

## Antifeedant and Toxicity Effects of *Zygophyllum geslini* (Zygophyllaceae) Aqueous Extract against the Desert Locust, *Schistocerca gregaria* (Forsk.) (Orthoptera: Acrididae)

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### KEY WORDS

Antifeedant  
Desert locust  
Food intake  
*Schistocerca gregaria*  
Toxicity  
*Zygophyllum geslini*

**ABSTRACT** The present study was conducted aiming to investigate the antifeedant and toxicity effects of *Zygophyllum geslini* aqueous extract against the desert locust *Schistocerca* under controlled laboratory conditions. Results revealed loss of weight, decrease of food intake, and biocidal activity against both sexes of the adult solitary desert locust, *Schistocerca gregaria*. There was growth inhibition in locusts and average fresh weight gain was  $0.291 \pm 0.042$  g/day and  $0.235 \pm 0.028$  g/day, respectively, for males and females against the weight gain of  $0.659 \pm 0.192$  and  $0.823 \pm 0.139$  g/day in controls under similar conditions. Coefficient of digestibility (CD) was 72.55 and 72.79%, respectively, compared to 95.27 and 93.78%, respectively, in control locusts. The total mortality of the treated individuals occurred after 15 days of treatment. The lethal time (LT<sub>50</sub>) calculated was 9.18 days and 9.38 days, respectively, for males and females after the treatment.

### INTRODUCTION

The desert locust, *Schistocerca gregaria* is known as a very destructive insect pest in North Africa (Ammar *et al.*, 2009). Chemical pesticides applied for locust control are a risk for humans, terrestrial non-target fauna, and aquatic ecosystems. Hence, the use of botanicals as insecticides is an eco-friendly strategy (Georges *et al.*, 2006; Koul, 2016). More than 2000 plant species belonging to 189 families are known to possess bioactive organic compounds against insects (Idrissi Hassani and Hermas, 2008; Sharma *et al.*, 2012). One of the most

potent plants has been the Indian neem tree *Azadirachta indica* whose oil from seeds is now marketed as a pesticide in North Africa (Al-Fifi, 2009). There are other plants which have been reported as potential insecticidal materials in Africa, such as *Cestrum parqui* (Ammar and N'cir, 2008), *Nerium oleander* (Harizia and Doumandji, 2014), and *Ammi visnaga* (Ghoneim *et al.*, 2014), which possess antifeedant or toxic effects against *S. gregaria*.

*Zygophyllum geslini* is a desert plant which belongs to Zygophyllaceae family, widely distributed in North Africa. It is used in folk medicine, for instance, as diuretic,

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anthelmintic, antidiabetic, antirheumatic, antiasthmatic, and antihypertensive agent (Jouad *et al.*, 2001; Eddouks *et al.*, 2002; Smati *et al.*, 2004). The most cited activities of this medicinal plant are its antioxidant, antifungal, antimicrobial, antiviral, and cytotoxic properties. In southern Algeria, it is used in traditional medicine for the treatment of diabetes (Ayad, 2012). No study has been reported so far for its insecticidal activity. Therefore, the objective of the present study was to investigate the efficacy of *Z. geslini* against *S. gregaria*, which is economically highly damaging pest of crops in Africa. The simple aqueous extract was studied so that such extracts could be easily prepared by marginal farmers in North Africa.

## MATERIALS AND METHODS

### Locust Rearing

Solitarious desert locusts used in this study were mass reared in the zoological laboratory of the Mascara University (Algeria). The breeding was performed under controlled laboratory conditions at a temperature of  $28 \pm 3^\circ\text{C}$ , relative humidity (RH) of  $65 \pm 5\%$ , and photoperiod of 12 h of light and 12 h of darkness. The locusts were reared in wooden cages of  $25 \text{ cm}^3$ . The front of the cages was equipped with a small door to facilitate feeding and cleaning. Adults aged between 5 and 8 days were used for the bioassay.

### Preparation of *Z. geslini* Aqueous Extract

Vegetative parts of *Z. geslini* were collected from the fields around Adrar (Algerian central Sahara). Plant materials (leaves, stems, and wood) were washed and air-dried for 3 days at room temperature. Thereafter, they were ground in a blender to obtain a fine powder. About 100 g of the powder were mixed with 1 L of distilled water, placed on a magnetic stirrer. Plant extract was filtered by passing through Whatman paper. The filtrate solution was used in the bioassay studies.

### Bioassay

Studies were conducted in the laboratory in transparent plastic containers of 1 L capacity covered by a fine mesh cloth for ventilation. Fresh leaf discs of *Brassica oleracea* L. (cabbage) of the same weight were dipped for 15 s in test solution. Control was fed with identical discs dipped in distilled water. After immersion, the discs were placed on filter paper at room temperature to remove excess moisture and subsequently transferred to containers. After 24 h feeding treated and control locusts were provided with normal fresh cabbage leaves. Adults (30 of them; 15 males and 15 females) were singly introduced in separate containers after 24 h starvation. A moist filter paper kept at the bottom of each container to maintain RH and to keep the leaf discs fresh. Three replicates, each of 30 adults, were maintained for each treatment. The

tests were conducted at a temperature of  $30 \pm 2^\circ\text{C}$ , an RH of  $65 \pm 5\%$ , and a photoperiod of 12:12 h LD. The food intake was assessed by fresh weight of locusts, and mortality was recorded daily until the total mortality of the treated locusts was achieved. The lethal time ( $LT_{50}$  and  $LT_{99}$ ) for absolute mortality was determined.

### Digestibility Coefficient and Consumption Index

The digestibility coefficient (DC) was determined by accurately measuring the quantity of cabbage leaves consumed by locusts and the weight of feces. It was calculated according to the following equation developed by Waldbauer (1968).

The consumption index (CI) was calculated taking into consideration the quantity of cabbage leaves consumed and the locust weight gain (final weight – initial weight final). CI was calculated according to the formula given by Boccad (1963).

$$CI = \frac{\text{Quantity of food consumed}}{\text{Fresh weight gain}}$$

The two nutritional indices (DC and CI) were calculated for males and females separately.

### Statistical Analysis

One-way ANOVA was used for analysis of the results after the mortality test. The comparisons were made to a degree of significance of 5%. Lethal times ( $LT_{50}$  and  $LT_{99}$ ) and their confidence intervals were estimated using probit analysis. Fit of the regression lines was verified by  $\chi^2$  test. Pro software was used for all statistical analyses.

## RESULTS

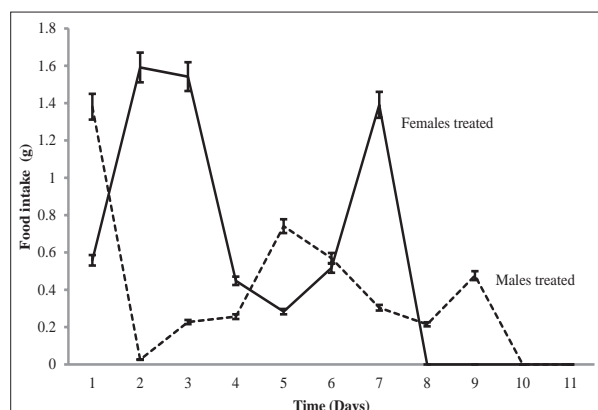
### Effect on Food Intake and Growth

As shown in Figure 1, the consumption of treated cabbage leaves was significantly lower among locusts. Daily mean gain of fresh weight calculated for the treated males and females was  $0.291 \pm 0.042 \text{ g}$  ( $F_{4,35} = 29.02$ ;  $P = 0.0001$ ) and  $0.235 \pm 0.028 \text{ g/day}$  ( $F_{4,35} = 32.37$ ;  $P = 0.0000$ ), respectively, while it was higher for the untreated locusts with  $0.659 \pm 0.192 \text{ g/day}$  ( $F_{4,35} = 27.13$ ;  $P = 0.0001$ ) and  $0.823 \pm 0.139 \text{ g/day}$  ( $F_{4,35} = 22.61$ ;  $P = 0.0001$ ), respectively, for males and females. The same trend was observed for consumption of treated cabbage leaves. Females and males consumed  $0.633 \pm 0.221 \text{ g/day}$  ( $F_{4,38} = 25.21$ ;  $P = 0.0001$ ) and  $0.419 \pm 0.186 \text{ g/day}$  ( $F_{4,38} = 27.79$ ;  $P = 0.0001$ ), respectively. The consumption of food was significantly higher in untreated locusts than in treated ones. The mean consumption of the control adults was

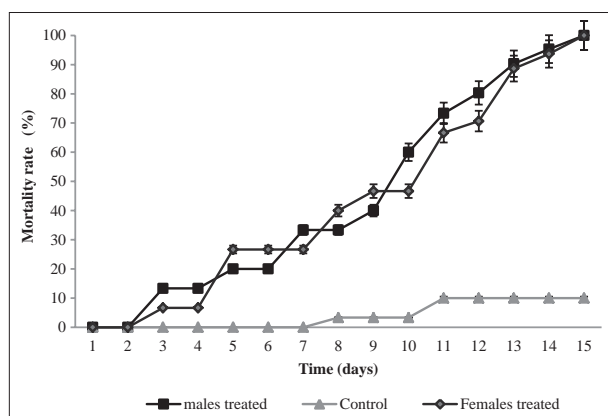
$0.888 \pm 0.328$  g/day ( $I_{4.38} = 22.58$ ;  $P = 0.0001$ ) for females and  $0.483 \pm 0.156$  g/day ( $F_{4.38} = 23.35$ ;  $P = 0.0001$ ) for males. This obviously points to the antifeedant action of *Z. geslini* aqueous extract against the locusts.

### Effect on Digestion and Subsequent Mortality

The mean daily weight of feces was significantly higher in treated locusts than in untreated ones. A mean of 0.114 g and 0.115 g of feces per day, respectively, for females and males fed with treated cabbage leaves was recorded. For the controls, these values were only 0.042 g for females and 0.033 g for males. The results of the digestibility coefficient (DC) are shown in Table 1, which indicate that the treated locust digestibility was lower (males = 72.55% and females = 72.79%) compared to the controls (males = 95.27% and females = 93.78%). As



**Fig. 1.** Effect of *Zygophyllum geslini* aqueous extract on food intake (g; mean  $\pm$  Standard error) in *Schistocerca gregaria* adults males and females. One-way ANOVA (significant difference,  $P < 0.05$ ).



**Fig. 2.** Mean ( $\pm$  standard error) cumulative mortality of *Schistocerca gregaria* males and females exposed to *Zygophyllum geslini* aqueous extract. One-way ANOVA (significant difference,  $P < 0.05$ ).

illustrated in Figure 2, the toxic activity of *Z. geslini* aqueous extract against *S. gregaria* was slower and was relative to the depletion in growth with duration. From the 3<sup>rd</sup> day, a significant mortality was recorded for both sexes and absolute mortality was achieved after 15 days post-treatment. Among controls, only 10% of mortality was recorded within the same period. The regression analysis revealed a significant relationship between the locust mortality and duration of treatment (males:  $R^2 = 0.824$ ; females:  $R^2 = 0.9126$ ). The  $LT_{50}$  and  $LT_{99}$  calculated values of *Z. geslini* aqueous extract against males and females of *S. gregaria* are shown in Table 2.  $LT_{50}$  and  $LT_{99}$  values were 8.38 days (8.54-9.70) and 15.10 days (14.06-16.76) for males and 9.18 days (8.75-9.96) and 17.05 days (15.79-18.89) for females, respectively.

### DISCUSSION

*Z. geslini* aqueous extract was effective in retarding the growth of locusts, ultimately leading to the mortality within 15 days post-treatment. The antifeedant effect was manifested by reduced consumption by locusts offered food treated with *Z. geslini*. The current results are in agreement with previous published reports on the effect of various plant extracts against *S. gregaria* including *Solanum sodomaeum*, *Peganum harmala*, *Ziziphus lotus* (Abbasi et al., 2005; Ould el Hadj et al., 2003), *Azadirachta*

**Table 1.** Effects of *Zygophyllum geslini* aqueous extract on the digestibility and food intake in *Schistocerca gregaria* adults.

Treatment	Males		Females	
	DC	CI	DC	CI
Control	95.27	3.22	93.78	3.41
<i>Z. geslini</i> aqueous extract	72.55	0.7	72.79	1.05

DC: Digestibility coefficient. CI: Consumption index. Each value is the mean of three replicates. One-way ANOVA (significant difference,  $P < 0.05$ )

**Table 2.** Log time response of *S. gregaria* adult males and females exposed to *Zygophyllum geslini* aqueous extract.

Lethal time (days)	Males	Females
$LT_{50}$	9.18 (8.54–9.70)	9.38 (8.75–9.96)
$LT_{90}$	12.51 (11.87–13.43)	13.68 (12.89–14.77)
$LT_{99}$	15.10 (14.06–16.76)	17.05 (15.79–18.89)
Slope $\pm$ SE	0.41 $\pm$ 0.05	0.32 $\pm$ 0.03
$P$ ( $\chi^2$ )	< 0.0001	< 0.0001

Each value is the mean of three replicates. LT values and there upper or lower confidence limits (case letters within a column) are significantly different ( $P < 0.05$ ).  $\chi^2$  indicates a satisfactory goodness of fit. LT: Lethal time

*indica*, *Jatropha curcas* (Zouitenetal., 2006; Hamadahetal., 2013; Bashir and El Shafie, 2013), and *Ammi majus* (Sayed et al., 2016). Antifeedant activity was depicted by low food intake, lower digestibility, and ultimately the growth inhibition. These findings were in agreement with the results reported by many authors for other plant extracts against *S. gregaria* including *Citrullus colocynthis*, *Cleome arabica* (Kemassi, 2012) *Melia azedarach*, *Nerium oleander*, *Inula viscosa*, *Eucalyptus occidentalis*, *Calotropis procera*, *Glinus litoides*, and *Ziziphus lotus* (Barbouche et al., 2001; Ould Ahmadou et al., 2001; Ould el Hadj et al., 2003; Abbasi et al., 2004; Harizia and Doumandji, 2014). In this study, the toxic effect of *Z. geslini* aqueous extract on *S. gregaria* was clearly due to reduced feeding and impact on digestibility of the food that subsequently led to the death of insects. *Cestrum parqui* (Barbouche et al., 2001), *Peganum harmala* (Abbasi et al., 2005), *Euphorbia guyoniana*, and *Citrullus colocynthis* (Kemassi, 2010) are also known to cause toxicity among *S. gregaria* locusts. Thus, we inferred that the antifeedant effect of *Z. geslini* extract could be attributed to physiological toxicity rather than the toxicity through neurosystem. This gets significant support from the histological studies by Idrissi Hassani and Hermas (2008), who reported that *Peganum harmala* extracts caused toxic effects in the digestive track of the desert locust, *Schistocerca gregaria*. The reduction of the external circular muscle in the digestive tract resulted in intestinal atrophy and striated epithelium. Such aberrations do result in inhibition of the growth and development or death of insects (Chen, 2008). The present results, therefore, provide the basis for further exploitation of *Z. geslini* plant to identify the active compound(s) and mechanism of action, specifically for locust control using extracts obtained by simple methods so that marginal farmers of East Africa could use them easily during any locust outbreak for their crop protection.

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