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Research Article
Insecticidal, Behavioral and Biological Effects of Chlorantraniliprole and Chlorfluazuron on Cotton Leafworm (*Spodoptera littoralis*)

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Abstract
Background and Objective: The cotton leafworm, *Spodoptera littoralis* (Lepidoptera: Noctuidae) is the most destructive pests and causing a great loss for several vegetables and field crops. So, the present study was aimed to evaluate and compare the effects of chlorantraniliprole and chlorfluazuron on certain behavioral and biological aspects of *S. littoralis* at different stages. **Materials and Methods:** Under laboratory conditions, the toxicity of chlorantraniliprole and chlorfluazuron against the egg masses, 2nd and 4th larval instars of *S. littoralis* were evaluated. The impact of tested insecticides on the feeding, oviposition of females and biological aspects of *S. littoralis* was also carried out. **Results:** Overall, chlorfluazuron was more toxic than chlorantraniliprole. According to repellency index (RI %), tested insecticides have a repulsive effect for the feeding of 2nd and 4th larval instars as well as for oviposition of females. Sublethal concentrations significantly reduced larval and pupal weight, adult survival, percent of pupation and adult emergence, female fecundity, fertility percentage, weight and protein content of ovaries. While, larval and pupal durations were increased. **Conclusion:** It was concluded that chlorantraniliprole and chlorfluazuron have insecticidal, behavioral and biological effects on *S. littoralis* stages and may be used as alternatives to conventional insecticides in IPM programs.

Key words: *Spodoptera*, repellent, biology, chlorantraniliprole, chlorfluazuron

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The cotton leaf worm, *Spodoptera littoralis* (Lepidoptera: Noctuidae) is one of the most destructive pests, which causes a significant economic loss for many economically-important vegetables and field crops belonging to 44 families. It can be found year around in Egypt feeding on numerous crops, include 73 species[1-4].

The excessive use of broad-spectrum insecticides, like pyrethroids, carbamates and organophosphates cause several environmental problems, destruction of natural enemy populations and development of resistance to different groups of insecticides[5].

Among the most promising chemical control tactics, the biorational control agents such as synthetic insect growth regulators (IGRs) and anthranilic diamides, which have novel modes of action and claimed to be safer for beneficial organisms[6,7]. Many Synthetic growth regulating insecticides (IGRs) and anthranilic diamides have been successfully used in IPM programs against many lepidopterous insects such as *S. littoralis* and *S. litura*[8-10].

Specific biochemical processes of certain insects is affected by synthetic growth regulating insecticides (IGRs), especially those which are essential for insect growth and development. The disruptions that IGRs can cause hormone regulations associated with insect metamorphosis can, ultimately, lead to insect death[11]. Chlorfluazuron (Group 15, IRAC) disrupts chitin synthesis during the molting process[12] and it has been used as reproductive inhibitor[13]. Chlorfluazuron can impact oogenesis and ovarian development[14,15], oviposition stimulating factors[16], inhibiting protein content in both ovaries and testes in newly emerged adults[17] and affect fecundity, fertility and hatchability.

Chlorantraniliprole (coragen®) is a new insecticide belonging to a newer class of selective insecticides (anthranilic diamides) (Groups 28, IRAC). This class of insecticides is effectively controlling lepidopterous insects, especially insects that have developed resistance to older classes of insecticides[10]. Anthranilic diamides bind to receptors in insect muscles (ryanodine) causing an uncontrolled release of calcium from internal stores in the sarcoplasmic reticulum, leading to feeding cessation, paralysis and death of target insects[18,19]. So far, there are few resistance cases to chlorfluazuron and chlorantraniliprole[20]. The development of alternative insect management strategies, allow the rational use of insecticides and adjust application timing are crucial in providing resistance management to various insecticides. This study aimed to evaluate and compare the effects of chlorantraniliprole and chlorfluazuron on certain behavioral and biological aspects of *S. littoralis* at different stages.

MATERIALS AND METHODS

Insect rearing: A laboratory strain of *Spodoptera littoralis* was reared in insect physiology lab, Department of Applied Entomology and Zoology, Faculty of Agriculture, Alexandria University, Egypt, on castor bean leaves, *Ricinus communis* L., under constant conditions of $27\pm2°C$ and RH $65\pm5\%$.

Tested insecticides: Two insecticides of different groups were tested for their efficacies, behavioral and biological effects on *S. littoralis* through the period from September, 2017-October, 2018. Chlorfluazuron (Topron® 5% EC) was produced by Agrochem Co., Alexandria. Chlorantraniliprole (Coragen® 20% SC) was produced by DuPont™ de Nemours Co.

Insecticidal activities of chlorantraniliprole and chlorfluazuron against *S. littoralis* at different life stages

Ovicidal activity: Egg-masses of *S. littoralis* at 0-24 h ages were counted with the hand lens (10X) and leaf disks containing 100 eggs were dipped for 20 sec in different concentrations of the tested insecticides. Another set of egg-masses (100 eggs) on leaf disks were dipped in water to represent the control. Each concentration, including the control, was replicated three times. Treated and untreated egg-masses were left to dry and kept at $27\pm2°C$, RH $65\pm5\%$. After maximum hatch, microscopic examination was made to calculate the hatchability for each treatment. The LC_{50} values were calculated using Biostat ver. (2.1) software for probit analysis[21].

Larvicidal activity: The efficacy of the tested insecticides, chlorantraniliprole and chlorfluazuron, was assessed against the 2nd and 4th larval instars of *S. littoralis*. Serial concentrations of each insecticide were prepared using distilled water. The 2nd larval instar was tested at 0.1, 0.5, 1, 2 and 5 mg L^{-1}. Whereas, the 4th larval instar was tested at 1, 5, 10, 20 and 30 mg L^{-1}. Castor bean leaves, almost equal in size, were dipped in the tested concentrations for 10 sec then left to dry. A set of castor leaves were dipped in distilled water only for the control. Each treatment was replicated 3 times (20 larvae per each). The larvae were allowed to feed on treated leaves and the mortality percentages were recorded after 48 and 96 h, corrected according to Abbott's formula[22]. The LC_{50} values were calculated as concentration-mortality regressions, which analyzed by Biostat ver. (2.1) software for probit analysis[21].

Repulsive effects of the tested insecticides

Antifeedant activity: Antifeedant activities of chlorantraniliprole and chlorfluazuron were studied for each 2nd and 4th larval instars of *S. littoralis* using leave discs in no choice test. The larvae were kept without food for 4 h before treatment. Fresh castor leave discs were dipped in 0.1, 0.5, 1, 2 and 5 mg L^{-1} for 2nd instar and 1, 5, 10, 20 and 30 mg L^{-1} for 4th instar for both insecticides. The discs were left to dry, weighed before being provided to the larvae. Discs for untreated control were dipped in distilled water only. Each treatment was replicated three times with 20 larvae for each replicate. After 24 h, larvae were removed and the remaining leave discs reweighed. The feeding deterrence (FD %) was calculated using Isman *et al.*[23] formula:

$$\text{FD (\%)} = \frac{\text{C} - \text{T}}{\text{C} + \text{T}} \times 100$$

where, C was the consumption of the control discs and T was the consumption of the treated discs.

Anti-oviposition activity: A pair of male and female pupae was separately put in 500 mL plastic cups with a ball of cotton dipped in 10% sugar solution for feeding and changed daily till egg-mass depositions. The newly emerged adults were left to feed and mate. Leaves of tafla were treated with concentrations (0.5, 1, 2, 5 and 10 mg L^{-1}) of tested insecticides and provided to adults for laying egg. Two days after the beginning of egg laying, adults were removed and the number of eggs laid on treated and control tafla leaves were counted using a binocular. Adult repellency and anti-oviposition effect were calculated according to Pascual-Villalobos and Robledo[24]:

$$\text{Repellency index (RI)} = \frac{\text{C} - \text{T}}{\text{C} + \text{T}} \times 100$$

where, C was the number of eggs in the control and T was the number of eggs in the treatment.

Effect of chlorantraniliprole and chlorfluazuron on biological aspects of *S. littoralis*: To assess the effects of tested insecticides on the biology of *S. littoralis*, fresh castor leaves were dipped in LC_{25} and LC_{50} equivalent concentrations of the two tested insecticides. The treated leaves were provided to newly hatched larvae as food. Another set of castor leaves dipped in distilled water were provided for untreated control. The leaves were changed daily. Three replicates were used for each treatment, with one hundred larvae were tested for each replicate. Larval weight (mg) was measure after 5, 10 and 15 days after treatment. Larval duration (days), percentage pupation, pupal duration (days), pupal weight (mg), percentage adult emergence, mean number of eggs laid each day over the course of the female lifespan (fecundity), the hatchability of laid egg (percent of fertility), weight and protein content of ovaries were recorded.

Effect of chlorantraniliprole and chlorfluazuron on ovarian weight and ovarian protein content of *S. littoralis* females: The effects of tested insecticides on ovarian weight and protein contents in newly emerged females were assessed by feeding the larvae on castor leaves treated with LC_{25} and LC_{50} equivalent concentrations of the tested insecticides. Castor leaves dipped in water were used as untreated control. Ovaries were weighed and dissected from newly emerged females. The ovaries were homogenized in 1 mL of Tris 50 mM buffered at pH 7. The homogenate was centrifuged at 2500 rpm for 10 min, then the supernatant was collected and used for protein estimation. The total protein was determined according to Bradford[25] using bovine serum albumin (BSA) as a standard protein. Absorbance was measured at 595 nm.

Statistical analysis: Statistical analysis of the obtained data and all the probable comparison combinations were analyzed in factorial design using SAS procedure[26] at probability level of 0.05. Means were compared using the least significant difference test (LSD).

RESULTS

Chlorantraniliprole and chlorfluazuron toxicity against *S. littoralis* stages: The efficacy of chlorantraniliprole and chlorfluazuron against different stages of *S. littoralis* was assessed based on LC_{50} values, which confirmed the high toxicity of chlorfluazuron against different stages compared to chlorantraniliprole (Table 1). Chlorfluazuron was the most effective against *S. littoralis* egg masses with LC_{50} value 1.24 mg L^{-1}. Chlorfluazuron was more toxic than chlorantraniliprole against 2nd and 4th larval instars whether after 48 or 96 h, with LC_{50} values 0.19, 0.09 for 2nd instar and 5.98, 1.42 mg L^{-1} for 4th instar. The LC_{50} values decreased over time of insecticide exposure. These results also showed that the 2nd instar larvae were more sensitive to the tested insecticides.

Repulsive effects of the tested insecticides: Insects usually choose appropriate plant for feeding and/or laying egg.

Table 1: Toxicity of chlorantraniliprole and chlorfluazuron against different stages of *S. littoralis*

Insecticide	Stage	Exposure time	LC_{25} (mg L^{-1})	LC_{50} (mg L^{-1})	Confidence limits Lower	Upper	Slope±SE*
Chlorantraniliprole	Egg	-	0.67	4.15	3.47	4.99	0.85±0.06
	2nd larvae	48	0.47	4.08	2.32	8.13	0.72±0.11
		96	0.05	0.27	0.19	0.38	0.93±0.11
	4th larvae	48	12.3	71.15	39.60	117.50	0.88±0.12
		96	0.95	3.49	2.69	4.44	1.19±0.11
Chlorfluazuron	Egg	-	0.10	1.24	0.93	1.79	0.62±0.06
	2nd larvae	48	0.06	0.19	0.15	0.24	1.38±0.17
		96	0.03	0.09	0.06	0.12	1.31±0.18
	4th larvae	48	0.84	5.98	4.25	8.86	0.84±0.12
		96	0.37	1.42	0.99	1.89	1.14±0.13

*SE: Standard error

Table 2: Antifeedant activity of chlorantraniliprole and chlorfluazuron against the 2nd and 4th larval instars of *S. littoralis* after 48 h from exposure

Insecticide/	Feeding deterrence (FD %)* 2nd instar larvae					4th instar larvae				
Conc. (mg L^{-1})	0.1	0.5	1	2	5	1	5	10	20	30
Chlorantraniliprole	2.3^{f}	5.6^{e}	8.7^{de}	13.6^{c}	15.9^{b}	3.40^{f}	6.2^{ef}	6.5^{ef}	9.9^{e}	17.8^{d}
Chlorfluazuron	6.8^{e}	9.2^{d}	12.4^{c}	16.6^{b}	25.5^{a}	20.90^{d}	33.7^{c}	40.4^{b}	44.9^{b}	62.7^{a}
$LSD_{0.05}$	1.97					4.49				

*Feeding deterrence $FD\,(\%) = \frac{C-T}{C+T} \times 100$[23], C: Consumption of control discs and T: Consumption of treated discs. Means followed by different letters are significantly different (p<0.05)

Table 3: Anti-oviposition activity of chlorantraniliprole and chlorfluazuron against *S. littoralis* females

Insecticide/	Repellency index (RI %)*				
Conc. (mg L^{-1})	0.5	1	2	5	10
Chlorantraniliprole	9.67^{h}	14.94^{f}	18.74^{e}	28.60^{c}	39.83^{b}
Chlorfluazuron	12.48^{g}	15.44^{f}	21.66^{d}	29.65^{c}	42.00^{a}
$LSD_{0.05}$	1.22				

$\text{Repellency index} = \frac{C-T}{C+T} \times 100$[24], C: Number of the eggs in the control and T: Number of the eggs in the treatment. Means followed by different letters are significantly different (p<0.05)

Therefore, dismissal strategy may be one of the most effective methods used in IPM programs or/and prevent insects from feeding or egg laying. Consequently, insects die and the number of off spring decreases. The two tested insecticides significantly affected the palatability of insects for food (Table 2). When comparing the repellent effects of the 1 and 5 mg L^{-1} concentrations on the 2nd and 4th larval instars, showed that chlorfluazuron seemed to prevent larval feeding, especially for the 4th instar, compared to chlorantraniliprole. Feeding deterrence percentages were 12.4 and 25.5% for the 2nd instar treated with chlorfluazuron compared to 20.9 and 33.7% for the 4th instar. These antifeedant effects of the tested insecticides may cause feeding cessation of larval stages, leading to protein deficiency in different stages and ultimate mortality.

Repellency index (RI %) showed the significant repulsive effect for egg laying of tested insecticides (Table 3). Like antifeedant effect, chlorfluazuron was more deterrence than chlorantraniliprole for females. This repulsive effect has a positive correlation with elevate in concentration. The highest repellency index 42% was recorded with 10 mg L^{-1} chlorfluazuron.

Impact of the tested insecticides on biological aspects of *S. littoralis*

Impact on larval and pupal weight: The tested insecticides reduced larval and pupal weight, especially when the larvae were exposed to chlorfluazuron LC_{50} (Fig. 1). The most affected stage was the 5 days larva, where its weight reduced from 52.6-27.3 mg, with percentage of reduction 48.19%. On

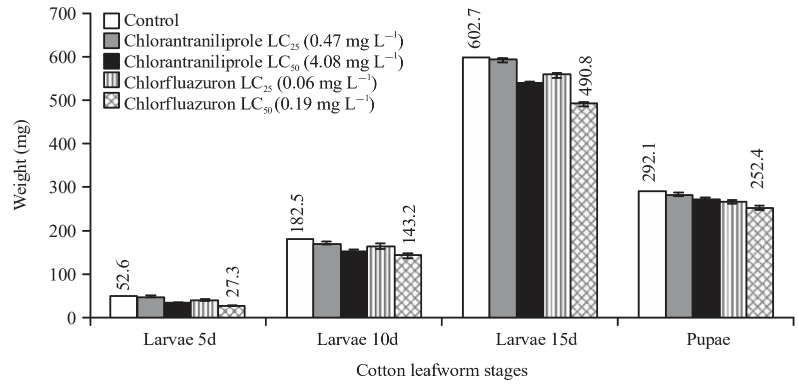

Fig. 1: Effect of chlorantraniliprole and chlorfluazuron at LC_{25} and LC_{50} concentrations on the weight of larvae after 5, 10 and 15 days from treatment and pupae of *S. littoralis*

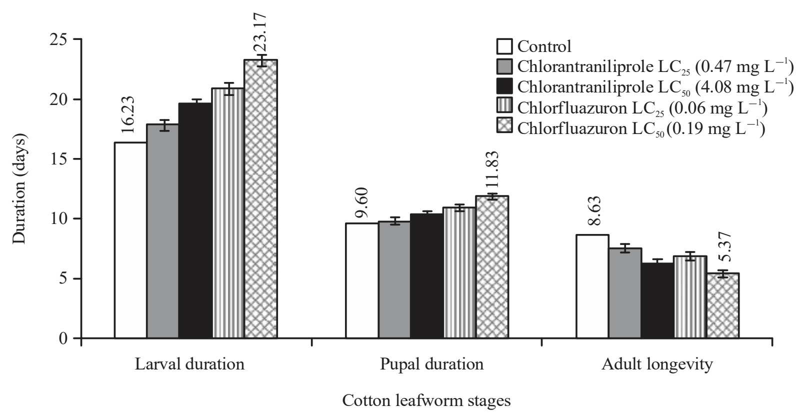

Fig. 2: Effect of chlorantraniliprole and chlorfluazuron at LC_{25} and LC_{50} concentrations on larval duration, pupal duration and adult survival of *S. littoralis*

the contrary, the pupal stage was the lowest affected stage, where, the weight reduced from 292.1-252.4 mg, with percentage of reduction 13.6%. These results synchronized with the previously mentioned results of antifeedant effect of the tested insecticides.

Impact of the tested insecticides on survival of *S. littoralis* life stages: The larval, pupal and adult survival was significantly affected by the sublethal concentrations of chlorantraniliprole and chlorfluazuron (Fig. 2). The duration of larval and pupal stages was increased, especially when the larvae were exposed to LC_{50} concentration of chlorfluazuron (0.19 mg L^{-1}), where it was 23.17 and 11.83 days for larval and pupal stages, respectively. On the contrary, adult survival was significantly decreased as a result of larval exposure to the tested insecticides. These results indicated that these two insecticides affect the survival of adults, decrease the available time for female to lay eggs and subsequently decrease female fecundity.

In addition to the decline effects of insecticides on stages duration, the application by chlorfluazuron caused malformations of produced stages as showed in Fig. 3-6. As compared with normal stages, treatments with the different concentrations of chlorfluazuron caused different degrees of abnormalities, in 2nd larvae (Fig. 3a-d), legless larva with huge head (Fig. 3b) curved larva with dark rings on the abdomen (Fig. 3c) and curved larva with a pupal cuticle on the dorsal region of the head and thorax (Fig. 3d). Also, the 4th instar larvae showed malformations due to the treatment (Fig. 4a-d), larva with distended thorax and sclerotized head (Fig. 4b) some malformations in head and thoracic legs (Fig. 4c) and distorted and sclerotized head (Fig. 4d). Application of early larval stage by chlorfluazuron produced abnormal pupae (Fig. 5a-d), partial molting of prepupae (Fig. 5b and c) and Larva-pupa intermediates (Fig. 5d). The adults of *S. littoralis*

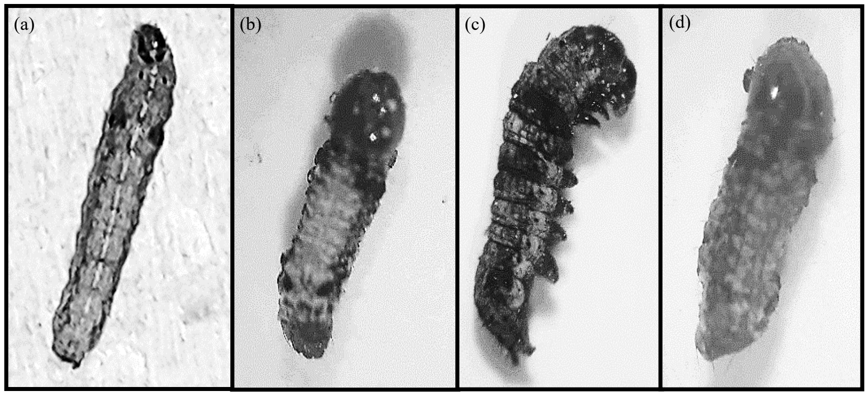

Fig. 3(a-d): Some abnormalities of the 2nd instar larvae of *S. littoralis* as a result of chlorfluazuron applications, (a) Control and (b-d) Distorted larvae

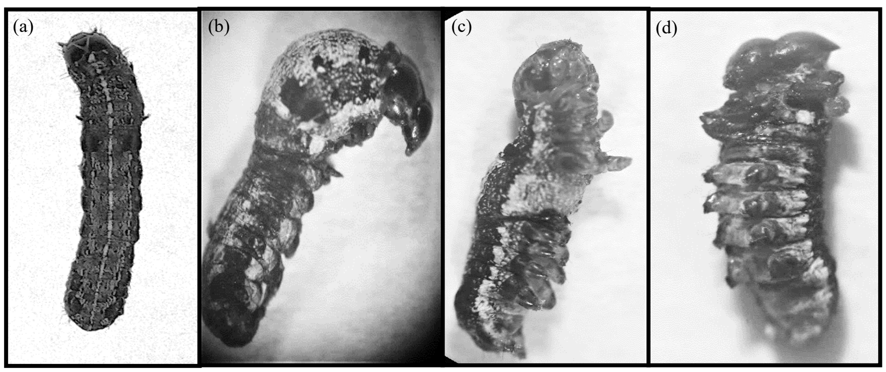

Fig. 4(a-d): Effect of chlorfluazuron applications on the 4th instar larvae of *S. littoralis*, (a) Control and (b-d) Some malformations

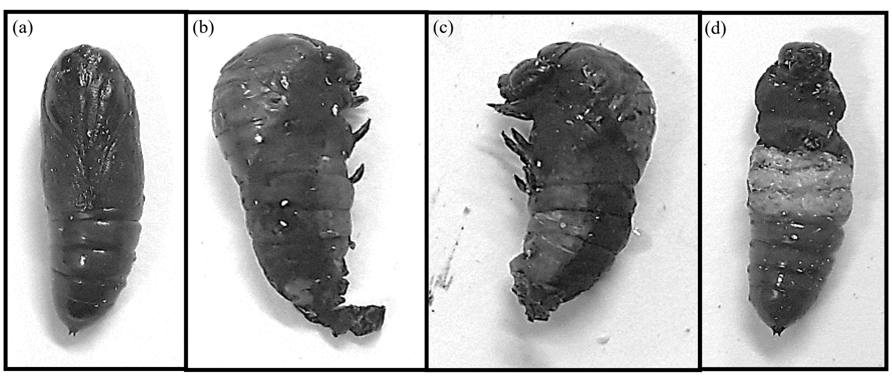

Fig. 5(a-d): Effect of chlorfluazuron applications on *S. littoralis* pupae, (a) Control and (b-d) Abnormal pupae

affected by the application where, adults failure to emerge from their pupal cuticle (Fig. 6a-d), the adult with short wings and unmolted mouthparts (Fig. 6b) and partial molting of pupae (Fig. 6c and d).

Percentages of pupation and adult emergence of *S. littoralis* as affected by tested insecticides: Chlorantraniliprole and chlorfluazuron significantly decreased percentages of pupation and adult emergence, especially when LC_{50} of chlorfluazuron was used in application (Fig. 7). The percent of pupation and adult emergence was 51.67 and 44.3%, respectively.

Effect of insecticides on fecundity and percentages of fertility of *S. littoralis* females: The exposure of larval stage to the tested insecticides significantly reduced fecundity and

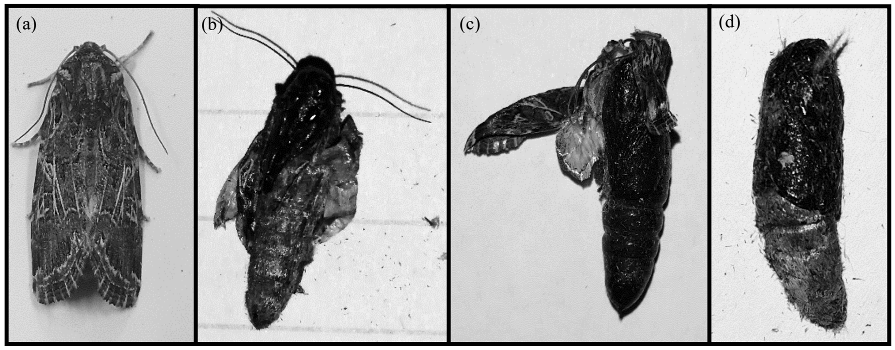

Fig. 6(a-d): Adult emergence of *S. littoralis* affected by chlorfluazuron applications, (a) Control and (B-d) Adults failure to emerge from their pupal cuticle

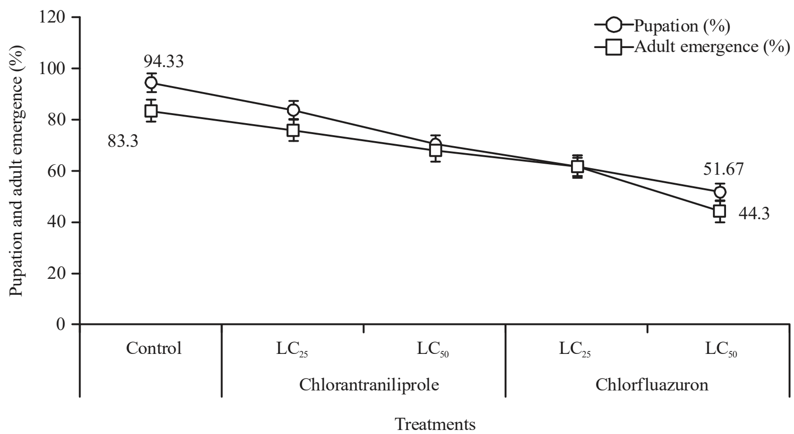

Fig. 7: Effect of chlorantraniliprole and chlorfluazuron at LC_{25} and LC_{50} concentrations on percentages of pupation and adult emergence of *S. littoralis* after larval application

Table 4: Effect of chlorantraniliprole and chlorfluazuron on ovarian weight and ovarian protein content

Treatments	Ovarian fresh weight (mg)	Protein (µg)/pair of ovaries	Protein (µg)/ovaries (mg)
Control	71.93^{a}	65.27^{a}	0.457^{a}
Chlorantraniliprole			
LC_{25}	68.00^{b}	40.70^{b}	0.317^{b}
LC_{50}	64.77^{c}	34.50^{c}	0.267^{c}
Chlorfluazuron			
LC_{25}	62.80^{c}	30.50^{c}	0.243^{c}
LC_{50}	55.87^{d}	20.23^{d}	0.180^{d}
$LSD_{0.05}$	2.71	6.11	0.058

Means within a column followed by different letters are significantly different ($p<0.05$)

fertility of females (Fig. 8). Chlorfluazuron was more effective than chlorantraniliprole. The LC_{50} concentrations cause greater declines in fecundity and fertility compared to the effect of LC_{25} concentrations. The application by LC_{50} concentrations resulted in reduction of fecundity from 855-498 with reduction percentage 42% chlorfluazuron and from 855-572 with reduction percentage 33.1% for chlorantraniliprole. The percent of fertility reduced from 95.33-52 and to 74.33% for chlorfluazuron and chlorantraniliprole, respectively.

Impact of insecticides on ovarian weight and ovarian protein content of *S. littoralis* females: Treated females with chlorantraniliprole and chlorfluazuron at LC_{25} and LC_{50} significantly reduced both of ovarian weight and protein contents of the ovaries compared to the untreated control (Table 4). The ovarian weights were 55.87 mg and 64.77 mg after larval application with chlorfluazuron and chlorantraniliprole at LC_{50} concentrations, respectively, compared to control 71.93 mg. There is no significant difference between the effect of

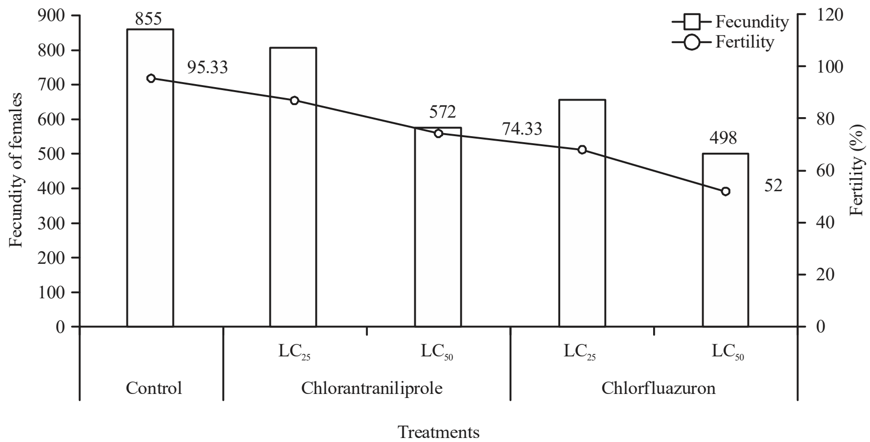

Fig. 8: Effect of chlorantraniliprole and chlorfluazuron at LC_{25} and LC_{50} concentrations on fecundity and percentages of fertility of *S. littoralis* females after larval application

chlorantraniliprole LC_{50} and chlorfluazuron LC_{25} on ovarian fresh weight or ovarian protein content.

DISCUSSION

The results confirmed the toxic effects of tested insecticides against the different stages of *S. littoralis*, with superiority of chlorfluazuron. These results were in agreement with those reported results of the highly toxicity of chlorfluazuron against *S. littoralis* larvae[27,28]. The application of chlorfluazuron (Topron®) found to reduce the cotton leafworm infestation about 85.7% and increased cotton yield[29].

There were various reports of the effects of chlorfluazuron against other insects. Higher dosages of chlorfluazuron significantly reduced *Spodoptera litura* population[14]. Similar toxic effect was also recorded against *Palpita indica* eggs[30], male pupae of *Tribolium castaneum*[31] and larvae of *Agrotis ipsilon* in comparison with conventional insecticides[32].

A good control of corn earworm in soybean by chlorantraniliprole was reported by Adams *et al.*[33]. The toxic effect of chlorantraniliprole was recorded against many insects such as apple maggot, blue berry maggot and cherry fruity[34], eggs and larvae of *Lobesia botrana*[35]. Chlorantraniliprole also was recommended for controlling *Tuta absoluta*[36] and showed better toxicity against *S. litura* population[37], *Helicoverpa armigera*, *A. ipsilon* and *S. litura*[38]. The mortality of *Amyelois transitella* eggs was doubled by adding chlorantraniliprole[39]. Toxicity of chlorantraniliprole was also reported against 2nd instar larvae of *Spodoptera cosmioides*[40]. The 2nd larval instar was the most sensitive stage to insecticides. This trend previously recorded for chlorfluazuron against *S. litura* larvae[41,42] and for chlorantraniliprole against *S. littoralis* larvae[43].

The tested insecticides significantly affected the palatability of insects for food and oviposition with advantage of chlorfluazuron, as it was more deterrence for insects, as well. These findings were in agreement with those found that chlorantraniliprole caused repellency against Asian subterranean termites and *Coptotermes gesteroi*[44]. Chlorantraniliprole activates the feeding cessation and finally insect death[18]. Unlike, the repellency effect, chlorantraniliprole does not have behavioral effects as food repellent[36].

Referring to the data of tested insecticides impacts on the biological aspects of *S. littoralis*, all treatments have a reduction effect on larval and pupal weight. By the same way, chlorfluazuron significantly decreased pupal weight of *A. ipsilon*[45]. On the contrary, *S. cosmioides* pupal weight increased by exposed larvae to sublethal concentrations of chlorantraniliprole[40].

Also, the tested insecticides significantly increased the duration of larval and pupal stages, while, they decreased adult longevity. This effect was suggested previously, chlorfluazuron increased *A. ipsilon* larval and pupal duration[32,45]. Chlorantraniliprole increased the *S. cosmioides* larval and pupal stages[40]. The tested insecticides significantly shortened female's longevity, hence the oviposition period was significantly reduced. These observations may explain the sharp decline in fecundity and fertility of females treated by these insecticides. Concerning the reduction effect on the adult longevity, it was reported for chlorfluazuron on *P. indica*[30] and on *A. ipsilon*[45]. This result disagreed with the recorded delaying action of chlorfluazuron on *Pectinophora gossypiella* adult longevity[46-48]. Chlorantraniliprole also prolonged the longevity of *S. cosmioides* adults[40].

All treatments with chlorfluazuron caused malformations of *S. littoralis* stages, this agreed with large extent with the recorded results that chlorfluazuron had the higher rates of deformed pupation of *S. littoralis*[28]. Chlorfluazuron also induced morphological abnormalities of *A. ipsilon* life stages[32].

Chlorantraniliprole and chlorfluazuron, significantly decreased pupation and adult emergence percentages of *S. littoralis* as similar as chlorfluazuron lower concentrations, caused significant reduction in pupation and adult emergence of *S. littoralis*[49]. The LC_{50} of chlorfluazuron significantly declined the pupation and adult emergence percentage of *A. ipsilon*[45]. On the contrary, chlorfluazuron had the higher rates of adult emergence for *S. littoralis*[28].

Furthermore, fecundity and fertility of *S. littoralis* females significantly decreased when the larval stage exposed to the tested insecticides. This result was confirmed for chlorfluazuron which significantly reduced *S. littoralis* fertility, fecundity and hatchability[28,49]. The effect of chlorfluazuron has been previously illustrated also for other insects such as *S. litura*[14], in *P. gossypiella*[46,47], in *P. indica*[30], *A. ipsilon*[32,45] and in *S. cosmioides* for chlorantraniliprole[40].

Tested insecticides significantly reduced ovarian weight and protein ovary contents. These results were indicated for chlorfluazuron against *S. litura*[14] and *A. ipsilon* females[45].

Although, the present study confirmed the effectiveness of chlorantraniliprole and chlorfluazuron against *S. littoralis*, further investigations may be needed in the field trial as well as using them in IPM programs for controlling this target pest in the future.

CONCLUSION

On the basis of overall findings, it was concluded that chlorantraniliprole and chlorfluazuron had impacts on the behavioral and biological aspects of *S. littoralis.* These tested insecticides provided a good control of *S. littoralis* and may be used as alternatives to conventional insecticides in IPM programs for controlling this target pest.

SIGNIFICANCE STATEMENT

This study suggested that the tested insecticides, regardless their toxic effect, disruptively affected the biological and behavioral aspects of *S. littoralis.* These effects are very important because offspring can then be reduced and as a consequence, the insect population can be maintained below a level of economic loss. This study will help the researcher to trend towards using other environmental safer insecticides from different classes and mode of actions which has become an unabated challenge in controlling cotton insect pests.

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