

## Efficacy of Some Pesticide Alternatives on the Desert Locust *Schistocerca gregaria* (Forsk.) Under Laboratory and Field Conditions

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**Abstract:** The efficacy of chlorantraniliprole (Coragen®), spinosad (Tracer®) and fipronil (Coatch®) was tested under laboratory conditions against the 5<sup>th</sup> nymphal instars and adult stages of the Desert Locust *Schistocerca gregaria* (Forsk.), using various concentrations of the mentioned compounds by feeding technique. Fipronil showed the highest efficacy on both stages, followed by spinosad while chlorantraniliprole caused lower mortality. The effect of sublethal concentrations (LC<sub>30</sub>) of the mentioned insecticides on the life span and fledging rate of 5<sup>th</sup> nymphal instar was investigated. 5<sup>th</sup> nymphal instar took 12.6, 15.6 and 11.6 days to fledge in the treatments of chlorantraniliprole, spinosad and fipronil respectively, which are significantly longer than the duration spent by the untreated 5<sup>th</sup> nymphal instar to fledge (8.8 days). Successful fledging rates of 5<sup>th</sup> nymphal instars were 42.6%, 75% and 25% for the treatments of chlorantraniliprole, spinosad and fipronil respectively, which are significantly lower than that of the untreated hoppers (100% fledged successfully). Deformation occurred in 30% of the 5<sup>th</sup> nymphal instars treated by LC<sub>30</sub> of fipronil and spinosad. Field tests, executed in Abu\_Ramad, southeast Egypt, showed that chlorantraniliprole at dose rate of 24 g. a. i. /ha, spinosad at dose rate of 15.12 g. a. i. /ha, and fipronil at dose rate of 0.4 g. a. i. /ha, resulted in 98, 99 and 100% mortality to mixed populations of hoppers and adults of *S. gregaria* within two days of field application.

**Key words:** Insects, *Schistocerca gregaria*, insecticide alternatives, fledging, field conditions

### INTRODUCTION

The Desert Locust, *Schistocerca gregaria* (Forsk.) is considered the most economically important insect pest in Egypt as well as in other African and Asian countries. The insects cause great damages to crops and pastures when they increase in numbers and form hopper bands or swarms.

The chemical control of locusts using the organophosphorous pesticides and synthetic pyrethroids is still the main tool to control locusts, while organochlorines were banned due to their persistence and severe effects on the environment (Lecoq, 2001). The widespread use of the synthetic pesticides has considerable negatives such as handling hazards, the development of insect resistance to insecticides, increased costs, concerns about insecticide residues, and great threats to both human and environmental health (Garriga and Caballero, 2011), which occurs due to pollution by the chemical pesticides such as toxicity to non-target organisms

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(Tingle, 1996) and to humans (Pretty, 1996). This study aims to find safer alternatives, for human and environment, than the conventional insecticides. The study suggests new alternative compounds from various groups of pesticides to control the desert locust including chlorantraniliprole from the anthranilic diamides group, spinosad as a biological agent and fipronil from phenylpyrazoles.

## Materials and methods

### *Test insects and bioassay*

The insects of the desert locust *S. gregaria* were reared under laboratory conditions. They were obtained from the stock culture maintained for several generations at the Locust Research Section, Plant Protection Research Institute (PPRI), ARC, Dokki, Giza. The insects were reared according to Robert *et al.*, (2002) in wooden framed cages measuring (55 x 55 x 60cm) and the insects were fed on branches of clovers, *Trifolium alexandrinum*. The locusts' cages were kept at  $30 \pm 3$  °C and 20-25 % Relative Humidity.

Feeding technique was used in the laboratory to study the effect of different concentrations of chlorantraniliprole 20% SC (Coragen®), spinosad 24% SC (Tracer®), and fipronil 20% SC (Coach®) on the mortality rates of one day old 5<sup>th</sup> nymphal instar and seven days old adults of *S. gregaria*. The hoppers and adults were treated separately, and subdivided into groups of 50 hoppers or adults for each treatment, with five replicates of ten nymphs or adults were assigned for each treatment. The hoppers and adults were starved for 24 hours and were fed on clover leaves dipped for 10 seconds in: 60, 240, 480 and 600 ppm of chlorantraniliprole, 30, 60, 120 and 180 ppm of spinosad and 0.1, 0.5, 1 and 2 ppm of fipronil. The leaves were air dried under room temperature for one hour before presenting to the nymphs and adults, and water dipped leaves was presented to the untreated hoppers and adults. The treated leaves were replaced with non-treated ones after 24 hr. the mortality was recorded after

1, 2 and 3 days of treatment. LC<sub>30</sub>, LC<sub>50</sub> and LC<sub>90</sub> were calculated using (Ldp line) software according to the method of Finney (1971).

### *Field trial*

Extensive field surveys were carried out in southeast Egypt during the winter breeding seasons of 2017/2018 and 2018/2019 (the winter breeding season extends from October to March every year) in order to find a suitable site for the field application. Surveys were conducted according to the technique explained in the Food and Agriculture Organization desert locust guidelines by Cressman (2001). No infestations occurred during the first breeding season because only light rains fell in that season. Whereas; heavy rains fell in the area at the beginning of the second season (2018/2019) resulted in providing favourable ecological conditions for desert locust breeding. Vegetation grew and soil moisture became suitable for egg laying by desert locust females. Isolated mature solitary adults were seen at the beginning of the season and copulating and laying occurred in various sites of Abu Ramad and Shalatyn (See the maps in figure 1). Hatching started at the end of December 2018, and worthy numbers of hoppers resulted from this breeding. The number of hoppers increased in January 2019 and reached 5 hoppers / m<sup>2</sup> (with 3<sup>rd</sup>, 4<sup>th</sup> and 5<sup>th</sup> instar nymphs), in addition to immature adults, at few sites in the area of Jabal Elba, while lower numbers were detected in the other survey areas.

The experimental site was selected to conduct the field test located in Abu\_Ramad at (22°15'North/36°23'East). Hoppers of medium to late instars and newly emerged adults were found at the site of the experiment. Four plots of 50 by 50 meters each were selected and demarcated by flags. In each plot, 4 nets of 1 m<sup>2</sup> each were fixed on the vegetation (they represent the replicates of each treatment) and a number of 30 hoppers and adults was collected from the

treatment site and were put under each of these nets. The nets in the plot allowed recording the mortality and prevented insects from escaping after spraying. The plots were aligned in parallel direction to the prevailing wind, in order to inhibit pollution of spray drift from one plot to the other during spraying. Control plot was put upwind in relation to the others and sprayed with water only. Spraying was executed in the early morning when conditions were suitable for spraying (wind speed: 2-3 m/second, measured using anemometer, temperature: 18°C. and relative humidity: 43%). Spraying was executed using Knapsack mistblower sprayer with flow scale graded from 1 to 5; the scale no 2 was selected and calibrated. The flow rate was 1200 ml /min.; spraying

height was 0.5 m above vegetation and walking speed of the operator was 40 m/min. = 2.4 km /hr. with swath width of 5 m. Mortality counts were recorded after different periods of treatment, i.e., 3, 6, 12, 24 and 48 hours of application considering the treated insects under the fixed nets in each plot. The green circles on the left map represent the sites with green vegetation and the yellow circles represent the sites with dry vegetation. Whereas; the blue “L” symbols on the right map represent the sites of mature adults of *S. gregaria* which can copulate and lay eggs.

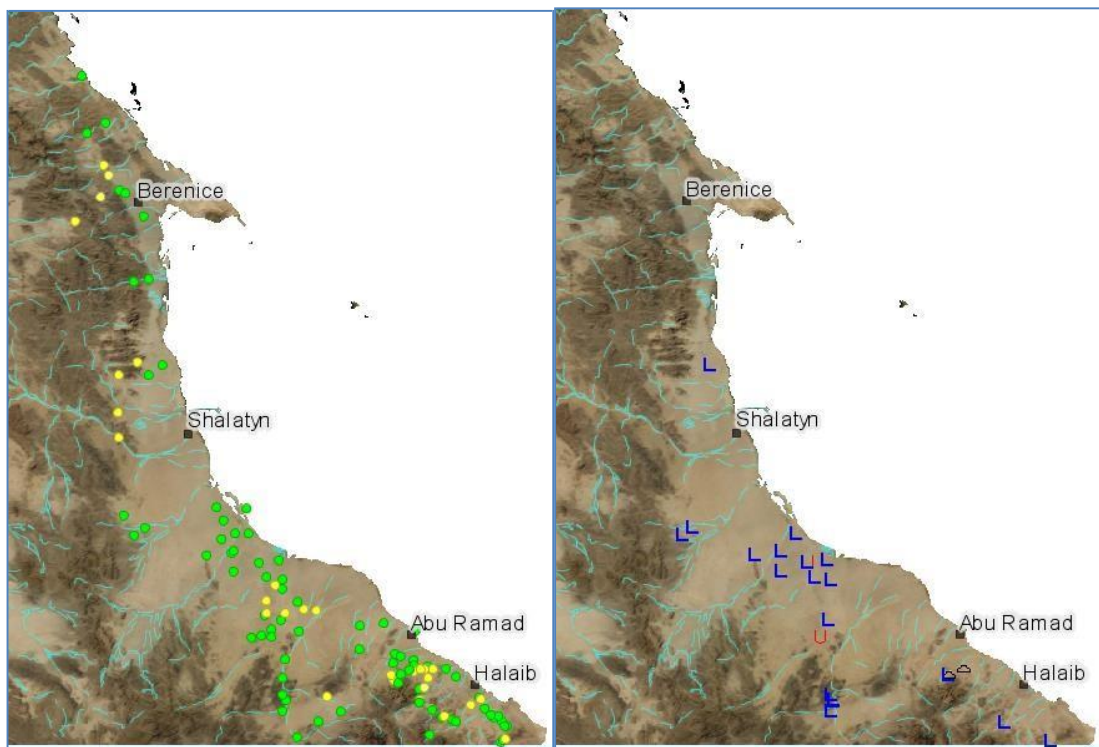


Figure 1: Maps showing vegetation state and desert locust infestations in December 2018 and January 2019 in southeast Egypt

## Results and discussions

### *The mortality percentages of the 5<sup>th</sup> nymphal instars and adults of S. gregaria under laboratory conditions*

The corrected mortality percentages due to the treatments by chlorantraniliprole, spinosad and fipronil were calculated by using Abbott's formula (1925) as follows:

$$\text{Corrected \% mortality} = \frac{(1 - \frac{n \text{ in T after treatment}}{n \text{ in Co after treatment}}) \times 100}{1}$$

Where n = insect population, T = treated and Co = control.

Data in table 1 indicates the corrected mortality rates of one-day old 5<sup>th</sup> nymphal instar after 1, 2 and 3 days of treatment with various concentrations of chlorantraniliprole, spinosad and fipronil. After treatment with 60, 240, 480 and 600 ppm of chlorantraniliprole, the mortality percentages were (20 % and 43.3%), (46.7% and 70%), (60% and 83.3%) and (70% and 96.7%) for the 5<sup>th</sup> nymphal instars and adults of *S. gregaria*, respectively. The finding agrees with those found by Cao *et al.*, (2017) in a laboratory trial which indicated that chlorantraniliprole (Prevathon®) was effective against 3<sup>rd</sup> instar hoppers of the oriental migratory locust, *Locusta migratoria* L.

In addition; the corrected mortality rates after 3 days of treatment with 30, 60, 120 and 180 ppm of spinosad were (34.48% and 62.1%), (55.2% and 79.3%), (86.2% and 100%) and (100% and 100 %) for the 5<sup>th</sup> nymphal instar and adults of *S. gregaria*, respectively. The result agrees with the finding by Kamel (2018) who found that spinosad (Tracer®) caused 100% mortality to the 4<sup>th</sup> instar hoppers of *S. gregaria* after 48 hours of treatment using feeding technique. Also, Said (2014) obtained similar results under laboratory conditions as he found that spinosad caused similar levels of mortality when 5<sup>th</sup> instar nymphs of *S. gregaria* were exposed to spinosad dipped clover leaves.

Moreover; the corrected mortality rates after 3 days of treatment with 0.1, 0.5, 1 and 2

ppm of fipronil were (51.9% and 55.6%), (85.2% and 88.9%), (96.30% and 100%) and (100 and 100%) for the 5<sup>th</sup> nymphal instars and adults of *S. gregaria*, respectively. This finding is in line with that found by Ibrahim (2018) who found that fipronil (Coach®), under laboratory conditions, achieved 100 % mortality after 24 hr. to the 4<sup>th</sup> nymphal instar of *S. gregaria* using a concentration of 0.5 ppm, and 55.6% mortality occurred to the same instar by using a concentration of 0.12 ppm after 48 hours of treatment.

The data in table 2 shows the values of LC<sub>30</sub>, LC<sub>50</sub> and LC<sub>90</sub> for *S. gregaria* after 3 days of treatment with above mentioned concentrations for each of the selected pesticides. The probit regression lines for the used concentrations of the tested insecticides against hoppers and adults are demonstrated graphically in figure 2.

The mentioned results indicate that adults of *S. gregaria* are more sensitive to all tested compounds than 5<sup>th</sup> nymphal instars. This could be due to the higher food consumption by the immature adults, and also can be due to the larger exposed body surface for adults when compared to hoppers, which allowed adults to be in better contact chances with the insecticide dipped leaves.

### *Effect of LC<sub>30</sub> of chlorantraniliprole, spinosad and fipronil on some biological aspects of S. gregaria*

Data in table 3 indicates the effects of sub lethal concentrations (LC<sub>30</sub>) of chlorantraniliprole, spinosad and fipronil on life span, hopper deformation and adult fledging of 5<sup>th</sup> nymphal instars of *S. gregaria*. Sub lethal concentrations represent the low doses of the insecticide which usually occur in the field after few days of applications. 5<sup>th</sup> nymphal instar spent an average of 12.6, 15.6 and 11.6 days to moult into adults for the treatments of chlorantraniliprole, spinosad and fipronil respectively. These periods are significantly longer than the duration of 8.8 days taken by the untreated 5<sup>th</sup> nymphal instars to fledge.

Deformation followed by death occurred in 30% of the hoppers treated with fipronil and spinosad (figure 3). Rates of hoppers that successfully moulted into adults were 42.6%, 75% and 25% for the treatments of chlorantraniliprole, spinosad and fipronil respectively, while 100% of the untreated hoppers fledged successfully. El\_Gammal *et*

*al.* (2004) found that cycloheximide (RNA and protein synthesis inhibitor) caused 72.5, 70 and 60% permanent 4<sup>th</sup> instar nymphs of *S. gregaria* after treatment with doses of 480, 200 and 100 µg / insect for each dose respectively.

**Table 1.** Corrected mortality percentages of 5<sup>th</sup> nymphal instars and adults of *S. gregaria* using different concentrations of chlorantraniliprole, spinosad and fipronil

Treats.	Days Conc. (ppm)	1 day		2 days		3 days	
		nymphs	adults	nymphs	adults	nymphs	adults
chlorantr-aniliprole	60	10	20	16.67	30	20	43.3
	240	23.3	33.33	33.33	56.7	46.7	70
	480	40	43.33	46.33	66.7	60	83.3
	600	46.7	66.67	53.33	91	07	96.7
spinosad	30	13.3	20	22.22	48.3	34.48	62.1
	60	23.3	43.33	50.19	69	55.17	79.3
	120	43.3	66.67	68.9	100	86.21	---
	180	67.7	100	83.63	---	100	---
fipronil	0.1	20	36.67	29.6	40.7	51.9	55.6
	0.5	53.67	63.33	77.8	78.2	85.2	88.9
	1	66.67	90	88.9	99.6	96.30	100
	2	93.33	100	96.3	---	100	---

**Table 2.** LC<sub>30</sub>, LC<sub>50</sub> and LC<sub>90</sub> values calculated after 3 days of treatments

Period	chlorantraniliprole			spinosad			fpronil		
	LC <sub>30</sub>	LC <sub>50</sub>	LC <sub>90</sub>	LC <sub>30</sub>	LC <sub>50</sub>	LC <sub>90</sub>	LC <sub>30</sub>	LC <sub>50</sub>	LC <sub>90</sub>
<b>Locust</b>									
<b>5<sup>th</sup> nymphal instar</b>	107.8	271	2610	30.7	46.2	125.7	0.05	0.1	0.62
<b>Adults</b>	39	85.7	587	17.4	26	68.6	0.048	0.09	0.40

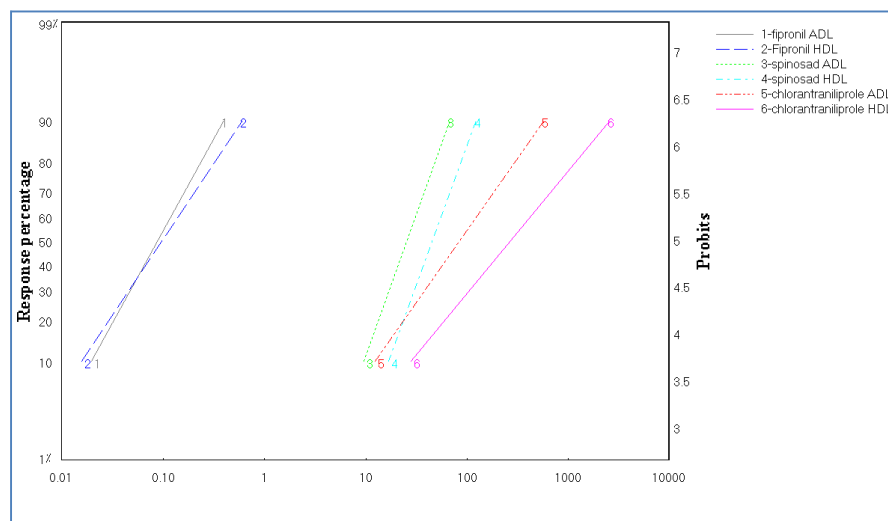


Figure 2: Toxicity lines of chlorantraniliprole, spinosad and fipronil on the 5<sup>th</sup> nymphal instars and adults of *S. gregaria* (ADL= adults of desert locust and HDL= hoppers of desert locust).

These nymphs were weak, inactive and stayed alive for more than 30 days. The mentioned study also found that the doses of 50 and 40  $\mu\text{g}/4^{\text{th}}$  instar nymphs resulted in 46.7 and 55.66 % deformed 5<sup>th</sup> instar nymphs which failed to shed their exuvia completely

and died. Additionally; the same study found that a dose of 30  $\mu\text{g}/4^{\text{th}}$  instar nymphs caused 50% of the resulting 5<sup>th</sup> nymphal instar to fail from reaching the adult stage, due to inability to shed off their exuvia in spite of the occurrence of the adult cuticle.

**Table 3.** The effect of LC<sub>30</sub> of chlorantraniliprole, spinosad and fipronil on some biological aspects of *S. gregaria*

Treatment	Hopper	Hopper	Adult
	duration (days)	deformation %	fledging %
<b>Chlorantraniliprole</b>	12.6 <sup>b</sup>	0% <sup>a</sup>	42.6 <sup>c</sup>
<b>Spinosad</b>	15.6 <sup>c</sup>	30% <sup>b</sup>	75 <sup>b</sup>
<b>Fipronil</b>	11.6 <sup>b</sup>	30% <sup>b</sup>	25 <sup>d</sup>
<b>Control</b>	8.8 <sup>a</sup>	0% <sup>a</sup>	100 <sup>a</sup>
<b>LSD (0.05%)</b>	1.86	0.56	2.56

Same letters are not significantly different

#### ***Efficacy of chlorantraniliprole, spinosad and fipronil on the desert locust S. gregaria under field conditions***

The data in table 4 indicates the mortality rates caused by chlorantraniliprole, spinosad and fipronil under field conditions. No mortality was recorded in the control plot after 2 days of application among the mixed population of hoppers and adults. After 3, 6,

12, 24 and 48 hr. of treatment with 2 ml/L of chlorantraniliprole (24 g. a. i. /ha), the mortality percentages were 0% 12%, 40%, 82% and 98% for mixed population of 3<sup>rd</sup>, 4<sup>th</sup>, 5<sup>th</sup> nymphal instars and immature adults of *S. gregaria*. The results agrees with those obtained under field conditions by Bradshaw *et al.*, (2013) who found that chlorantraniliprole (Coragen® at dose rate of 2 oz/A, and Prevathon® at dose rates of 7.8 oz/A and 13.6 oz/A), as anthranilic diamide

compounds, could reduce the populations of rangeland grasshoppers.



**Figure 3.** Malformed hoppers (a) and failure of moulting (b) caused by sub-lethal concentrations of spinosad ( $LC_{30}$ ) in *S. gregaria*

The mortality percentages caused by 1 ml/L of spinosad (15.12 g. a. i./ha) after 3, 6, 12, 24 and 48 hr. of treatment were 2% 18%, 69%, 92% and 99% for mixed population of 3<sup>rd</sup>, 4<sup>th</sup>, 5<sup>th</sup> nymphal instars and immature adults of *S. gregaria*. The results agree with those found by Hosny *et al.*, (2010) who indicated that spinosad at the concentration of 65 ml/100 L caused 75% and 100% mortality among *S. gregaria* nymphs after 24 and 48 hr. respectively. The study also found that spinosad caused 83.3 and 100% mortality after 24 and 48 hr. when applied against common grasshoppers at Baharia Oasis at concentration of 50 ml/100 L. Additionally; in her MSc thesis, Kamel (2018) found that spinosad (Tracer®) caused

high rate of mortality to the hoppers of *S. gregaria* after 48 hr. of field treatment.

The mortality percentages after 3, 6, 12, 24 and 48 hr. post treatment with 0.031 ml/L of fipronil (0.4 g. a. i./ha) were 20% 55%, 84%, 96% and 100% for mixed population of 3<sup>rd</sup>, 4<sup>th</sup>, 5<sup>th</sup> nymphal instars and immature adults of *S. gregaria*. Similar results were found by Abdel-Fattah *et al.* (2012), when applying fipronil (Regent®) in the field against the nymphal instars of *S. gregaria* and *Euprepocnemis plorans plorans*. As well, the finding also agrees with that by Abdel-Fattah and Ammar (2005) in the field against the 4<sup>th</sup> and 5<sup>th</sup> nymphal instars of *S. gregaria*. They found that fipronil (Reagent®) could eliminate 92.8% of the hopper population within 2 days of treatment.

**Table 4.** Mortality percentages of *S. gregaria* caused under field conditions

Time after treatment (hr.)	chlorantraniliprole	spinosad	fipronil	Chloropyrifos	Control
3	0	2	20	74	0
6	12	18	55	90	0
12	40	69	84	100	0
24	82	92	96	---	0
48	98	99	100	---	0





**Figure 4.** One of the plots at the site of treatment demarcated by flags



**Figure 5.** Images showing the dead adults and hopper in various instars after the field test

### **In conclusion**

The present study aimed to find new alternatives to the conventional chemical insecticides against the desert locust *S. gregaria*, by testing the efficacy of chlorantraniliprole, spinosad and fipronil on the hopper and adult stages of *S. gregaria*. The results indicated that all the tested pesticides caused satisfactory mortality rates within one to three days of treatment against both stages under laboratory conditions.

Whereas; under field conditions, these products could reduce the locust stages in two days as well as the standard product Chlorzan® (chlorpyrifos) which could eliminate the infestation within 12 hr. The mentioned compounds also affected some biological aspects in the treated 5<sup>th</sup> nymphal instar hoppers when used at sublethal concentrations including elongation of hopper duration, malformation and failure of ecdysis, and reduction in the fledging rates.



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