Efficiency of the chitin synthesis inhibitor lufenuron (cga-184699) on growth, development and morphogenesis of *Schistocerca gregaria* (orthoptera: acrididae).

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**ABSTRACT**

This paper deals with the objective of investigating the effects of Lufenuron (CGA-184699) on the growth, development and morphogenesis of the desert locust *Schistocerca gregaria*. Five concentration levels (1000, 500, 250, 125 and 62.5 ppm) were given through the fresh plant food to the newly moulted (4ᵗʰ or 5ᵗʰ) instar or late-aged 5ᵗʰ instar nymphs. All results were obtained 24 h after feeding.

The growth of Lufenuron-treated nymphs was profoundly inhibited because their weight gain was drastically reduced. Such reducing action of Lufenuron was dose-dependent after treatment of 4ᵗʰ instar nymphs but at the higher two concentration levels after treatment of newly moulted 5ᵗʰ instar nymphs and at the higher three concentration levels after treatment of late-aged 5ᵗʰ instar nymphs. After treatment of the last instar nymphs, early or late-aged, the developmental rate detrimentally regressed as a response to the prohibiting action of Lufenuron on the development. In contrast, such rate was promoted during significantly shortened duration after treatment of 4ᵗʰ instar nymphs, may be to accelerate the development for avoiding additional adverse effects of Lufenuron.

Lufenuron exhibited an inhibitory effect on the adult emergence after treatment of last instar nymphs, regardless of the timing of treatment. On the other hand, Lufenuron exerted no effect on this vital process after treatment of 4ᵗʰ instar nymphs. Moreover, the present compound, at certain concentration levels, induced the adults to emerge in a rate more than that on control congeners. However, the emerged adults suffered a morphogenic action of Lufenuron because different deformed females were produced in increasing % as, at least, the higher three concentration levels were increased. In addition, the adult females spent only shortened longevity and then died. The shortening effect was dose-dependent after treatment of 4ᵗʰ instar nymphs.

**Kew Words**: *Schistocerca gregaria*, Lufenuron, growth, development, emergence, morphogenesis, longevity.

**INTRODUCTION**

Because the use of insecticides for controlling insect pests has several disadvantages to various environmental aspects, including human health and economics, numerous institutions have extensively searched alternatives such as insect growth regulators (IGRs) including juvenile hormone analogues (JHAs), chitin synthesis inhibitors (CSIs) and ecdysteroids (for reviews, see: Post and Vincent, 1973; Slama, 1974; Staal, 1975; El-Ibrashy, 1984; Hoffman and Lorenz, 1998; Tunaz and Uygun, 2004). Retnakaran *et al.* (1985) identified benzyolphenyl ureas (BPUs), JHAs (or juvenoids), antijuvenoids and miscellaneous IGRs as 4 distinct classes of growth
regulators. The BPUs have been subjected to intensive investigations because of their commercial importance and their interference with the moulting and other physiological processes (Soltani et al., 1993; Casida and Quistad, 1998; Ghoneim et al., 2006). The present investigation deals with various growth and developmental impacts of the CSI, Lufenuron (CGA-184699) on the desert locust *Schistocerca gregaria*.

**MATERIALS AND METHODS**

**Experimental Insect:**

A gregarious stock culture of *Schistocerca gregaria* (Forsk.) was raised by a sample from the established culture of Locust and Grasshopper Res. Division, Agric. Res. Center, Giza, Egypt. The insects were reared under crowded breeding conditions outlined by Hunter-Jones (1961) and Hassanein (1965). Newly hatched hoppers were kept in wooden cages with wire-gauze sides (40x40x60 cm) and small door in the upperside to allow the daily feeding and cleaning routine. The bottom was covered with 20 cm layer of sterilized sand. Each cages was equipped internally with 60 W electric bulb for lightening (17:7 LD) and warming (32±2 C.). The relative humidity varied from 70-80% following the introduction of fresh food plant to 60-70% several hours later. Successive generations were raised before obtaining the nymphs for the present experimental work. Fresh food plant was clover *Medicago sativa* along the period of study except few weeks every year because of the absence of this plant species. During these weeks, insects were fed on *Sesbania egyptiaca*. All experiments were conducted with *M. sativa* only.

**Lufenuron Preparation and Administration:**

Five concentration levels of the chitin biosynthesis inhibitor Lufenuron were prepared using the distilled water: 1000, 500, 250, 125 and 62.5 ppm. A technical concentrate 10% of Lufenuron (Match, CGA-184699) was used. Its chemical formula is: N-{{{ 2,5-dichloro-4-(1,1,2,3,3-hexafluoro-propoxyl)-phenyl} amino}-2,6-difluorobenzamide (CA)}}}. The concentration range was chosen depending on some preliminary trials carried out on the present insect species. Feeding technique was applied using fresh clean clover leaves (*M. sativa*) after dipping for 3 minutes in each concentration level. Feeding on treated food plant was allowed for 24 h for the newly moulted penultimate (4th) instar, newly moulted last (5th) instar or late-aged (5-day old) last instar nymphs. Control insects had been allowed to feed on untreated food plant and kept under the same laboratory conditions. Three replicates (10 nymphs/rep.) were carried out for each treatment. Each individual nymph was kept in a suitable glass vial provided with a thin layer of sterilized sand. The vials were carefully located in a cage supported with a suitable electric bulb for lightening and warming.

**Criteria Studied and Calculations:**

Growth, development, metamorphosis and morphogenesis were determined as detailed herein. The fresh body weight was recorded every day using an electric digital balance. The weight gain was calculated as follows: initial weight (before the beginning of experiment) – final weight (at the end of experiment). The growth inhibition was calculated as follows: \{a- A/A\}x 100, where: a: maximal weight of treated nymphs, A: maximal weight of control nymphs. The developmental duration of nymphal instars, treated or control, was estimated using Dempster' equation (1957). The developmental rate was calculated according to the equation: Developmental rate = 100/mean duration (in days). The adult emergence was estimated in %
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whatever the morphogenesis was perfect or defected. All morphogenic aberrations were counted, calculated in % and recorded in photographic plates. The adult longevity comprised all adult physiological phases: maturation period, reproductive lifetime and post-oviposition period. It was calculated in mean days ±SD.

Statistical Analysis:
Data obtained were analyzed using the Student t-distribution and were refined by Bessel's correction (Moroney, 1969) for testing the significance of difference between means.

RESULTS
Treatments of the newly moulted penultimate instar nymphs:

a) Growth and Developmental Effects of Lufenuron:

Assorted data in Table (1) obviously show the enormous action of Lufenuron on growth and development of S. gregaria. The nymphal growth was prohibited since the weight gain pronouncedly decreased as the concentration level (concentration level) was increased. For some details, while nymphs gained 0.281±0.113 g (not significant) at the lowest concentration level, the reduction of their weight gain increased until 0.120±0.01 g (p< 0.001) at the highest concentration level. Another parameter may be informative, because the somatic growth change% of control nymphs was recorded as 83.80±9.68% vs 76.70±12.15 and 25.14±12.14% at 62.5 and 1000 ppm, respectively. In addition, the highest growth inhibition% (35.82%) was calculated after treatment with the highest concentration level of Lufenuron.

The developmental rate, on the other hand, was undergone to the action of Lufenuron, but in a reverse correlation. As for example, it was 11.76 at 62.5 ppm and 14.49 at 1000 ppm (vs 10.52 of control congeners). Depending on these data, Lufenuron promoted the nymphal rate of development through shortened time intervals (e.g., 6.90±1.03 days at 1000 ppm, vs 9.50±1.15 days of control congeners).

Table (1): Growth and developmental effects of Lufenuron on Schistocerca gregaria after treatment of the newly moulted penultimate instar nymphs.

<table>
<thead>
<tr>
<th>Conc. (ppm)</th>
<th>Mean weight (g ± S.D.)</th>
<th>Weight gain (g ± S.D.)</th>
<th>Change (%)</th>
<th>Growth inhibition (%)</th>
<th>Duration (days ± S.D.)</th>
<th>Develop. Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000.0</td>
<td>0.430 ± 0.091 d</td>
<td>0.120 ± 0.010 d</td>
<td>25.14 ± 12.14 d</td>
<td>35.82 %</td>
<td>6.90 ± 1.03 d</td>
<td>14.49</td>
</tr>
<tr>
<td>500.0</td>
<td>0.437 ± 0.089 d</td>
<td>0.183 ± 0.034 d</td>
<td>38.94 ± 18.16 d</td>
<td>76.70 %</td>
<td>7.00 ± 1.41 d</td>
<td>14.85</td>
</tr>
<tr>
<td>250.0</td>
<td>0.457 ± 0.173 c</td>
<td>0.216 ± 0.075 b</td>
<td>46.59 ± 24.30 c</td>
<td>25.14 %</td>
<td>7.00 ± 2.05 b</td>
<td>14.85</td>
</tr>
<tr>
<td>125.0</td>
<td>0.495 ± 0.183 b</td>
<td>0.258 ± 0.112 a</td>
<td>57.05 ± 25.06 b</td>
<td>21.34 %</td>
<td>8.10 ± 2.76 a</td>
<td>12.34</td>
</tr>
<tr>
<td>062.5</td>
<td>0.606 ± 0.127 a</td>
<td>0.281 ± 0.113 a</td>
<td>76.70 ± 12.15 a</td>
<td>9.55 %</td>
<td>8.50 ± 2.17 a</td>
<td>11.76</td>
</tr>
<tr>
<td>Control</td>
<td>0.670 ± 0.053</td>
<td>0.375 ± 0.105</td>
<td>83.80 ± 9.68</td>
<td>0.00 %</td>
<td>9.50 ± 1.15</td>
<td>10.52</td>
</tr>
</tbody>
</table>

Conc. (ppm): concentration (part per million), Mean ± S. D. followed with same letter (a) are not significantly (p>0.05), (b): significantly different (p<0.05), (c): highly significantly different (p<0.01), (d): very highly significantly (p<0.001). Develop. Rate: Developmental rate.

b) Metamorphosing and Morphogenic Effects of Lufenuron:

Just a look at the data of Table (2), the eclosion of treated adults had astonishingly exceeded that of control congeners. This metamorphosing event was unexpectedly promoted by Lufenuron and increased by increasing concentration level. Whatever, several grades of affected morphogenesis were recorded. The %s of
malformed adults increased as the conc. level was ascended, especially the higher three ones (14.2, 28.5 & 40.0% at 250, 500 % 1000 ppm, respectively). Various symptoms or shapes of deformation are shown in Plate (1), such as: incomplete eclosion with twisted legs and curled wings. It is easy to say all these adult derangements might be due to the morphogenic action of Lufenuron (for more details, see Table 2).

Table (2): Adult performance as affected by Lufenuron after treatment of the newly moulted penultimate instar nymphs of Schistocerca gregaria.

Not only the adult morphogenesis and metamorphosis but also the adult longevity was pronouncedly affected by Lufenuron. Those successfully emerged adults lasted short longevity and then died. Generally, longevity was found in a reverse correlation with the concentration level of Lufenuron.

Treatments of the newly moulted last instar nymphs:

a) Growth and Developmental Effects of Lufenuron:

By the careful examination of the data given in Table (3), it can be concluded that Lufenuron considerably affected the nymphal growth and development. The nymphal weight gain was reversely correlated to the conc. level. It was deduced as 0.515±0.263 and 0.497±0.138 g at the two lower concentration levels, while as 0.362±0.131 and 0.128±0.102 g at the two higher concentration levels.

The change% supported the previously mentioned finding (78.86±18.7 and 38.56±15.36 % at 62.5 and 1000 ppm, respectively, vs 85.71±16.46 % of control congeners). In addition, the highest growth inhibition was found as 23.39 % at the highest concentration level of Lufenuron.

Table (3): Growth and developmental effects of Lufenuron on Schistocerca gregaria after treatment of the newly moulted last instar nymphs.

<table>
<thead>
<tr>
<th>Conc. (ppm)</th>
<th>Mean weight (g ± S.D.)</th>
<th>Weight gain (g ± S.D.)</th>
<th>Change (%)</th>
<th>Growth inhibition (%)</th>
<th>Duration (days ± S.D.)</th>
<th>Develop. Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000.0</td>
<td>0.881 ± 0.203 b</td>
<td>0.128 ± 0.102 d</td>
<td>38.56 ± 15.36 d</td>
<td>23.39</td>
<td>07.8 ± 1.95 d</td>
<td>12.82</td>
</tr>
<tr>
<td>500.0</td>
<td>0.885 ± 0.216 a</td>
<td>0.362 ± 0.131 c</td>
<td>56.41 ± 11.14 d</td>
<td>23.04</td>
<td>08.5 ± 1.95 c</td>
<td>11.76</td>
</tr>
<tr>
<td>250.0</td>
<td>0.876 ± 0.325 a</td>
<td>0.488 ± 0.116 a</td>
<td>68.15 ± 23.25 a</td>
<td>22.08</td>
<td>08.9 ± 2.46 a</td>
<td>11.23</td>
</tr>
<tr>
<td>125.0</td>
<td>0.943 ± 0.322 a</td>
<td>0.497 ± 0.138 a</td>
<td>75.71 ± 23.01 a</td>
<td>18.12</td>
<td>09.3 ± 2.58 a</td>
<td>10.75</td>
</tr>
<tr>
<td>062.5</td>
<td>0.968 ± 0.337 a</td>
<td>0.515 ± 0.263 a</td>
<td>78.86 ± 18.76 a</td>
<td>15.82</td>
<td>10.1 ± 1.10 a</td>
<td>09.90</td>
</tr>
<tr>
<td>Control</td>
<td>1.151 ± 0.244</td>
<td>0.536 ± 0.168</td>
<td>85.71 ± 16.46</td>
<td>00.00</td>
<td>10.9 ± 0.98</td>
<td>09.17</td>
</tr>
</tbody>
</table>

Conc. (ppm), a, b, c, d, Develop. Rate : see footnote of Table (1).
Data of the same table clearly provide a dissimilar action of Lufenuron on the nymphal developmental rate, since increased by increasing concentration level (9.90 and 12.82 at 62.5 and 1000 ppm, respectively, vs 9.17 of control congeners). That is to say, Lufenuron hastened the nymphal development through shortened durations (10.1±1.10 and 7.8±1.95 days at the same mentioned concentration levels, respectively, vs 10.9±0.98 days of control congeners).

**b) Metamorphosing and Morphogenic Effects of Lufenuron:**

Data assorted in Table (4) demonstrate the possible effects of Lufenuron on the adult performance of *S. gregaria* after treatment of the newly moulted last instar nymphs. Firstly, the adult emergence was partially blocked. This blockage was seen parallely to the concentration level reaching 40% (at 1000 ppm) in comparison to 100% of control adults.

Aside with the metamorphic action of Lufenuron, it remarkably affected the adult morphogenesis. The highest % of adult deformity was recorded at the higher two concentration levels. Also, various symptoms of such deformation can be easily observed in Plate (1).

Moreover, the emerged adults survived only a shortened longevity which could be attributed to the death-accelerating action of Lufenuron. The shorter longevities were 37.00±3.96 and 37.50±4.60 days at 1000 and 500 ppm, respectively (compared to 48.30±2.55 days of control adults).

**Table (4):** Adult performance as affected by Lufenuron after treatment of the newly moulted last instar nymphs of *Schistocerca gregaria*.

<table>
<thead>
<tr>
<th>Conc. (ppm)</th>
<th>Deform.</th>
<th>Emerg.</th>
<th>Longevity*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000.0</td>
<td>50.00</td>
<td>040</td>
<td>37.00 ± 3.96 d</td>
</tr>
<tr>
<td>500.0</td>
<td>50.00</td>
<td>060</td>
<td>37.50 ± 4.60 c</td>
</tr>
<tr>
<td>250.0</td>
<td>16.66</td>
<td>060</td>
<td>40.50 ± 4.27 b</td>
</tr>
<tr>
<td>125.0</td>
<td>28.57</td>
<td>070</td>
<td>43.50 ± 3.51 a</td>
</tr>
<tr>
<td>062.5</td>
<td>22.20</td>
<td>090</td>
<td>47.75 ± 4.11 a</td>
</tr>
<tr>
<td>Control</td>
<td>00.00</td>
<td>100</td>
<td>48.30 ± 2.55</td>
</tr>
</tbody>
</table>

Conc. (ppm), a, b, c, d: see footnote of Table (1). Emerg., Deform., *: see footnote of Table (2).

**Treatments of the late-aged last instar nymphs:**

**a) Growth and Developmental Effects of Lufenuron:**

After treatment of the late-aged last instar nymphs, the obtained results were arranged in Table (5). An inhibitory action of Lufenuron can be easily detected because the treated nymphs were prevented to gain normal somatic increments, especially at the higher three concentration levels (0.468±0.137, 0.340±0.131 & 0.316±0.116 g at 250, 500 & 1000 ppm, respectively, vs 0.598±0.233 g of their control correspondings). Moreover, the growth inhibition % expressed and confirmed the previously denoted data since it increased by the increasing concentration level (as for example, 9.90 and 42.23 % at 62.5 and 1000 ppm, respectively). Also, Lufenuron
prohibited the nymphal development because their life duration was prolonged consecutively to the ascending concentration level and vice versa (Table 5).

Table (5): Growth and developmental effects of Lufenuron on *Schistocerca gregaria* after treatment of the late-aged** last instar nymphs.

<table>
<thead>
<tr>
<th>Conc. ppm</th>
<th>Mean weight (g ± S.D.)</th>
<th>Weight gain (g ± S.D.)</th>
<th>Change (%)</th>
<th>Growth inhibition (%)</th>
<th>Duration (days ± S.D.)</th>
<th>Develop. Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000.0</td>
<td>0.930 ± 0.285 d</td>
<td>0.316 ± 0.116 c</td>
<td>41.39 ± 10.16 d</td>
<td>42.23</td>
<td>10.20 ± 2.78 c</td>
<td>09. 80</td>
</tr>
<tr>
<td>500.0</td>
<td>1.112 ± 0.375 c</td>
<td>0.340 ± 0.131 b</td>
<td>64.61 ± 11.27 a</td>
<td>31.05</td>
<td>09.80 ± 3.40 b</td>
<td>10.20</td>
</tr>
<tr>
<td>250.0</td>
<td>1.271 ± 0.398 b</td>
<td>0.468 ± 0.137 b</td>
<td>65.46 ± 11.07 a</td>
<td>21.11</td>
<td>09.50 ± 2.34 b</td>
<td>10.52</td>
</tr>
<tr>
<td>125.0</td>
<td>1.296 ± 0.483 a</td>
<td>0.490 ± 0.275 a</td>
<td>67.85 ± 15.66 a</td>
<td>19.87</td>
<td>08.01 ± 2.12 a</td>
<td>12.34</td>
</tr>
<tr>
<td>62.5</td>
<td>1.450 ± 0.222 a</td>
<td>0.518 ± 0.281 a</td>
<td>70.19 ± 5.66 a</td>
<td>09.90</td>
<td>07.80 ± 2.20 a</td>
<td>12.82</td>
</tr>
<tr>
<td>Control</td>
<td>1.610 ± 0.223</td>
<td>0.598 ± 0.233</td>
<td>70.64 ± 10.88</td>
<td>00.00</td>
<td>06.80 ± 1.85</td>
<td>14.70</td>
</tr>
</tbody>
</table>

Conc. (ppm), a, b, c, d, Develop. Rate and No. of insect used for each replicates of treatment and control: see footnote of Table (1). ** the 5-day old nymphs of last instar were treated with Lufenuron.

** b) Metamorphosing and Morphogenic Effects of Lufenuron:

Data given in Table (6) evidently reveal the affected adult performance, by Lufenuron treatments against the last instar nymphs.

The adult emergence was blocked in different degrees depending on the conc. levels of Lufenuron. These successfully eclosed adults suffered a morphogenic action of Lufenuron because the highest deformity (57.14%) had been recorded at the highest concentration level. However, the adult deformity increased by increasing conc. level. Several malformed adults have been shown in Plate (1). Only short longevity, but statistically insignificant, was lasted by the treated adult females ending in death.

Table (6): Adult performance as affected by Lufenuron after treatment of the late-aged** last instar nymphs of *Schistocerca gregaria*.

<table>
<thead>
<tr>
<th>Conc. (ppm)</th>
<th>Deform.</th>
<th>Emerg.</th>
<th>Longevity*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000.0</td>
<td>57.14</td>
<td>070</td>
<td>41.75 ± 3.24 a</td>
</tr>
<tr>
<td>500.0</td>
<td>28.50</td>
<td>070</td>
<td>43.30 ± 4.02 a</td>
</tr>
<tr>
<td>250.0</td>
<td>37.50</td>
<td>080</td>
<td>43.25 ± 3.81 a</td>
</tr>
<tr>
<td>125.0</td>
<td>22.20</td>
<td>090</td>
<td>43.33 ± 3.88 a</td>
</tr>
<tr>
<td>62.5</td>
<td>22.20</td>
<td>090</td>
<td>42.25 ± 2.06 a</td>
</tr>
<tr>
<td>Control</td>
<td>00.00</td>
<td>100</td>
<td>44.79 ± 3.85</td>
</tr>
</tbody>
</table>

Conc. (ppm), a and b: see footnote of Table (1). Emerg., Deform., *: see footnote of Table (2). **: see footnote of Table (5).

** DISCUSSION

Growth of *S. gregaria* as influenced by Lufenuron.

Studies on different insects have shown that chitin synthesis inhibitors (CSIs) can affect the production of the peritrophic matrix of the locust *Locusta migratoria* (Clarke et al., 1977) and the blowfly *Calliphora erythrocephala* (Becker, 1978).
These chemicals also affect hardening of the cuticle of the boll weevil *Anthonomus grandis grandis* (Haynes and Smith, 1994) and development of the pupal integument of the yellow mealworm *Tenebrio molitor* (Soltani *et al*., 1987).

The diflubenzuron (DFB), pioneer of the Bezoylphenyl ureas (BPUs), affects the growth and development, among other important criteria, of several insect species (Osman, 1984; Soltani-Mazouni, 1994; Khebbeb *et al*., 1997; Basiouny, 2000). Reduction of the body weights, weight gain, or the growth in general, was reported for several species by different CSIs, such as: *Musca domestica* (Bakr *et al*., 1991), *Spodoptera littoralis* (Ghoneim *et al*., 1998), *Spodoptera exempta*, *Mamestra brassicae* and *Galleria mellonella* (Smagghe and Degheele, 1994).

In the present study, five concentration levels of each of the CSI (Lufenuron, CGG-184699) were given to the newly moulted penultimate, newly moulted last, or late-aged last instar nymphs of *S. gregaria* through the fresh food. Lufenuron obviously deteriorated the growth of nymphs because their weight gain drastically decreased as the concentration level was increased after treatment of the newly moulted 4th instar nymphs but at the higher two concentration levels after treatment of the last instar (early or late-aged) nymphs.

The present results resemble, to a great extent, those results of other BPUs against different insect species (Mitsui *et al*., 1980; Estal *et al*., 1994; Mondall and Port, 1995; Parween, 1996a). Also, decreased body weight gain and inhibited growth were caused by cyromazine on the house fly *M. domestica* (El-Oshar *et al*., 1985), IKI-7899 on the grey flesh fly *Parasarcophaga argyrostoma* (Ghoneim and Ismail, 1995c), chlorfluazuron on *S. gregaria* (Tiwari, 2000) and by Lufenuron and Diofenolan (CGA-59205) on *M. domestica* (Ghoneim *et al*., 2004).

**Lufenuron Effects on the Development of *S. gregaria***

Prolongation of the immature stages of different insect species had been recorded for several BPUs (and CSIs, in general), such as IKI-7899 against *S. littoralis* (Morsi, 1985), DFB against *Trogoderma granarium* (Vir, 1988), hexaflumuron (XRD-473) and Bay Sir-8514 against *Tribolium castaneum* (Estal *et al*., 1994; Parween, 1996a), DFB and furyltriazine against *T. granarium* (Saxena and Kumar, 1991), Bay Sir-8514 or IKI-7899 against *S. gregaria* (Abdel-Magid, 1993), IKI-7899 and XRD-473 against *Eupripocnemis plorans* (Mohamed, 1998), DFB, XRD-473 and CME-13406 against *S. gregaria* (Coppen and Jepson (1996a), Bay Sir-8514 against *M. stabulans* (Ghoneim *et al*., 1992), IKI-7899 against *P. argyrostoma* (Ghoneim and Ismail, 1995c), DFB against *S. littoralis* (Radwan *et al*., 1978), Bay Sir-8514 against *Tribolium confusum* (El-Sayed *et al*., 1984), IKI-7899 against *Culex pipiens* (Bakr *et al*., 1989), XRD-473 and Bay Sir-8514 against *Aedes aegypti* (Mohapatra *et al*., 1996).

On the contrary, CGA-184699 and CGA-59205 failed to affect the developmental duration or rate of the immature stages of *M. domestica* (Ghoneim *et al*., 2004). Moreover, some CSIs induced the developmental rate along shortened duration, as seen in the present study on *S. gregaria* after treatment with Lufenuron at certain physiological ages of nymphs. So, many similar findings can be obtained by the literature, as for example, Tanani (2001) recorded shortened developmental duration of *Rhynchophorus ferrugineus* by CGA-184699 and CGA-59205 and El-Sheikh (2002) observed shortened larval duration of *Agrotis ipsilon* by Flufenoxuron. Also, Flufenoxuron exhibited a shortening effect on the developmental duration of *S. gregaria* at certain concentration levels and insignificant lengthening effect at other concentration levels (communication with Tanani, 2007).
A variation in the developmental action was clearly observed by the action of Lufenuron, in the present study. Whereas Lufenuron promoted the developmental rate along significantly shortened duration after treatment of the newly moulted nymphs (of 4th or 5th instar), it retarded such rate along pronouncedly prolonged duration after treatment of the late-aged last instar nymphs. Anyhow, the considerably shortened nymphal duration usually indicates a fostered developmental rate may be for avoiding a further serious action of Lufenuron during the normal duration.

The presence of great variation in effects of BPUs (or CSIs, in general) on the insect development may be largely due to the large species-variations in respect to relative potency of various BPUs on different insect species. This variation may also be resulted from the different mechanisms of ecdysteroid metabolism existing in different insects (Whisenten et al., 1989). However, the inhibitory action of CSIs on the development (as expressed in prolonged developmental duration) in various insect species may be explained by causing an imbalance in the hormone titers at critical times of moulting because the proper balance in the hormone titers is necessary for normal growth and transformation into the pupal stage (Retnakaran et al., 1985; Sehnal and Bryant, 1993).

**Adult Performance of *S. gregaria* as affected Lufenuron.**

In regard to the *Adult emergence* of *S. gregaria*, in the present study, no inhibitory effect could be detected after treatment of the newly moulted penultimate instar nymphs with Lufenuron. On the contrary, a considerable inhibitory action was exerted on the adult emergence after treatment of the late-aged last instar nymphs.

However, partial or complete blocking of the adult emergence, of other than the orthopterans, have been documented for several CSIs such as: IKI-7899 against *S. littoralis* (Morsi, 1985), CME-13406, XRD-473, DFB, IKI-7899 & Bay Sir-8514 against *Culex pipiens* and *Culex quinquefasciatus* (Mulla and Darwazeh, 1988), CME-13406 and IKI-7899 against *M. domestica* (El-Kordy et al., 1989; Ghoneim et al., 2004), XRD-473 against some mosquito species (Vasuki and Rajavel, 1992), DFB against *S. littoralis* (Gamal et al., 1994), IKI-7899 against *P. argyrocestoma* (Ghoneim and Ismail, 1995), DFB against the stone fly *Pelloperta arcuata* (Griffith et al., 1996), DFB and some of its analogues against *Musca domestica* (Basiouny, 2000), IKI-7899 against *S. littoralis* (Mesbah et al., 1996; Bakr et al., 2005), IKI-7899 against *Pectinophora gossypiella* (El-Nemaky, 2000), IKI-7899 against *Earias insulana* (El-Nemaky and Azab, 2004), Lufenuron (CGA-184699) against *Lobesia botrana* (Saenz-de-Cabezon et al., 2006), etc… In contrast, CME-13406 exhibited no influence on the adult emergence of the grasshopper *Aiolopus thalassinus* (Schmidt et al., 1993).

Whatever these contradictory results, a number of suggestions have been introduced to shed some light on the mode of action of CSIs since Mulder and Gijswijt (1973) supposed that the ingestion of these compounds by insect larvae disturbs the endocuticular deposition during moulting process because they block the chitin synthesis. The blockage of chitin synthesis occurs due to disruption of the function of connecting N-acetylglucose amine moieties to the chitin chain in spite of that the coupling of uridine diphosphat-N-acetyl-glucose amine (UDPAG), the ultimate chitin precursor, to the chitin synthetase still proceeds (Post et al., 1974). However, the exact mode of action of these CSIs on the adult transformation and eclosion is still puzzling (Merzendorfer and Zimoch, 2003).

**Adult differentiation and morphogenesis** of various insect species had been impaired by the action of different CSIs, such as: DFB against *S. littoralis* (Radwan et al., 1978), *Glossina morsitans* (Jordan et al., 1979), *Simulium vittatum* (Lacy and Mulla,
Efficiency of lufenuron (cga-184699) on morphogenesis of Schistocerca gregaria (Rao and Mehrotra, 1986), S. gregaria (Bakr et al., 1989), T. molitor (Soltani et al., 1992), M. stabulans (Basiouny, 2000), Bay Sir-8514 against Tribolium confusum (El-Sayed et al., 1984), M. domestica (Miller and Schmidtman, 1985), C. pipiens (Bakr et al., 1989), M. stabulans (Ghoneim et al., 1992), Synthesiomyia nudiseta (Khalaf, 1993); IKI-7899 against S. gregaria (Aboel-Ela et al., 1993; El-Gammal et al., 1993), P. argyroptoma (Ghoneim and Ismail, 1995), M. stabulans (Basiouny, 2000); XRD-473 against some mosquito species (Vasuki and Rajavel, 1992); Diofenolan against Cydia pomonella and Cydia molesta (Streibert et al., 1994); XRD-473 and IKI-7899 against Eupripocnemis plorans (Mohamed, 1998), M. stabulans (Basiouny, 2000) and Rh. ferrugineus (Tanani, 2001), chlorfluazuron against S. gregaria (Tiwari, 2000). On the contrary, neither CGA-184699 nor CGA-59205 caused adult deformities in M. domestica, irrespective of the dose or time of treatment (Ghoneim et al., 2004). Also, Flufenoxuron could not cause nymphal deformations but only adult morphogenic defects of S. gregaria (communication with Tanani, 2007).

In the present study on S. gregaria, the adult morphology was significantly subjected to a deteriorating action of Lufenuron because various deformed adults were observed. Such morphogenic action of Lufenuron increased proportionally to the increasing higher three concentration levels against the newly moulted penultimate instar nymphs.

However, no nymphal deformities, permanent nymphs, nymphal-adult intermediates, supernumerary nymphal instar, extramoult or adultoids of S. gregaria were observed in the present study, but only adult malformations which appeared as twisted legs, coiled antennae, curled wings as well as adult failure to get rid the last nymphal exuvia. Generally, these defected features may provide relevant evidence to a morphogenic action of Lufenuron. Each of them seriously interferes, directly or indirectly, with the programme of adult morphogenesis...

In addition, several hypotheses have been introduced to explain the mode of action of CSIs on the morphogenesis including: direct inhibition and/or interference with chitin synthase (Deul et al., 1978), effect on the chitinase levels comprising that chitin is being digested faster than deposited (Soltani et al., 1993), interference with juvenile hormone and ecdysteroid metabolism causing a disruption in the chitin metabolic system (Yu and Terriere, 1975), inhibition of chitin synthase by metabolites of CSIs (Cohen and Casida, 1980), inhibition of protease(s) that activate the chitin synthase zymogen (Leighton et al., 1981), inhibition of DNA synthesis (Mitlin et al., 1977), inhibition of glycosyl transferases that are involved with synthesis of lipid-linked oligosaccharides in cell membranes which possibly provide primer molecules for chitin synthase (Mayer et al., 1980), and/or inhibition of facilitated diffusion and active transport across cell membranes of nucleosides and amino acids (Mayer et al., 1988).

**Adult longevity** of S. gregaria was significantly shortened after the nymphal treatments with Lufenuron, in the present study, but in no certain trend. These results agree with shortening effects of DFB on T. molitor (Soltani et al., 1983), of IKI-7899 and Flufenoxuron on Agrotis ipsilon (Shaurub et al., 1999; El-Skeikh, 2002), of CGA-184699 and CGA-59205 on M. domestica (Ghoneim et al., 2004) and of Flufenoxuron on S. gregaria (personal observation). Adult longevity depends on healthy immature stages. Digestive disorders such as starvation, disturbance in metabolism, degeneration of peritrophic membrane and accumulation of faecal materials at the hind gut may be the cause of untimely adult mortality as a result of...
CSIs exposure (Soltani, 1984; Parween, 1997a). Generally, the shortened adult longevity can be explicated by the accumulation of toxic xenobiotics in the insect body which upsets a complicated balance of factors such as absorption, excretion and detoxification (Abdel-Al, 1996; Mustafa, 2002).

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Plate (1): Various shapes of the adult deformation of Schistocerca gregaria were recorded after nymphal treatment with the chitin biosynthesis inhibitor, Lufenuron. Several aberrations can be seen in comparison to the normal adult (a), such as: deformed legs and shortened antennae (b), retained nymphal exuvium (c), abnormally developed wings and legs (d).
كفافه مثبط تخلق الكيتين لوفينورون في التأثير على النمو ويعود للكيماويات المشكل للجراد الصحراوي شيستوركما الجريبياري (مستفيضات الأجنحة: الجراديات).

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استهدفت هذه الورقة بحث تأثيرات مركب لوفينورون في نمو وإمالة وتشكل الجراد الصحراوي شيستوركما الجريبياري. ومن أجل هذا، تمّ استخدام محوريات الدور الرابع (حديثة الإسلاخ)، وحوريات الدور الخامس (حديثة الإسلاخ والتمدّد في العمر) بخمس تركيزات من المركب، هي: 1000، 500، 250، 125، 62.5 جم م.، من خلال التناول الذي تناوله الحوريات لحم واحد فقط، وبعدّ تمّ تدوين جميع الملاحظات.

تعرض نمو المحوريات المحملة لثبيت كبير، إذ تنازلت أوزانها المكتملة تنازلاً بالغاً على التوازي مع نمو وخصائص مستوى التركيز المستعمل. هذا بعدّ تمّ استخدام محوريات الدور الرابع، أما بعدّ معاملة محوريات الدور الخامس، فقد تمّ تحويل نمو وخصائص مستوى التركيز بعد استخدامات أعلى تركيزات. كما تساهم التثبيت تدربياً بعد معاملة محوريات الدور الخامس المقدمة في العمر باثلة تركيزات.

وبخصوص معدل النمو، فقد سجلت النتائج انحداراً شديداً له بعدّ معاملة محوريات الدور الأخير، حديثة الإسلاخ والتمدّد في العمر، وذلك استجابة لفعل مركب لوفينورون في الدماء. وعلى العكس، فقد حفز هذا المركب النمو في المحوريات التي تمّ معاملتها في بداية الدور الرابع، مما حضّراً على قضاء فترة قصيرة جداً، ربما لتفادي المزيد من الآثار التثبيت الهائلة.

أدى مركب لوفينورون أيضاً، فعلاً كابحاً لزروج الياقات بعدّ معاملة المحوريات بتكرارات منه، بصرف النظر عن تفتيت النمو. ومن جهة أخرى، فإنّ المركب لم يتحمّل تأثيراً ملحوظاً في هذه العملية التحولية بعد معاملة محوريات الدور الرابع. وأكثر من هذا، فقد شمع لوفينورون، باستخدام تركيزات معينة منه، على وزن الياقات حتّى فاق معه معدل وزن الياقات الوضعية!!

وعلى أيّة حال، فإنّ الياقات التي نجت في الزروج عانت من الفعل التشكلي لمركب لوفينورون وقد ظهر هذا جلياً في الأشكال المشوهة التي فعت على أعداد من هذه الياقات، وقد تساهمت نسبة الموتى على الأقلّ بعد استخدام تمّ على ثلاتة تركيزات، واصفة إلى هذا، فقد اكتسبت فترة حياة قصيرة ثمّ ماتت، وقد انتهى القصور في فترة حياتها مع تصادع مستوى التركيز بعد معاملة حوريات الدور الرابع.