Effect of Some Insect Growth Regulators on the Carbohydrates of Desert Locust, *Schistocerca Gregaria* (Orthoptera: Acrididae)

Ahmed S El-Ebiarie

Department of Zoology, Faculty of Science, Helwan University, Cairo, Egypt
aselebiarie@hotmail.com

Abstract: The newly moulted last (5^{th}) instar nymphs of the desert locust *Schistocerca gregaria* were treated with two concentrations (1000, and 62.5 ppm) of three IGRs: pyriproxyfen, tebufenozide and lufenuron. The carbohydrate content was determined in haemolymph and fat body of the early-aged, mid-aged and late-aged nymphs of the same instar, as well as of 1- and 4-day old adult females. Pyriproxyfen continuously prohibited the nymphs to gain normal carbohydrate content in haemolymph along the nymphal life. A reversal effect was achieved by tebufenozide. The effect of lufenuron was varied on the carbohydrate content of haemolymph. In addition, a stimulating action of all IGRs on the nymphs of all ages was detected with few exceptions. Pyriproxyfen drastically affected the carbohydrate content of haemolymph of 1-day old adults but a carbohydrate increment was determined for the 4-day old adults (at the low concentration level). Concerning with tebufenozide, an inducing effect was exerted on adults to attain excess carbohydrates in the haemolymph at the low concentration level only. Moreover, the enhancing action of lufenuron was exhibited on the metabolite, regardless of the adult age or the concentration level. With regard to the carbohydrate content of fat body in adults, pyriproxyfen treatments of nymphs resulted in reduced carbohydrates in 1-day old adults. In contrast, carbohydrates slightly increased in fat bodies of adults of both ages as response to the action of both tebufenozide and lufenuron, regardless of their concentration levels.
The interference of pyriproxyfen, tebufenozide and lufenuron with the metabolism of an essential energy source, carbohydrate, for all biological processes in nymphs and adults of the desert locust *S. gregaria* provides appreciable evidence to a promising use of these IGRs against this destructive pest.
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1. Introduction

Nobody lacks knowledge about the serious hazards of the famous desert locust *Schistocerca gregaria* (Forsk.) on the economy, especially the agricultural wealth and food supply for man. A migratory swarm of this pest usually contains 50 million locusts covering an area of several square kilometers. Such swarm can continuously fly for 20 hours every day passing through 2400 kilometers. Astonishingly, locusts of only a part of a moderate swarm have devouring an amount of food plants suffice for 2500 persons!!

Although chemical pesticides are invaluable in controlling insect populations both in the field and storage, their indiscriminate use has resulted in the destruction of beneficial insects and has caused environmental hazards. Moreover, insecticide resistance has already developed in many insects which is now a great concern in post-harvest ecosystems throughout the world (**Subramanyam and Hagstrum, 1995; Arthur, 1996**). These problems have resulted in the search for alternative control agents which are less toxic to non-target animals and the environment. In this regard, the insect growth regulators (IGRs) which regulate the insect population through the disruption of moulting and metamorphosis have captured the interest of entomologists (**Mondal and Parween, 2000**).

A lot of literature was reported for assorting these compounds in two categories. The first category includes juvenoids (juvenile hormone analogues) and antijuvenoids which mimic the action of authentic JH or inhibit its role in the insect growth and development (**Slama, 1974; Retnakaran *et al*., 1985**). Some of the most famous compounds are methoprene, hydroprene, kinoprene, fenoxycarb, pyriproxyfen and precocenes I and II. The second category comprises those compounds inhibiting the chitin biosynthesis, such as diflubenzuron, chlorflauzuron, triflumuron, Flufenoxuron, hexaflumuron, lufenuron, diofenolan, teflubenzuronk triflumuron, and novaluron, or interfering with the moulting process in general such as tebufenozide (RH-5992), methoxyfenozide (RH-2485), halofenozide (RH-0345) and chromofenozide (ANS-118) (**Staal, 1975; Ghoneim *et al*., 1992; Dallaire *et al*., 2004; Doucet *et al*., 2007; Kebbeb *et al*., 2008; Ghasemi *et al*., 2010; Zibaee *et al*., 2011**).

Carbohydrates play an important role for the structure and functions of all tissues during metamorphosis as well as for the normal functioning of the male and female reproductive organs and embryonic development (*cf*. **Chippendale, 1978**). On the other hand, the carbohydrate content in the haemolymph is an important indicator of the level of metabolism in insects, and a dynamic balance of the absorption, metabolism, and utilization by different tissues **Zhu *et al*. (2012)** Therefore, the present study was carried out aiming to evaluate the effects of three IGRs, Pyriproxyfen, tebufenozide and lufenuron, on the carbohydrate content of both the haemolymph and fat body of the economically dangerous locust, *Schistocerca gregaria*.

2. Material and Methods

Experimental Insect:

Successive generations of the desert locust *S. gregaria* (Forsk.) were maintained for several years under the gregarious conditions in Department of Zoology, Faculty of Science, Al-Azhar university, Egypt. It was originated by a sample provided from Locust and Grasshopper Res. Division, Plant Protection Research Institute, Giza, Egypt. The culture was raised and handled under crowded breeding conditions described by **Hassanein (1965)**. The hoppers were reared in wooden cages with wire-gauze sides (40x40x60 cm) and small door in the upper side to allow the daily feeding and cleaning routine. Each cage was equipped internally with 60 W electric bulb for lightening (17:7 LD) and warming (32±2 ºC.). The relative humidity varied from 30-50% following the introduction of fresh food plant to 50-70% several hours later. Nymphs and adults were allowed to feed on fresh leaves of leguminous plant Medicago *sativa*. Daily routine of cleaning and monthly routine with an antiseptic agent had been carried out for all cages.

Insect Growth Regulators and Nymphal Treatments:

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. A technical grade of Tebofenozide (RH-5992) was also used. Its chemical name is 1-N-t-butyl-1 (3, 5-dimethyl benzoyl)-2-(4-ethylbenzoyl) hydrazine (Rohm and Haas Company, Philadelphia, PA). **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)}}}.

Two concentration levels of each IGR (1000 and 62.5 ppm) were prepared using the distilled water. 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 the concentration level and then offered to the newly moulted last (5^{th}) instar nymphs. The control nymphs had been provided with fresh clean clover leaves after dipping in distilled water. Three replicates (10 nymphs/rep.) were carried out for each treatment or controls. Each individual nymph was kept in a suitable glass vial whose bottom covered with a thin layer of sterilized sand. All vials were carefully located in a cage provided with a suitable electric bulb for lightening and warming.

Determination of Carbohydrates:

After treatment the newly moulted last (5^{th}) instar nymphs, haemolymph of last (5^{th}) instar nymphs [1-day old (early-aged), 4-day old (mid-aged) and 7-day old (late-aged)] and adult females [0-day old (newly emerged) and 4-day old] was drawn out from the coxal joint into Eppendorff Pipetman containing few milligrams of phenoloxidase inhibitor (phenylthiourea) to prevent tanning or darkening and then diluted 5× with saline solution 0.7%. The haemolymph samples were then centrifuged at 2000 r.p.m. for 5 min, and only the supernatant fractions were used for assay directly or frozen until use. Three replicates were used and the haemolymph of two individuals were never mixed. The same nymphs and adults (treated or control) have been dissected to collect their fat body (visceral and parietal) and then homogenized in a saline solution (the fat body of one insect / 1 ml saline solution 0.7 %) using a fine electric homogenizer, tissue grinder for 2 min. Homogenates were centrifuged at 4000 r.p.m. for 15 min. The supernatant was used directly or frozen until the use for the enzymatic determination. Three replicates were used and the fat bodies from two individuals were avoided to be mixed.

Total carbohydrate (as glycogen) content of haemolymph or fat body was quantitatively determined by using the anthrone reagent according to **Singh and Sinha (1977**) and utilizing the Spectrophotometer at 620 mμ.

Analysis of Data:

Data obtained were calculated as mean±SD and analyzed using the Student t-distribution and were refined by Bessel's correction (**Moroney, 1956**) for testing the significance of difference between means at probability 0.05, 0.01 and 0.001.

3. Results

Effects of IGRs on the carbohydrate content of nymphs:

The carbohydrate content was determined in the haemolymph and fat bodies of early-aged (1-day old), mid-aged (4-day old) and late-aged (7-day old) nymphs. Data of carbohydrate content of haemolymph of nymphs are assorted in Table I and Fig. 1. Pyriproxyfen prohibited the nymphs to gain normal carbohydrate content in haemolymph. It was pronouncedly depleted along the developmental stage. The strongest prohibiting effect of pyriproxyfen was exhibited in the late-aged nymphs (35.47±2.52 and 48.35±3.77 mg/ml at high and low concentration levels, respectively, in comparison with 59.40±3.52 mg/ml of control nymphs). Meanwhile, the least prohibiting effect of pyriproxyfen was exhibited early on the carbohydrate content of nymphal haemolymph (31.42±2.57 and 35.37±3.51 mg/ml at high and low concentration levels, respectively, in comparison with 37.25±2.34 mg/ml of control nymphs).

A reversal effect on the carbohydrate content of nymphal haemolymph was achieved by tebufenozide. Significantly or non-significantly increasing carbohydrate content was estimated along the nymphal life. Tebufenozide, with its high concentration, remarkably enhanced the nymphs to gain excess carbohydrates (%Changes were, +29.91, +4.14 and +46.8 in the haemolymph of early-, mid- and late-aged nymphs, respectively).

With regard to lufenuron, variable effect was exhibited on the carbohydrate content of nymphal haemolymph. Slightly decreased content was measured for the early-aged nymphs (of 1-day old) (%Changes were, -26.8 and -2.41 at high and low concentrations, respectively) but considerably increased content was recorded for nymphs of other ages.

In addition to haemolymph, the metabolic effects of the present IGRs were investigated in fat body during the nymphal instar. As obviously shown in (Table II and Fig. 2), promoting action of all IGRs on the nymphs of all ages was observed with few exceptions. Pyriproxyfen enhanced the carbohydrate content in fat bodies of early- and mid-aged nymphs but exhibited a delayed inhibitory effect on carbohydrates of late-aged nymphs (28.51±1.89 and 30.25±2.74 mg/gm at high and low concentration levels, respectively compared with 34.04±2.81 mg/gm of control congeners). The strongest promoting action of pyriproxyfen was exerted at its low concentration on carbohydrate content of fat body of the early-aged nymphs (%Change was +26.48) while its greatest reducing action was exerted at its high concentration (%Change was -16.17).

Data distributed in the same table clearly show a general enhancement of carbohydrate content in nymphs of all ages after treatment with lufenuron. Moreover, treatment with the high concentration (1000.0 ppm) resulted in conspicuously increased carbohydrate content (% Changes were: + 9.18, +25.43 and 13.52 in early-, mid- and late-aged nymphs, respectively).

On the other hand, tebufenozide exhibited contradictory effects on the metabolite, depending on the concentration level, because treatment with the high concentration led to increasing carbohydrates while with the low concentration led to decreasing carbohydrates.

Effects of IGRs on the carbohydrate content of adults:

After treatment of the newly moulted last instar nymphs with the two concentration levels of each of the present IGRs, the carbohydrate content was estimated in haemolymph and fat body of adult females of two ages: 1-day old and 4-day old (with the ovarian maturation period).

In the light of data summarized in (Table III and Fig. 3), pyriproxyfen drastically affected the carbohydrate content of haemolymph of 1-day old adults (56.37±2.20 and 70.52±2.25 mg/ml at high and low concentration levels, respectively, as compared to 74.64±2.50 mg/ml of control adults) but a carbohydrate increment was determined for the 4-day old adults at the low concentration level of pyriproxyfen, no adults survived until this age after nymphal treatment with the high concentration level of pyriproxyfen .

The same trend was observed when tebufenozide was used. An encouraging effect to attain excess carbohydrates in the haemolymph only at the low concentration level was observed while no adults emerged after nymphal treatment with the high concentration level. Moreover, the enhancing action of lufenuron was exhibited on the metabolite, regardless of the adult age or the concentration level of the IGR. However, this enhancement was conspicuously detected in the 4-day old adults (%Changes were +8.67 and +5.20 at high and low concentration levels, respectively).

To recognize the metabolic effects of the present IGRs on the carbohydrate content of fat body in adults, data of Table (IV) and Fig. 4 show that the pyriproxyfen treatments of nymphs resulted in significantly (at 1000.0 ppm) or non-significantly (at 62.5 ppm) reduced carbohydrates in the fat bodies of 1-day old adults but no data are available for 4-day old ones because they died before reaching this age. In contrast, carbohydrates slightly increased in fat bodies of adults of both ages as response to the action of both tebufenozide and lufenuron, regardless of their concentration levels.

Table I. Total carbohydrate content (mg/ml ± SD) in the nymphal haemolymph after treatment of the newly moulted last instar nymphs of *Schistocerca gregaria* with some IGRs (mean± SD).

IGRs	Conc. (ppm)	Last instar nymphs (Age in days)					
		1-day old	%Change	4-day old	%Change	7-day old	%Change
Pyriproxyfen	1000.0	31.42 b ± 2.57 (b)	-15.59	37.32 ± 2.14(d)	-22.61	35.47 ± 2.52 (d)	-40.4
	62.5	35.37 ± 3.51 (a)	-5.1	42.35 ± 3.70 (a)	-12.24	48.35 ± 3.77(d)	-18.68
	Controls	37.25 ± 2.34	_	48.21 ± 2.56	_	59.46 ± 3.52	_
Tebufenozide	1000.0	48.33 ± 4.98 (d)	29.91	50.23 ± 1.28 (a)	4.14	87.20 ± 2.52 (d)	46.8
	62.5	40.56 ± 2.70 (a)	8.87	47.72 ± 3.10 (a)	1.37	55.77 ± 3.71 (a)	6.22
	Controls	37.25 ± 2.34	_	48.21 ± 2.56	_	59.46 ± 3.52	_
Lufenuron	1000.0	36.21 ± 1.58 (a)	-26.8	55.35 ± 4.82 (b)	14.73	68.21 ± 2.38 (d)	14.81
	62.5	36.36 ± 1.92 (a)	-2.41	50.62 ± 3.21 (a)	5.00	60.27 ± 3.57 (a)	1.34
	Controls	37.25 ± 2.34	_	48.21 ± 2.56	_	59.46 ± 3.52	_

Conc.:concentration, mean ± SD followed with the letter (a): is not significantly different (P >0.05), (b): significantly different (P<0.05), (c): highly significantly different (P <0.01), (d): very highly significantly different (P <0.001).

Fig. 1. Total carbohydrate content (mg/ml) in the nymphal haemolymph after treatment of the newly moulted last instar nymphs of *Schistocerca gregaria* with some IGRs.

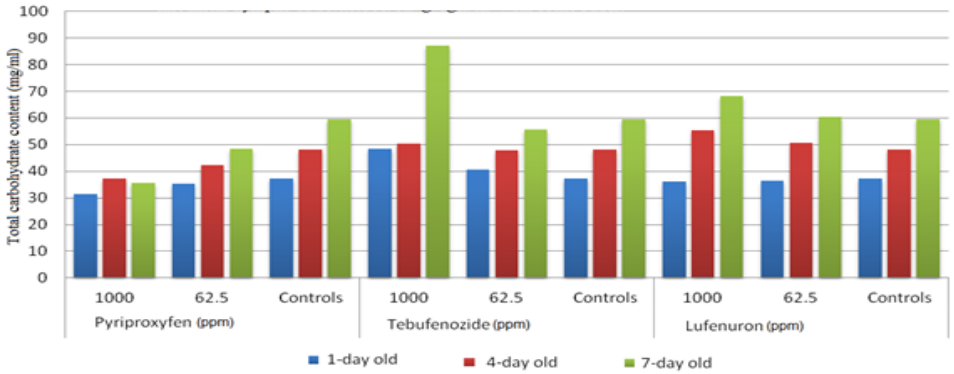


Table II. Total carbohydrate content (mg/g±SD) in the nymphal fat body of *Schistocerca gregaria* after treatment of the newly moulted last instar nymphs with some IGRs

IGRs	Conc. (ppm)	Last instar nymphs (Age in days)					
		1-day old	%Change	4-day old	%Change	7-day old	%Change
Pyriproxyfen	1000.0	20.71 ± 2.51 (a)	11.89	25.78 ± 3.26 (a)	12.71	28.51 ± 1.89 (d)	-16.17
	62.5	23.45 ± 2.11 (b)	26.48	23.46 ± 3.50 (a)	2.67	30.25 ± 2.74 (a)	-11.17
	Controls	18.52 ± 2.56	_	22.85 ± 3.44	_	34.04 ± 2.81	-
Tebufenozide	1000.0	22.56 ± 1.83 (a)	21.62	37.25 ± 1.40 (d)	63.15	50.62 ± 3.96 (d)	48.82
	62.5	15.46 ± 2.33 (a)	-16.75	20.62 ± 3.86 (a)	-9.64	33.64 ± 2.63 (a)	-1.18
	Controls	18.52 ± 2.56	_	22.85 ± 3.44	_	34.04 ± 2.81	_
Lufenuron	1000.0	20.23 ± 2.11 (a)	9.18	28.63 ± 2.45 (b)	25.43	38.61 ± 3.07 (a)	13.52
	62.5	19.25 ± 1.51 (a)	3.94	28.34 ± 2.67(b)	10.96	36.73 ± 2.51 (a)	7.93
	Controls	18.52 ± 2.56	_	22.85 ± 3.44	_	34.04 ± 2.81	_

Conc., a, b and d: See footnote of Table (I).

Fig. 2. Total carbohydrate content (mg/g) in the nymphal fat body of *Schistocerca gregaria* after treatment of the newly moulted last instar nymphs with some IGRs

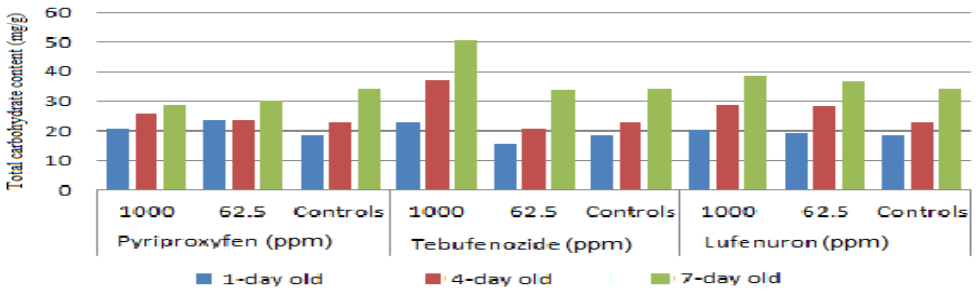


Table III. Total carbohydrate content (mg/ml±SD) in the adult haemolymph after treatment of the newly moulted last instar nymphs of *Schistocerca gregaria* with some IGRs.

IGRs	Conc. (ppm)	Adult stage (Age in days)			
		1-day old	%Change	4-day old	%Change
Pyriproxyfen	1000.0	56.37 ± 2.20 (d)	-24.53	=	_
	62.5	70.52 ± 2.25 (a)	-5.49	73.48 ± 3.58 (a)	6.06
	Controls	74.64 ± 2.5	_	69.21 ± 1.89	_
Tebufenozide	1000.0	=	_	-	_
	62.5	78.66 ± 3.11 (a)	5.44	76.81 ± 4.52 (b)	1.98
	Controls	74.64 ± 2.5	_	69.21 ± 1.89	_
Lufenuron	1000.0	77.48 ± 2.52 (a)	3.75	75.21 ± 2.34 (c)	8.67
	62.5	75.25 ± 3.57 (a)	0.82	72.86 ± 2.31 (a)	5.2
	Controls	74.64 ± 2.50	_	69.21 ± 1.89	_

Conc., a, c and d: See footnote of Table (I). =: adults died.

Fig. 3. Total carbohydrate content (mg/ml) in the adult haemolymph after treatment of the newly moulted last instar nymphs of *Schistocerca gregaria* with some IGRs.

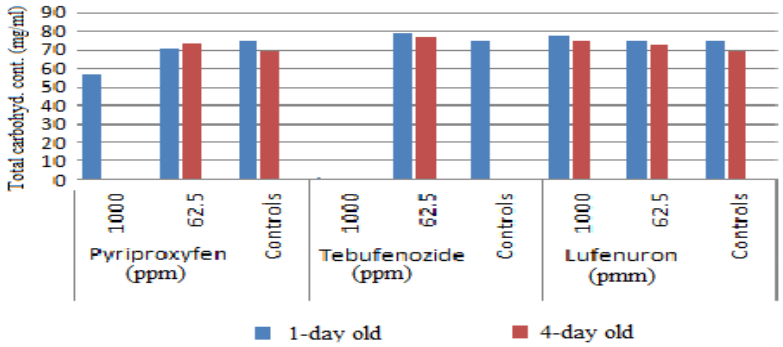
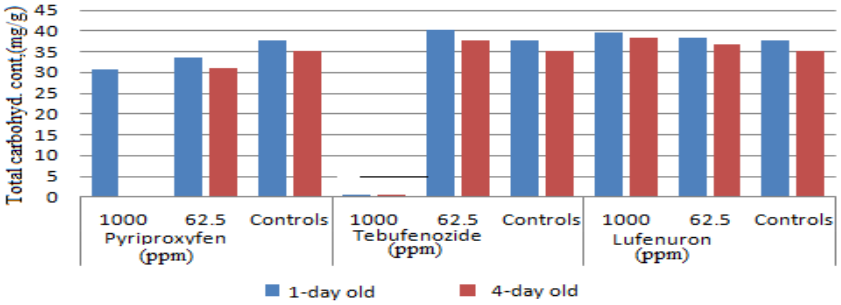


Table IV. Total carbohydrate content (mg/g±SD) in the adult fat body of *Schistocerca gregaria* after treatment of the newly moulted last instar nymphs with some IGRs.

IGRs	Conc. (ppm)	Adult stage (Age in days)			
		1-day old	%Change	4-day old	%Change
Pyriproxyfen	1000.0	30.62 ± 2.02 b	-19.04	=	-
	62.5	33.46 ± 2.52 a	-11.46	31.21 ± 3.42 a	-11.68
	Controls	37.85 ± 2.57	_	35.33 ± 1.84	_
Tebufenozide	1000.0	=	-	=	_
	62.5	40.25 ± 2.77 a	6.34	37.63 ± 1.25 a	6.42
	Controls	37.85 ± 2.57	_	35.33 ± 1.84	_
Lufenuron	1000.0	39.57 ± 3.14 a	4.49	38.26 ± 1.79 a	9.06
	62.5	38.26 ± 2.50 a	10.5	36.75 ± 2.77 a	3.96
	Controls	37.85 ± 2.57	_	35.33 ± 1.84	_

Conc., a and b: See footnote of Table (I). =: see footnote of Table (III).

Fig. 4. Total carbohydrate content (mg/g) in the adult fat body of *Schistocerca gregaria* after treatment of the newly moulted last instar nymphs with some IGRs.



4. Discussion

Some authors estimated increasing carbohydrate content in some insect species as a response to the action of different insect growth regulators (IGRs) while others reported reversed results. These contradictory findings may be attributed to the differences in species sensitivity, the potency of the IGRs, or the developmental stage (**Ghoneim *et al*., 2003**).

In general, no certain trend of the metabolic effects of the present IGRs was detected because pyriproxyfen continuously prohibited the nymphs to gain normal carbohydrate content in haemolymph but a reversal effect was achieved by tebufenozide. Significant or non-significant increasing carbohydrate content was estimated along the nymphal life. With regard to lufenuron, variable effect was exhibited on the haemolymph carbohydrates because slightly decreased content was measured for the early-aged nymphs but considerably increased content was recorded for nymphs of other ages. In addition, a stimulatory action of all IGRs on the fat body carbohydrates of nymphs of all ages was detected with few exceptions.

As it has been reported for many insects, different IGRs affected the carbohydrates. Various juvenoids (JHAs), and IGRs in general, prohibited the carbohydrate content in some insects, e.g. *Spodoptera littoralis* by the JHA isopropyl 3,7,11-triethyl-2,4-dodecadiote (**Ismail, 1980**); *Schistocerca gregaria* by fenoxycarb (**El-Gammal *et al*., 1989**); *Musca domestica* by methoprene (**Abou el-ela *et al*., 1990**); *Synthesomyia nudiseta* by some IGRs (**Abou el-ela *et al*., 1993**); the newly formed and late-aged pupae of *Rhynchophorus ferrugineus* by lufenuron and diofenolan (**Ghoneim *et al*., 2003**), *M. domestica* by lufenuron and diofenolan (**Ghoneim *et al*., 2006**). Also carbohydrate content in some tissues of the developmental stages of different insects was decreased by some insecticides (**Shakoori *et al*., 1988; Mandal and Chaudhuri, 1992; Radwan and Shaurub, 1995; El-Bokl *et al*., 1998**)

As detected in the present study on *S. gregaria*, tebufenozide enhanced the nymphs to gain more carbohydrate in the haemolymph along their life while lufenuron exhibited a similar inducing effect only on the mid- and late-aged nymphs. Moreover, all IGRs stimulated the nymphs of all ages to accumulate excess carbohydrates in their fat bodies. However, the increasing carbohydrate content was obtained by several insects after treatment with different IGRs, e.g. kinoprene significantly induced the carbohydrate content in the last instar larvae of *S. littoralis* (**Fouda and Amer, 1990**); chlorfluazuron and mevalonic acid (separately or combined) promoted the last instar larvae and pupae of *S. littoralis* to gain various increments of carbohydrate in haemolymph and fat body (**Ghoneim, 1994**); increasing carbohydrate content of *S. gregaria* was triggered by chlorfluazuron (**El-Gammal *et al*., 1993**); diflubenzuron-applied pupae or adult females of *Tenebrio molitor* had excessive carbohydrate (**Soltani *et al*., 1987; Soltani-Mazouni *et al*., 1999**); the mid-aged pupae of *Rh. Ferrugineus* were fostered to accumulate excess carbohydrates after treatment of prepupae with lufenuron and diofenolan (**Ghoneim *et al*., 2003**); topical application of lufenuron or diofenolan onto the late last (3^{rd}) instar larvae of *M. domestica* led to increasing carbohydrates all over the pupal life, with few exceptions (**Ghoneim *et al*., 2006**); novaluron-treated 4^{th} instar larvae of the mosquito *Culiceta longiareolata* caused increasing carbohydrate content starting from the day 5 post-treatment (**Bouaziz *et al*., 2011)**.

The varied effects of pyriproxyfen, tebufenozide and lufenuron on the carbohydrate content in haemolymph or fat bodies of nymphs of *S. gregaria*, recorded in this study may be due to their hormonal actions on the carbohydrate metabolism because each type of hormonally conditioned developmental cycles can be characterized by the determined pattern in the course of the total body metabolites, such as carbohydrates, is affected by JH (**Orr, 1964; Price, 1973; Imboden and Luscher, 1976)**. Also, the production or utilization of the main body metabolites, such as carbohydrates, under the control of JH (or IGRs, in general) was suggested by several authors (**Slama, 1965; Slama and Hodkova, 1975**; **Gade, 2004; Sugumarau, 2010**).

In addition, the disturbance in carbohydrate content of *S. gregaria* nymphs, as evidently recorded by the current results after treatment with pyriproxyfen, tebufenozide or lufenuron, can be understood in the light of the ability of the organism to modify the synthesis of certain metabolite and disrupt the functionality of the organism (**Rodriguez-Ortega *et al*., 2003**). Other studies show that the carbohydrate reserves vary in agreement with the different developmental stages of the insect. They increase during the rest periods, like metamorphosis, and decrease during the growth periods, like the stages of maturation of the gonads in insects (**Bouaziz *et al*., 2011**). On the other hand, decreasing content of carbohydrates after treatment with IGRs may be attributed to their antifeeding action (**Salem, 1994**), to a decrease in the trehalase activity (**El-Shiekh, 2002**), or to their effects on the carboxylase activity (**Mukherjee and Sharma, 1996**).

The present work included, also, the assessment the effects on carbohydrates in haemolymph and fat bodies of the adult females of *S.*

gregaria after treatment of the newly moulted last instar nymphs with pyriproxyfen, tebufenozide or lufenuron. Pyriproxyfen drastically affected the haemolymph carbohydrate content of 1-day old adults but a carbohydrate increase was determined for 4-day old adults (at 62.5 ppm). Tebufenozide exhibited an inducing action on the haemolymph carbohydrate content (at 62.5 ppm) and lufenuron exhibited similar effect, regardless of the adult age or the concentration level. Considering the carbohydrate content in fat body of adults, pyriproxyfen treatment of nymphs resulted in reduced carbohydrates in 1-day old adults. In contrast, carbohydrates slightly increased in fat bodies of adults of both ages as a response to the action of tebufenozide and lufenuron, regardless of their concentration level. However, inducing or reducing effects of some IGRs on the carbohydrate content of adults belonging to various insects species were reported , e.g. increasing carbohydrates in adults of *Chrysocoris stolli* (**Saha *et al*., 1986)** and *S. littoralis* **(Abdel-Hafez *et al*., 1988**) after treatment with some IGRs. In addition, **Ezz and Fahmy (2009**) estimated increasing carbohydrate content of adult mealybug *Ferrisia virgata* at day 4 and significantly decreasing carbohydrate content after 10 days post-treatment. The reducing or inducing of pyriproxyfen, tebufenozide or lufenuron on the carbohydrate content of adult *S. gregaria*, in the present study, may be due to the extended action of each (**Anwar and Abdel-Mageed, 2005).**

In conclusion, the results obtained in the present study show a disturbing interference of pyriproxyfen, tebufenozide and lufenuron with the metabolism of the essential energy source, carbohydrates, in nymphs and adults of the desert locust *S. gregaria* which can provide an appreciable evidence to a promising use of these IGRs against this destructive pest as environmentally-friendly alternatives of the synthetic chemical insecticides. However, more research is needed for detecting the mode of action of each IGR in addition to ascertain the receptors involved in responding to its action.

Corresponding author
Ahmed S El-Ebiarie
Department of Zoology, Faculty of Science, Helwan University, Cairo, Egypt
aselebiarie@hotmail.com

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