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Comparative Insecticides Toxicity against Third Instar *Spodoptera frugiperda* Populations in Southern India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A laboratory bioassay using the topical application method was conducted to determine the relative toxicity of various insecticides against the fall armyworm, *Spodoptera frugiperda* (J. E. Smith), under controlled conditions at the Department of Entomology, Professor Jayashankar Telangana Agricultural University, Rajendranagar, Hyderabad. The study aimed to evaluate the effectiveness of Chlorantraniliprole 18.5% SC, Emamectin benzoate 5% SG, Spinetoram 11.7% SL, Lambda-cyhalothrin 5% EC and Thiodicarb 75% WP against 3rd instar larvae of *S. frugiperda* sourced from four regions in South India: Andhra Pradesh, Karnataka, Tamil Nadu, and Telangana. The insecticides were ranked in terms of toxicity (LC_{50}) as follows: Emamectin benzoate (0.99 to 1.02 ppm) > Spinetoram (1.14 to 1.21 ppm) > Chlorantraniliprole (1.5 to 2.14 ppm) > Lambda-cyhalothrin (31.5 to 35.62 ppm) > Thiodicarb (427.36 to 557.37 ppm). Among these, emamectin benzoate was identified as the most toxic, with the lowest LC_{50} value in Karnataka and Tamil Nadu (0.99 ppm), while Thiodicarb was the least toxic, showing the highest LC_{50} value in Telangana (557.37 ppm).

Keywords: Toxicity; insecticides; instar Spodoptera frugiperda; armyworm.

1. INTRODUCTION

The fall armyworm, *Spodoptera frugiperda* (J. E. Smith) an invasive pest species, was first identified in Karnataka, affecting maize crops in mid-May 2018 (Sharanabasappa et al*.,* 2018). As a highly polyphagous insect, the fall armyworm has an extensive host range, feeding on 353 plant species, including vital crops like maize, sorghum, sugarcane, rice, wheat, cowpea, groundnut, potato, soybean, and cotton (Matti & Patil, 2019; Ayra-Pardo et al*.,* 2024). Since its initial detection, the pest has rapidly spread across various Southern states of India, particularly targeting maize fields (Mahadevaswamy et al*.,* 2018; Sharanabasappa et al*.,* 2018). Its destructive feeding habits and capability for long-distance migration pose a serious threat to agriculture, with the potential for widespread dispersal across regions (Nagoshi et al*.,* 2018).

Several insecticides have shown effectiveness against the fall armyworm; however, their widespread and unregulated use has led to the development of resistance, resulting in sporadic pest outbreaks and subsequent crop failures (Ahmad et al*.,* 2007). Considering this challenge, the current study was designed to evaluate the toxicity of insecticides against this pest under laboratory conditions. The findings from this study will serve as baseline data for future assessments of insecticide susceptibility and support integrated pest management (IPM) strategies for managing field infestations of the fall armyworm.

2. MATERIALS AND METHODS

2.1 Fall Armyworm Collection

In 2023, fall armyworm larvae were collected from maize fields in four locations of South India: Telangana (Chintakunta: 18.43°N, 79.09°E), Andhra Pradesh (Brahmanapalli: 16.51°N, 79.82°E), Karnataka (Channanakere: 12.46°N, 76.78°E), and Tamil Nadu (TNAU: 11.01°N, 76.93°E). These larvae were then reared in the laboratory at the Department of Entomology, Professor Jayashankar Telangana Agricultural University, Hyderabad, Telangana, India.

2.2 Rearing

The first instar larvae hatched from egg masses collected from the maize fields of South India were transferred to plastic rearing boxes, each equipped with small ventilation holes in the cap to ensure proper airflow. These plastic boxes, pre-loaded with artificial diet for the developing instars, were introduced into a Biological Oxygen Demand incubator (BOD) within the laboratory calibrated to maintain optimal environmental conditions (27 ± 1°C (temperature), 65 ± 5% relative humidity (RH) (Ge et al*.,* 2021). When larvae were reaching the third instar stage, each larva was carefully placed into individual compartments of twenty-five well rearing trays containing artificial diet, to reduce the potential risk of cannibalism among the larvae. Following the pupation, the pupae were collected and relocated into adult cages furnished with honey solution to aid and facilitate the process of oviposition. Susceptible population was also reared as mentioned above.

2.3 Insecticides

The commercial formulations of insecticides tested in the bioassays against fall armyworm included:

1	Chlorantraniliprole 18.5% SC
2	Emamectin benzoate 5% SG
3	Spinetoram 11.7% SL
4	Lambda-cyhalothrin 5% EC
5	Thiodicarb 75% WP

These insecticides were sourced from the local market in Telangana

Preparation of stock solution of insecticides: A one percent stock solution of each test insecticide was prepared using the following formula (Neal, 1976).

Stock solution = Required concentration (1%) / % formulation of test insecticide * 100

2.4 Quantity of Water taken for the Preparation of Solution

To prepare the necessary serial dilutions, a 1% stock solution (250 mL) was initially prepared. Each insecticide was tested across a broad range of concentrations. Depending on the mortality rates observed, the concentrations were refined to a narrower range until larval mortality levels were between 10% and 90% (Wei et al*.,* 2021).

2.5 Laboratory Bioassay

To determine the median lethal concentration (LC_{50}) of various insecticides, a slightly modified version of the topical bioassay method was utilized (Al-Sarar et al*.,* 2006). Laboratory bioassays were conducted using F_1 generation larvae to assess the toxicity of insecticides on third instar *Spodoptera frugiperda*. Insecticides in their commercial formulations were dissolved in distilled water to create stock solutions, from which seven working concentrations were prepared via serial dilution. Using a micro-applicator, one microliter of each concentration was applied topically to the dorsum of the thorax of each larva. Distilled water was used as the control for all treatments. Each concentration was tested on a population of 30 larvae, with three replicates for each. After treatment, the larvae were transferred to rearing trays with insecticide-free artificial diet. Mortality was recorded after 72 hours, with larvae that failed to move following a gentle stimulation with a camel's hair brush being considered dead.

2.6 Observations

Mortality of the treated larvae was recorded at 24, 48 and 72 hours post-treatment by counting the dead or moribund individuals. Mortality at the 72-hour mark was used as the endpoint for evaluating the toxicity of the test insecticides (Fisk and Wright, 1992). The mortality data were analyzed using probit analysis (Finney, 1971), and the LC_{50}, intercept (a), slope of the regression line (b) and regression equation were determined using SPSS (Statistical Package for Social Sciences) version 16.0 software (Verma et al*.,* 2024).

3. RESULTS AND DISCUSSION

Among the five insecticides tested against third instar *Spodoptera frugiperda* larvae using the topical application method, emamectin benzoate was the most toxic, exhibiting the lowest LC_{50} values (0.99 to 1.02 ppm). It was followed by spinetoram (1.14 to 1.21 ppm), chlorantraniliprole (1.5 to 2.14 ppm), lambda-cyhalothrin (31.5 to 35.62 ppm), and thiodicarb (427.36 to 557.37 ppm). Probit analysis of the bioassay data for insecticides showed minimal variation in LC_{50} values across different populations. The smallest range of LC_{50} values was observed for emamectin benzoate (0.99 to 1.02 ppm), while thiodicarb exhibited the largest variation (427.36 to 557.37 ppm). For chlorantraniliprole, the Karnataka population had the lowest LC_{50} value (1.5 ppm), while the Telangana population had the highest (2.14 ppm). Emamectin benzoate displayed similar trends, with the lowest LC50 values found in both the Karnataka and Tamil Nadu populations (0.99 ppm), and the highest in the Telangana population (1.02 ppm). For lambda-cyhalothrin, the Telangana population had the lowest LC_{50} value (6.86 ppm), and the Karnataka population showed the highest (7.64 ppm). Spinetoram's lowest LC_{50} value was recorded in the Karnataka population (1.14 ppm), while the highest was seen in the Telangana population (1.21 ppm). Lastly, thiodicarb had the lowest LC_{50} in the Telangana population (427.36 ppm) and the highest in the Andhra Pradesh population (557.37 ppm) (Table 1).

Table 1. Mortality rates of fall armyworm larvae in response to insecticides using topical application method at 72-hour post-exposure

Insecticide	State	LC_{50} value	χ2	d.f (n-2)	Slope ± S. E	Regression equation
	Andhra Pradesh	1.644	1.163	3	1.523±0.075	Y=-0.329+1.523X
	Karnataka	1.500	3.185	3	1.114±0.072	Y=-0.195+1.114X
	Tamil Nadu	1.783	4.307	3	1.553±0.076	Y=-0.390+1.553X
Chlorantraniliprole 18.5 % SC	Telangana	2.139	3.341	3	1.483±0.077	Y= -0.490+1.483X
Emamectin benzoate 5 % SG	Andhra Pradesh	1.01	4.459	3	1.50±0.059	Y= -0.007+1.50X
	Karnataka	0.99	1.894	3	1.51+0.059	Y= 0.007+1.51X
	Tamil Nadu	0.99	1.103	3	1.55±0.059	Y= 0.001+1.55X
	Telangana	1.020	4.018	3	1.551±0.059	Y=-0.014+1.551X
Spinetoram 11.7 %SC	Andhra Pradesh	1.166	4.706	3	1.398±0.058	Y=-0.093+1.398X
	Karnataka	1.142	3.432	3	1.552±0.059	Y=-0.089+1.552X
	Tamil Nadu	1.147	1.907	3	1.380±0.058	Y=-0.082+1.380X
	Telangana	1.212	4.041	3	1.435±0.059	Y=-0.120+1.435X
Lambda cyhalothrin 5% EC	Andhra Pradesh	35.482	4.220	3	2.550±0.293	Y=-3.953+2.550X
	Karnataka	35.621	1.679	3	2.23±0.276	Y=-3.46+2.23X
	Tamil Nadu	33.994	0.542	3	2.12±0.267	Y=-3.25+2.12X
	Telangana	31.516	4.722	3	2.07±0.261	Y=-3.10+2.07X
Thiodicarb 75 %WP	Andhra Pradesh	557.370	3.496	3	1.569±0.340	Y=-4.310+1.569X
	Karnataka	477.786	4.601	3	1.075±0.294	Y=-2.881+1.075X
	Tamil Nadu	504.889	3.290	3	1.441±0.329	Y= -3.894+1.441X
	Telangana	427.359	3.550	3	1.099±0.299	Y=-2.891+1.099X

All values are non-significant at p> 0.01; d.f: Degrees of Freedom

The current results are consistent with those of Argentine et al. (2002) and Deshmukh et al. (2020) who found emamectin benzoate 5% SG to be the most toxic insecticide to *S. frugiperda* larvae. Likewise, Hardke et al. (2011) reported that LC_{50} values for chlorantraniliprole and spinetoram were significantly lower compared to other insecticides when tested using diet-incorporated assays against *S. frugiperda*. The high toxicity of chlorantraniliprole and emamectin benzoate was also observed in studies by Zhang et al. (2022), and Zhang et al. (2023). Sisay et al. (2019) found that spinetoram treatments caused the highest mortality in fall armyworm, followed by chlorantraniliprole, spinosad, and lambda-cyhalothrin. In thiodicarb bioassays, LC_{50} values ranged from 320 to 641 ppm, with a significantly higher LC_{50} observed in larvae from the Newellton strain compared to the SIML reference strain (Mascarenhas et al*.,* 1996). Toxicity studies indicated that emamectin benzoate, chlorantraniliprole, and spinetoram had very low LC_{50} values compared to lambda-cyhalothrin and thiodicarb. However, comparing our results to other studies is challenging due to the use of different bioassay methods for assessing fall armyworm susceptibility. These results provide valuable baseline susceptibility data for the insecticides currently used to control fall armyworm. Such data will be useful for monitoring changes in susceptibility as the use of these insecticides increases in maize fields across the Southern states of India.

4. CONCLUSION

Probit analysis of the bioassay data revealed minimal variation in LC_{50} values across different populations, consistent for all insecticides tested. The narrowest range of LC_{50} values was observed for emamectin benzoate (0.99 to 1.02 ppm), while the greatest variation occurred with thiodicarb (427.36 to 557.37 ppm). Among the insecticides, emamectin benzoate was the most toxic, with the lowest LC_{50} value recorded in Karnataka and Tamil Nadu (0.99 ppm), while thiodicarb was the least toxic, exhibiting the highest LC_{50} value in Telangana (557.37 ppm).

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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