

**Effects of the wild plant, *Fagonia bruguieri* on the adult performance and phase transition of *schistocerca gregaria* (orthoptera: acrididae)**

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### ABSTRACT

The treatment of penultimate and last nymphal instar of *Schistocerca gregaria* with *Fagonia bruguieri* resulted in a partial blocking of the adult emergence in proportion to the concentration level, irrespective of the type of the extract. A dose-dependent suppression of adult survival potential was determined after treatment of penultimate instar nymphs. Similar dose-dependent mortality of the emerged adults was recorded after treatment of last nymphal instar with the methanolic and n-butanolic extracts.

With regard to the adult morphogenesis after treatment of penultimate instar nymphs with different *F. bruguieri* extracts, the most deranging effect was exhibited by methanolic extract. After treatment of last nymphal instar, the adult morphogenesis was considerably affected by both the methanolic extract and n-butanolic extract, parallel to the concentration.

Irrespective of the time of nymphal treatment, sexual maturity of *S. gregaria* adults was hastened by both the methanolic extract and petroleum ether extract of *F. bruguieri*, especially at the higher two concentration levels. In contrast, n-butanolic extract exhibited a delaying effect on sexual maturity, especially at the higher two concentration levels.

Significantly shortened longevity was recorded after treatment of penultimate instar nymphs with methanolic and petroleum ether extracts but prolonged longevity was observed after treatment with n-butanolic extract. Treatment of the last nymphal instar with n-butanolic extract, especially at the higher two concentration levels resulted in accelerated adult aging (as indicated by remarkably shortened longevity).

A solitarization tendency of the gregarious adults was activated after nymphal treatment with the n-butanolic extract because some adults appeared with greenish color of both the external morphology and haemolymph.

**Keywords:** *Schistocerca gregaria*, *Fagonia bruguieri*, emergence, survival potential, morphogenesis, sexual maturity, longevity, solitarization.

### INTRODUCTION

Chemical pollution by insecticides has been increasing in a large scale due to vast usage for eradication of various pests and harmful insects and to protect agricultural production (Matsumura, 1975). Consequently, an intensive effort has been made to find alternative methods of pest control. Botanical insecticides and microbial pesticides are highly effective, safe, and ecologically acceptable (Matthews, 1999). Botanical insecticides are naturally occurring chemicals extracted from plants. As a consequence of concern about the environmental persistence of synthetic pesticides

and their potential toxicity to humans, beneficial insects, and domestic animals, there is renewed interest in natural products to control pests (Senthil Nathan, 2006).

The desert locust *Schistocerca gregaria* ranks together with other migratory locusts-amongst the most important crop pests in Africa. Damage caused by the desert locust is a consequence of its polyphagous behaviour, high density of the population, and the nature to aggregate and swarm. Each individual gregarious locust is able to consume roughly its own weight (about 2 grams) of foliage daily. In the last century alone, there were seven periods of numerous plagues, the longest of which lasted intermittently for 13 years (Lindsey, 2002). Dense swarms of adults, or marching bands of hoppers, can inflict considerable economic harms during only a short time.

Since publication of the theory of phase polymorphism by Uvarov (1927), it has been recognized that both *Locusta migratoria* and *Schistocerca gregaria* occur in solitary and gregarious forms. A large number of studies have already been performed in search of the exogenous and endogenous causes of these phase changes. The focus has been on investigating changes from solitary to gregarious status, since only gregarious locusts form large migratory swarms are capable of inflicting serious damage to crops. No striking interpretation was introduced more than the suggestion about the role of ecdysteroids, juvenoids, and possibly also pheromones in initiating and regulating these processes (Pener, 1983). Hormonal signals modulate life span and reproduction (Tatar *et al.*, 2003; Taguchi and White, 2008; Russell and Kahu, 2007; Piper *et al.*, 2008; Toivonen and Partridge, 2009).

The present investigation was undertaken to find out the effects of different extracts from the wild plant *Fagonia bruguieri* on the adult performance of the desert locust including survival, emergence, morphogenesis, sexual maturity, and longevity. In addition, possible effect of the present plant extracts on the phase transition of *S. gregaria* was studied.

## MATERIALS AND METHODS

### I) The Insect:

A gregarious stock culture of the desert locust, *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 upper side to allow the daily feeding and cleaning routine. The bottom was covered with 20 cm layer of sterilized sand. Each cage was equipped internally with 60 W electric bulb for lightening (17:7 L: D) and warming (32±2 °C). The relative humidity varied from 70-80% following the introduction of fresh food plant and reaches to 60-70% several hours later. Successive generations were raised before obtaining the nymphs for the present experimental work. Fresh clover *Medicago sativa* was fed along the period of study except for few weeks every year due to absence of this plant species. During these weeks, insects were fed on *Sesbania aegyptiaca*. All experiments were conducted with *M. sativa* only.

### II) Plant Extracts:

*Fagonia bruguieri* var. is a perennial wild herb distributed in all deserts in Egypt but profusely spread in Sinai. It is, also, distributed in several areas in Asia and North Africa. It systematically belongs to family Zygophyllaceae. The aerial parts of the plant (leaves, stems and flowers) were collected from the region of Saint Catherin (Sinai) during flowering stage, and kindly identified by Dr. Abdo Marey, Faculty of

Science, Al-Azhar University (Cairo). The collected samples were air-dried, powdered and kept in tightly closed amber coloured glass containers for protecting from light, at low temperature.

Dried and pulverized powder of *F. bruguieri* was separately extracted with methanol, petroleum ether and n-butanol solvents, respectively. Extracts were concentrated to dryness under reduced pressure.

### III) Nymphal Treatments:

The used concentration levels of the methanolic extract were: 15, 7.5, 3.7, 1.8 and 0.9% but of the petroleum ether extract and n-butanolic extract they were: 30.0, 15.0, 7.5, 3.7 and 1.8%.

The newly moulted 4<sup>th</sup> (penultimate), or 5<sup>th</sup> (last) instar nymphs of *S. gregaria* were fed on fresh leaves of *M. sativa* after dipping in the different concentration levels of each extract. After dipping for three minutes, the treated leaves were allowed to dry before offering to the nymphs. A day after treatment, all nymphs (treated and control) were provided with untreated fresh food plant. Ten replicates (one nymph/replicate) were used for each concentration. Each individual nymph was isolated in a glass vial provided with a thin layer of sterilized sand as a floor. All vials were located in a large cage having a suitable electric bulb. After feeding for 24 hrs on the treated leaves, the nymphs were carefully weighed every day using a digital balance and also examined for recording the mortality and different observations.

### IV) Physiological Criteria Studied:

The emergence of successfully metamorphosed adults was estimated in percentage according to Jimenez - Peydro *et al.* (1995) as follows:

$$[\text{No. of completely emerged adults} / \text{No. of larvae}] \times 100$$

Some adult deformities were observed. The percentage of morphogenic deformation was calculated according to Vargas and Sehnal (1973) as follows:

$$[\text{No. of deformed adults} / \text{No. of larvae}] \times 100$$

In addition to the total adult longevity, pre-oviposition period (gonad maturation), oviposition period (reproductive life-time), and post-oviposition period were also measured.

The sexual maturity has been taken place through the time interval elapsed between the female adult emergence and the day of the changed colour of body (from red or pink to yellow). This time interval was measured because at its end the adult female will be sexually mature and acceptable to mate.

The solitarization tendency of the adults appeared with green colour and other solitary features. The phase transition was estimated in percentage.

### V) Statistical Analysis of Data:

Data obtained were analyzed by the Student's *t*-distribution, and refined by Bessel correction (Moroney, 1956) for the test significance of difference between means.

## RESULTS

After application of different concentrations of plant extracts for 24 hrs, the following results were recorded:

### 1) Effect on adult emergence by *F. bruguieri* Extracts :

Data of Table (1) showed that treatment of penultimate instar nymphs with *F. bruguieri* resulted in a partial blocking of the adult emergence in proportion to the concentration level, irrespective of the extract. At 7.5, 3.7 & 1.8% concentration levels of methanolic extract, adult emergences were 57.1, 75.0 and 87.9% respectively, in comparison with 88.9% emergence of control adults. The adult

emergences were 44.4, 37.5 and 50.0% at the highest three concentration levels of petroleum ether extract, in comparison with 90.0% emergence of control adults. Also, the highest three concentration levels of n-butanolic extract caused 71.4, 75.0 and 88.9% of adult emergence respectively, in comparison with 88.9% emergence of control adults.

Depending on the data listed in the same table, the treatment of last nymphal instar with *F. bruguieri* extracts resulted also in considerably partially blocked adult emergence, irrespective of the concentration level. Such blocked adult emergence was seen in a dose-dependent trend after treatment with methanolic extract reaching the minimal percentage (40% in comparison with 90% control emergence). Neither the petroleum ether extract nor the n-butanolic extract caused blocking of adult emergence in a similar trend but only the strongest blocking action was exhibited at the highest two concentration levels of each (50 and 60% in comparison with 90% emergence of control adults) for each extract.

## 2) Affected Adult Morphogenesis by *F. bruguieri* Extracts:

The adult morphogenesis was deranged especially after treatment of the penultimate instar nymphs with the methanolic and n-butanolic extracts (Table 1). But in case of petroleum ether extract, the deformed adults appeared only at the highest concentration.

Table 1: Some criteria of the adult performance of the desert locust *Schistocerca gregaria* as affected by *Fagonia bruguieri* extracts.

Solvent	Conc. (%)	Treatment of 4 <sup>th</sup> instar nymphs			Treatment of 5 <sup>th</sup> instar nymphs		
		Emergence (%)	Deformed (%)	Longevity (Mean days±SD)	Emergence (%)	Deformed (%)	Longevity (Mean days±SD)
Methanol	15.0	-	-	-	40.0	50.0	40.1 ± 1.0 d
	07.5	57.1	25.0	36.7 ± 1.5 b	50.0	40.0	42.2 ± 1.0 d
	03.7	75.0	16.7	37.7 ± 2.5 b	60.0	16.7	51.5 ± 1.5 a
	01.8	87.9	25.0	42.3 ± 2.1 a	70.0	14.3	51.2 ± 1.2 a
	00.9	88.5	14.3	41.0 ± 1.7 a	80.0	0.0	53.0 ± 0.6 a
	Controls	88.9	00.0	43.3 ± 2.4	90.0	0.0	53.0 ± 1.0 a
Petroleum ether	30.0	44.4	25.0	49.3 ± 1.2 c	50.0	40.0	38.0 ± 1.0 c
	15.0	37.5	00.0	50.0 ± 2.6 b	60.0	33.3	40.7 ± 1.5 c
	07.5	50.0	00.0	53.0 ± 1.7 a	80.0	00.0	47.3 ± 3.2 a
	03.7	60.0	00.0	55.0 ± 3.6 a	80.0	00.0	48.0 ± 2.0 a
	01.8	66.7	00.0	54.7 ± 2.9 a	80.0	00.0	50.0 ± 4.4 a
	Controls	90.0	00.0	54.7 ± 0.6	90.0	00.0	51.7 ± 3.2 a
n-butanolic	30.0	71.4	20.0	62.6 ± 3.6 b	50.0	40.0	41.3 ± 1.5 c
	15.0	75.0	16.7	61.0 ± 2.5 b	60.0	16.7	52.3 ± 2.1 a
	07.5	88.9	25.0	58.7 ± 2.4 b	90.0	22.2	52.0 ± 3.0 a
	03.7	88.9	00.0	58.0 ± 2.6 a	90.0	22.2	52.3 ± 3.5 a
	01.8	88.9	00.0	58.0 ± 3.0 a	90.0	11.1	52.7 ± 4.0 a
	Controls	88.9	00.0	54.7 ± 0.6	90.0	00.0	53.0 ± 2.6 a

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

With regard to the effects of *F. bruguieri* on the adult morphogenesis after treatment of last nymphal instar with different extracts, (Table 1) showed the

considerably affected morphogenesis by both the methanolic extract and n-butanolic extract, parallel to the concentration level of each. Similar trend could not be observed after treatment with petroleum ether extract which intervened in this important physiological process as observed in 40.0 and 33.3% of adult malformations. The adult deformities could be generally observed in the following features:

- a. Adult failure to completely get rid of the last nymphal exuvia, where the nymphal exuvia remained attached to the adult body.
- b. Adult with curled legs and coiled incompletely developed short antennae.
- c. Adults with crumpled wings and transparent posterior area (Plates 1, 2).
- d. Inhibited Adult Survival Potential by *F. bruguieri* Extracts:

After treatment of the penultimate instar nymphs, the measured toxicity for adults was exhibited ranging from 0.0 to 33.3% of mortalities (Fig. 1).

With regard to the lethality of *F. bruguieri* on the last nymphal instar a dose-dependent mortality of the emerged adults by both the methanolic and n-butanolic extracts was observed. The most drastic lethal effect could be detected at the highest concentration level of methanolic extract (50% mortality) and both of petroleum and n-butanolic extracts (40% mortality). No lethal effect was exerted at the lower three concentration levels of petroleum ether extract (Fig. 1).

### 3) Inhibited Adult Survival Potential by *F. bruguieri* Extracts:

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### 4) Delayed Adult Sexual Maturity by *F. bruguieri* Extracts:

After treatment of penultimate instar nymphs, data of the most important criteria of the respective potentiality are illustrated in (Fig. 2).

As clearly seen in the previously mentioned figure, both the methanolic extract and petroleum ether extract of *F. bruguieri* hastened the sexual maturation rate as the maturation period was significantly shortened ( $P < 0.05$ ) especially at the higher two concentration levels. In contrast, n-butanolic extract exhibited a suppressing effect on such rate because the sexual maturation period was pronouncedly prolonged, regardless of the concentration level.

After treatment of last nymphal instar, (Fig. 2) diagrammed the data which display an insignificant shortening effects of both the methanolic extract and petroleum ether extract on the sexual maturation period and subsequently only a slight enhancing action on the adult females. Opposingly, such sexual maturation period extended significantly especially at the higher two concentration levels of n-butanolic extract ( $27.0 \pm 1.0$  and  $27.0 \pm 1.0$  days, vs.  $23.7 \pm 1.2$  days of controls) indicating a delayed rate of sexual maturity.

### 5) Influenced Adult Longevity by *F. bruguieri* Extracts:

As shown in Table (1), the adult longevity was affected by different extracts of *F. bruguieri* after treatment of the penultimate instar nymphs. At the highest concentration of methanolic extract the longevity recorded zero, whereas the longevity at concentration levels 7.5 and 3.7% were  $36.7 \pm 1.5$  and  $37.7 \pm 2.5$  days, respectively compared with  $43.3 \pm 2.4$  days of control adults. In case of petroleum ether extract, values of longevity were  $49.3 \pm 1.2$  and  $50.0 \pm 2.6$  days at concentration

levels 30.0 and 15.0% in comparison with  $54.7 \pm 0.6$  days of control adults. Prolonged longevity was observed after treatment with n-butanolic extract ( $62.6 \pm 3.6$ ,  $61.0 \pm 2.5$  and  $58.7 \pm 2.4$  days at concentration levels 30.0, 15.0 and 7.5%, compared with  $54.7 \pm 0.6$  days of control adults). In other words, the nymphal treatments with methanolic and petroleum ether extracts hastened the adult senility since these adults were accelerated to reach the death point. In contrast, the nymphal treatment with n-butanolic extract resulted in the delaying of such adult senility since these adults lasted an extended longevity.

After treatment of the last nymphal instar with *F. bruguieri* extracts, the adult aging was accelerated as data of Table (1) clearly showed pronouncedly shortened longevity especially at the highest two concentration levels of methanolic and petroleum ether extracts. For n-butanol only the highest concentration significantly shortened longevity.

#### **6) Induction of Solitarization Tendency by *F. bruguieri* Extracts:**

There is an important evidence of the solitarizing effect of n-butanolic extract in the present study as 50 % of the deformed adults appeared with relatively small sized body and greenish colour of external morphology and haemolymph, at the concentration level 7.5 %, after treatment of the penultimate instar nymphs and at the concentration level 30%, after treatment of the last instar nymphs (Plate 3).

## **DISCUSSION**

### **1) Affected Adult Emergence:**

Complete or partial blockage of adult emergence was reported for different insects by various botanicals such as the blocked emergence of *Musca domestica* by azadirachtin (Azt.) (Naqvi *et al.*, 2007), of *Rhynchophorus ferrugineus* by Azt. (Abdel-Ghaffar *et al.*, 2008), and of *Tribolium castaneum* by the methanolic extracts from *Centaurium erythrae* and *Pteridium aquilinum* (Jbilou *et al.*, 2008).

In the present study, the treatment of penultimate instar nymphs of *S. gregaria* with *F. bruguieri* extracts resulted in a partial blockage of the adult emergence proportionally to the concentration level, irrespective of the extract. Also, the treatment of last nymphal instar resulted in considerably deranged adult emergence, irrespective of the concentration level. Such blocked emergence was easily seen in a dose-dependent trend after treatment with the methanolic extract. Since the eclosion hormone, a blood-born factor arising from the central nervous system (Truman and Riddiford, 1970) triggers eclosion in a wide range of insect orders including Orthoptera (Truman, 1981), the *F. bruguieri* extracts probably prevented this hormone from being released at the appropriate time. Hence the eclosion hormone appears to be affected by a certain active ingredient(s) contained in the *F. bruguieri* extracts. However, the identities of such effective component(s) as well as the exact mode of action need further investigation.

### **2) Effect on Adult Morphogenesis:**

In the present study, the adult morphogenesis program of *S. gregaria* was disrupted by *F. bruguieri* extracts after treatment of the penultimate instar nymphs. For last nymphal instar, adult deformities increased with increasing level of methanolic extract. The adult deformities varied between a failure to completely get rid of the last nymphal exuvia and curled legs, coiled shortened antennae and crumpled wings with transparent external area.

The present results of disturbed adult morphogenesis of *S. gregaria* are in agreement with results reported for many insect species treated by different extracts

from the neem tree or other plant species. For examples, Schmutterer *et al.* (1993) observed morphogenic defects in adults of *S. gregaria* after treatment of the last instar nymphs with neem oil. Adult deformities of *S. gregaria* were caused by an essential oil from *Ageratum conyzoides* (Pari *et al.*, 2000). Various malformed moths of *S. littoralis* were caused by Neemazal (Ghoneim *et al.*, 2000). Topical application of the ethanolic extract from *Cyprus rotendus* onto the penultimate instar nymphs of *S. gregaria* resulted in the formation of defected adults (Bakr *et al.*, 2008). Several adult defects were observed in *R. ferrugineus* after treatment with Azt. (Abdel-Ghaffar *et al.*, 2008).

The adult malformation of *S. gregaria* can be easily attributed to the intervening of *F. bruguieri* extracts with the hormonally controlled program of morphogenesis. This may be due to the modification of the ecdysteroid titer, which in turn leads to changes in lysosomal enzyme activity causing overt morphological abnormalities (Josephraj Kumar *et al.*, 1999).

### **3) Affected Adult Survival:**

A dose-dependent toxicity of *F. bruguieri* extracts was determined for the adults of *S. gregaria* after treatment of the penultimate instar nymphs, with few exceptions. After treatment of the last nymphal instar, a dose-dependent mortality of the emerged adults was recorded by both the methanolic and n-butanolic extracts. Moreover, the methanolic extract exhibited stronger mortal potency against adults than petroleum ether and n-butanol extracts.

Many research articles reported the toxicity of different plant species against the immature stages of various insect pests, whereas the reported lethal effects of botanicals on the adults of insect species are scarcely available in the literature. However, the recorded toxicity of *F. bruguieri* extracts against the adults of *S. gregaria*, in the present study, are in agreement with the lethal activity of certain plant extracts against the adults of different insects such as *Tribolium castaneum* (Naqvi and Perveen, 1991), *Muscina stabulans* (Ghoneim and Al-Dali, 2002) and *M. domestica* (Amer *et al.*, 2004). The adult mortality of *S. gregaria*, in the present study, may be attributed to the feeding inhibition which lead to continuous starvation and subsequently death (Ghoneim *et al.*, 2000) or to the effect of certain active ingredients in the *F. bruguieri* extracts on the homeostasis leading to increasing body water loss and subsequently the death (Amer *et al.*, 2004). In addition, the increasing mortal potency of the present *F. bruguieri* extracts with the increasing concentration level may be explicated by the existence of some secondary metabolites such as certain alkaloids affecting the maintenance of life through disrupting the enzymatic pattern or hormonal hierarchy (Dorn *et al.*, 1986; Kartal *et al.*, 2003).

### **4) Delayed Sexual Maturity:**

In Orthoptera, the sexual maturity usually needs a time interval elapsed between the days of adult emergence until the day of laying the first egg pod. During such period the ovaries, or testes, were developed and the adult will be sexually mature. Generally, the pre-oviposition period, i.e. the sexual maturation period, may be informative for exploring the sexual maturity rate because the shorter period indicates the faster rate and *vice versa*. Physiologically, there are some factors interfering with this important physiological process.

The delaying effect exhibited by the extracts from *F. bruguieri* on the sexual maturity of *S. gregaria* is, generally, in accordance with similar results on the same insect or some other insects by the action of some botanicals, such as ethanolic extract from *M. volkensii* (Meliaceae) (Nasseh *et al.*, 1993). Also, delayed sexual maturity of adult females of *M. domestica* was caused by an aqueous extract from *Hyoscyamus*

*muticus* (Abou El-Ela *et al.*, 1995), of *Euprepocnemis plorans* was caused by the neem preparation Margosan-0 (Abdel-Ghaffar, 1998), and of *Spilostethus pandurus* (Hemiptera) was caused by LD<sub>50</sub> of Azt. (El-Sherif, 1998). Moreover, some extracts from *C. rotendus* prevented the sexual maturity of *S. gregaria* (Bakr *et al.*, 2008 & 2009).

However, the mode of action of the *F. bruguieri* extracts on the sexual maturity of *S. gregaria* is still unknown, but some active substances in this plant species may affect the levels of responsible hormone (s).

##### **5) Influenced Adult Longevity:**

The adult longevity was considerably affected after treatment with some neem products to tropical armyworm *Spodoptera litura* (Guyar and Mehrotra, 1983). Also, treatment of the cotton leafworm *S. littoralis* with extracts from *Melia azaderach* resulted in shortened adult longevity (Schmidt *et al.*, 1997; Hassan, 2002). On the other hand, some plant oils or extracts, such as Jojoba, could not affect the adult longevity (Amer *et al.*, 2004).

In the present study, significantly shortened adult longevity of *S. gregaria* was recorded after treatment of the penultimate instar nymphs with methanolic and petroleum ether extracts from *F. bruguieri*. Remarkably prolonged longevity (which may be an indicator to the delayed aging) was observed after treatment with n-butanolic extract. After treatment of the last nymphal instar, the adult longevity was pronouncedly shortened indicating accelerated aging, especially at the highest concentration level of n-butanolic extract (30%).

A suggestion of the presence of active ingredients in the present *F. bruguieri* extracts may be appreciated to explain the effect on adult longevity. Such ingredients may be of a hormonal nature because there is a close relation between certain hormones and adult longevity (or aging in general). In *Drosophila*, representatives of peptide hormone, lipophilic hormones and bioactive amines have been shown to modulate longevity by manipulations that directly decrease hormone production (Broughton *et al.*, 2005), through inactivating mutations in hormone receptors or their downstream targets (Clancy *et al.*, 2001; Simon *et al.*, 2003) or by polymorphic alterations in the genes required for hormone biosynthesis (Carbone *et al.*, 2006). At least one of the *Drosophila* insulin-linked peptides expressed in the median neurosecretory cells (which produce the prothoracicotropic hormone) is likely to contribute to the endocrine regulation of longevity (Toivonen and Partridge, 2009). However, similar findings should be intensively investigated for desert locust *S. gregaria*, in foreseen future.

##### **6) Induced Solitarization Tendency:**

The phase shift from gregaria to solitaria in the desert locust *S. gregaria* was reported by some extracts from *M. volkensii* (Rembold and Mwangi, 1989; Nasseh *et al.*, 1993). A clear tendency to solitarization, indicated by green intermediates or solitary forms with little black pigments, was observed after treatment of the gregarious phase of *S. gregaria* with seed oil from *Azadirachta indica* (Nicol and Schmutterer, 1991; Schmutterer *et al.*, 1993). Also, treatment of 1<sup>st</sup> and 3<sup>rd</sup> instar nymphs of *Locusta migratoria migratorioides* resulted in behavior toward the solitary phase (intermediate green-brown forms and less activity) (Schmutterer and Freres, 1990). Topical application of *S. gregaria* nymphs with neem oil elicits a reaction similar to reduction in population density supporting a hypothesis of 'solitarization' induced by neem (Langewald *et al.*, 1995). Also, the treatment of 1-day old gregarious penultimate or last instar nymphs of *S. gregaria* with the ethanolic extract

from *C. rotundus* resulted in a tendency to solitary phase in adult females (Bakr *et al.*, 2008).

In the present study, there is an important evidence of the solitarizing effect of n-butanolic extract from *F. bruguieri* because 50% of the adults appeared with greenish color of external morphology and haemolymph, at the concentration level 7.5%, after treatment of the penultimate instar nymphs and at the concentration level 30% after treatment of the last nymphal instar. Therefore, the n-butanolic solvent could extract a solitarizing factor from the present wild plant *F. bruguieri*. The phase transition in the present study can be explained on the hormone or pheromone basis. Hormonally, the allatectomy (surgical removal of corpora allata, responsible for the production of juvenile hormone, JH) resulted in no gregarious behavior in the locusts (Richard *et al.*, 2001). Such observation rationally explains the higher activity of corpora allata in solitary *S. gregaria* causing higher titers of JH in the haemolymph and a green colouration of the cuticle (Uvarov, 1966). Pheromonally, the existence of 'gregarization pheromone' was postulated by Nolte (1963) and Gillett and Phillips (1977). The solitarization effect of *F. bruguieri* extracts, in the present study, may be due to their influence on this pheromone or to its influence on the hormonal system of the insect (Langewald *et al.*, 1995). For some detail, JH influences the response of the olfactory interneurons in the antennal lobe to the aggregation pheromone, whereas the responsiveness of antennal receptors neurons is not changed (Richard *et al.*, 2001).

In conclusion, it is reasonable to suggest the existence of a juvenilizing, and subsequently antigregarizing, substances in the *F. bruguieri* extracts used in the present study but more deep investigation is needed to disclose some aspects of our suggestion since juvenilizing effects of some other plant species, such as *Ajuga chamaepitys*, were determined (Jacobson, 1989). The phase transition in the present study can be explained on the hormone or pheromone basis. Hormonally, the allatectomy (surgical removal of corpora allata, responsible for the production of juvenile hormone, JH) resulted in no gregarious behavior in the locusts (Richard *et al.*, 2001). Such observation rationally explains the higher activity of corpora allata in solitary *S. gregaria* causing higher titers of JH in the haemolymph and a green colouration of the cuticle (Uvarov, 1966). Pheromonally, the existence of 'gregarization pheromone' was postulated by Nolte (1963) and Gillett and Phillips (1977). The solitarization effect of *F. bruguieri* extracts, in the present study, may be due to their influence on this pheromone or to its influence on the hormonal system of the insect (Langewald *et al.*, 1995). For some detail, JH influences the response of the olfactory interneurons in the antennal lobe to the aggregation pheromone, whereas the responsiveness of antennal receptors neurons is not changed (Richard *et al.*, 2001).

In conclusion, it is reasonable to suggest the existence of a juvenilizing, and subsequently antigregarizing, substances in the *F. bruguieri* extracts used in the present study but more deep investigation is needed to disclose some aspects of our suggestion since juvenilizing effects of some other plant species, such as *Ajuga chamaepitys*, were determined (Jacobson, 1989).

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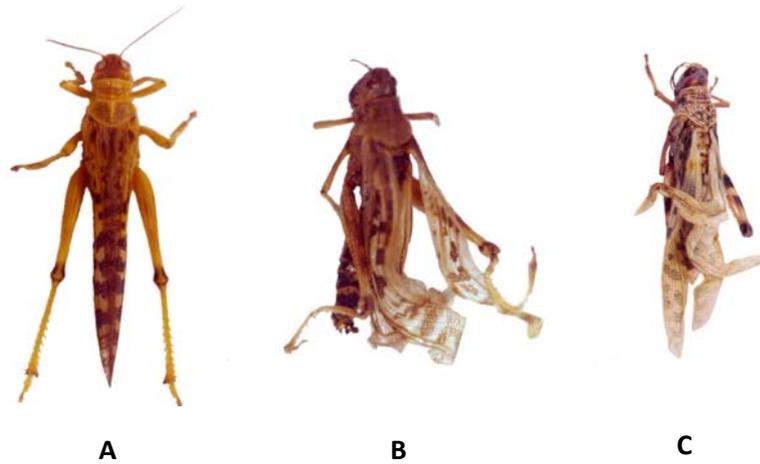


Plate 1: Different adult malformations of *Schistocerca gregaria* were produced as a result of the nymphal treatments with plant extracts. A) Normal adult. B) Adult with curled legs, incompletely developed antennae and crumpled wings with transparent posterior area. C) Crumpled wings with transparent posterior area and coiled antenna.

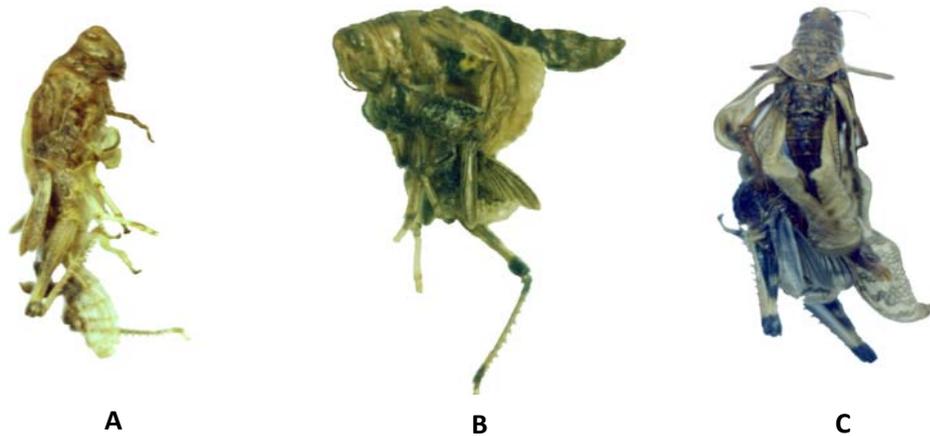


Plate 2: Different degrees of adult failure to completely get rid the last nymphal exuvia as a result of the nymphal treatments with plant extracts. A) Nymphal exuvia was attached to abdomen, wings and legs. B) Nymphal exuvia was attached to wings, legs and mouth parts. C) Nymphal exuvia was attached to the wings.

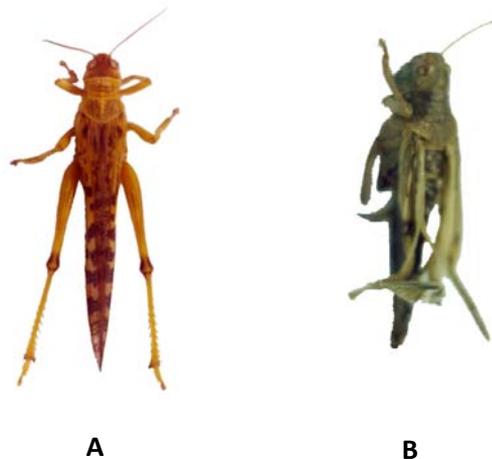


Plate 3: Phase shift of *Schistocerca gregaria* from gregaria to solitaria was caused in certain percentages as a result of the nymphal treatments with some concentration levels of the present plant extracts. A) Normal gregarious adult. B) Solitarized adult.

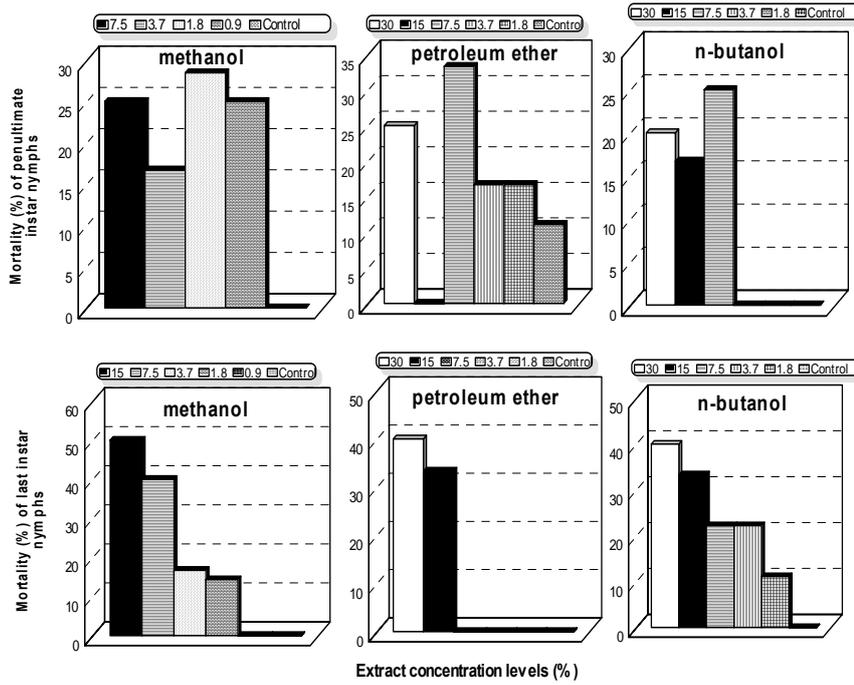


Fig. 1: Lethal effect (%) of *Fagonia bruguieri* extracts on the adults of *Schistocerca gregaria* after treatment of early penultimate instars nymphs and last nymphal instars.

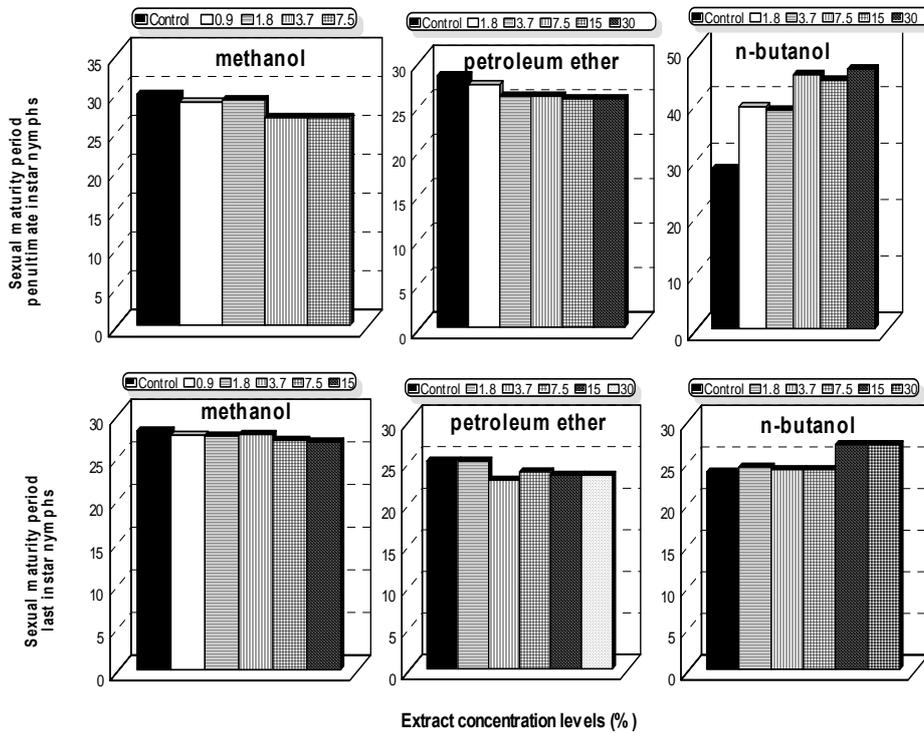


Fig. 2: Sexual maturity (in days) of *Schistocerca gregaria* adults after treatment of early 4th instar nymphs or early 5th instar nymphs with *Fagonia bruguieri* extracts (methanol, petroleum ether and n-butanol)

## ARABIC SUMMARY

**تأثير نبات فاجونيا بروجيري البرى على تشكل الطور البالغ وتحول الطور الغيربالغ للجراد الصحراوى  
(مستقيمة الأجنحة)**

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أدت معالجة طور الحورية الأخير للجراد الصحراوى بتركيزات نبات الفاجونيا إلى تأخر التحول إلى الطور البالغ. وقد تعين بقاء الطور البالغ حيا على التركيزات المستعملة من مستخرج النبات. وبالمثل فقد تحددت نسبة موت وحياة الأطوار البالغة من الحوريات المعالجة بتركيزات المستخلص بالبيتانول والميثانول. ولقد تأثر الشكل الخارجى للطور البالغ الناتج من الطور الأخير من الحوريات المعالجة بمستخرج النبات بالميثانول وكان الأكثر تأثيرا. كما أثرت تركيزات مستخرج النبات بالميثانول والبيتانول على الشكل الخارجى للطور البالغ الناتج من الطور الرابع من الحوريات المعالجة. ولقد أزداد معدل البلوغ الجنسى للطور البالغ عند استخدام مستخلص النبات بالميثانول والأثير وخاصة أعلى تركيزين، وعلى عكس ذلك كان التأثير عند استخدام المستخلص بالبيتانول. ولقد سجلت مدة بقاء الطور البالغ الناتج من الطور الأخير (المعامل بمستخرجى الميثانول والأثير) نقصانا واضحا، ولكن هذه المدة طالت عند استخدام مستخرج البيتانول. أما فى حالة معالجة الطور الرابع من الحوريات بمستخرج البيتانول وخاصة التركيزين الأخيرين أدت إلى سرعان شيخوخة الطور البالغ (نقصان مدة بقاء الطور البالغ). ولقد لوحظ تغير اللون إلى على الأخضر فى الشكل الخارجى وكذلك الدم للطور للطور البالغ مما يدل تحولة إلى الحالة الأنفرادية.