



RESEARCH ARTICLE

Comparative toxicity of chlorantraniliprole and spinetoram against *Spodoptera litura* (Fabricius) under laboratory conditions

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Abstract

Spodoptera litura (Fabricius) is a destructive polyphagous pest of pulse crops, including green gram (*Vigna radiata* (L.) R.Wilczek), causing severe defoliation and significant yield losses. Identifying insecticides with high toxicity and rapid action is essential for effective management of this pest. The present study evaluated the comparative toxicity of chlorantraniliprole and spinetoram against 11 day old larvae of *S. litura* under laboratory conditions. Larval bioassays were conducted using the leaf-dip method and mortality was recorded at 12, 24, 48 and 72 hr after treatment (HAT). Probit analysis was performed to estimate lethal concentrations (LC) and compare the relative toxicity of the two insecticides. The toxicity of both insecticides increased with exposure time, as indicated by a progressive decline in LC₅₀ values. Chlorantraniliprole consistently exhibited greater toxicity than spinetoram throughout the study. At 24 HAT, chlorantraniliprole exhibited a substantially lower LC (0.008 %) than spinetoram (0.064 %), indicating approximately 8-fold greater toxicity. The difference in toxicity gradually decreased with prolonged exposure and both insecticides exhibited an identical LC₅₀ value (0.002 %) at 72 HAT, resulting in high larval mortality. Overall, both insecticides were effective against *S. litura* larvae. However, chlorantraniliprole produced faster and greater toxic effects than spinetoram. These findings support the use of chlorantraniliprole as a rapid-acting insecticide and highlight the potential of both molecules for the integrated pest management (IPM) of *S. litura* in green gram.

Keywords: chlorantraniliprole; comparative toxicity; green gram; integrated pest management; LC₅₀; spinetoram; *Spodoptera litura*

Introduction

Green gram (*Vigna radiata* (L.) R.Wilczek), commonly known as mung bean, is an important pulse crop widely cultivated in India and other Asian countries. Rich in approximately 24 % protein, vitamins and minerals, it serves as a major source of dietary protein, particularly in vegetarian diets (1, 2). The crop also improves soil fertility through biological nitrogen (N) fixation, supporting sustainable agricultural systems. However, its productivity is substantially constrained by several insect pests that attack the crop at various growth stages.

Among the major insect pests associated with green gram are *Helicoverpa armigera*, *Maruca vitrata*, *Etiella zinckenella*, *Mylabris phalerata* and *Spodoptera litura*. Of these, the tobacco caterpillar, *S. litura* (Fabricius) (Lepidoptera: Noctuidae), is recognised as one of the most destructive defoliators of pulse crops. The larvae feed voraciously on leaves, tender shoots and reproductive structures, often resulting in substantial reductions in crop yield and quality. Insect pest infestations have been reported to cause yield losses of nearly 20 % in pulse crops, while severe infestations of *S. litura* alone may result in crop losses ranging from 25.8–100 % depending on crop stage, pest density and prevailing environmental conditions (3). The pest is highly polyphagous, attacking more than

100 cultivated plant species and is widely distributed across tropical and subtropical regions (4). Its high reproductive potential, rapid population build-up, migratory behaviour and remarkable adaptability enable it to develop into serious outbreaks within a short period, making its management a persistent challenge for growers.

Chemical insecticides continue to play a central role in the management of *S. litura* because they provide rapid and dependable control of damaging larval populations (5). Nevertheless, extensive and repeated application of insecticides has led to the development of resistance in several field populations, thereby reducing the effectiveness of many commonly used compounds (6–8). Under such circumstances, periodic evaluation of insecticide susceptibility and the establishment of baseline toxicity data become essential for designing effective resistance management strategies and ensuring the long-term sustainability of chemical control measures.

Among the insecticides currently employed against lepidopteran pests, chlorantraniliprole and spinetoram have gained considerable importance because of their unique modes of action and high biological efficacy. Chlorantraniliprole, belonging to the anthranilic diamide group, acts by activating insect ryanodine receptors, resulting in uncontrolled calcium release from muscle cells. This disruption causes immediate feeding cessation, muscular

paralysis and eventual death of the insect (9, 10). Due to its excellent activity against lepidopteran pests and its distinct mode of action, chlorantraniliprole has become an important tool in insecticide resistance management programmes (11). Spinetoram, on the other hand, is a semi-synthetic derivative of the naturally occurring spinosyns produced by *Saccharopolyspora spinosa* and acts primarily as an allosteric modulator of nicotinic acetylcholine receptors (nAChRs) in the insect nervous system. It exhibits broad-spectrum activity against several economically important insect pests, particularly species belonging to Lepidoptera, Thysanoptera and Diptera. Previous studies have demonstrated its effectiveness against *S. litura* and *H. armigera*, highlighting its potential as a valuable component of integrated pest management programs (12).

Considering the economic importance of *S. litura* in green gram cultivation and the widespread use of chlorantraniliprole and spinetoram for its management, information on their comparative toxicity is essential for optimising their field use and monitoring changes in pest susceptibility over time. Therefore, the present investigation was undertaken to determine the median lethal concentration (LC₅₀) of chlorantraniliprole and spinetoram against 11 day old larvae of *S. litura* under laboratory conditions and to compare their relative toxicities.

Materials and Methods

The present study was conducted to evaluate the toxicity of selected insecticides against *S. litura* under laboratory conditions. Bioassay experiments were carried out in the Nanotechnology Laboratory, Department of Entomology, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India. The experiment consisted of seven concentrations of chlorantraniliprole (0.044, 0.022, 0.011, 0.006, 0.002, 0.001 and 0.0007 % active ingredient (a. i.)) and seven concentrations of spinetoram (0.04, 0.02, 0.01, 0.005, 0.003, 0.0025 and 0.000125 % a. i.) along with untreated control (0 %) (Table 1) with each treatment replicated three times in a completely randomised design (CRD) to minimise experimental variation and ensure reliable comparisons among treatments.

Larval mortality data recorded during the bioassays were analysed using Probit analysis as described previously for the estimation of dose-response relationships (13). Regression equations, fiducial limits and lethal concentration values (LC₃₀, LC₅₀ and LC₉₀) were determined to assess the relative toxicity of the tested insecticides. Mortality observations were also used to estimate median lethal time (LT₅₀) values along with their associated standard errors. Statistical analyses were performed using STPR software and *p* values were subsequently estimated in Microsoft Excel considering chi-square statistics and corresponding degrees of freedom, which facilitated accurate estimation of toxicity parameters and enabled a comprehensive comparison of the efficacy of the insecticidal treatments.

Table 1. Concentrations of chlorantraniliprole and spinetoram used in leaf-dip bioassay

S. No	Treatment	Chlorantraniliprole (%)	Spinetoram (%)
1	T ₁	0.044	0.04
2	T ₂	0.022	0.02
3	T ₃	0.011	0.01
4	T ₄	0.006	0.005
5	T ₅	0.002	0.003
6	T ₆	0.001	0.0025
7	T ₇	0.0007	0.000125
8	T ₈	0	0

Materials

Chlorantraniliprole 18.5 SC (FMC, India) and Spinetoram 11.7 SC (Corteva Agriscience, India) were used in the bioassays.

Collection and mass rearing of test insects

A laboratory culture of *S. litura* was established using egg masses collected from the Crop Research Centre (CRC), Pantnagar. The collected egg masses were transferred to the Nanotechnology Laboratory, Department of Entomology, College of Agriculture, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, where the insect culture was maintained for subsequent bioassay studies. The insects were reared in sterilised plastic containers (30 × 20 cm) and provided with fresh castor leaves (*Ricinus communis* L.) as a food source. The culture was maintained under controlled environmental conditions of 27 ± 1 °C temperature and 70–80 % relative humidity to ensure healthy growth and development of the insect population.

Fresh castor foliage was supplied daily after removing uneaten leaf material and accumulated larval excreta to maintain hygienic rearing conditions. To minimise the effects of overcrowding and competition, 30–40 larvae were maintained in each container (Fig. 1). Upon reaching the 5th instar, the larvae were transferred to glass jars containing a 5 cm layer of sterilised vermiculite to facilitate pupation. The resulting pupae were carefully collected and surface-sterilised with 0.02 % sodium hypochlorite solution for 2 min before being placed separately for adult emergence.

Newly emerged moths were maintained in clean glass jars and provided with a 5 % sugar solution as a food source. Folded butter paper strips were placed inside the jars to serve as oviposition substrates. The egg masses laid by the adults were collected periodically and disinfected using 0.002 % sodium hypochlorite solution for 2 min to reduce the risk of nuclear polyhedrosis virus (NPV) contamination. After rinsing thoroughly with distilled water, the eggs were maintained under humid conditions until hatching. The neonate larvae were subsequently reared on fresh castor leaves and maintained separately to obtain a continuous supply of healthy and uniform-aged larvae for toxicity bioassays, following the procedure outlined (14).

Bioassay of *Spodoptera litura* in the laboratory conditions

The toxicity of the selected insecticides against *S. litura* was evaluated using the leaf-dip bioassay method described (15). Initially, stock solutions of the test insecticides were prepared based on their active ingredient content. A broad range of concentrations was generated through serial dilution and screened against 11 day old larvae to determine the concentration range producing measurable mortality. Based on the preliminary bioassay results, seven concentrations expressed as percentage of active ingredient (% a. i.) in spray solution were selected for detailed dose-response studies and estimation of LC₅₀ values (Table 1).



Fig. 1. Rearing of *Spodoptera litura* in the laboratory for the experiment.

Fresh castor leaf discs measuring 6 × 6 cm were immersed in the respective insecticidal solutions for 40 sec to ensure uniform deposition of the test compounds on the leaf surface. Leaf discs treated with distilled water alone served as the untreated control. After air-drying at room temperature, the treated leaf discs were individually placed in 9 cm diameter Petri dishes lined with moist cotton and filter paper to maintain leaf turgidity throughout the experimental period. To promote uniform feeding behaviour, the larvae were deprived of food for 10 hr prior to exposure. Ten larvae were released onto each treatment and each concentration was replicated three times (A total of 30 larvae used per treatment). The untreated control was maintained under identical conditions, with each replicate considered an independent experimental unit. Larval mortality was recorded at (12, 24, 48 and 72 hr) and used for subsequent toxicity analysis.

Observations recorded

Larval mortality was assessed at 12, 24, 48 and 72 hr after treatment (HAT) in both treated and control groups. Larvae were classified as dead when they failed to respond to gentle stimulation with a fine camel-hair brush. Individuals exhibiting severe intoxication symptoms, such as an inability to move or feed and showing only minimal physiological activity, were considered moribund and were included in the mortality assessment. To account for any background mortality occurring in the untreated control, the observed mortality data were corrected using Abbott's formula (Eq. 1) prior to statistical analysis (16). The corrected mortality along with relative toxicity (Eq. 2) values were subsequently used for the estimation of toxicity parameters and comparison of insecticidal efficacy among treatments (3).

$$\text{Corrected mortality \%} = \frac{\text{Treatment mortality (\%)} - \text{control mortality (\%)}}{100 - \text{control mortality (\%)}} \times 100$$

Eq. (1)

The relative toxicity of the insecticides was determined using the toxicity ratio based on LC₅₀ values (Eqn. 2) (3).

$$\text{Relative toxicity ratio} = \frac{\text{LC}_{50} \text{ (less toxic insecticide)}}{\text{LC}_{50} \text{ (more toxic insecticide)}}$$

Eq. (2)

Results

Median lethal concentration (LC₅₀)

The toxicity of chlorantraniliprole 18.5 % SC and spinetoram 11.7 % w/w against 11 day old larvae of *S. litura* was assessed at different post-treatment intervals through Probit analysis (Table 2). For both insecticides, LC₅₀ values declined progressively as the exposure period increased, indicating that toxicity increased with longer contact duration. In chlorantraniliprole-treated larvae, the LC₅₀ value decreased from 0.11 % at 12 HAT to 0.008 % at 24 HAT and further declined to 0.004 and 0.002 % at 48 and 72 HAT, respectively. A comparable pattern was observed with spinetoram, where the LC₅₀ value declined from 0.15 % at 12 HAT to 0.064 % at 24 HAT, followed by 0.018 % at 48 HAT and 0.002 % at 72 HAT.

Comparison of the LC₅₀ estimates revealed differences in the relative toxicities of the two insecticides. At 12 HAT, chlorantraniliprole exhibited a slightly lower LC₅₀ value (0.11 %) than spinetoram (0.15 %), suggesting greater potency during the early phase of exposure. This difference became more pronounced at 24 HAT, where chlorantraniliprole recorded an LC₅₀ value of 0.008 % compared with 0.064 % for spinetoram. A similar trend was evident at 48 HAT, with LC₅₀ values of 0.004 and 0.018 % for chlorantraniliprole and spinetoram, respectively. The consistently lower LC₅₀ values observed for chlorantraniliprole across these exposure intervals demonstrate its higher effectiveness against *S. litura* larvae under laboratory conditions.

By 72 HAT, both insecticides produced the same LC₅₀ value of 0.002 %, indicating that extended exposure enhanced their insecticidal activity to a comparable level. Nevertheless, chlorantraniliprole generally required lower concentrations to achieve equivalent mortality during the earlier observation periods, reflecting a faster and stronger toxic action.

Table 2. Concentration-mortality response of chlorantraniliprole and spinetoram against *Spodoptera litura* larvae

Insecticide	Degrees of freedom	χ^2	P value	Hours of exposure	Regression equation $Y = a + bx$	Lethal concentration (LC) values (%)			Fiducial limits (LC ₅₀)	
						LC ₃₀	LC ₅₀	LC ₉₀	Lower	Upper
Chlorantraniliprole	5	7.19	0.207	12	$Y = 2.79 + 0.81x$	0.024	0.11	3.98	0.03	0.44
	5	1.82	0.873	24	$Y = 2.70 + 0.95x$	0.002	0.008	0.19	0.005	0.01
	5	1.59	0.902	48	$Y = 2.90 + 0.93x$	0.001	0.004	0.11	0.002	0.007
	5	6.1	0.297	72	$Y = 1.37 + 1.42x$	0.0009	0.002	0.17	0.001	0.003
Spinetoram	5	0.61	0.988	12	$Y = 2.14 + 0.92x$	0.042	0.15	3.78	0.032	0.73
	5	1.82	0.873	24	$Y = 2.64 + 0.79x$	0.014	0.064	2.55	0.022	0.19
	5	1.59	0.902	48	$Y = 2.63 + 0.94x$	0.005	0.018	0.39	0.01	0.03
	5	6.1	0.297	72	$Y = 3.04 + 0.94x$	0.0007	0.002	0.06	0.002	0.004

Not significant at $P = 0.05$.

Median lethal time (LT₅₀)

The median lethal time (LT₅₀) values of chlorantraniliprole and spinetoram against 11 day old larvae of *S. litura* are presented in Table 3. Chlorantraniliprole recorded an LT₅₀ value of 31.96 hr at a concentration of 0.006 %, whereas spinetoram exhibited an LT₅₀ value of 61.03 hr at 0.005 %. The lower LT₅₀ value observed for chlorantraniliprole indicates that it induced 50 % larval mortality within a comparatively shorter period following treatment. Although both insecticides caused rapid mortality of *S. litura* larvae, chlorantraniliprole exhibited a slightly faster toxic response under laboratory conditions.

Relative toxicity

The relative toxicity demonstrated clear differences in the effectiveness of chlorantraniliprole and spinetoram against 11 day old larvae of *S. litura* at different post-treatment intervals (Table 2). Overall, chlorantraniliprole exhibited greater toxicity than spinetoram during most of the observation period, although the magnitude of this superiority varied with exposure time.

At 12 hr HAT, chlorantraniliprole was moderately more toxic than spinetoram, as indicated by a relative toxicity value of 1.36. The disparity between the two insecticides became more pronounced at 24 hr, when the relative toxicity reached 8.00, representing the highest value observed during the experiment. At 48 HAT, chlorantraniliprole continued to maintain higher activity, with a relative toxicity value of 4.50, confirming its superior efficacy during the intermediate stages of exposure.

As the exposure duration increased, the difference in toxicity between the two insecticides gradually diminished. By 72 HAT, the relative toxicity value was 1.00, indicating that chlorantraniliprole and spinetoram produced comparable levels of toxicity against *S. litura* larvae. The similarity in toxicity observed at the final assessment suggests that extended exposure enhanced the effectiveness of spinetoram, enabling it to achieve a response equivalent to that of chlorantraniliprole (Fig. 2). Despite this convergence at the later stage, chlorantraniliprole consistently demonstrated greater toxic potency over much of the experimental period, highlighting its stronger and more rapid insecticidal action under laboratory conditions.

Discussion

Among the newer insecticides available for the management of lepidopteran pests, chlorantraniliprole and spinetoram are recognised for their high efficacy against economically important crop pests. Evaluating their toxicity against *S. litura* is essential for selecting effective insecticides and developing resistance management strategies. Accordingly, the present study compared the toxicological performance of these two insecticides against 11 day old larvae of *S. litura* (17).

The results clearly demonstrated that chlorantraniliprole was more toxic than spinetoram throughout the observation period, with the greatest difference occurring during the early stages of exposure. At 24 HAT, chlorantraniliprole recorded an LC₅₀ value of 0.008 %, compared with 0.064 % for spinetoram, indicating approximately 8-fold greater toxicity. However, the difference gradually declined with increasing exposure time and both insecticides produced comparable toxicity after 72 hr. These findings suggest that chlorantraniliprole provides more rapid larval control, whereas spinetoram requires a longer exposure period to achieve a similar level of mortality.

The present results are consistent with earlier reports identifying chlorantraniliprole as one of the most effective insecticides against *S. litura*. Previous studies have shown that chlorantraniliprole exhibits greater efficacy than conventional insecticide mixtures and several other insecticides, making it a reliable option for managing field populations of this pest (18). Similarly, it was reported chlorantraniliprole to be more toxic than flubendiamide and emamectin benzoate against *S. litura*, further supporting its superior larvicidal activity (19). Comparable observations were also reported, which demonstrated the high toxicity of chlorantraniliprole even at very low concentrations (20).

The enhanced performance of chlorantraniliprole is likely related to its distinctive mode of action. As a diamide insecticide, it activates insect ryanodine receptors, causing continuous calcium (Ca) release from muscle cells, which leads to rapid feeding cessation, muscle paralysis and eventual death. This rapid interruption of feeding is particularly important in pulse crops because it limits foliage damage before larval mortality occurs. In contrast, spinetoram acts primarily on nicotinic acetylcholine receptors, disrupting nerve impulse transmission and producing mortality through a different physiological pathway. Although highly effective, its toxic action was comparatively slower under the present experimental conditions.

The lower LT₅₀ recorded for chlorantraniliprole (31.96 hr) than for spinetoram (61.03 hr) further confirms its faster insecticidal action. Similar observations were reported, which found chlorantraniliprole to produce higher larval mortality than spinetoram against lepidopteran pests (21). The consistency of these findings across different studies indicates that chlorantraniliprole not only possesses greater intrinsic toxicity but also suppresses larval feeding more rapidly, making it particularly suitable for situations where immediate crop protection is required.

Overall, the present study demonstrates that both insecticides are effective against *S. litura*; however, chlorantraniliprole offers a clear advantage by providing faster and more potent larval control. Its rapid action and high efficacy make it a valuable component of integrated pest management programmes for pulse crops. Nevertheless, its use should be integrated with insecticide rotation and other resistance management practices to maintain its effectiveness and delay the development of resistance in field populations.

Table 3. Time mortality response of chlorantraniliprole and spinetoram against *Spodoptera litura* larvae

Insecticide	Degrees of freedom	χ^2	P value	Concentration (%)	Regression equation	Lethal time (LT) values in hours			Fiducial limits (LT ₅₀)	
						LT ₃₀	LT ₅₀	LT ₉₀	Lower	Upper
Chlorantraniliprole	5	0.91	0.969	0.006	$Y = 2.61 + 1.59x$	15.11	31.96	202.04	23.13	44.16
Spinetoram	5	2.63	0.757	0.005	$Y = 1.91 + 1.73x$	30.59	61.03	334.09	40.62	91.70

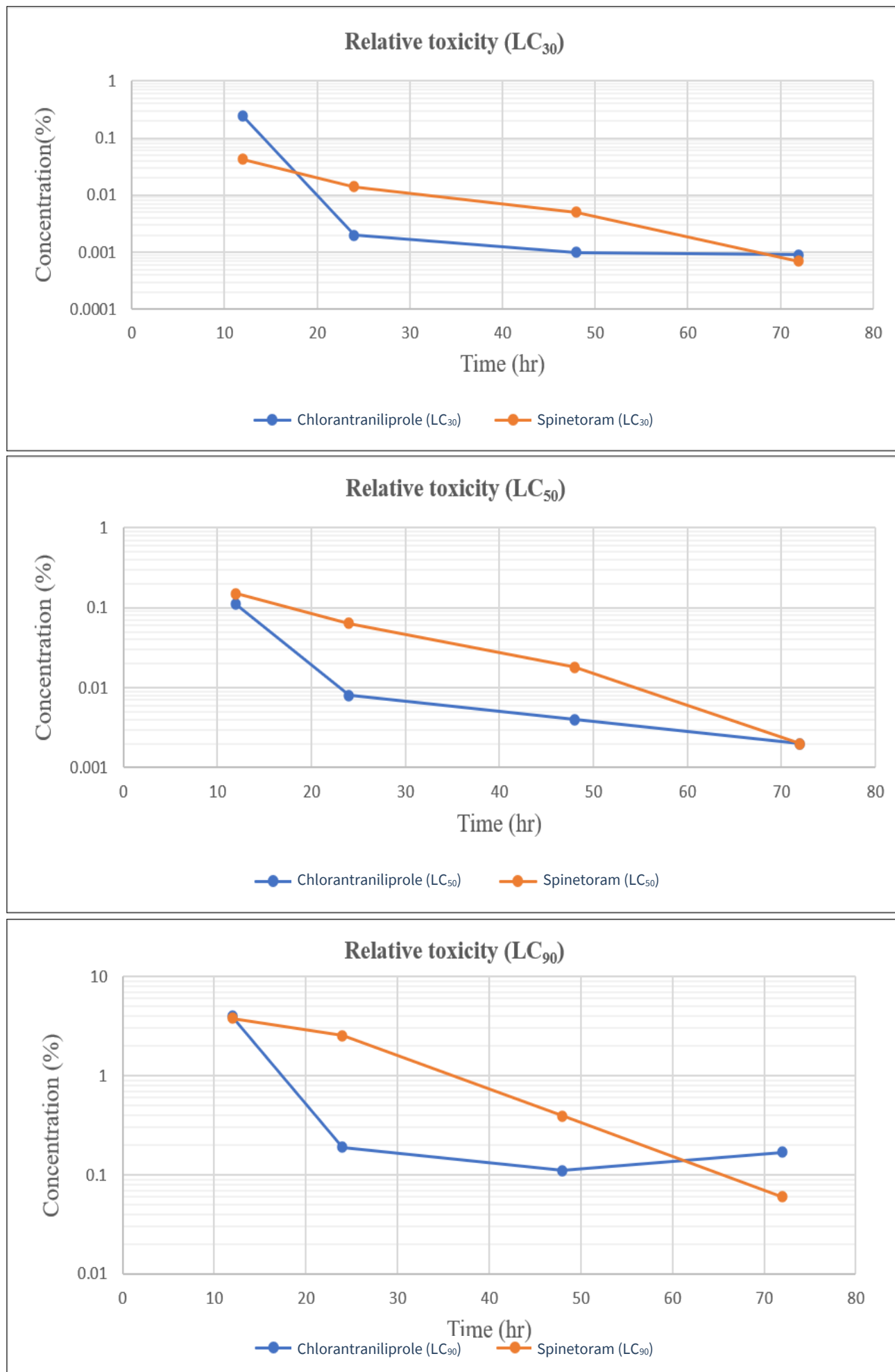


Fig. 2. Relative toxicity (LC₃₀, LC₅₀ and LC₉₀) of chlorantraniliprole and spinetoram against time on *Spodoptera litura* larvae.

Conclusion

In conclusion, both chlorantraniliprole and spinetoram exhibited considerable toxicity against 11 day old larvae of *Spodoptera litura*, with their toxic effects becoming more pronounced as the exposure period increased. However, chlorantraniliprole consistently required lower concentrations to achieve comparable levels of mortality, indicating greater toxicity than spinetoram. At earlier exposure periods, chlorantraniliprole was more toxic than spinetoram based on LC₅₀ values, demonstrating its superior efficacy. Although the differences in toxicity between the two insecticides decreased with extended exposure and both compounds provided effective larval control at 72 hr, chlorantraniliprole achieved more rapid suppression of larval populations. The results indicate that both insecticides can play an important role in the management of *S. litura*. However, chlorantraniliprole offers a distinct advantage because of its greater potency and faster insecticidal action at relatively lower concentrations.

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Authors' contributions

NK contributed to the conceptualisation of the study, methodology development, investigation, formal analysis and preparation of the original draft manuscript. DLD contributed to formal analysis, data analysis and manuscript review. JPP was responsible for providing resources, formal analysis, validation and supervision of the study. All authors read and approved the final version of the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used ChatGPT in order to check grammar and sentence structure. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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