Al-Azhar Bull. Sci. Vol. 18, No. 2 (Dec.): pp. 59-81, 2007.

DEVELOPMENTAL AND MORPHOGENIC RESPONSES OF *SCHISTOCERCA GREGARIA* (ORTHOPTERA: ACRIDIDAE) TO THE JUVENOID PYRIPROXYFEN (S- 31183).

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Abstract

To investigate the effects of Pyriproxyfen (S-31183) on the growth, development and morphogenesis of the desert locust *Schislocerca gregaria*, five concentration levels (1000, 500, 250, 125 and 62.5 ppm) were given through the fresh clover leaves as food to nymphs of three developmental ages: newly moulted penultimate *(4^{th})* instar, newly moulted last *(5^{th})* instar and late-aged last in star. All results were obtained 24 h after feeding.

Pyriproxyfen exhibited a remarkable inhibitory effect on the nymphal growth and consequently nymphs were prevented to obtain more than one-third of weight gain of control congeners at the highest concentration level. Also, the developmental rate was increasingly depressed as the concentration level was increased, almost, in all treatments. The controls had the fastest developmental rate among all nymphs.

The adult females were hindered to emerge proprtionally to the increasing concentration level of Pyriproxyfen. Moreover, some adults were completely prevented to emerge after treatment of the penultimate instar nymphs with the highest concentration level. In addition, Pyriproxyfen exerted a profound action on the adult morphogenesis. The degree of adult deformation was dose-dependent after treatment of the newly moulted 4^{th} or 5^{th} instar nymphs. After treatment of these nymphs, also, the adult longevity was elaborately shortened while the treatment of late-aged *5th* instar nymphs resulted in an insignificant prolongation of the adult longevity.

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

Introduction

Juvenile hormone analogues (JHAs) can function as agonists or antagonists or a mixture of both with natural JHs (Kramer and Staal, 1981). The JH has two distinct biochemical effects: one during the larval stage and the other in the adult stage. During larval stage, JH suppress metamorphic change during moulting; and in the adult it induces vitellogenin synthesis during ovarian development. The JHAs interfere with important biochemical mechanisms such as the secretion and

transportation of natural JHs from the secretory site to the target site, degradation, excretion and feedback control (Retnakaran *et al.,* 1981). Hence, their biological effects are very complex, and vary from one analogue to another. Also, the response to different compounds differs among the species (Mondal and Parween, 2000).

Pyriproxyfen (S-31183) {2-[1-methyl-2-(4-phenoxyphenoxy)-ethoxy]-pyridine} has a juvenile hormone activity against different insect species. Its activity was studied against some lepidopterous pests (Ascher and Eliyahu, 1988; Gadallah *et al.*, 1990), houseflies and mosquitoes (Estrada and Mulla, 1986; Mulla *et al.,* 1986; Kawada *et al.,* 1988; Schafeer and Miura, 1990; Ghoneim *et al.,* 1992), cockroaches (Kawada *et al.,* 1989; Ross and Cochran, 1990), termites (Su and Scheffrahn, 1989), scale insects (Cooper and Oetting, 1985) and locusts (De Kort and Koopmanschap, 1990; Ghoneim and Ismail, 1995).

The present study was carried out to investigate the effects of Pyriproxyfen on growth, development and morphogenesis of the desert locust *Schistocerca gregaria* as a laboratory collaboration for controlling this dangerous agricultural pest.

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 ± 2C.). 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 eagyptiaca*. All experiments were conducted with *M. sativa* only.

Pyriproxyfen Administration:

Five concentration levels of the juvenoid Pyriproxyfen were prepared using the

distilled water: 1000, 500, 250, 125 and 62.5 ppm. Pyriproxyfen (S-31183) is a product of Sumitomo Chemical Co. Ltd., Pesticides Division, Osaka, Japan, with the chemical formula: {2- [1-methyl-2-(4-phenoxy-phenoxy) ethyl] pyridine} (Kawada *et al.,* 1988). The concentration range was chosen depending on some preliminary trials carried out on the present insect species. 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 *(4^{th})* instar, newly moulted last *(5^{th})* 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:

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 % 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.

Analysis of Data:

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 Development:

After treatment of the newly moulted penultimate instar nymphs with different concentration levels of Pyriproxyfen, growth and developmental data were distributed in Table (1). Data of this table easily reveal different degrees of Pyriproxyfen action on growth and development. Inspite of the, insignificant, increase of the weight gain, the treated nymphs seemingly failed to obtain more than $^1/_3$ of the weight gained by their control congeners. Another parameter may provide a substantiating evidence for the effect of Pyriproxyfen since change % was estimated as 15.81 ± 11.66, at 1000 ppm (vs 97.95 ± 12.88 of controls). Thus, the control nymphs exhibited a change% in their body growth exceeding 6 times higher than the 1000 ppm-treated nymphs. Also, growth inhibition was the highest (49.61%) at the highest concentration level but the lowest (4.04%) at the lowest concentration level. Thus, growth inhibition at the highest concentration level of Pyriproxyfen was 12 times greater than that caused at the other concentration levels.

Developmental rate, on the other hand, run in a reverse correlation to the concentration level, with few exceptions. Control nymphs developed, generally, in a faster rate since they stayed the shortest duration before the final nymphal moult (13.62 ± 2.30, at 1000 ppm, and 13.05 ± 1.70 days, at 500 ppm, vs 8.80 ± 1.46 days of control congeners). With few exceptions, the penultimate instar considerably extended in a parallel relationship to the concentration level.

b) Metamorphosis and Morphogenesis:

Referring to the data of Table (2), a profound effect of Pyriproxyfen on the adult performance can be easily seen. The adult emergence was precluded increasingly as the concentration level was increased. The maximal blocking action could be obviously detected when the treated nymphs failed to metamorphose, i.e., no emergence could be observed after treatment with the highest concentration level.

The morphogenic programme, however, was impaired by Pyriproxyfen, especially after treatment with its lower three concentration levels, because various deformations in increasing %s were recorded reaching 50% at 500 ppm (no morphogenic disorders were observed among control insects). Plate (1) shows different photos of adult deformities as an effect of Pyriproxyfen on the programme of metamorphosis and morphogenesis. As easily seen some adults failed to completely cast the nymphal exuvia, some appeared with sharply twisted legs, severely curled wings, atrophied antennae, abdominal torsion...etc.

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

Conc. (ppm)	Mean weight (g ± S.D.)	Weight gain (g ± S.D.)	Change (%)	Growth inhibition (%)	Duration (days ± S.D.)	Develop. Rate
1000.0	0.324 ± 0.131 d	0.125 ± 0.075 d	15.81 ± 11.66 d	49.61	13.62 ± 2.30 d	07.34
500.0	0.336 ± 0.110 d	0.201 ± 0.050 d	32.71 ± 10.50 d	47.74	13.05 ± 1.70 d	07.68
250.0	0.465 ± 0.165 b	0.248 ± 0.180 a	85.11 ± 08.42 b	27.68	14.84 ± 3.41 d	07.10
125.0	0.567 ± 0.362 a	0.311 ± 0.172 a	65.16 ± 17.65 b	11.81	10.77 ± 2.53 a	09.28
062.5	0.617 ± 0.240 a	0.317 ± 0.114 a	68.76 ± 19.51 a	04.04	09.50 ± 1.96 a	10.52
Control	0.643 ± 0.154	0.390 ± 0.197	97.95 ± 12.88	00.00	08.80 ± 1.46	11.36

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.

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

Conc. (ppm)	Emerg.	Deform.	Longevity*
1000.0	00.00	00.00	=
500.0	33.33	00.00	46.81 ± 3.74 b
250.0	40.00	50.00	52.92 ± 3.08 a
125.0	71.41	20.00	53.24 ± 4.21 a
062.5	77.70	14.28	55.06 ± 3.81 a
Control	90.00	00.00	53.90 ± 4.31

Conc. (ppm), a and b: see footnote of Table (1). Emerg.: Emergence (%), Deform.: Deformation (%). *: Mean days ± SD

The successfully emerged adults suffered the action of this juvenoid since they lasted only short longevity. Longevity was shortened parallely to the increasing concentration level reaching 46.81 ± 3. 74 days $p < 0.05$ (vs 53.90 ± 4.31 days of control congeners). On the other hand adult, longevity was prolonged, but insignificantly, at the lowest concentration level.

Treatments of the newly moulted last instar nymphs:

a) Growth and Development:

As clearly shown in Table (3), a drastic reducing action of Pyriproxyfen on the weight gain was exerted and increased as the concentration level was ascended. As for example, weight gain of 1000 ppm-treated last instar nymphs was 0.198:1:0.037, $p < 0.001$vs 0.686 ± 0.264 g of control congeners. Thus, these nymphs obtained almostly $^1/_3$ of that weight gain of the control congeners. Another confirmatory parameter for this level, reducing action can be provided by growth inhibition% which increased by increasing concentration reaching 66.42% at the highest concentration level. With few exceptions, Pyriproxyfen affected the development of nymphs because the duration was pronouncedly prolonged and developmental rate suffered a retarding action. Such prolongation of the developmental duration

increased as the concentration level was increased. Shortly, all treated nymphs achieved developmental rate remarkably less than that of controls (for more details, see table 3).

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

Conc. (ppm)	Mean weight (g ± S.D.)	Weight gain (g ± S.D.)	Change (%)	Growth inhibition (%)	Duration (days ± S.D.)	Develop. Rate
1000.0	0.423 ± 0.160 d	0.198 ± 0.037 d	23.42 ± 09.71 d	66.42	16.74 ± 3.250 d	5.97
500.0	0.485 ± 0.311 d	0.321 ± 0.156 d	52.71 ± 07.73 c	61.66	15.81 ± 2.510 a	6.32
250.0	0.823 ± 0.466 b	0.467 ± 0.263 a	66.42 ± 13.61 c	34.68	16.24 ± 3.620 d	6.16
125.0	0.993 ± 0.152 a	0.581 ± 0.215 a	75.41 ± 09.88 a	21.19	12.41 ± 2.500 a	8.05
062.5	1.085 ± 0.436 a	0.612 ± 0.144 a	78.34 ± 11.20 a	13.88	12.21 ± 1.780 a	8.19
Control	1.262 ± 0.244	0.686 ± 0.264	84.86 ± 12.56	00.00	10.80 ± 0.866	9.25

Conc. (ppm), a, b,. c, d, Develop. Rate: see footnote of Table (1).

b) Metamorphosis and Morphogenesis:

After treatment of the newly moulted last instar nymphs with different conc. levels of Pyriproxyfen, several aspects of the adult performance were influenced (Table 4). Almostly, blocking of the adult emergence increased proportionally to the ascending concentration However, the downmost emergence (50%) was observed at the highest concentration level.

In addition, Pyriproxyfen pronouncedly affected the adult morphogenesis because different malformations were recorded in two extremes: the strongest (60%) at the highest concentration level and the weakest (12.5%) at the lowest concentration level. Several features or symptoms of such impaired adult morphogenesis are shown in Plate (1).

Generally, all treated adult females lasted remarkably s longevity than their control congeners. Moreover, longevity shortage increased significantly by increasing concentraton level (at least $p < 0.05$).

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

Conc. (ppm)	Emerg.	Deform.	Longevity*
1000.0	050	60.0	39.99 ± 2.67 d
500.0	060	50.0	41.43 ± 3.56 c
250.0	060	50.0	43.36 ± 2.68 b
125.0	070	28.2	43.62 ± 1.63 b
062.5	080	12.5	46.53 ± 5.74 a
Control	100	00.0	49.60 ± 2.54

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

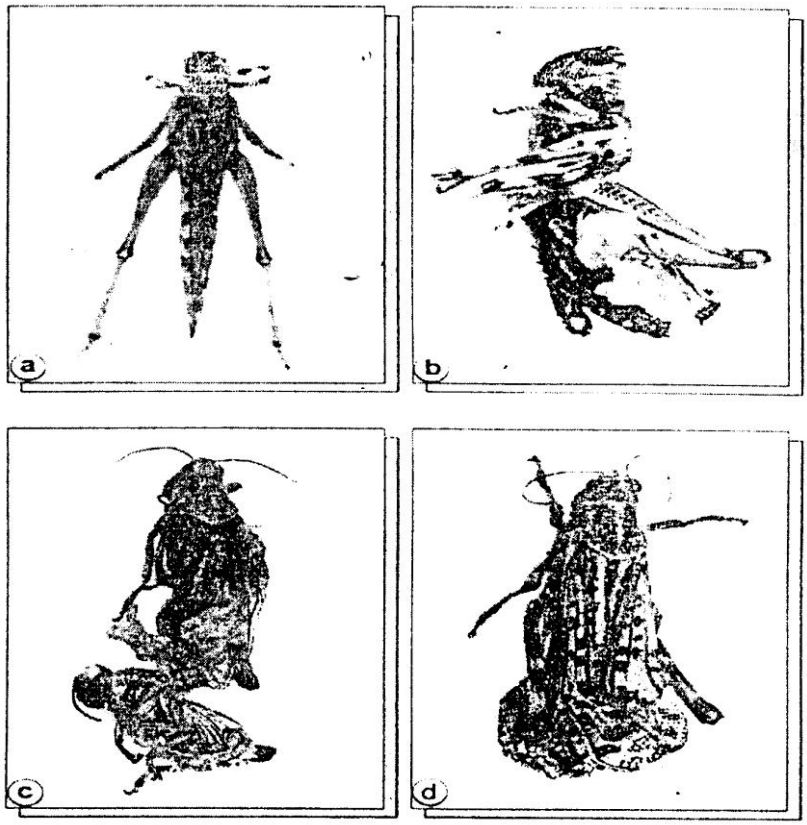

Plate (1): The juvenile hormone analogue, Pyriproxyfen caused some adult deformities after treatment of different concentrations to the penultimate or last ins tar nymphs of Schistocerca gregaria. Far from the normal adult (a), various shapes of the impaired morphogenesis can be seen such as: atrophied antennae and shortened legs (b), attached nymphal exuvium and corrupted wings (c), abnormally developed extremities of the wings and abdominal torsion (d).

Treatments of the late-aged last instar nymphs:

a) Growth and Development:

According to data of Table (5), Pyriproxyfen seriously affected growth and development of the nymphs, regardless of the concentration level. After treatment of the last instar nymphs at a late age, their growth was considerably halted since weight gain regressed proportionally to the ascending concentration level. Among treated nymphs, 1000 ppm-treated nymphs gained only $^{1}/_{3}$ of weight obtained by 62.5 ppm-treated or even control congeners. In addition, growth inhibition % elegantly substantiated such results since it increased by increasing concentration level.

Data of the previously cited table, also, clearly show a regression of the developmental rate of nymphs, approximately in a reverse trend to the concentration level. As a result, nymphs spent an extended duration before metamorphosis into adults. Such prolongation increased, as the concentration level was increased.

b) Metamorphosis and Morphogenesis:

Possible effects of Pyriproxyfen on the morphogenesis and metamorphosis programmes of S. *gregaria* after treatment of the late-aged last instar nymphs with different concentration levels can be shown by Table (6). A blocking action of this juvenoid on the adult eclosion increased as the concentration level was increased. The adult emergence, however, varied between 50% at 1000 ppm and 80% at 62.5 ppm.

Furthermore, the adult morphogenic programme was deranged but in no certain trend. Whereas no adult deformities were observed at 125 ppm, only 33.33% was recorded at 500 ppm. In respect to the adult longevity, insignificant effect of Pyriproxyfen was detected.

Discussion

Inhibitory action of Pyriproxyfen

on the growth of *Schistocerca gregaria.*

The different insect species variously respond to the hormone analogues (and insect growth regulators IGRs, in general) depending on several factors such as: structure of the IGR itself, dose, application method, timing of treatment, etc... Subsequently, literature contains different, and sometimes contradictory, results. Among lepidopterans, a negative correlation of Pyriproxyfen to the larval body weight of the spiny bollworm *Earias insulana* (Hewady, 1990). For *Spodoptera exempta*, *Spodoptera exigua*, *Mamestra brassicae* and *Garellia mellonella*), Smagghe and Degheele, (1994a) estimated some reductions of weight gain and feeding by the action of the ecdysteroid Tebufenozide (RH-5992). By the action of the same ecdysteroid, larvae and nymphal body weights of the spruce budworm *Choristoneura fumiferana* were significantly affected (Cadogen *et al.,* 1997). Also, the larval maximal body weight and weight gain (or mean body weight, in general) of *Spodoptera littoral is* drastically decreased by Tebufenozide (Ghoneim *et al.,* 1998) and by Pyriproxyfen (Sakr *et al*, 2005).

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

Conc. (ppm)	Mean weight (g ± S.D.)	Weight gain (g ± S.D.)	Change (%)	Growth inhibition (%)	Duration (days ± S.D.)	Develop. Rate
1000.0	0.893 ± 0.427 d	0.171 ± 0.053 d	16.71 ± 05.77 d	46.52	12.15 ± 3.240 d	08.23
500.0	0.9560 ± 0.333 d	0.337 ± 0.110 c	22.61 ± 11.72 c	42.75	12.25 ± 2.410 d	08.16
250.0	1.211 ± 0.342 b	0.460 ± 0.115 a	63.47 ± 09.53 a	27.54	10.15 ± 4.330 b	09.85
125.0	1.410 ± 0.431 a	0.481 ± 0.170 a	66.32 ± 11.53 a	15.56	10.65 ± 3.670 a	09.38
062.5	1.440 ± 0.341 a	0.496 ± 0.150 a	68.42 ± 9.54 a	13.77	09.17 ± 3.240 a	10.90
Control	1.670 ± 0.376	0.549 ± 0.155	70.56 ± 9.28	00.00	06.85 ± 0.669	14.59

Conc. (ppm), a, b,. c, d, Develop. Rate: see footnote of Table (1). ** the 5-day old nymphs of last instar were treated with Pyriproxyfen.

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

Conc. (ppm)	Emerg.	Deform.	Longevity *
1000.0	050	20.00	43.82 ± 4.66 a
500.0	060	33.33	41.81 ± 5.64 a
250.0	070	14.28	43.34 ± 2.40 a
125.0	070	00.00	40.83 ± 1.75 a
062.5	080	12.50	40.65 ± 2.54 a
Control	100	00.00	40.21 ± 3.82

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

Among dipterans, remarkably reduced larval body weight of *Musca domestica* was caused by fenoxycarb (Ro 13-5229) (Fouda *et al.*, 1991). Cyromazine exhibited an inhibitory action on the body weight of the medfly *Ceratitis capitata* (Vinuela *et al.*, 1993). Also, decreasing larval maximal body weights of *Parasarcophaga argyrostoma* were caused by Pyriproxyfen (Ghoneim and Ismail, 1995 c).

Among orthopterans, and specifically the desert locust S. *gregaria.* Pyriproxyfen promoted the nymphal growth as the maximal body weight was increased (Ghoneim and Ismail, 1995a). On the contrast, Rp 13-5229 inhibited the body weight in a dose-dependent correlation (Ghoneim and Ismail, 1995b).

Likewise, no effect on the body weight was achieved by some IGRs against *Leptinotarsa decemlineata, Diabrotica virgifera, Podisus sagitta* and *Locusta migratoria* (Smagghe and Degheele, 1994). Also, no effect was recorded for RH-5849 on the larval maximal body weight of *M domestica* (Ghoneim *et al.*, 1991) and of *Periplaneta americana* and *Oncopeltus fasciatus* (Darvas *et al.*, 1992).

In the present study, Pyriproxyfen, detrimentally inhibited growth of nymphs

was recorded, since the weight gain considerably decreased, regardless to the timing of treatment or the concentration level. As for example, at the highest concentration level" nymphs were prohibited to obtain more than weight gain of control congeners after treatment of the penultimate or last instar nymphs. Also, the growth inhibition % varied among the treated nymphs and was dose-dependent. Unfortunately, we have no conceivable interpretation of the inhibitory action of Pyriproxyfen on the growth, right now.

Affected development of *Schistocerca gregaria* **by Pyriproxyfen.**

Again, the susceptibility of insect species to IGRs depends on several factors belonging to the species itself, the compound characteristics, or the experimental conditions. For some details, Tebufenozide is more potent than the prototype ecdysone agonist RH-5849. It exhibited considerable specificity toward Lepidoptera and is far more toxic than RH-5849, while having much lower toxicity toward non-lepidopteran species (Dhadialla and Carlson, 1998). Also, the induction of ecdysteroid inactivation by administration of ecdysone agonists to larvae of other insect orders is discussed using *L. migratoria* (migratory locust) and S. *gregaria* (desert locust) among Orthoptera; *Tenebrio molitor* (yellow mealworm), *Leptinotarsa decemlineata* (Colorado potato beetle) and *Dicranorrhina micans* (African rose beetle) in Coleoptera; and *M domestica* (house fly) within Diptera (Williams *et al.*, 2002).

In the present study, also, the juvenoid Pyriproxyfen promoted the nymphal development along shortened developmental duration, only after treatment of the newly moulted penultimate instar nymphs. Such results are in accordance with those obtained by Tebufenozide in S. *gregaria* (personal observation). On the other hand, the Pyriproxyfen-treatments of the last instar nymphs (early or late) resulted in prolonged duration of nymphs indicating a retarding action of this juvenoid on the developmental rate in a dose-dependent manner. This retarding action was recorded for several insect species by the same juvenoid, such as the desert locust S. *gregaria* (Ghoneim and Ismail, 1995a; Vennard *et al.*, 1998), the cut worm *Agrotis ipsilon* (El-Sheikh, 2002). Also, various juvenile hormone analogues (JHAs) (and IGRs, in general) caused prolonged duration of the immature stages, such as 20-hydroxyecdysone against S. *gregaria* (Leis *et al.*, 1985), fenoxycarb (Ro 13-5229) against *Schistocerca americana* (Bowers and Ortego, 1991), methoprene and hydroprene against *Tribolium castaneum* (Ishaaya and Yablonski, 1976; Smet *et al.*, 1989) and *Ephestia cautella* (Shaaya and Pisarev, 1986), hydroprene against

Callosobruchus maculates (Rup and Chopra, 1984), Ro 13-5229 against S. *gregaria* (Ghoneim and Ismail, 1995 b), Tebufenozide against O. *nubilalis* (Trisyono and Chippendate, 1997).

As seen in the present study and other recorded results in the available literature, the juvenoids (or IGR's, in general) can cause shortening or lengthening effects on the developmental duration, i.e., induce or retard such development. These inconsistent results of such effect need to be explained. The prolongation of nymphal duration may be interpreted with the alteration of timing of prothoracicotropic hormone release which governs the insect metamorphosis. Sehnal (1976) suggested that the inhibitory influence of juvenoids increased as the larvae grow through successive larval instars. This suggestion may be acceptable for the endopterygote insects such as S. *littoralis* but not for the exopterygotes such as S. *gregaria*, in the present study.

However, the shortening or lengthening of the developmental periods by IGRs may be attributed to their effect on the release of ecdysteroids indirectly, by interfering with the neuroendocrine sites responsible for the release of tropic hormone, especially the prothoracicotropic hormone (Subrahmanyam *et al.,* 1989). In addition, IGRs caused an imbalance in the hormone titers. This may occurred at times of pre- or post-critical time for moult and hence shortening or elongating in the larval or the pupal durations was determined because the proper balance in the hormone titers is necessary for normal growth (Sehnal and Bryant, 1993).

Adult Performance of *Schistocerca gregaria*

as Influenced by Pyriproxyfen.

Adult emergence can be partially or completely blocked by the .11 !As (or IGRs, in general). The degree of blockage depends on several factors belonging to the compound, the insect species, or the experimental manipulation. The highest blocking degree of adult emergence of *M domestica* was caused by the highestconc. level ofRH-5849 (Ghoneim *et al.,* 1991). Hydroprene reduced the adult eclosion in *Tribolium confusum* and *Trogoderma granarium* (EI-Sayed, 1988). Methoprene effectively inhibited the adult emergence of *Sitotroga cerealella* (Stockel and Edwards, 1981) and *Alphitobius diaperinus* (Edwards and Abraham, 1985). Methoprene suppressed the adult emergence of *Delia radicum* (Gmdan *et al.,* 1989). Cycloheximide (30 pg/nymph) completely prevented the adult transformation of S. *gregaria* (Ghoneim, 1988). Pyriproxyfen seriously affected the adult emergence of

Earias insulana (Hewady, 1990), Ro 13-5229 inhibited the adult emergence of *M. domestica* (Fouda *et al.,* 1991), *Parasarcophaga argyrostoma* (Ghoneim and EI-Ibiari, 1995), *Culex pipiens* (Dorn *et al.*, 1981), and *Culex tarsalis* (Mulla *et al.,* 1986). As well as, Pyriproxyfen halted the adult eclosion of *P. argyrostoma* (Ismail, 1995) and of S. *littora/is* (Bakr *et al.,* 2005).

In the present study, the nymphal treatments with Pyriproxyfen led to hindered emergence of adults parallely to the concentration level. Furthermore, some adults were completely prevented to emerge at the highest concentration level against the newly moulted penultiillate instar nymphs. Generally, the blocked adult emergence of S. *gregaria* in the present study comes in accordance with the previously mentioned results of different insects.

Whatever, the prohibiting action of juvenoids (or IGRs, in general) can be explained by blocking thy maturation of imaginal discs which are the primodia of adult integumentary structures (Schneiderman, 1972). Also, and as suggested by Sehnal (1983) for juvenoids, the inhibited adult emergence may by attributed not to the function and growth of insect cells but to the prevention of the adult differentiation.

With regard to the ***adult differentiation and morphogenesis,*** different abnormalities have been caused by several IGRs. As well as, deranged developmental programmes and impaired morphogenic processes have been reported for various insect species and resulted in: extramoult, supernumerary larval instar', giant larvae, larval-pupal and/or pupal-adult (in Endopterygota), nymphal-adult (in Exopterygota) intermediates, adultoids, etc... Some of these were produced in *Blatella germanica* (Kramer *et al.,* 1989) by hydroprene; *Anopheles farauti* (Suzuki *et al.,* 1989), *Muscina stabulans* (Ghoneim *et al.,* 1992; Nassar, 1995), *Bemesia tabaci* (Kawada *et al.,* 1989), *P. argyrostoma* (Ghoneim and Ismail, 1995 c) by Pyriproxyfen; *Tribolium confusum* (Smet *et al.,* 1989) by methoprene; *Diploptera punctata* (Mathai and Nail, 1991) by hydroprene; *Corcyra cephalonica* (Bhargava and DevrajUrs, 1992) by fenoxycarb; etc... It is noteworthy that the degree of morphogenic activity exhibited by juvenoids or ecdysteroids differs with the method of application, dose administred, species and age of the treated insects (Bowers *et al.,* 1965; Retnakaran *et al.,* 1985; Parween, 2000).

In addition, several works on locusts showed similar morphogenic disorders by various juvenoids, such as Pyriproxyfen in *L. migratoria (De* Kort and Koopmanschap, 1991; Edwards *et al.,* 1993), S. *gregaria* (Ghoneim and Ismail,

1995a; Vennard *et al.,* 1998; EI-Sukkary, 2003); Ro 13-5229 in S. *americana* (Bowers, 1991, 1995), *L. migratoria migratoroides* (Othman and Schmidt, 1998), S. *gregaria* (Ghoneim and Ismail, 1995b; Saiful-Islam, 1995); methoprene in S. *gregaria* (SaifulIslam, 1995), *L. migratoria* (Nemec, 2003), etc. . .

In the present study, neither extramoult, permanent nymphs, nymphal-adult intermediates, nor adultoids of S. *gregaria* could be produced by Pyriproxyfen or Tebufenozide although Ghoneim and Ismail (1995a) reported such features on the same orthopteran by the same juvenoid Pyriproxyfen but the method of administration was topical application. Several adult deformities (such as: curled wings, coiled antennae, twisted legs and failure of completely getting rid the last nymphal exuvia) were observed because Pyriproxyfen exhibited a remarkable deteriorating action on the adult morphogenesis, regardless to the nymphal instar' under treatment. Moreover, such action was dosedependent when Pyriproxyfen was given to the newly moulted nymphs (of *4th* or *5th* instar). These adult deformities by the nymphal treatments of S. *gregaria* with Pyriproxyfen may be explained by the. hormonal unbalance during the adult differentiation. In general, a detailed or exact interpretation may be available by further investigation in future.

Beside the effects of Pyriproxyfen on the adult emergence and morphogenesis of S. *gregaria,* in the present study, the *adult longevity* was also affected. Pyriproxyfen treatments of newly moulted nymphs resulted in shortened adult longevity paraIlely to the concemration level. On the other hand, insignificantly extended longevity was recorded after treatment of the late-aged last instar nymph.

The shortening action of these IGRs on the adult longevity of S. *gregaria,* in the present study, is in accordance with that recorded by (Metwally and Landa, 1972; Cogburn, 1988; MuraliBaskaran and Janarthana, 1988), while the prolongation of adult longevity - as seen in the present study- may be unique or rarely observed. Unfortunately, no physiologically precised explanation of these varied effects of Pyriproxyfen on the adult longevity of S. *gregaria* is available right now.

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الملخص العربي

الاستجابات الانمائية والتشكلية في الجراد الصحراوي شيستوسركاجريجريا (مستقيمات الأجنحة : الجراديات) لشبيه هرمون الفتوة بيربروكسيفين

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أجريت الدراسة الحالية لبحث تأثيرات مركب بيربروكسيفين في نمو وإنماء وتشكل الجراد الصحراوي **شيستوسركا جريجاريا . وقد تم تحضير خمسة تركيزات (1000 ، 500 ، 250 ، 125 ، 62.5 ج ف م) عوملت بها حوريات الدور الرابع (حديثة الإنسلاخ) ، وحوريات الدور الخامس (حديثة الإنسلاخ والمتقدمة في العمر) ، وذلك عن طريق الغذاء الطازج الذى تناولته الحوريات ليوم واحد ، وبعده تم تدوين الملاحظات .**

أبدى مركب بيربروكسيفين تأثيرا تثبيطيا ملحوظا في نمو الحوريات ، وبالتالي فقد احبطت في اكتسابها لأوزان جسدية كالتي اكتسبتها الحوريات الضابطة . فعلي سبيل المثال ، حرمت الحوريات من إحراز أكثر من ثلث ما أحرزته الحوريات الضابطة ، وذلك بعد استعمال أعلى تركيز . كذلك انخفض معدل الإنماء انخفاضا متزايدا مع تصاعد مستوي التركيز ، في جميع المعاملات تقريبا . وكانت الحوريات الضابطة صاحبة أسرع معدل إنماء بين جميع الحوريات .

أعاق مركب بيربروكسيفين بزوغ اليافعات إعاقة تزايدت مع تصاعد مستوي التركيز . واشتد تأثير المركب في هذه العملية حتي أنه منع اليافعات من البزوغ منعا تاما ، وذلك بعد معاملة حوريات الدور الرابع بأعلي تركيز ، كما أفسد المركب الحالي تشكل اليافعات ، وكانت درجة تشوه اليافعات متزايدة مع تزايد مستوي التركيز المستعمل ضد حوريات الدور الرابع أو الدور الخامس الحديث .

وبعد معاملة هذه الحوريات ، أيضا ، قصرت فترة حياة اليافعات قصرا كبيرا ، بينما أدت معامل حوريات الدور الخامس المتقدمة العمل إلي إطالة فترة حياة اليافعات ، وإن كانت إطالة غير ملحوظة .