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Preliminary larvicidal effect of seed oil from *Cleome arabica* L. on fifth instar larvae of *Schistocerca gregaria* (Orthoptera: Acrididae)

Efecto larvicida preliminar del aceite de semilla de *Cleome arabica* L. en larvas de quinto estadio de *Schistocerca gregaria* (Ortópteros, Acrididae)

Ait aoudia Ahmed[1]; Kemassi Abdellah[1,2*]; Herouini Amel[1]; Taibaoui Zakaria[1]; Derouiche Rima[1]; Bouziane Nawal[2]; Cherif Rekia[1]; Ould el hadj Mohamed Didi[2]

[1] University of Ghardaia, Research Laboratory "Mathematics and Applied Sciences", POB 455, Ghardaia, Algeria.
[2] Research Laboratory "Ecosystem protection in arid and semi-arid zones". Kasdi Merbah University, Ouargla, POB 511, Ouargla, Algeria.
* Corresponding author: Kemassi Abdellah, akemassi@yahoo.fr

ABSTRACT

In present study, the toxicity of seed oils from *Cleome arabica* L. (Capparidaceae) was tested on L5 larvae of *Schistocerca gregaria*, Forsk. (Orthoptera, Acrididae). The forced administration of 60 μL/individual of this vegetable oil leads to the death of all the treated larvae either before or after a few days of exuviation (imaginal molt). Signs of intoxication were observed a few hours after treatment, i.e. movement disorders, diarrhea, inability to take food and weight loss. Male L5 larvae seem more sensitive than female L5, mortality rates were around 90.91% and 36.36% respectively after 16 days. The TL50 recorded in treated L5 larvae was around 11 days.

Keywords — *Schistocerca gregaria*, L5 larvae, seed oil, *Cleome arabica*, toxicity, Sahara.

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RESUMEN

En el presente estudio, se probó la toxicidad de los aceites de semillas de *Cleome arabica* L. (Capparidaceae) en larvas L5 de *Schistocerca gregaria*, Forsk. (Ortópteros, Acrididae). La administración forzada de 60 μL/persona de este aceite vegetal provoca la muerte de todas las larvas tratadas antes o después de unos días de exuviación (muda imaginal). Se observaron signos de intoxicación pocas horas después del tratamiento, es decir, trastornos del movimiento, diarrea, incapacidad para ingerir alimentos y pérdida de peso. Las larvas macho L5 parecen más sensibles que las hembras L5, las tasas de mortalidad rondaron el 90,91 % y el 36,36 %, respectivamente, después de 16 días. El TL50 registrado en las larvas L5 tratadas fue de alrededor de 11 días.

Keywords — *Schistocerca gregaria*, larva L5, aceite de semilla, *Cleome arabica*, toxicidad, Sahara.

1. INTRODUCTION

Acridians, and locusts in particular, are fearsome crop pests that threaten the food resources of many rural populations, particularly in the African and Asian continents. There are around 12,000 locust species in the world, 500 of which can cause damage to agriculture, about 20 species of them are ferocious pests, of which the desert locust *Schistocerca gregaria* Forskal is the best known species for its voracity, polyphagia, dispersal and damage (Lecoq, 1998).

The desert locust is characterized by its polyphagia and its ability to migrate over distances up to thousands of kilometers, causing damage by invading cultivated fields, pastures and other green ecosystems. Which resulted in considerable crop losses in more than 60 African and Asian countries (Steedman, 1988; Launois-Luong *et al*., 1988).

Chemical control using various insecticides is the most effective way to control and eradicate locusts swarms, but the use of chemical pesticides causes serious environmental problems such as the poisoning of humans and livestock, a harmful effect on auxiliary and useful fauna (Launois-Luong *et al.*, 1988).

Faced with this worrying situation, the scientific community has turned towards the development of biological control, including the use of plant extracts, essential oils and isolated compunds. To this end, several notorious studies have shown the insecticidal possibilities of natural products, including the work of Ould el hadj *et al*., 2006; Kemassi *et al.*, 2010, 2013, 2014, 2018, Aitaoudia *et al.*, 2021.

The L5 larvae and adults of *S. gregaria* fed with fragments of cabbage mixed in the acetone extract of the leaves of the three plants (*Melia azedarach*, *Azadirachta indica*, *Eucalyptus globulus*) show varied mortality rates (Ould el hadj *et al.*, 2006). Various mortality rates were observed in some L5 larvae and adults of *S. gregaria* fed cabbage leaves dusted in *Euphorbia guyoniana* noisy leaf extract (Kemassi *et al*., 2010). The L5 larvae and adults of *S. gregaria* treated with the essential oil of *Peganum harmala* leaves exhibit acute toxicity which is manifested by the mortality of a few individuals (Kemassi *et al*., 2013). Pure foliar essential oils of *P. harmala* and *Cleome arabica* sprayed on L5 larvae and imagos of *S. gregaria* cause a mortality rate

of 100% (Kemassi *et al.*, 2014). Moreover, different mortality rates were observed in L5 larvae and desert locust imagoes fed on cabbage leaves treated with the acetone extract of *C. arabica* (Kemassi *et al.*, 2018). L5 larvae treated by forced oral injection of two seed oils from two *P. harmala* and *Datura stramonium* plants show different mortality percentages (Aitaoudia *et al.*, 2021).

Therefore, the current study focuses on the effect of *C. arabica* seed oil on some biological parameters of L5 larvae of *S. gregaria*.

The C*leome* sp. is a species belonging to the Capparidaceae family. Locally, it is called "*Netten*" and "*Netteina*" because of the nauseating odor emanating from the plant. The flower has a calyx with 4 sepals, 4 purple-brown or yellow colored petals bordered with brown-purple, 6 stamens and 4 ovaries in 1 compartment carried by a short foot (podogyne), the capsule is more than 20 mm long stipitate, siliquiform, with 2 valves separating from the placentas (Quezel and Santa., 1963, Baba Aissa., 2000).

Cleome arabica is an annual herbaceous plant with a height of 30-60 cm of a grayish-green color, glandular, slimy, characterized by a fetid odor (Beniston, 1984), erect and branched stems and three-leaved leaflets. The fruit has two open silique valves, and the seeds are covered with hairs as long as the diameter of the seeds (Ozenda, 1991) (Fig. 1).

2. METHODOLOGY

2.1. Biological material

The biological material used in this work consists of mature seeds of *C. arabica* and in order to control the insect before it is winged the fifth-stage larvae of *S. gregaria* are retained.

2.2. Rearing of *Schistocerca gregaria*

The individuals resulting from the laying of two pairs of solitary adults captured in March 2020 from irrigated cereal perimeters under pivots in the *Hassi-L'fehal* area (Ghardaïa region of the northern Algerian Sahara) were kept in a parallelepiped cage with a wooden frame. The dimensions of the cage were 1.2 m x 0.80 m x 0.70 m. The cage was covered with a fine wire mesh. A small sliding door on the front of the cage allowed access. The bottom of the cage had circular openings where nesting boxes filled with moistened sand were placed. The individuals were maintained at a temperature of 33±02 °C, continuous lighting and a relative humidity of 57±05%. Food consisted mainly of Poaceae including durum wheat (*Triticum durum* L.), barley (*Hordeum vulgare* L.), grass (*Stenotaphrum americanum* L.), but also cabbage leaves (*Brassica oleracea* L.) (Brassicaceae). The renewal of the food, the cleaning of the cage, the humidification and the checking of the nest boxes were carried out daily.

Fig. 1 A-B. *Cleome arabica* at fruiting stage (Oued Metlili, Region of Ghardaïa-Northern Algerian Sahara, April 2020). A) Whole plant. B) Seed.

Fig. 1 C-D. *Cleome arabica* at fruiting stage (Oued Metlili, Region of Ghardaïa-Northern Algerian Sahara, April 2020). C) Fruiting brunches. D) Fruiting close-up.

2.3. Seed oil extraction

Ripe seeds of *C. arabica* were collected from plants sampled in *Oued Metlili* (Ghardaïa region of Algerian northern Sahara). The harvested seeds were cleaned of any kind of impurity and then left to dry in the oven set at 40°C for 24 hours. After drying, the grinding process was carried out by using a cutting mill of the M20 Universal type, IKA®. The recovered powder was stored in a hermetically sealed and disinfected glass jar.

Extraction of oil from *C. arabica* seeds was carried out in hexane by the Soxhlet device with a capacity of 250 ml. The extraction lasted six hours at a temperature of 50°C. The extract collected was avapor of the Hei-VAP Heidolphtype, this device eliminates the hexane, and recovers the pure vegetable oil.

2.4. Bio-tests

The toxicity test was carried out orally by injecting a volume of 60 μL of seed oil into the L5 larvae of the desert Locust using a micropipette. The larvae of the control batch were injected with a volume of 60 μL of distilled water. It is important to note that before the application of the test, the L5 larvae were fasted for 24 hours to empty their digestive tracts and to starve them. Immediately after the treatment, the L5 larvae of the desert Locust were placed individually in closed and perforated boxes and fed daily with fragments of *Brassica oleracea* L. cabbage leaves (Brassicaceae) of known surface area and weight.

The weight of the L5 larvae, the weight of feces, the surface area of the uningested fragments of cabbage leaves and other observations made in both the control and the treated batch were constantly monitored. The experiment was followed until the total mortality of the treated larvae or their transition to the imago stage.

To carry out this work, insects were divided into two batches, a treated and a control batch, each of them included 22 L5 larvae (11 males and 11 females).

2.5. Studied Parameters

In this study, our objective was to test the action of *C. arabica* seed oil on *S. gregaria* L5 larvae. The biological parameters studied were mortality, food consumption, weight growth, digestion, motricity, molting, etc.

2.5.1. Use of the results

2.5.1.1. Cumulative mortality— Mortality was the most important criterion for evaluating the toxic effect of a natural or synthetic product. In our study mortality was studied by several formulas, mortality rating and lethal time 50 (TL50).

The calculation of the percentage of cumulative mortality of L5 larvae is carried out according to the following formula applied by Tedonkeng Pamo *et al.*, 2002:

Observed mortality = [Number of deaths/Total number of individuals] x 100

2.5.1.2. Lethal Time 50 (TL50).— Lethal time 50 (TL50) is the time required for the 50% of individuals in the treated population to die following exposure to a

given product. It was estimated from the probit regression line corresponding to the percentages of mortality corrected according to the logarithms of the treatment duration (Ramade, 2007). Corrected mortality was estimated by applying Schneider's formula:

$$\text{Corrected mortality (\%)} = Mc = [M2 - M1 / 100 - M1] \times 100$$

Mc: % corrected mortality;
M2: % mortality in the treated population;
M1: % mortality in the control population.

2.5.1.3. Effect on digestion.— In order to evaluate the effect of the seed oil on the digestion of desert Locust L5 larvae, the apparent digestive utilization coefficient (DUCa), the consumption index (CI) and the digestive conversion coefficient (DCC) were estimated.

2.5.1.3.1. Apparent Digestive Utilization Coefficient (DUCa).— The Apparent Digestive Utilization Coefficient (DUCa) is the percentage of ingested nutrients that will not end up in the feces. The DUCa is determined according to Walbauer's equation (1968):

$$DUCa = ((\text{Ingested Quantity} - \text{weight of feces}) / \text{Ingested Quantity}) \times 100$$

2.5.1.3.2. Consumption index (CI).— The Consumption Index (CI) is obtained by calculating the ratio between the quantity of food consumed by an animal during a given period and the live weight gain during the same time (Boccard, 1963). It is estimated by the following formula:

$$CI = \text{Ingested Quantity} / \text{live weight gain}$$

2.5.1.3.3. Digestive Conversion Coefficient (DCC).— The Digestive Conversion Coefficient (DCC) corresponds to the ratio between the increase in the weight of the animal during 24 hours and the quantity of food ingested during the same period (Walbauer, 1968). It is estimated by the following formula:

$$DCC (\%) = [(\text{Live weight gain}) / (\text{Amount of food ingested})] \times 100$$

2.5.1.3.4. Statistical Analysis.— The experimental results were statistically analyzed using a one-way analysis of variance ANOVA and when the results were significant at $p=0.5$. Tukey's test (HSD) was used. The 2012 version of XLSTAT software was used to interpret the experimental results of the various tests.

3. RESULTS

3.1. Effect on mortality

Schistocerca gregaria L5 larvae were sensitive to *C. arabica* seed oils; this sensitivity was manifested by the death of treated individuals. The cumulative mortality percentages recorded in both, control L5 larvae and the treated with *C. arabica* seed oil are shown in Table 1.

A mortality rate of 63.64% was recorded after 16 days in L5 larvae of *S. gregaria* treated with *C. arabica* seed oil. Males of L5 larvae recorded a mortality rate of 90.91% and 36.36% for female. However, no mortality was observed in the control L5 larvae of *S. gregaria* which completed their fledglings after 8±0.5 days (Table 1). *Cleome arabica* seed oil can be said to have a lethal effect on *S. gregaria* L5 larvae (Fig. 2). Blackening of the cuticle was observed in some dead L5 larvae following treatment with *C. arabica* seed oil (Fig. 3). The 27.27% of L5 larvae treated with this seed oil died following the blocking of the exuviation phenomenon (Fig. 4). The percentage of L5 larvae of *S. gregaria* treated with *C. arabica* seed oil able to complete their imaginal molts was 36.36%, of which 13.63% showed anomalies in the legs and wings (Fig. 5), and 22.72% were able to complete their molts successfully. In addition, sub-lethal effects were observed on L5 larvae of *S. gregaria* treated with *C. arabica* seed oil, such as a decrease in locomotor activity and the loss of water in the form of diarrhea.

3.2. Lethal time 50 evaluation (LT50)

The evaluation of the lethal time 50 allows us to study the action of mortality caused by this seed oil in relation to time. To determine the lethal time 50 of *C. arabica* seed oil on L5 larvae of *S. gregaria*, the probit regression line of the mortality rate was drawn as a function of the logarithms of the treatment times (Fig. 6). The time

Table1. Cumulative mortality rate recorded in control L5 larvae treated with *C. arabica* seed oil.

Time [days]	Experimental batches [Mortality rates %]	
	Control	*C. arabica*
1	0	0
2	0	0
3	0	4.54
4	0	22.73
5	0	27.27
6	0	27.27
7	0	31.82
8	0	36.36
9	0	40.91
10	Imago	45.45
11	Imago	50
12	Imago	50
13	Imago	50
14	Imago	59.10
15	Imago	59.10
16	Imago	63.64

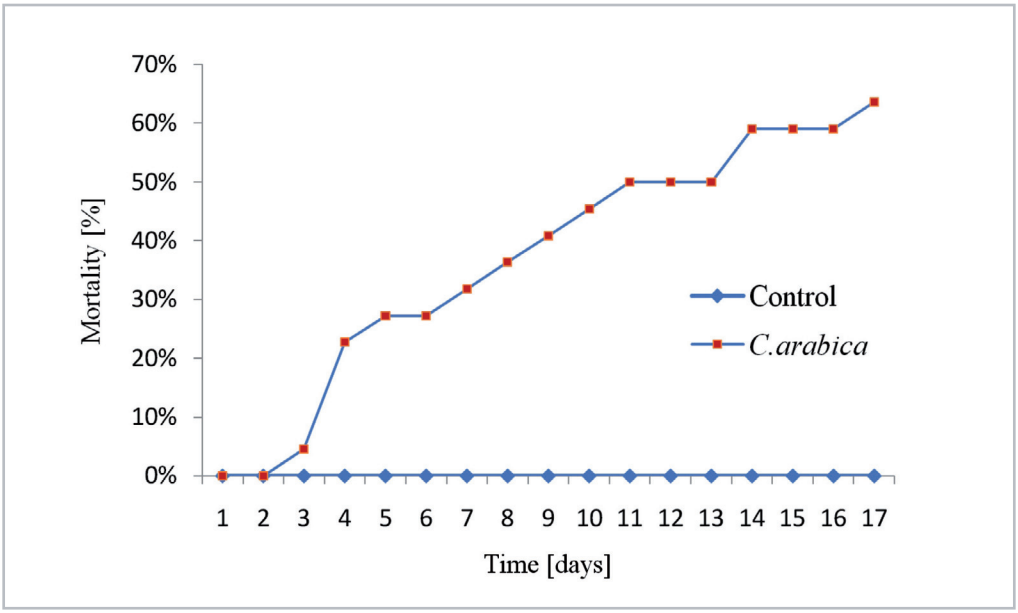

Fig. 2. Variation over time of mortality rate observed in control L5 larvae treated with *C. arabica* seed oil.

Fig. 3. Blackening observed in L5 larvae of *S. gregaria* treated with *C. arabica* seed oil.

required for 50% of the population of treated L5 larvae to die was on the order of 11 days (Fig. 6). The lethal time 50 obtained was high, this means that the mortality action of *C. arabica* seed oil was slow in time but with a high mortality rate of 63.64% after 16 days.

3.3. Effect on food intake

The average amounts of daily food consumption recorded in the treated and control batches of *S. gregaria* L5 larvae were grouped together in Table 2. The average daily

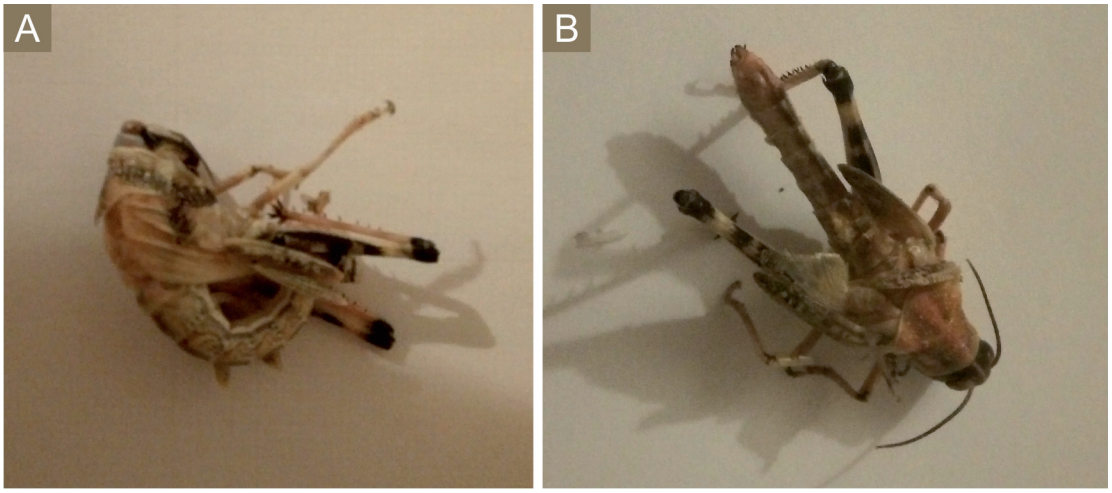

Fig. 4 A-B. Dead L5 larvae following the inability to molt observed in *S. gregaria* L5 treated with *C. arabica* seed oil.

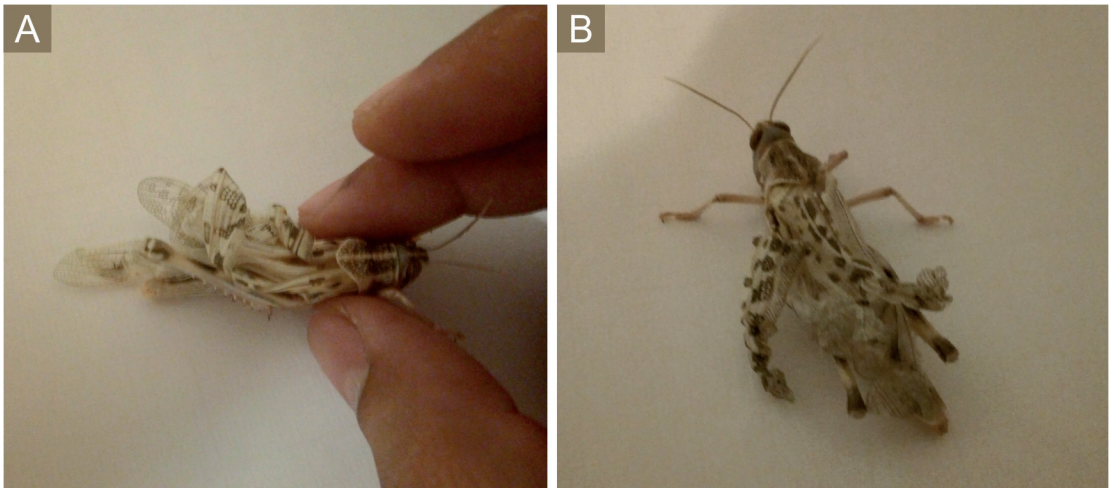

Fig. 5 A-B. Morphological abnormalities observed in L5 muer larvae of *S. gregaria* treated with *C. arabica* seed oil.

consumption of fresh cabbage leaves made by the control L5 larvae was 1.55 ± 0.87 g/day, including 1.29 ± 0.81 g/day in males and 1.8 ± 0.95 g/day in females. While the average daily consumption recorded in L5 larvae treated with *C. arabica* seed oil was 0.46 ± 0.44 g/day, with a difference in consumption according to sex, males presented an average daily consumption of 0.31 ± 0.25 g/day which was lower compared to the average daily consumption of females, which was 0.70 ± 0.27 g/day, this means that males were more sensitive to the deterrent effect of the seed oil compared to females. The average daily consumption of L5 larvae of *S. gregaria* treated with *C. arabica* seed oil was significantly lower compared to the control group. This low consumption recorded in the treated L5 larvae can be explained by the action of *C. arabica* seed oil on insects' appetite.

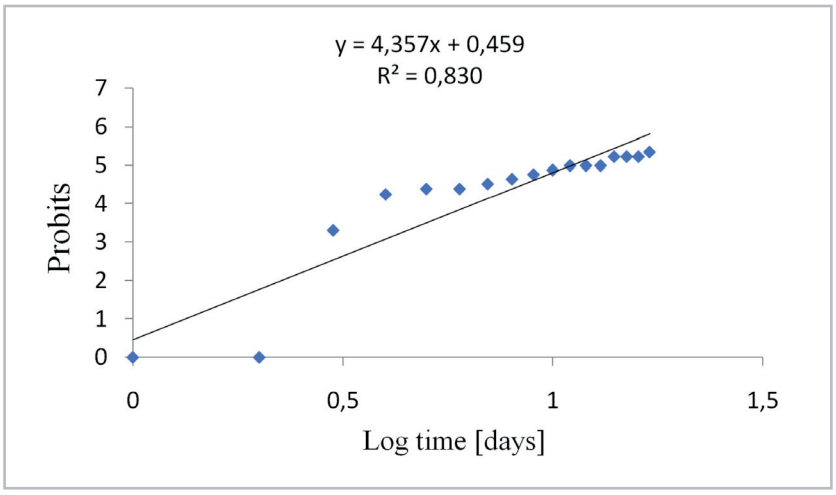

Fig. 6. Regression line of mortality rate recorded in L5 larvae treated with *C. arabica* seed oil as a function of time.

3.4. Effect on growth and development

The anti-appetizing effect of *C. arabica* seed oil on treated *S. gregaria* L5 larvae was manifested by a decrease in weight gain. The different values of the average daily weight of the L5 larvae control group and that of the larvae treated with *C. arabica* seed oil were shown in Table 3. The weight gain in L5 larvae treated with *C. arabica* seed oil recorded in males and females were respectively of the order of 3.66% and 24.89%. The control group of L5 larvae recorded a weight gain of around 53.38% in males and 53.33% in females. The weight gain of the treated L5 larvae was lower compared to the control L5 larvae (Fig. 7).

Table 2. Variation over time of the average consumption of cabbage leaves recorded in control *S. gregaria* L5 larvae treated with *C. arabica* seed oil.

Time [days]	Experimental batches [Consumption in grams]	
	Control	*C. arabica*
1	1.95 ± 0.79 (A)	0.62 ± 0.47 (B)
2	2.24 ± 0.64 (A)	1.01 ± 0.96 (B)
3	2.68 ± 0.95 (A)	1.3 ± 0.63 (B)
4	2.70 ± 0.78 (A)	1.11 ± 0.65 (B)
5	1.67 ± 0.96 (A)	0.87 ± 0.53 (B)
6	0.57 ± 0.72 (A)	0.72 ± 0.53 (A)
7	0.17 ± 0.31 (B)	0.69 ± 0.56 (A)
8	0.79 ± 0.76 (A)	0.55 ± 0.44 (A)
9	1.18 ± 0.73 (A)	0.28 ± 0.3(B)
10	Imago	0.08 ± 0.20
11	Imago	0.07 ± 0.23
12	Imago	0.00 ± 0.00
13	Imago	0.00±0.00
14	Imago	0.00 ± 0.00
15	Imago	0.00 ± 0.00
16	Imago	0.00 ± 0.00
17	Imago	Imago

Table 3. Daily variation in weight recorded in control *S. gregaria* L5 larvae treated with *C. arabica* seed oil.

Time [days]	Experimental batches [Weight variation in grams]	
	Control	*C. arabica*
1	0.75 ± 0.13 (A)	0.68 ± 0.12 (A)
2	1.21 ± 0.22 (A)	0.74 ± 0.17 (B)
3	1.40 ± 0.22 (A)	0.82 ± 0.26 (B)
4	1.58 ± 0.22 (A)	0.99 ± 0.29 (B)
5	1.74 ± 0.23 (A)	1.11 ± 0.27 (B)
6	1.81 ± 0.22 (A)	1.19 ± 0.32 (B)
7	1.77 ± 0.26 (A)	1.29 ± 0.35(B)
8	1.67 ± 0.27 (A)	1.36 ± 0.34 (B)
9	1.67 ± 0.20 (A)	1.45 ± 0.46 (A)
10	Imago	1.52 ± 0.44
11	Imago	1.56 ± 0.28
12	Imago	1.46 ± 0.30
13	Imago	1.33 ± 0.26
14	Imago	1.31 ± 0.25
15	Imago	1.16 ± 0.15
16	Imago	0.90 ± 0.00
17	Imago	Imago

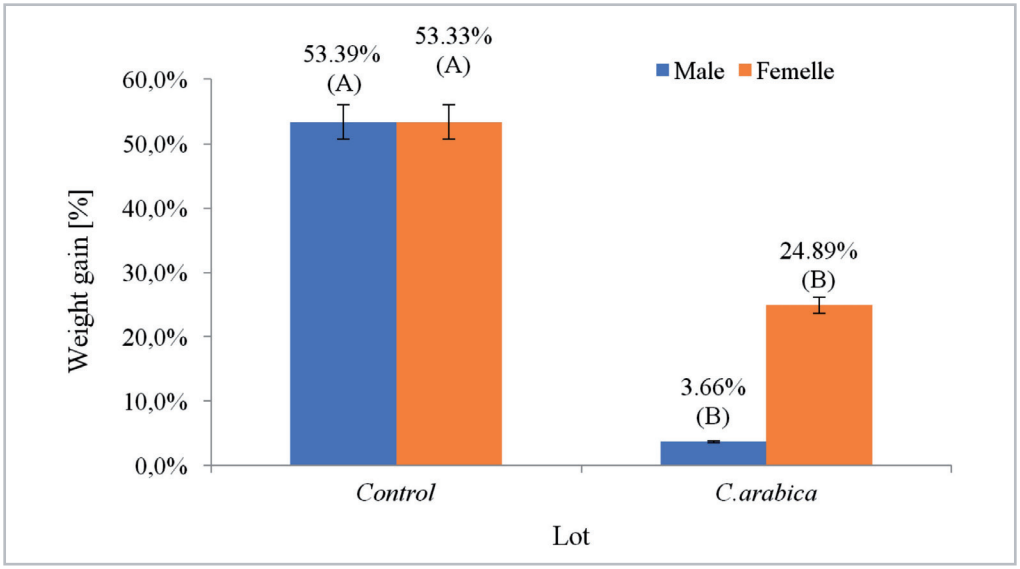

Fig. 7. Variation of the weight compared to the initial weight of L5 larvae of control *S. gregaria* and treated with *C. arabica* seed oil.

3.5. Effect on digestion

It appears that this vegetable oil caused digestive problems in the treated L5 larvae of *S. gregaria*, reflected by the different averages of apparent digestive utilization coefficient (DUCa) and digestive conversion coefficient (DCC) and of the consumption index (CI), which were clearly lower compared to those estimated in the control larvae (Table 4). These results attest to the harmful action of *C. arabica* seed oil, which caused digestive disturbances that appeared in L5 larvae through several symptoms of intoxication such as the difficulty in converting ingested food into weight and liquefied feces.

Table 4. Digestive parameters estimated for control *S. gregaria* L5 larvae treated with *C. arabica* seed oil.

	Parameters	Apparent digestive utilization coefficient (DUCa) [%]	Consumption Index (CI)	Digestive conversion coefficient (CCD) [%]
Experimental batches	Control	70.63 ± 19.55 (A)	15.74 ± 3.51 (A)	9.48 ± 8.84 (A)
	C. arabica	40.67 ± 33.14 (B)	9.44 ± 11.49 (B)	-5.63 ± 9.62 (B)

The average apparent digestive utilization coefficients (DUCa) in control *S. gregaria* L5 larvae and in the treated with *C. arabica* seed oil were respectively 70.63±19.55% and 40.67±33.14%. The values obtained in the treated L5 larvae were lower than those obtained in the control group.

The average digestive conversion coefficient (DCC) obtained in L5 larvae treated with C. *arabica* seed oil was of the order of -5.63±9.62%, this value was significantly lower than that of the control L5 larvae which recorded an average value of 9.48±8.84%. This negative value of the average digestive conversion coefficient (DCC) was explained by the weight loss caused by the effect of this vegetable oil on the treated L5 larvae which was due to the decrease in the digestive conversion capacity of food into weight. The results of the consumption index in the treated L5 larvae were 9.44 ± 11.49, significantly lower than the value obtained in the control L5 larvae, which recorded a value of 15.74 ± 3 .51. This drop in the CI in the treated L5 larvae was explained by the weight loss caused by the effect of *C. arabica* seed oil which caused difficulties in absorption and conversion of food into weight.

4. DISCUSSIONS

4.1. Effects on mortality

The action of *C. arabica* seed oil on L5 larvae of *S. gregaria* caused a mortality rate of 63.64% including 90.91% of males and 36.36% females after 16 days. It seems that males are more sensitive to this seed oil compared to females because the weight of males is less important than the weight of females. Several treated L5 larvae died due to molting difficulties or following a blockage of the exuviae phenomenon. Some L5 larvae from the treated population were able to complete their imaginal molt with deformities in wings and legs, whereas in the control L5 larvae no mortality was observed. A mortality rate of 10% was recorded in L5 larvae of *S. gregaria* fed on cabbage leaves treated with the crude leaf extract of *C. arabica*. Similarly, the action of essential oils of *C. arabica* on L5 larvae recorded a mortality rate of 100% after 14 days (Lebbouz, 2010). In L5 larvae fed with cabbage leaves treated with acetone extract of *C. arabica*, a mortality percentage of 76.67% was noted in male L5 larvae and 86.67% in female L5 larvae. The ingestion of cabbage leaves treated with the alkaloid extract of *C. arabica* generated mortality percentages of the order of 70.0% in batches of male L5 larvae and 63.33% for female L5 larvae (Kemassi *et al*., 2018). Oral administration of 60μL of *D. stramonium* seed oil resulted in a 100% mortality

rate in treated L5 larvae which eventually died after 16 days. While *P. harmala* seed oil caused a 50% mortality rate in L5 larvae of *S. gregaria* after 12 days (Aitaoudia *et al.*, 2021). The application of a dose of 8.9 x 107 spores/ml of *Metarhizium anisopliae Metsch* to L5 larvae of *S. gregaria* recorded a mortality rate of 83.33% after 15 days (Djezzar, 2007).

According to Kemassi *et al*., 2018, the alkaloid extract caused a toxic and lethal effect on L5 larvae of *S. gregaria*. The *C. arabica* plant contains various secondary substances like steroids, flavonoids, triterpenes, anthraquinones, saponins, resins, tannins, glycosides, alkaloids (Madi, 2018). In light of this observation, it can be concluded that the lethal effect of *C. arabica* seed oil was probably due to the toxic secondary substances contained in the seed oil of this spontaneous plant.

4.2. Evaluation of Lethal Time 50 (TL50)

In this study, a lethal time 50 of 11 days was recorded in L5 larvae of *S. gregaria* treated with *C. arabica* seed oil. In L5larvae of *S. gregaria* treated with total alkaloids of *C. arabica*, a lethal time 50 of the order of 8.77 days in males and of the order of 11.19 days in females was obtained (Kemassi *et al*., 2018). The application of essential oils of *C. arabica* on the L5 larvae gave a TL50 of the order of 13.74 days. Similarly, a TL50 of the order of 50.12 days was obtained in the L5 larvae fed on leaves of *B. oleracea* treated with *C. arabica* leaf extract (Lebbouz, 2010). The L5 larvae fed on cabbage leaves soaked in the acetone leaf extract of three spontaneous plants, *A. indica*, *M. azedarach* and *E. globulus* recorded, respectively, TL50 of the order of 7.5 days, 8.2 days and 10.4 days (Ould el hadj *et al*., 2003). A lethal time 50 of 6.79 days was recorded in L5 larvae of *S. gregaria* treated with a dose of 7.3 x 108 spores/ml of *Bacillus subtilis* (Mohand kaci, 1998).

4.3. Effect on food intake

In the present study, the amounts of cabbage ingested by *S. gregaria* L5 larvae treated with *C. arabica* seed oil were reduced and compared to the control group.

Several plants defend themselves and reduce the destructive attacks of pests by the secretion or presence of certain repellent allelic chemical plant substances and other toxic substances, which makes some plants be totally rejected by several insects (Fränkel, 1959). *Schistocerca gregaria* larvae fed on *Glinus lotoides* exhibited food abstinence due to the repellent effect of the plant (Idrissi-Hassani, 2000). According to Simone and Joern, 1994, the repellent effect of the plant was due to the presence of inhibitory allelochemical compounds and phago-stimulating substances.

All in all, it can be concluded that this low consumption recorded in the treated L5 larvae may be the result of the presence of inhibitory allelochemicals in the seed oil of *C. arabica* which acted negatively on the appetite of this locust.

4.4. Effect on growth and development

In the present work, L5 larvae treated with *C. arabica* seed oil showed poor weight gain compared to the control group.

L5 larvae and adults of *S. gregaria* treated with the injection of floral solutions of *Nerium oleander* (Apocynaceae) and *Lonicera japonica* (Caprifoliaceae) recorded a low weight progression (Belhadi, 2005). The imagos of *S. gregaria* fed with wheat leaves sprayed by the extracts of *M. azedarach* (Miliaceae) and *N. oleander* (Apocynaceae) and *Inula viscosa* (Asteraceae) showed a decrease in weight (Tail, 1998).

According to Rao and Mehrotra (1977), alkaloids have an anti-appetizing effect, which causes a drop in the weight of individuals. Research has proven that terpenoid compounds had a repellent effect which produced an inhibitory action on growth in the juvenile stages (Sieber and Rembold, 1983). The *C. arabica* plant contains triterpenes and other secondary substances (Madi, 2018).

In consideration of these results, it can be said that the poor weight gain exhibited in L5 larvae of *S. gregaria* treated with *C. arabica* seed oil was probably due to secondary substances contained in the *C. arabica* plant, such as triterpenes, which have an inhibiting action on the growth of larvae and other toxic metabolites which have an anti-appetizing effect.

4.5. Effect on digestion

The L5 larvae of *S. gregaria* treated with *C. arabica* seed oil had lower averages of apparent digestive utilization coefficient (DUCa), digestive conversion coefficient (DCC) and consumption index (CI) compared to control L5 larvae.

The mesenteron is the part of the digestive tract responsible for absorbing all the nutrients from the food ingested by the locust. According to Hamadi *et al*., 2021, the forced oral injection of essential oil of *Origanum glandulosum* Desf. (Lamiaceae) caused the destruction of the peritrophic membrane of the mesenteron of *S. gregaria* as well as the total degradation of the brush border of epithelial cells and the appearance of ulcerations due to ruptures at the level of the epithelial layer, which appears very granular, and in certain places these cells are strongly vacuolated. The diameter of this portion of the digestive tract seemed greater, probably resulting from a relaxation of the muscular base, caused by the action of the essential oil of *O. glandulosum* on the circular muscular tunic.

According to Kemassi *et al.*, 2019, L5 individuals and imagos of *S. gregaria* fed with cabbage leaves treated with leaf extracts of *C. arabica* presented anomalies and deformities in the intestine which were manifested by the absence of the peritrophic membrane and an increase in diameter, irregularities of the borders of the epithelial base and ulcerations at the level of epithelial tissue.

Taking into consideration these findings, it can be explained that the decrease in apparent digestive utilization coefficients (DUCa), digestive conversion coefficient (DCC) and consumption index (CI) may be due to the effect of *C. arabica* seed oil on the digestive tract of the treated L5 larvae, which probably caused alterations and lesions in the mesenteron.

5. CONCLUSION

Forced oral administration of 60 μL of *C. arabica* seed oil in L5 larvae of *S. gregaria* caused the death of several treated individuals after a few days of treatment. It also seemed that this seed oil caused other intoxication symptoms like: reduction in locomotor activity, reduction in food intake, reduction in growth, ventral depigmentation, difficulty in absorption and digestive conversion, deformity following molting and inability to molt. From this study, it can be concluded that *C. arabica* seed oil is toxic to *S. gregaria* L5 larvae.

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