International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2025): 5.29
IJABR 2025; 9(10): 188-192
www.biochemjournal.com
Received: 18-08-2025
Accepted: 20-09-2025

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Insecticide resistance in the field populations of whitebacked planthopper, *Sogatella furcifera* (Horváth) (Hemiptera: Delphacidae) from two rice-growing regions of Telangana

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DOI: https://www.doi.org/10.33545/26174693.2025.v9.i10c.5948

Abstract
The whitebacked planthopper (WBPH), *Sogatella furcifera* (Horváth), is one of the major pests of rice throughout Asia. The widespread use of insecticides to control WBPH has resulted in the development of insecticide resistance, leading to frequent failures in effective pest management. The aim of this study was to evaluate the insecticide resistance in the field populations of *Sogatella furcifera* from two rice-growing regions of Telangana *viz*., Rajendranagar and Nalgonda to two insecticides *viz*., imidacloprid and triflumezopyrim, during the *Kharif* season of 2024. The Rajendranagar and Nalgonda populations exhibited high resistance to imidacloprid, with resistance ratios of 18.65-fold and 33.19-fold respectively, while resistance to triflumezopyrim was comparatively low, with resistance ratios of 1.57-fold and 2.1-fold respectively. The results obtained will be beneficial for implementing IPM strategies for the effective use of insecticides against WBPH.

Keywords: Telangana, rice, *Sogatella furcifera*, imidacloprid, triflumezopyrim, resistance

Introduction
Rice (*Oryza sativa* L.) is the staple food of more than half of the world's population making it the most important food grain crop globally. Asia accounts for over 90% of global rice production and consumption (Kushwaha *et al*. 2019) [7]. The rice crop is attacked by more than 100 species of insects; 20 of them can cause economic damage (Pathak and Khan, 1994). Among the insect pests, planthoppers constitute a large group of phytophagous insects belonging to the order Hemiptera. In Asia, two planthoppers of economic importance are the brown planthopper (BPH), *Nilaparvata lugens* (Stål) and the whitebacked planthopper (WBPH), *Sogatella furcifera* (Horváth) both belonging to the family Delphacidae (Catindig *et al*. 2009) [2]. The whitebacked planthopper, *S. furcifera* (Horváth) (Hemiptera: Delphacidae), is widely distributed across Asia and is regarded as a significant pest of rice in the region (Liu *et al*. 2010) [13]. It is widely distributed across South Asia, Southeast Asia, East Asia, South Pacific islands and Australia (Liu *et al*. 2023) [14]. It feeds on the phloem and causes decrease in leaf area, plant height, dry weight, leaf and stem nitrogen concentration, chlorophyll content and photosynthetic rate (Rubia-Sanchez *et al*. 1999; Watanabe and Kitagawa, 2000) [19, 22], ultimately leading to yield losses. Both adult and nymphal stages of the planthopper suck sap and inject toxic saliva into plant tissues, inducing "hopper burn", a condition that leads to the wilting and drying of leaves and tillers. The Southern rice black-streaked dwarf virus (SRBSDV) can be effectively transmitted by the whitebacked planthopper in a persistent circulative propagative manner (Zhou *et al*. 2013) [23]. Chemical insecticides have traditionally been used to control the WBPH and continue to be the primary method for its prevention and management (Li *et al*. 2021) [11].
Monocrotophos and acephate from the organophosphate group as well as carbaryl, fenobucarb, isoprocarb and carbosulfan from the carbamate group have been widely used for an extended period. Since the late 1990s, neonicotinoids such as imidacloprid, thiamethoxam and clothianidin have been widely used against WBPH in many rice-growing regions in India (Lakshmi *et al*. 2010) [8]. Even though very effective, the indiscriminate use of these insecticides has led WBPH to develop resistance to several classes of insecticides including

organophosphates, carbamates, pyrethroids, neonicotinoids, pyridine azomethines, insect growth regulators and phenylpyrazoles (Mao *et al*. 2021) [15]. Therefore, determining the resistance levels in field populations of *S. furcifera* to frequently used insecticides is crucial for the successful management of this pest (Li *et al*. 2021) [11].

The indiscriminate use of insecticides has led to the development of resistance in *S. furcifera* to several commonly used insecticides. Therefore, study about the possible resistance patterns and the underlying mechanisms governing the insecticide resistance is essential for the effective management of this pest. In India, only a few studies have been conducted in this regard. In this study, we assessed the resistance of *S. furcifera* populations to two commonly used insecticides (imidacloprid and triflumezopyrim) in populations collected from two different rice-growing regions of Telangana (Rajendranagar and Nalgonda), along with a laboratory reared susceptible strain.

Materials and Methods

Collection and rearing of *S. furcifera*

Field populations of *S. furcifera* collected from two different rice-growing regions of Telangana (Table 1) were used to study the susceptibility to two insecticides. Both nymphs and adults were collected from the paddy field during the *Kharif* season of the year 2024 using an aspirator. The insects were transferred to potted rice plants, covered with cylindrical mylar cages fitted with nylon mesh tops, then brought to the glasshouse and placed in a 2x2 sq. ft rearing cage alongside pots of 40-day old TN1 (Taichung Native 1, a WBPH susceptible rice variety) rice plants for rearing. The rearing cages were labelled with the respective location names and the date of collection. The field-collected populations (F_0) were reared in cages within the glasshouse to obtain the F_1 generation. Third-instar nymphs from the F_1 generation were used for subsequent bioassay studies. The bioassay study involves the estimation of median lethal dose (LD_{50}) of the insecticides against the field populations of *S. furcifera*. The response of *S. furcifera* populations from the two rice-growing regions of Telangana were compared with the susceptible laboratory culture maintained for over five years (more than 20 generations) without any exposure to insecticides at ICAR-Indian Institute of Rice Research (IIRR), Hyderabad.

Bioassay

Bioassays were conducted on third instar nymphs of *S. furcifera* using the rice stem dipping method (Zhuang and Shen, 2000) [25]. Rice plants at the tillering stage were uprooted, washed and cut into 20 cm long stems with roots and air dried to remove excess water. Three stems were grouped together and dipped in insecticide concentrations for 30 seconds, then air dried at room temperature. After drying, the treated stems were fixed in 500 ml plastic cups filled with water. Ten third instar nymphs were released onto each stem and covered with a cylindrical mylar cage with a nylon mesh tied above. There were six concentrations (six treatments) for each insecticide, with three replicates per treatment, exposing a total of 30 nymphs per concentration. Stems dipped exclusively in water served as the untreated control. All treatments were maintained at a temperature of 27±1 °C, 70-80% relative humidity and a 16-hour light/8-hour dark photoperiod. Commercial formulations of insecticides used for the bioassay are presented in table 2.

The efficacy of insecticides against WBPH populations was assessed by recording the mortality at specific time intervals. Mortality was recorded after 72 hours of exposure to imidacloprid and after 96 hours of exposure to triflumezopyrim. Nymphs were considered as dead if they failed to respond to gentle prodding with a fine brush.

Table 1: Details of different locations and collection dates of *S. furcifera* populations used for insecticide resistance studies

State	Rice-growing region	Date of Collection	Coordinates
Telangana	Rajendranagar	21 October 2024	17.30º N, 78.52º E
	Nalgonda	10 October 2024	16.85º N, 79.47º E

Table 2: List of insecticides used in this study

Insecticide	Trade name	Manufacturer	Chemical group	Mode of action
Imidacloprid 17.8% SL	Confidor	Bayer Crop Science	Neonicotinoid	Nicotinic acetylcholine receptor (nAChR) competitive modulators
Triflumezopyrim 10% SC	Pexalon	Corteva griscience	Novel mesoionic class	

Statistical analysis

The percentage mortality for each insecticide concentration along with the control was calculated. Corrected percent mortality was determined using Abbott's formula (Abbott, 1925) [1]. Mortality data was analysed by Probit analysis using the POLO plus software (LeOra Software 2002, Berkeley, CA, USA) [1] to estimate the lethal concentration values (LC_{50}). Subsequently, the Resistance Ratio (RR) for each insecticide was determined using the below formula.

$$RR = \frac{LC_{50} \text{ of Resistant population}}{LC_{50} \text{ of Susceptible population}}$$

Results and Discussion

Resistance status of WBPH populations to imidacloprid 17.80% SL

S. furcifera populations collected from two different rice-growing regions of Telangana exhibited varying levels of resistance to imidacloprid after 72 hours of exposure during the *Kharif* season of 2024. The LC_{50} values were 38.05 ppm for Rajendranagar population and 67.71 ppm for Nalgonda population, whereas the susceptible laboratory strain exhibited an LC_{50} value of 2.04 ppm (Table 3, Fig 1).

Table 3: Resistance levels of field populations of *S. furcifera* to imidacloprid 17.80% SL during *Kharif*, 2024

Population	LC_{50}[a] (ppm)	Fiducial limits (95% limits)		Slope±SE[b]	X^2 (df)[c]	Resistance ratio (RR)
		Lower	Upper			
Rajendranagar	38.05	25.51	54.39	1.29±0.21	0.58 (4)	18.65
Nalgonda	67.71	45.16	106.67	1.2±0.22	0.37 (4)	33.19
Susceptible	2.04	0.02	5.76	1.26±0.42	0.89 (4)	-

a-LC_{50} at 95% confidence limits; b-standard error; c-degrees of freedom

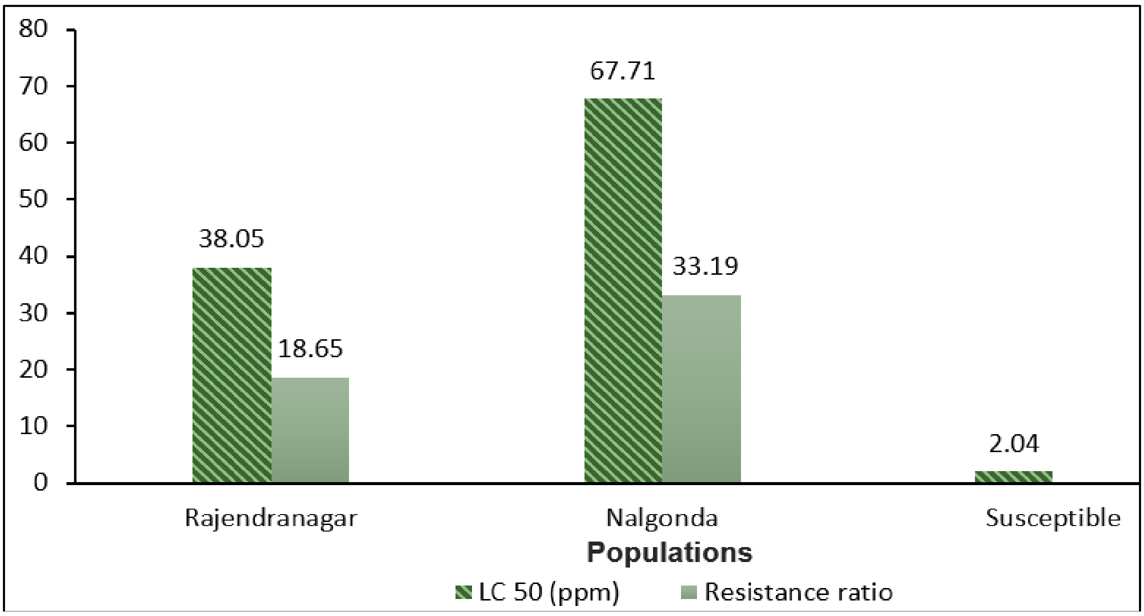

Fig 1: LC_{50} and resistance ratios of *S. furcifera* populations to imidacloprid 17.80% SL

Resistance ratios to imidacloprid were 18.65-fold for Rajendranagar population and 33.19-fold for Nalgonda population compared to the laboratory susceptible strain (Table 3, Fig 1).

Imidacloprid, a neonicotinoid insecticide, acts by binding selectively to insect nicotinic acetylcholine receptors (nAChRs), competitively inhibiting neurotransmission and leading to paralysis and death (Tomizawa and Casida, 2005). Numerous studies around the world have documented considerable variation in susceptibility to imidacloprid among the WBPH populations across different geographical regions. Raj *et al.* (2020) [18] found that *S. furcifera* populations from Tamil Nadu exhibited 2.8 to 6.2-fold resistance to imidacloprid, with the highest resistance recorded in Nagapattinam populations. Li *et al.* (2021) [10, 11] found that *S. furcifera* populations from China exhibited imidacloprid resistance levels ranging from 2.09 to 62.55-fold. Li *et al.* (2020) [10, 11] reported that *S. furcifera* populations from China exhibited imidacloprid resistance levels between 4.05 and 31.81-fold. Jin *et al.* (2017) [6] reported that *S. furcifera* populations from Guizhou Province, China, exhibited moderate resistance to imidacloprid, with resistance ratios ranging from 0.71 to 26.06-fold. Su *et al.* (2013) [20] found that about 32% of *S. furcifera* populations from eastern China exhibited moderate resistance to imidacloprid, with resistance levels up to 7.6-fold higher than that of susceptible strain.

Resistance status of WBPH populations to triflumezopyrim 10% SC

S. furcifera populations collected from two different rice-growing regions of Telangana exhibited varying levels of resistance to triflumezopyrim after 96 hours of exposure during the *Kharif* season of 2024. The LC_{50} values were 0.22 ppm for Rajendranagar population and 0.30 ppm for Nalgonda population, whereas the susceptible laboratory strain exhibited an LC_{50} value of 0.14 ppm (Table 4, Fig 2).

Table 4: Resistance levels of field populations of *S. furcifera* to triflumezopyrim 10% SC during *Kharif*, 2024

Population	LC_{50}[a] (ppm)	Fiducial limits (95% limits)		Slope ± SE[b]	X^2 (df)[c]	Resistance ratio (RR)
		Lower	Upper			
Rajendranagar	0.22	0.16	0.29	1.72±0.27	1.85 (4)	1.57
Nalgonda	0.30	0.23	0.39	2.12±0.39	0.83 (4)	2.14
Susceptible	0.14	0.10	0.20	1.52±0.22	0.76 (4)	-

a-LC_{50} at 95% confidence limits; b-standard error; c-degrees of freedom

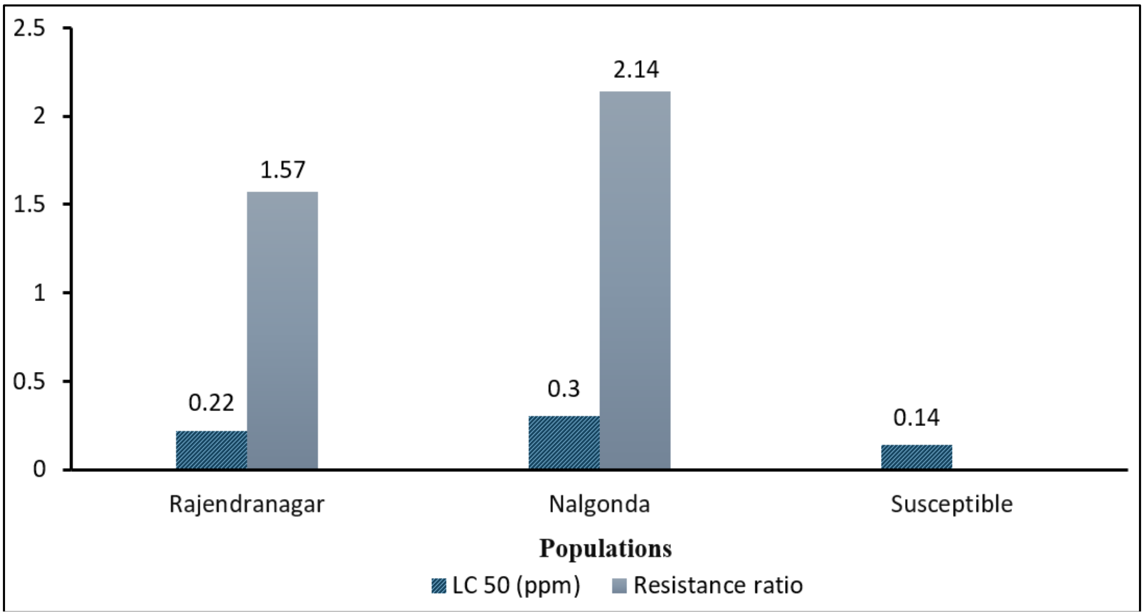

Fig 2: LC_{50} and resistance ratios of *S. furcifera* populations to triflumezopyrim 10% SC

Resistance ratios to triflumezopyrim were 1.57-fold for Rajendranagar population and 2.14-fold for Nalgonda population compared to the laboratory susceptible strain (Table 4, Fig 2).

Triflumezopyrim, a novel mesoionic insecticide, controls planthopper by binding to and inhibiting the orthosteric site of nicotinic acetylcholine receptors (nAChRs), thereby disrupting the normal neural signalling and causing over-excitation of insect nervous system (Cordova *et al*. 2016; Holyoke *et al*. 2017 and Zhu *et al*. 2018) [3, 5, 24]. Similar findings have been reported by numerous researchers worldwide, who observed varying levels of susceptibility among *S. furcifera* populations from different regions *viz*., Li *et al*. (2020) [10, 11] reported that *S. furcifera* populations from China were largely susceptible to triflumezopyrim (0.77 and 3.23-fold). Priyadharshini *et al*. (2022) [17] reported that *N. lugens* populations from Tamil Nadu exhibited LC_{50} values ranging from 0.280 to 0.848 ppm to triflumezopyrim, with only minimal resistance detected in Nagapattinam population, indicating its high efficacy. Chinese populations of *N. lugens* were susceptible to triflumezopyrim, with resistance ratios between 0.2 and 1.1-fold as reported by Datta *et al*. (2021) [4]. Liao *et al*. (2021) [12] reported that field populations of *N. lugens* from China exhibited low resistance to triflumezopyrim (LC_{50} = 0.05 to 0.29 mg/L) (RR = 1.3 to 7.3-fold) during 2015-2018.

Conclusion

The present study investigated the insecticide resistance status of *Sogatella furcifera* populations from two rice-growing regions of Telangana *viz*., Rajendranagar and Nalgonda, to imidacloprid and triflumezopyrim during the *Kharif* season of 2024. Both field populations exhibited significant resistance to imidacloprid, with resistance ratios of 18.65-fold for Rajendranagar and 33.19-fold for Nalgonda. In contrast, resistance to triflumezopyrim remained relatively low, with resistance ratios of 1.57-fold and 2.14-fold for Rajendranagar and Nalgonda populations, respectively, compared to the laboratory susceptible strain. These findings indicate that imidacloprid is becoming less effective for the management of *S. furcifera* in these regions, while triflumezopyrim remains a viable management option. Regular monitoring of insecticide resistance and implementation of resistance management strategies are essential for the sustainable control of this economically important rice pest. Future research should focus on understanding the underlying resistance mechanisms and exploring alternative insecticides to ensure effective long-term management of *S. furcifera*.

Disclaimer (Artificial Intelligence)

Author(s) hereby declares that no generative AI technologies such as large language models (ChatGPT, Copilot, etc.) and text-to-image generators have been used by them during writing or editing manuscripts.

Acknowledgements

The author(s) sincerely thank the Chairman of the Advisory Committee and the teaching faculty of the Department of Entomology, College of Agriculture, Rajendranagar, PJTAU, Hyderabad, for their invaluable support and guidance throughout this study. The authors also express their gratitude to friends for their constant encouragement and assistance during the conduct of the experiment.

Competing Interests

None

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