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Full Length Research Paper

Effect of certain insect growth regulators on the lipid content of some tissues of the desert locust *Schistocerca gregaria*

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The present study was carried out to investigate the metabolic effects of pyriproxyfen, tebufenozide or lufenuron on the lipid content in two different tissues: hemolymph and fat body of the early-, mid- and late-aged old nymphs as well as 1- and 4-days old adult females. Hemolymph lipid content of the early-aged nymphs had been subjected to a reducing effect after treatment with high concentration of insect growth regulators (IGRs). With the age of nymphs, all IGRs could significantly or non-significantly reduce the lipid content of hemolymph. Concerning the lipid content in fat bodies of nymphs, a predominant inhibitory effect of all IGRs was detected. With regard to the adults, nymph treatments led to remarkable or slightly decreased lipids in the hemolymph, as an exceptional case; because the lipid content non-significantly increased in 4-day old adults after treatment with low concentration level of lufenuron. The current IGRs unexceptionally exhibited inhibitory effects on the lipids of adult fat bodies.

Key words: *Schistocerca gregaria*, lipids, fat body, hemolymph, nymph, adult, pyriproxyfen, tebufenozide, lufenuron.

INTRODUCTION

Nowadays, alternative methods for pest control are being appreciated. One of the alternatives is the so called insect growth regulators (IGRs). These compounds are highly effective against various insects and other pests that have become resistant to organic insecticides. Meanwhile, all these compounds are less toxic to mammals and non target organisms because of their non-toxic effect and their quick disintegrating abilities (Carter, 1975; Staal, 1975; Zurfleuh, 1976; Oberlander et al., 1978, 1979; Ishaaya et al., 1987; Kostyukovsky et al., 2000; Ghasemi et al., 2010).

Since the target sites of common insecticides on insects and mammals are known to be similar, it is desirable to develop insecticides whose primary target site does not exist in mammals for selective toxicity. IGRs may belong to this type of (selective) insecticides and can be grouped according to their mode of action, as follows chitin synthesis inhibitors (that is, of cuticle formation) and substances that interfere with the action of insect hormones (Tunaz and Uygun, 2004).

Pyriproxyfen is a pyridine-based juvenile hormone agonist that competes for juvenile hormone binding site receptors in insects, mimicking the action of juvenile hormone and thus, maintaining an immature state (Sullivan and Goh, 2008). This compound has a relatively low toxicity for mammals and was first registered in Japan in 1991 for controlling public health pests (Miyamoto et al., 1993).

The non-steroidal ecdysone agonist tebufenozide (RH-5992) is a novel caterpillar control agent with unusually high target selectivity (Carlson, 2000). It was found to be much more potent against and selective towards larval Lepidoptera than was RH-5849 (Carlson et al., 1994; Dhadialla et al., 1998). Under the trade names Confirm®, Mimic®, and Romdan®, it is now widely used on several crops in the world Spruce budworm larvae (*Choristoneura fumiferana*) upon ingesting tebufenozide (RH-5992) stop feeding and go into a precocious, incomplete molt, leading eventually to death (Retnakaran

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et al., 2001). Tebufenozide could disrupt the growth and development of *Spodoptera exigua* because the larval period was elongated and the fecundity was decreased and the ratios of survival, pupation, emergence and hatch of the larvae were also decreased (Linrui et al., 2006).

Lufenuron (RS)-1-[2,5-dichloro-4-(1,1,2,3,3,3-hexafluoropropoxy)-phenyl]-3-(2,6-difluorobenzoyl)-urea is known as an insect development inhibitor / insect growth regulator. It is active against larval developmental stages causing cuticular lesions and interfering in the chitin biosynthesis (Dean et al., 1998; Moriello et al., 2004). It is principally used for controlling the cat flea *Ctenocephalides felis* (Dean et al., 1998), being also active against diptera (Wilson and Cryan, 1997). It is also employed to control pests of several vegetal crops, including the citrus rust mite *Phyllocoptruta oleivora* (Bueno and Freitas, 2004) and adult predators of cotton pests, such as earwings, ladybugs, spiders, mirids and green lacewings (Castane et al., 1996; Angeli and Forti, 1997; Javaid et al.,, 1999) Lufenuron is used for controlling fungal infections in several animal species, due to its capacity to tear chitin from fungal cell wall, as well as, to inhibit the synthesis polymerization and deposition of chitin Based on results obtained by Alves et al. (2011), lufenuron was not interfered in the entomopathogenic fungus and *Metarhizium anisopliae* conidia germination when used in a concentration of 1 mg/ml and increased it to 700 µg/ml.

Lipids are important source of energy for insects. Lipid turnover in insects is regulated by neuroendocrine-controlled feed-back loops (Downer, 1985). Quantity of lipids available for the reserves seems to be the result of a balance between the catch of food and the requests for reserves by processes such as maintenance, growth and reproduction, and this balance is disturbed by any toxic product (Canavoso et al., 2001). Although the first site of action of JHAs in particular and IGRs in general is the endocrine system, many biochemical and physiological changes have been reported to occur in different metabolism pathways (Leonardi et al., 2001; Kim et al., 2002; Etebari et al., 2007). The present study is an extension of previous studies which dealt with the effects of certain IGRs on some metabolic parameters in the desert locust *S. gregaria*. It particularly aims to assess the action of pyriproxyfen, tebofenuzide and lufenuron on the lipid content of hemolymph and fat bodies of nymphs and adults.

MATERIALS AND METHODS

The experimental insect

Successive generations of the desert locust *S. gregaria* (Forskål) (Orthoptera: Acrididae) were maintained for several years under the gregarious conditions in Department of Zoology, Faculty of Science, Al-Azhar university, Cairo, Egypt. It was originated 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 (40×40×60 cm). Each cage was equipped internally with 60 W electric bulb for lightening (17:7 LD) and warming (32 ± 2°C). The relative humidity varied from 30 to 70%. Nymphs and adults were allowed to feed on fresh leaves of leguminous plant *Medicago sativa*.

Insect growth regulators

Some of the insect growth regulators used is as follows:

- 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 Tebufenozide (RH-5992) was 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)}}}.

All insect growth regulators were provided from Institute of Plant Protec., Ministry of Agric., Giza, Egypt.

Nymphal treatments

Two concentration levels of each IGR were prepared using the distilled water: 1000 and 62.5 ppm. 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 min in the concentration level and then offered to the newly molted last fifth instar nymphs. The control nymphs had been provided with fresh clean clover leaves after dipping them in distilled water. 30 nymphs were used for each treatment or controls. Each individual nymph was kept in a suitable glass vial whose bottom was 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.

Lipid determination

Hemolymph of 1, 4 and 7 days old of instar nymphs 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 hemolymph samples were then centrifuged at 2000 r.p.m. for 5 min, and only the supernatant were used for assay directly or frozen until use. 3 replicates (1 nymph/replicate) were used for sampling the hemolymph.

The same nymphs (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 use for the enzymatic determination. Three replicates (one nymph/replicate) were used for sampling the fat body.

Dealing with the adult females of 0-day old (newly emerged) and 4-day old, the same work for hemolymph and fat bodies was carried out.

Quantitative determination of the total lipid content of hemolymph or fat body was conducted according to the technique of Folch et al. (1957) and lipid estimation was taken place by phosphovanilin reagent depending on Knight et al. (1972) and using the

Spectrophotometer at 520 nm.

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

Newly molted last (5^{th}) instar nymphs of the desert locust *S. gregaria* were treated (through the fresh food plant) with a high (1000.0 ppm) or a low (62.5 ppm) concentration level of pyriproxyfen (juvenoids), tebufenozide (ecdysone agonist) or lufenuron (chitin synthesis inhibitor). The present study was carried out to investigate the metabolic effects on the lipid content of two different tissues: hemolymph and fat body. Lipid content was determined for the early- (1-day old), mid- (4-day old) and late-aged old (7-day old) nymphs as well as for 1- and 4-day old adult females.

With respect to the control insects, the current results indicated that the lipid content of the fat body was higher than that of the hemolymph. In other words, when the lipid content of the fat body is high, the lipid content of the hemolymph is low and *vice versa*.

Influenced lipid content of nymphs by the IGRs

The disturbance of lipid content of nymphal hemolymph was varied according to the potency of IGR as well as the developmental age (Table 1). Hemolymph lipid content of the early-aged nymphs had been subjected to a reducing effect after treatment with the high concentration level of pyriproxyfen, tebufenozide or lufenuron (20.54 ± 3.25, 20.17 ± 3.48 and 20.54 ± 3.22 mg/ml by pyriproxyfen, tebufenozide and lufenuron, respectively, as compared to 22.25 ± 3.21 mg/ml of controls). Reversely, treatment with the low concentration level of each IGR resulted in increasing lipid content. The strongest promoting effect on hemolymph lipids of these early-aged nymphs was exhibited by tebufenozide (34.87 ± 7.52 mg/ml, at low concentration level, in comparison with 22.25 ± 3.21 mg/ml of control nymphs). With the age of nymphs, all IGRs could significantly or non-significantly reduce the lipid content of hemolymph. The maximal reducing effects on hemolymph lipids was exhibited by pyriproxyfen (Change%: -59.34, at the high concentration level) in the mid-aged nymphs and by lufenuron (Change%: -59.85, at the high concentration level) in the late-aged nymphs while the minimal reducing effects was exhibited by pyriproxyfen (Change%: -7.64 and -2.61 at the high concentration level) in both early- and late-aged nymphs, and lufenuron (Change%: -8.19 at the low concentration level) in mid-aged nymphs.

With regard to the lipid content in fat bodies of nymphs, data assorted in Table 2 obviously show a predominant inhibitory effect of all IGRs, regardless of the concentration level or the nymphal age. Moreover, the most drastic inhibitory effect was exhibited by pyriproxyfen (Change% s: -28.0, - 63.38 and – 64.71, at the high concentration level, in early-, mid- and late-aged nymphs, respectively). Also, the strongest prohibiting action for both tebufenozide and lufenuron was recorded in the late-aged nymphs (Change% s: -50.59, at the high concentration level of tebufenozide) and in the mid-aged nymphs (Change% s: -31.69, at the high concentration level of lufenuron), respectively (Table 2).

Influenced lipid content of adults by the IGRs

The estimation of lipid content in the adult stage was carried out for 1- and 4-day old females (within the ovarian maturation period). It suffices to see the data of Table 3 for concluding that pyriproxyfen, tebufenozide and lufenuron-nymphal treatments resulted in remarkably or slightly decreased lipids in the hemolymph with an exceptional case because the lipid content non-significantly increased in 4-day old adults after treatment with the low concentration level of lufenuron (29.45 ± 3.50 vs. 28.16 ± 5.11 mg/ml of control adults). However, adults died just after emergence as affected by the extended lethal effect of tebufenozide (at the high concentration level) but 4-day old adults died as affected by the extended lethal effect of pyriproxyfen (at the high concentration level). Therefore, the lipid content could not de determined in these two cases. It can be concluded from data of Table 3, also, that lufenuron (at the high concentration level) exerted the greatest prohibiting action on the hemolymph lipids (Change% s: - 54.46 and – 54.44 in 1- and 4-day old adults, respectively).

As clearly shown in Table 4, the current IGRs unexceptionally exhibited inhibitory effects on the lipids of adult fat bodies whatever the concentration level or the adult age. For some details, the most deteriorated lipid content in fat body was caused by pyriproxyfen at high concentration level (27.41 ± 3.54 mg/gm, as compared to 97.33 ± 5.24 mg/gm of adult congeners) for 1-day old adults, while a similar effect was exhibited by lufenuron at high concentration level only for 4-day old adults (55.62 ± 4.22 mg/gm, as compared to 87.25 ± 2.42 mg/gm of control congeners).

DISCUSSION

The lipids are necessary as a source of energy in live creatures such as insects. Insects obtain lipids from the food sources or synthesize them from within the bodies (Gilbert, 1967). It has been reported that the lipid accumulation is more likely to be related to lack of juvenile hormone (Hill and Ezzat, 1974). Hence, the lipid turnover in insects is regulated by neuroendocrine-

Table 1. Total lipid content (ng/ml ± SD) of the hemolymph of the desert locust *Schistocerca gregaria* nymphs as influenced by some IGRs after treatment of the early last instar nymphs.

IGRs	Conc. (ppm)	Last instar nymphs (Age in days)					
		1-day old	Change %	4-day old	Change %	7-day old	Change %
Pyriproxyfen	1000	20.54 ± 3.25[a]	-7.64	7.44 ± 2.81[d]	-59.34	19.77 ± 2.42[a]	-2.61
	62.5	25.43 ± 2.65[a]	14.41	16.34 ± 2.48[a]	-10.92	16.34 ± 2.22[a]	-19.7
	Controls	22.25 ± 3.21	-	18.35 ± 4.32	-	20.34 ± 3.42	-
Tebufenozide	1000	20.17 ± 3.48[a]	-9.43	12.45 ± 1.43[b]	-34.2	8.33 ± 1.77[d]	-58.96
	62.5	34.87 ± 7.52[d]	57.07	15.13 ± 4.24[a]	-17.55	19.32 ± 2.26[a]	-4.92
	Controls	22.25 ± 3.21	-	18.35 ± 4.32	-	20.34 ± 3.42	-
Lufenuron	1000	20.54 ± 3.22[a]	-7.86	15.66 ± 3.22[a]	-14.42	8.15 ± 2.41[d]	-59.85
	62.5	25.61 ± 4.85[a]	15.31	9.82 ± 2.22[c]	-8.19	17.88 ± 4.50[a]	-12.31
	Controls	22.25 ± 3.21	-	18.35 ± 4.32	-	20.34 ± 3.42	-

Conc.: concentration, mean ± SD followed with the same 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).

Table 2. Total lipid content (mg/g ± SD) of the fat body of the desert locust *Schistocerca gregaria* nymphs as influenced by some IGRs after treatment of the early last instar nymphs.

IGRs	Conc. (ppm)	Last instar nymphs (Age in days)					
		1-day old	Change %	4-day old	Change (%)	7-day old	Change (%)
Pyriproxyfen	1000.0	63.51 ± 2.45[d]	-28	34.25 ± 2.33[d]	-63.38	26.54 ± 2.45[d]	-64.71
	62.5	81.53 ± 2.42[b]	-7.29	87.34 ± 4.89[a]	-6.62	70.52 ± 3.54[a]	-6.62
	Controls	88.26 ± 4.22	-	93.48 ± 4.85	-	75.17 ± 5.12	-
Tebufenozide	1000.0	84.35 ± 5.34[a]	-4.42	82.54 ± 3.34[c]	-11.57	37.15 ± 4.22[d]	-50.59
	62.5	82.15 ± 4.62[a]	-6.92	88.59 ± 4.28[a]	-5.24	59.33 ± 2.57[d]	-24.99
	Controls	88.26 ± 4.22	-	93.48 ± 4.85	-	75.17 ± 5.12	-
Lufenuron	1000.0	85.66 ± 6.40[a]	-2.94	63.85 ± 2.54[d]	-31.69	66.61 ± 5.32[c]	-11.31
	62.5	80.35 ± 2.51[c]	-8.95	74.88 ± 5.48[d]	-19.82	57.65 ± 3.88[d]	-23.5
	Controls	88.26 ± 4.22	-	93.48 ± 4.85	-	75.17 ± 5.12	-

Conc., concentration, mean ± SD followed with the same 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).

controlled feedback loops (Downer, 1985).

In the present study on the desert locust *Schistocerca gregaria*, the disturbance of lipid content in hemolymph of last instar nymphs was varied according to the potency of the IGR (pyriproxyfen, tebufenozide or lufenuron) as well as the developmental age (1-, 4- or 7-day old nymphs). Hemolymph lipid content of the early-aged nymphs had been subjected to a reducing effect after treatment with the high concentration level (1000.0 ppm) of pyriproxyfen (juvenoids or JHA), tebufenozide (ecdysone agonist) or lufenuron (chitin synthesis inhibitor). Reversely, treatment with the low concentration level (62.5 ppm) of each IGR resulted in an increase of lipids, especially by the action of tebufenozide. However, the lipid content of hemolymph was significantly or non-significantly depleted in mid- and late-aged nymphs. Concerning the lipid content in fat bodies of nymphs, a dominant inhibitory effect of all IGRs was detected, regardless of the concentration level or the nymphal age. The strongest inhibitory effect was exhibited on nymphs of all ages by pyriproxyfen but on mid-aged nymphs by tebufenozide and on late-aged nymphs by lufenuron.

Results of the present study to some extent agree with those reported results on different insects by various IGRs in a side but disagree with others on the other side. Decreased lipid content was recorded for the rice moth *Corcyera cephalonica* by the action of pyriproxyfen (Mandal and Chaudhuri, 1992), for the cotton leaf worm *Spodoptera littoralis* by (Bay Sir-8514) (Ahmad et al., 1989) and for the same insect by pyriproxyfen (Ahmed,

Table 3. Total lipid content (mg/ml ± SD) of the hemolymph of the desert locust *Schistocerca gregaria* adults as influenced by some IGRs after treatment of the early last instar nymphs.

IGRs	Conc. (ppm)	Adult stage (Age in days)			
		1-day old	Change (%)	4-days old	Change (%)
Pyriproxyfen	1000	20.52 ± 3.24[a]	-8.48	=	-
	62.5	19.54 ± 4.41[a]	-12.94	22.64 ± 2.25[a]	-19.16
	Controls	22.41 ± 5.48	-	28.16 ± 5.11	-
Tebufenozide	1000	=	-	-	-
	62.5	21.15 ± 4.73[a]	-5.8	20.43 ± 5.84[a]	-27.4
	Controls	22.41 ± 5.48	-	28.16 ± 5.11	-
Lufenuron	1000	10.25 ± 3.49[d]	-54.46	12.85 ± 4.25[d]	-54.44
	62.5	20.51 ± 1.82[a]	-8.48	29.45 ± 3.50[a]	4.62
	Controls	22.41 ± 5.48	-	28.16 ± 5.11	-

Conc., concentration, mean ± SD followed with the same 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). =: adults died.

Table 4. Total lipid content (mg/g ± SD) of the fat body of the desert locust *Schistocerca gregaria* adults as influenced by some IGRs after treatment of the early last instar nymphs.

IGRs	Conc. (ppm)	Adult stage (Age in days)			
		1-day old	Change (%)	4-day old	Change (%)
Pyriproxyfen	1000	27.41 ± 3.54[d]	-71.87	=	-
	62.5	88.53 ± 3.22[c]	-9.04	84.85 ± 4.66[a]	-3.85
	Controls	97.33 ± 5.24	-	87.25 ± 2.42	-
Tebufenozide	1000	=	-	-	-
	62.5	88.76 ± 3.27[c]	-8.8	80.15 ± 6.54[b]	-8.14
	Controls	97.33 ± 5.24	-	87.25 ± 2.42	-
Lufenuron	1000	56.81 ± 2.63[d]	-41.62	55.62 ± 4.22[d]	-36.23
	62.5	88.67 ± 6.73[c]	-8.9	85.33 ± 4.85[a]	-2.14
	Controls	97.33 ± 5.24	-	87.25 ± 2.42	-

Conc., concentration, mean ± SD followed with the same 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).=: =: adults died.

2001). Also, lipid levels in the hemolymph and fat body of 6th instar larvae of the spruce budworm *Choristoneura fumiferana* were severely depleted as a result of fenoxycarb treatments (Mulye and Gordon, 1993). The decrease lipid content in the pupae of *S. littoralis* was estimated after larval treatment with mevalonic acid (Ghoneim, 1994). However, lufenuron and diofenolan treatments resulted in decreasing lipids at the start and end days of pupae of the red palm weevil *Rhynchophora ferrugineus* but increasing lipids were estimated for mid-aged pupae (Ghoneim et al., 2003).

In addition, diofenolan treatments remarkably reduced the lipid content along the pupal stage of the house fly *Musca domestica* except the last day at which pupae gained more lipids (Amer et al., 2005). Lipid levels in the hemolymph of silkworm *Bombyx mori* larvae were declined throughout the experimental period but were elevated initially in the fat body and then lowered (Etebari et al., 2007). Injection of 0.1 pmol of the synthetic adipokinetic hormone (Peram-AKH II) onto the American cockroach *Periplaneta americana* led to a significant reduction of the levels of neutral lipids and phospholipids in hemolymph (Michitsch and Steele, 2008). Lipid content in the whole body of *Plodia interpunctella* larvae was reduced as a response to the action of 20-hydroxyecdysone and azadirachtin (Rharrabe et al., 2008) or to pyriproxyfen (Ghasemi et al., 2010). Pyriproxyfen treatments resulted in decreasing lipid content in hemolymph and fat body of the sunn pest *Eurygaster integriceps* nymphs (Zibaee et al., 2011).

Instead of the inhibition of lipid content by IGRs, activation of this metabolite was reported by some authors using different IGRs against various insect species (Amer, 1990; Ghoneim, 1994; Soltani-Mazouni et al., 1999; Bouaziz et al., 2011).

The current results, for *S. gregaria*, evidently show dominant inhibitory effects of pyriproxyfen, tebufenozide and lufenuron on the lipid content of fat body of nymphs, regardless of their age or the concentration level. Also, similar inhibitory effects of these IGRs were recorded on the lipid content of hemolymph of nymphs after 2 days of treatment. On the other hand, the hemolymph lipid content of 1-day old nymphs was variably affected depending upon the concentration level of all IGRs because increasing lipids were detected at the high concentration (1000.0 ppm) but decreasing lipids were estimated at the low concentration level (62.5 ppm). Hence, it is reasonable to conclude that the present IGRs generally prohibited the nymphs to attain normal lipid level in hemolymph or fat body in spite of the difference in the nature of each tissue. These findings are controversial to the trend of lipids in control nymphs, where the lipid content had been increased in hemolymph as it is decreasing in fat body and *vice versa*. Therefore, the present IGRs pronouncedly interfered with not only the synthesis of lipids but also their mobilization as promoted to convert into other metabolites or fatty acids. This suggestion may be supported by the increasing cholesterol in the mid gut brush border membrane of silkworm *B. mori* larva after treatment with fenoxycarb (JHA) (Leonardi et al., 2001) or in the hemolymph of 120 h post-treatment of silkworm larvae with pyriproxyfen (JHA) (Etebari et al., 2007).

Although pyriproxyfen and tebufenozide are classified in the group interfering with the action of insect hormones, and lufenuron is classified in the chitin synthesis inhibitors Tunaz and Uygun, 2004), all compounds vigorously acted as lipid inhibitors on the desert locust *S. gregaria*, in the present study, since the intense metabolic modifications are related to the various hormonal systems and under neuroendocrine control (Gade et al., 1997) or are transported from the storage site (fat body) *via* the hemolymph towards the user organs, in particular cuticular synthesis (Dapporto et al., 2008) and vitellogenesis (Zhou and Miesfeld, 2009). In addition, the odd case of lipid increasing a day after treatment with pyriproxyfen, tebufenozide or lufenuron, in the present study, may be attributed to the accumulation of carbohydrates which might lead to an inverse in their conversion rate to lipids as a reverse material (Tanani et al., 2012).

With regard to the adult females in the present study, pyriproxyfen, tebufenozide and lufenuron-treatments of nymphs resulted in considerably or slightly decreased lipids in the hemolymph of both 1- and 4-day old adults. There was an exceptional case because lipid content non-significantly increased in 4-day old adults after nymphal treatments with 62.6 ppm lufenuron whereas it exhibited the strongest prohibiting effect on hemolymph lipids at the concentration level 1000.0 ppm. Furthermore, these IGRs unexceptionally exerted inhibitory actions on the lipid content in fat bodies of adults, irrespective of their age.

The reported works on the lipids in hemolymph or fat body of adults of other insect species, as affected by IGRs, are unfortunately scarce. On the other hand, lipids were detected in other tissues such as ovaries and testes after treatment with some IGRs. For example, lipid content in ovaries of the cut worm *Spodoptera litura*, *T. molitor*, the Mediterranean flour moth *Ephestia kuehniella*, *P. interpunctella* and *S. litura* was depleted as a response to chlorfluazuron, flucycloxuron, tebufenozide, pyriproxyfen and chlorfluazuron, respectively (Perveen and Miyata, 2000; Hami et al., 2004; Kebbeb et al., 2008; Ghasemi et al., 2010; Perveen, 2012). The depletion of lipids in ovaries of treated insects could be understood in the light of reduced ovaries due to the effects of IGRs on oogenesis or/and vitellogenesis (Kanost et al., 1990; Shaaya et al., 1993; Ghasemi et al., 2010).

However, the exact interpretation of lipid depletion in hemolymph and fat body of adult *S. gregaria*, in the present study, remains speculative. On the other hand, this desert locust, like nearly all other insects capable of flying long distances, mobilizes lipids stored in the fat body to meet the energy requirements for sustained flight. These lipids are transported *via* the hemolymph to flight muscles, where they are completely oxidized to CO_2 and H_2O. If it is possible to intervene and reduce this metabolic activity, then this has two consequences for *S. gregaria*. One is that the insect then lacks the fuel it needs for flight activity, and the other is that its water regime is disturbed. In the extremely arid regions inhabited by these insects, the water from oxidation of lipids and other foodstuffs is needed by them to regulate processes at the cellular level (Al-Fifi, 2009). So, the lipid depletion in hemolymph and fat body of adults, as recorded by the current results, will reflect on the insect migration defect and this will result in control of this migratory destructive insect. Frankly, the transportation problems between different organs, such as hemolymph, fat body, flight muscles and gonads, still need further studies to accurately investigate the lipid mobilization.

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