. App. Sci. Res. 2012; 8(10):51-61.
109. Farnesi LC, Brito JM, Linss JG, Pelajo-Machado M, Valle D, Rezende GL. Physiological and morphological aspects of Aedes aegypti developing larvae: effects of the chitin synthesis inhibitor novaluron. PLoS One. 2012 Jan 24; 7(1):e30363.
110. NourElhouda D, Hamid B, Ali B, Noureddine S. Biological effects of a benzoylphenylurea derivative (Novaluron) on larvae of Culex pipiens (Diptera: Culicidae).
111. Djeghader NE, Aïssaoui L, Amira K, Boudjelida H. Impact of a chitin synthesis inhibitor, Novaluron, on the development and the reproductive performance of mosquito Culex pipiens. World Applied Science Journal. 2014; 29(7):954-60.
112. Mahmoudvand M, Moharramipour S, Iranshahi M. Effects of pyriproxyfen on life table indices of Plutella xylostella in multigenerations. Psyche: A Journal of Entomology. 2015 Oct 28; 2015.
113. Moawad GM, Khedr AA. The influence of juvenile hormone on the pink bollworm Pectinophora gossypiella (Saund)[Egypt]. Agricultural Research Review. 1982.
114. Kandil MA, El-Zaher TR, Rashad AM. Some biological and biochemical effects of chitin synthesis inhibitors on pink bollworm Pectinophora gossypiella (Saunders). Ann. of Agric. Sci. Moshtohor. 2005; 43(4):1991-2002.
115. Sabry AK. Effect of some pesticides with different target sites on the pink bollworm, Pectinophora gossypiella (Saunders). Archives of Phytopathology and Plant Protection. 2013 May 1; 46(8):942-51.
116. El-Khayat EF, Amira MR, Abd-El Zaher TR, El-Din AM, Salim HS. Toxicoloical and Biological Studies of Some Pesticidal Formulations against Pectinophora gossypiella (Saunders) (Lepidoptera: Gelechiidae).
117. Salem MSM. Latent effect of different compounds on *Pectinophora gossypiella* (Saunders). J. Plant Protec. Path. (Mansoura Univ. Egypt), 2015; 6(2): 269-279.
118. Subrahmanyam B, Müller T, Rembold H. Inhibition of turnover of neurosecretion by azadirachtin in Locusta migratoria. Journal of insect Physiology. 1989 Jan 1; 35(6):493499-7500.
119. Nasiruddin M. The protection of barley seedlings from attack by Schistocerca gregaria using azadirachtin and related analogues. Entomologia experimentalis et applicata. 1994 Mar 1; 70(3):247-52.
120. Liu TX, Chen TY. Effects of the insect growth regulator fenoxycarb on immature Chrysoperla rufilabris (Neuroptera: Chrysopidae). Florida Entomologist. 2001 Dec 1:628-33.
121. Murthy KS, Ram GM. Studies on the efficacy of a new chitin synthesis inhibitor Rimon (novaluron 10 EC) on American bollworm Helicoverpa armigera Hubn. attacking cotton. Resources management in plant protection during twenty first century. 2002 Nov 15; 2:165-8.
122. Mascari TM, Mitchell MA, Rowton ED, Foil LD. Evaluation of novaluron as a feed-through insecticide for control of immature sand flies (Diptera: Psychodidae). Journal of medical entomology. 2007 Jul; 44(4):714-7.
123. Nwankwo EN, Okonkwo NJ, Ozumba NA, Okafor EG. Comparative Studies on the Larvicidal Action of Novaluron (Mosquiron® 100EC) and Moringa Oliefera (LAM) Seed Oil against Aedes Aegypti (Diptera: Culicidae) Larvae. African Research Review. 2011; 5(1).
124. Lohmeyer KH, Pound JM, Yeater KM, May MA. Efficacy of novaluron as a feed-through for control of immature horn flies, house flies, and stable flies (Diptera: Muscidae) developing in cow manure. Journal of medical entomology. 2014 Jul 1; 51(4):873-7.
125. Sammour EA, Kandil MA, Abdel-Aziz WF. The reproductive potential and fate of chlorfluazuron and leufenuron against cotton Leafworm. Spodoptera littoralis. 2008:62-7.
126. Kamaruzzaman AH, Reza AM, Mondal KA, Parween S. Morphological abnormalities in Tribolium castaneum (Herbst) and Tribolium confusum Duval due to cyromazine and pirimiphos-methyl treatments alone or in combination. ISJ. 2006; 3:97-102.

127. Saryazdi AG, Hejazi JM, Saber M. Residual toxicity of abamectin, chlorpyrifos, cyromazine, indoxacarb and spinosad on Liriomyza trifolii (Burgess)(Diptera: Agromyzidae) in greenhouse conditions. Pesticidi i fitomedicina. 2012; 27(2):107-16.
128. Al-Mekhlafi FA, Mashaly AM, Wadaan MA, Al-Mallah NM. Effect of different applicable conditions of the insect growth regulator (Cyromazine) on the Southern cowpea weevils, Callosobruchus maculatus Reared on Peas. Pakistan J. Zool. 2012 Apr 30; 44(2):481-8.
129. Tanani MM. Study on the effects of certain IGRs and plant extracts on some physiological aspects of the red palm weevile Rhyncophorus ferrugineus (Curculionidae: Coleoptera). Unpublished M. Sc. Thesis, Fac. Sci., Al-Azhar Univ., Cairo, Egypt. 2001.
130. Sáenz-de-Cabezón Irigaray FJ, Marco V, Zalom FG, Pérez-Moreno I. Effects of methoxyfenozide on Lobesia botrana Den & Schiff (Lepidoptera: Tortricidae) egg, larval and adult stages. Pest management science. 2005 Nov 1; 61(11):1133-7.
131. Mahmoudvand M, Abbasipour H, Garjan AS, Bandani AR. Decrease in pupation and adult emergence of Plutella xylostella (L.) treated with hexaflumuron. Chilean Journal of agricultural research. 2012 Apr 1; 72(2):206.
132. Wang QL, Liu TX. Effects of Three Insect Growth Regulators on Encarsia Formosa (Hymenoptera: Aphelinidae), an Endoparasitoid of Bemisia tabaci (Hemiptera: Aleyrodidae). Journal of Economic Entomology. 2016 Dec 1; 109(6):2290-7.
133. Al-Sharook Z, Balan K, Jiang Y, Rembold H. Insect growth inhibitors from two tropical Meliaceae: effect of crude seed extracts on mosquito larvae1. Journal of applied Entomology. 1991 Jan 12; 111(1-5):425-30.
134. Mayer RT, Chen AC, DeLoach JR. Characterization of a chitin synthase from the stable fly, Stomoxys calcitrans (L.). Insect Biochemistry. 1980 Jan 1; 10(5):549-56.