ANSF APPLIED AND NATURAL SCIENCE FOUNDATION

Journal of Applied and Natural Science
14(1), 73 - 82 (2022)
ISSN : 0974-9411 (Print), 2231-5209 (Online)
journals.ansfoundation.org

Research Article

Bioefficacy of ethiprole + pymetrozine against the white-backed planthopper *Sogatella furcifera* (Howard), in rice (ADT – 46)

V. Priyadharshini*
Department of Entomology, Annamalai University, Chidambaram (Tamilnadu), India
R. Ayyasamy
Department of Entomology, Annamalai University, Chidambaram (Tamilnadu), India
C. Kathirvelu
Department of Entomology, Annamalai University, Chidambaram (Tamilnadu), India

*Corresponding author. Email: priyadharshinivelayutham1996@gmail.com

Article Info
https://doi.org/10.31018/jans.v14i1.3185
Received: November 29, 2021
Revised: February 5, 2022
Accepted: February 9, 2022

How to Cite
Priyadharshini, V. *et al.* (2022). Bioefficacy of ethiprole + pymetrozine against the white-backed planthopper *Sogatella furcifera* (Howard), in rice (ADT – 46). *Journal of Applied and Natural Science*, 14(1), 73 - 82. https://doi.org/10.31018/jans.v14i1.3185

Abstract
The nymphs and adults of white-backed planthoppers (*Sogatella furcifera*, Howard) remove plant sap resulting in yield loss. Indiscriminate use of insecticides, results in the development of resistance by insects and ill effects on the environment opening the new era of chemicals with novel modes of action with good bioefficacy, higher selectivity, low mammalian toxicity and safety to the environment. Therefore, the introduction of newer insecticide molecules with alternate modes of action will play a serious role in pest management programs. Hence, an experiment was conducted to evaluate the bioefficacy of ethiprole + pymetrozine against white-backed planthopper of rice (ADT – 46) under laboratory and field conditions at Annamalai University, Chidambaram during 2018-20. Ethiprole + pymetrozine @ (T1 - 36.91 + 138), (T2 - 40.13 + 150) and (T3 - 45.47 + 170) g a.i ha^{-1} with standard checks T4 - pymetrozine @ (150) g a.i ha^{-1}, T5 - buprofezin @ (200) g a.i ha^{-1} and T6 - ethiprole + imidacloprid @ (50 + 50) g a.i ha^{-1} were evaluated against white-backed planthopper. The standard checks were of positive control *i.e.,* reference insecticides which is in common use The results revealed that T3 recorded the lowest population of white-backed planthopper/hill at 15 day after spraying (1.13 hoppers/hill in August – December 2018 and 1.79 hoppers/hill in August – December 2019 respectively) giving better yield. The population of natural enemies was comparatively lower in all insecticidal treatments than in the control.

Keywords: ADT–46 rice, Bioefficacy, Ethiprole, Pymetrozine, White-backed planthoppe

INTRODUCTION

Rice (*Oryza sativa*, Linnaeus) is an important staple food crop grown in India. It has nutritional and commercial value (Zainab and Singh, 2016). Rice provides 20-80 percent of dietary energy and 12-17 percent of dietary protein (Patel *et al*., 2018). The gap between potential and actual yield revealed that numerous factors act as yield constraints. In addition to abiotic factors such as floods and droughts, the maximum yield loss is due to biotic factors such as weeds and insect pests (Karunaratnel *et al*., 2007). Rice crops in India suffered approximately 25 percent yield loss due to insect pests during 2007-08, amounting to 32 million tonnes of rice worth 240 billion Indian rupees (Dhaliwal *et al*., 2010). The annual yield loss to rice caused by planthoppers alone was one million tons during 1970-1990 (Cheng *et al*., 2003). Plants near maturity also develop hopper burns if highly infested by WBPH/BPH (WBPH - White-backed planthopper and BPH – Brown planthopper) (Sandeep Kumar *et al.,* 2015).

Among various pests, white-backed planthoppers (*Sogatella furcifera*) of the family Delphacidae and order Hemiptera are significant rice pests in Asia (Hu *et al*., 2017). It adversely affects plant growth *viz*., wilting and chlorosis resulted in a "hopperburn" (Kulshreshtha, 1974). Farmers prefer the use of insecticides as the most effective pest management method (Schreinemachers *et al*., 2017) compared to other methods because of its higher efficacy (Fishel, 2007). Indiscriminate use of insecticides may pollute biodiversity (Mahmood *et al*., 2015). Hence, it is necessary to introduce novel groups and novel formulations of insecticides for an economic and effective pest management methods and compatibility with natural enemies and environment.

Thus, the present study was carried out to investigate the bioefficacy of ethiprole (10.7 %) + pymetrozine (40 %) WG in managing white-backed planthoppers (*S. furcifera)* under laboratory and field conditions. Ethiprole is a phenylpyrazole insecticide that acts on the γ-aminobutyric acid-dependent neurotransmission system in insects (Food safety Commission, 2004). Pymetrozine is the only representative pyridine azomethine, and has been developed worldwide for managing aphids and whiteflies in field crops, vegetables, ornamentals, cotton, hop, deciduous fruit, and citrus, and of the brown planthopper, *Nilaparvata lugens* (Stal), in rice (Fluckiger *et al*., 1992a, b). The compound appears to have great promise in integrated pest management (IPM) programs due to its high degree of selectivity, low mammalian toxicity, and safety to birds, fish, and non-target arthropods. It has now been discovered that binary mixtures comprising ethiprole and pymetrozine have unexpectedly high activities in the control of insects, acari, or nematodes, and fungi or microorganisms. These activities are synergistic, which means that the observed activity of the composition is higher than the sum of the activities of the single components (European patent application, 2012). This study has the objective of testing the safety of ethiprole (10.7 %) + pymetrozine (40 %) WG to the natural enemies of white -backed planthopper (*S. furcifera*) in rice (ADT - 46) ecosystem were also studied and the yield data were also recorded.

MATERIALS AND METHODS

Mass culturing of *S. furcifera*

The original colony of the test insects was started by one pair of adults. They were mass reared on susceptible rice variety TN 1 which provided insect food and suitable sites for oviposition. Forty day-old potted rice plants inside a plastic cage were covered by fine mesh nylon cloth with adult insects. Four potted plants in a cage were sufficient to maintain 250 to 400 hoppers. This method provided a continuous supply of test insects (Sardar *et al*., 2019).

Laboratory experiments

To determine the efficacy of insecticides on the mortality percentage of white-backed planthoppers an experiment was conducted in the laboratory of the Entomology Department, Annamalai University. The seedlings of 30 day-old rice plants (TN 1) were transplanted into pots. The rice plants grown in pots were sprayed with insecticides as per the treatment schedules (Table 1). The control pot with TN 1 rice plants was sprayed with water only. Plants in the pots were covered with cylindrical mylar film cages and ten white-backed planthopper nymphs were released in each pot. The mortality of insects was recorded at 1, 4, 24, 48 and 72 hours after exposure to treated plants. The experiment was laid out in a completely randomized design with three replications (Jhansi Lakshmi *et al.,* 2010).

Field Experiments

Two field experiments were conducted to evaluate the bioefficacy of ethiprole (10.7 %) + pymetrozine (40 %) WG against white-backed planthoppers in rice. The first experiment was conducted during August - December 2018 and the second experiment was conducted during August - December 2019 using the rice variety ADT- 46 at Annamalai University at Chidambaram.

The experiments were laid out in a randomized block design. The plot size was 20 m^2 with a spacing of 20 X 10 cm in both seasons. Each treatment was replicated thrice. The treatments were conducted with a pneumatic knapsack sprayer at 375 l/ha of spray volume and sprayed twice during the cropping period. The first application was given 45 days after transplanting rice (based on ETL), followed by the next application at fortnight intervals. Applications were made during morning hours to avoid photooxidation of the insecticides.

Method of assessment of *S. furcifera*

Observations of the white-backed planthopper population were recorded on 10 randomly selected hills per plot (Bambawale *et al*., 2011) one day before spraying (DBS), and 1, 3, 7, 10 and 14 days after each spray and these data are presented as the average number of insects/hill. Each hill was hit several times with hands and the number of nymphs and adults that fell on the water were counted.

Assessment of natural enemies

In field trials, the population of natural enemies *viz.,* spiders *Paradoxa pseudoannulata* (Boes) and mirid bugs *Cyrtorhinus lividepennis* (Reuter) were recorded in ten randomly selected hills per plot and then the mean population was determined (Seni and Naik, 2017).

Table 1. Treatment schedules used in the study

Treatments	Treatments	Dose (g.a.i/ha)
T1	Ethiprole (10.7 %) + pymetrozine (40 % WG)	36.91 + 138
T2	Ethiprole (10.7 %) + pymetrozine (40 % WG)	40.13 + 150
T3	Ethiprole (10.7 %) + pymetrozine (40 % WG)	45.47 + 170
T4	Std.check Pymetrozine (50 % WG)	150
T5	Std.check Buprofezin (25 % SC)	200
T6	Std. Check Ethiprole (40 %) + Imidacloprid (40 % WG)	50 + 50
T7	Untreated control	-

Yield

Paddy grains were harvested from each plot. The grain yield was recorded for individual treatments and computed per hectare.

Statistical analysis

The populations of white-backed planthoppers, spiders and mirid bugs were transformed using angular and square root transformations for statistical analysis. A randomized block design and a completely randomized design were followed for field and laboratory studies respectively. The analysis was carried out by transforming the percent mortality data into angular transformation values and mean numbers into square root transformation values (Gomez and Gomez, 1984); (Panse and Sukhatme, 1957). The mean values of treatment were then separated using Duncan's multiple range test (DMRT) (Duncan, 1951).

The corrected percent reduction in the field population was determined by using the formula of Henderson and Tilton, 1955 as follows.

Corrected percent reduction =100 × [1 – {(Ta × Cb) / (Tb × Ca)}] ……… Eq. 1

Where

T_a - Number of insects in the treatment after spraying

T_b - Number of insects in the treatment before spraying

C_a - Number of insects in the untreated check after spraying

C_b - Number of insects in the untreated check before spraying

RESULTS AND DISCUSSION

Laboratory experiment

Various doses of ethiprole (10.7 %) + pymetrozine (40 %) WG as per treatment schedules registered 63.33 – 76.67 percent mortality and 83.33 – 100 percent mortality against white-backed planthoppers after 4 and 72 hours of exposure to treated plants.

The standard checks T3, T5 and T6 registered 60.00 - 70.00 percent mortality and 80.00 – 90.00 percent mortality respectively against white-backed planthopper after 4 and 72 hours of exposure to treated plants (Table 2).

Field experiments

First season (August – December 2018)

The pretreatment population of white-backed planthoppers ranged from 9.00 to 10. hoppers/hill (Table 3). At 1 DAT, the lowest number (2.67 hoppers/hill) of hoppers was observed in the T3 treatments, which was on par with T2 (3.33 hoppers/hill) treatments. The next lowest number of hoppers was observed in the treatments T4 (4.67 hoppers/hill) followed by T6 (5.33 hoppers/hill). The population of hoppers was on par in the T1 (6.33 hoppers/hill) and T5 (6.67 hoppers/hill) treatments. However, the highest population of white-backed planthoppers was noticed in the untreated control (9.33 hoppers/hill)). A similar trend was observed at 7, 10 and 14 days after the first spray. The same trend was noticed at 3, 7, 10 and 14 days after the second spray (Table 3).

Second season (August – December 2019)

The pretreatment population of white-backed planthoppers ranged from 10.67 to 11.67 hoppers/hill (Table 4). At 1 DAT, the lowest number (4.67 hoppers/hill) of hoppers was observed in the T3 treatments, which was on par with T2 (5.33 hoppers/hill) treatments. The next lowest number of hoppers was observed in the treatments T4 (6.33 hoppers/hill) and it was on par with T6 (6.67 hoppers/hill). The population of hoppers was on par in the T1 (8.33 hoppers/hill) and T5 (8.67 hoppers/hill) treatments. However, the highest population of white-backed planthopper was noticed in untreated control (11.67 hoppers/hill)). A similar trend was observed at 7, 10 and 14 days after the first spray. The same trend was noticed at 3, 7, 10 and 14 days after the second spray (Table 4).

The results of the present research can be interpreted with earlier studies conducted by Bhanu (2015) who reported that pymetrozine 50WG@ 175 and 200 g a.i ha^{-1} were effective in the management of brown planthoppers and white-backed planthoppers in rice. Singh *et al*. (2018) reported that pymetrozine 50WG@ 300 and 400 g a.i ha^{-1} were effective against brown planthoppers, white-backed palnthoppers and green leafhoppers in rice. Kumaran *et al*. (2007) and Misra (2008) reported that ethiprole 10SC@ 50 g a.i ha^{-1} reduced the population of planthoppers in rice. Hence, the earlier studies reported that pymetrozine 50WG as a single product resulted in effective management of hoppers, whereas ethiprole 10SC as a single product reduces the hopper population in rice ecosystems. But ethiprole on combining with pymetrozine, effectively manages the whitebacked-planthoppers in rice ecosystems which is evident from the present study.

Toxicity to natural enemies

The effects of T1, T2, T3, T4, T5, T6 (Treatment schedules) on the spiders *Paradoxa pseudoannulata* (Boes) and mirid bugs *Cyrtorhinus lividepennis* (Reuter) in rice ecosystems were as follows

Spiders (*P. pseudoannulata)*

First season (August – December 2018)

The pretreatment population of spiders ranged from 6.33 to 7.33 numbers/ten plants. After two rounds of spraying, the mean population of spiders/ten plants was highest in the untreated control (7.50 spiders/ten plants). T1 recorded 7.00 spiders/ten plants. T2 and T3 recorded 6.50 and 6.17 spiders/ten plants respectively.

Table 2. Laboratory efficacy of ethiprole (10.7 %) + pymetrozine (40 %) WG on the mortality of *S. furcifera*

Tr. no.	Treatments	Percent mortality of white-backed planthopper					
		1 hour	4 hours	24 hours	48 hours	72 hours	Mean
T1	Ethiprole (10.7 %) + pymetrozine (40 %) WG @ 36.91 + 138 g a.i ha^{-1}	50.00 (44.98)^{cde}	63.33 (52.75)^{bcde}	66.67 (54.76)^{cde}	70.00 (56.98)^{cde}	83.33 (66.12)^{cde}	66.67
T2	Ethiprole (10.7 %) + pymetrozine (40 %) WG @ 40.13 + 150 g a.i ha^{-1}	63.33 (52.75)^{ab}	73.33 (59.19)^{ab}	80.00 (63.90)^{ab}	90.00 (74.98)^{ab}	96.67 (83.85)^{ab}	80.67
T3	Ethiprole (10.7 %) + pymetrozine (40 %) WG @ 45.47 + 170 g a.i ha^{-1}	70.00 (56.98)^{a}	76.67 (61.20)^{a}	86.67 (68.83)^{a}	96.67 (83.85)^{a}	100.00 (90.00)^{a}	86.00
T4	Market Std. Check Pymetrozine (50 %) WG @ 150 g a.i ha^{-1}	56.67 (48.83)^{bc}	70.00 (56.77)^{abc}	73.33 (58.98)^{bc}	80.00 (63.90)^{bc}	90.00 (74.98)^{bc}	74.00
T5	Market Std. Check Buprofezin (25 %) SC @ 200 g a.i ha^{-1}	43.33 (41.14)^{def}	60.00 (50.83)^{cdef}	63.33 (52.75)^{cdef}	66.67 (55.05)^{cdef}	80.00 (63.41)^{cdef}	62.67
T6	Market Std. Check Ethiprole 40 %+ Imidacloprid 40 % WG @ 50 + 50 g a.i ha^{-1}	53.33 (46.90)^{bcd}	66.67 (54.76)^{abcd}	70.00 (56.98)^{bcd}	73.33 (58.98)^{cd}	86.67 (68.83)^{cd}	70.00
T7	control	0.00 (0.00)^{g}	0.00 (0.00)^{g}	0.00 (0.00)^{g}	0.00 (0.00)^{g}	0.00 (0.00)^{g}	-
	SE(d)	2.85	3.48	3.85	6.87	5.72	-
	CD (P=0.05)	6.18	7.53	8.34	14.88	12.38	-

*Mean of three replications; Values in parenthesis are angular transformed values;In a column means followed by a common letter are not significantly different by DMRT(P=0.05); SE(d) - Standard error of difference, CD - Critical difference

The standard checks *viz.,* T4, T6 and T5 recorded comparatively lesser population such as 5.83, 5.42 and 4.83 spiders/ten plants over control (7.50 spiders/ten plants) respectively (Table 5).

Second season (August – December 2019)

The pretreatment population of spiders ranged from 4.00 to 4.67 numbers/ten plants. After two rounds of spraying, the mean population of spiders per ten plants was highest in the untreated control (5.17 spiders/ten plants). T1 recorded 4.17 spiders/ten plants. T2 and T3 recorded 3.75 and 3.17 spiders/ten plants respectively. The standard checks *viz.,* T4, T6 and T5 recorded comparatively lesser population such as 2.84, 2.50 and 2.17 spiders/ten plants over control (5.17 spiders/ten plants) respectively (Table 6).

Similar findings on safety of insecticides on spiders were in accordance with pymetrozine 50WG@ 0.5 g l^{-1} which had lesser adverse effect on spiders (Deekshita *et* al., 2017) and Rama Gopala Varma *et al.* (2003) reported that the population of spiders was lower in ethiprole 10EC@ 50 g a.i ha $^{-1}$ which was not due to the toxicity of this insecticide but due to availability of few planthoppers to spiders. As, pymetrozine 50WG and ethiprole 10SC as a seperate product does not have adverse effect on the natural enemies. Likewise, the combination of ethiprole and pymetrozine also proved to be safer for the spiders in the rice ecosystems.

Mirid bugs (*C. lividepennis)*

First season (August – December 2018)

The pretreatment population of mirid bugs ranged from 4.00 to 4.33 numbers/ten plants. After two rounds of spraying, the mean population of mirid bugs/ten plants was highest in the untreated control (4.83 mirid bugs/ten plants). T1 recorded 3.92 mirid bugs/ten plants. T2 and T3 recorded 3.58 and 3.25 mirid bugs/ten plants respectively. The standard checks *viz.,* T4, T6 and T5 recorded comparatively lesser population such as 2.92, 2.58 and 2.25 mirid bugs/ten plants over control (4.83 mirid bugs/ten plants) respectively (Table 7).

Second season (August – December 2019)

The pretreatment population of mirid bugs ranged from 2.67 to 3.33 numbers/ten plants. After two rounds of spraying, the mean population of mirid bugs/ten plants was highest in the untreated control (3.92 mirid bugs/ten plants). T1 recorded 2.92 mirid bugs/ten plants. T2 and T3 recorded 2.58 and 2.25 mirid bugs/ten plants respectively. The standard checks *viz.,* T4, T6 and T5 recorded comparatively lower populations such as 1.92, 1.58 and 1.25 mirid bugs/ten plants than the control (3.92 mirid bugs/ten plants) (Table 8).

Similar findings on the safety of insecticides on mirid

Table 3. Field efficacy of ethiprole (10.7 %) + pymetrozine (40 %) WG against *S. furcifera* (August – December 2018)

Tr. no.	Treatments	Number of white-backed planthopper per hill* (First application)					Number of white-backed planthopper per hill* (Second application)				Pooled mean	Percent reduction over control
		PTC	3 DAT	7 DAT	10 DAT	14 DAT	3 DAT	7 DAT	10 DAT	14 DAT		
T1	Ethiprole (10.7 %) + pymetrozine (40 %) WG @ 36.91 + 138 g a.i ha^{-1}	9.67 (3.27)	6.33 $(2.71)^{de}$	4.67 $(2.38)^{de}$	3.33 $(2.08)^{de}$	4.00 $(2.24)^{cde}$	3.67 $(2.15)^{cde}$	3.33 $(2.08)^{cde}$	2.67 $(1.91)^{de}$	2.33 $(1.82)^{cd}$	3.79	71.31
T2	Ethiprole (10.7 %) + pymetrozine (40 %) WG @ 40.13 + 150 g a.i ha^{-1}	10.00 (3.31)	3.33 $(2.08)^{ab}$	2.33 $(1.82)^{ab}$	1.67 $(1.63)^{ab}$	2.00 $(1.72)^{ab}$	1.67 $(1.63)^{b}$	0.67 $(1.28)^{ab}$	0.33 $(1.14)^{ab}$	0.00 $(1.00)^{a}$	1.50	88.64
T3	Ethiprole (10.7 %) + pymetrozine (40 %) WG @ 45.47 + 170 g a.i ha^{-1}	9.33 (3.21)	2.67 $(1.91)^{a}$	2.00 $(1.73)^{a}$	1.33 $(1.52)^{a}$	1.67 $(1.63)^{a}$	1.00 $(1.38)^{a}$	0.33 $(1.14)^{a}$	0.00 $(1.00)^{a}$	0.00 $(1.00)^{a}$	1.13	91.44
T4	Market Std. Check Pymetrozine (50 %) WG @ 150 g a.i ha^{-1}	9.00 (3.16)	4.67 $(2.38)^{c}$	3.33 $(2.08)^{bc}$	2.33 $(1.82)^{bc}$	3.00 $(1.99)^{abc}$	2.67 $(1.91)^{bc}$	2.33 $(1.82)^{c}$	1.33 $(1.52)^{c}$	1.00 $(1.38)^{b}$	2.58	80.46
T5	Market Std. Check Buprofezin (25 %) SC @ 200 g a.i ha^{-1}	10.00 (3.31)	6.67 $(2.77)^{ef}$	5.00 $(2.44)^{def}$	4.33 $(2.31)^{e}$	4.67 $(2.38)^{def}$	4.33 $(2.31)^{def}$	4.00 $(2.23)^{def}$	3.33 $(2.08)^{def}$	3.00 $(1.99)^{cde}$	4.42	66.54
T6	Market Std. Check Ethiprole 40 %+ Imidacloprid 40 % WG @ 50 + 50 g a.i ha^{-1}	9.33 (3.21)	5.33 $(2.52)^{cd}$	4.33 $(2.31)^{cd}$	3.00 $(2.00)^{d}$	3.67 $(2.16)^{abcd}$	3.33 $(2.08)^{cd}$	3.00 $(2.00)^{cd}$	2.33 $(1.82)^{cd}$	2.00 $(1.73)^{bc}$	3.37	74.49
T7	Un treated control	9.00 (3.16)	9.33 $(3.21)^{g}$	9.67 $(3.27)^{g}$	11.67 $(3.56)^{f}$	13.00 $(3.74)^{g}$	13.67 $(3.83)^{g}$	14.67 $(3.96)^{g}$	16.00 $(4.12)^{g}$	17.67 $(4.32)^{f}$	13.21	-
	SE(d)	0.12	0.10	0.11	0.11	0.16	0.15	0.13	0.14	0.16	-	-
	CD (P=0.05)	NS	0.22	0.24	0.25	0.34	0.33	0.29	0.31	0.35	-	-

*Mean of three replications; Values in parenthesis are angular transformed values; In a column means followed by a common letter are not significantly different by DMRT(P=0.05); SE(d) - Standard error of difference, CD - Critical difference, NS - Non significant, DAT - Days after treatment, PTC – Pretreatment count

Table 4. Field efficacy of ethiprole (10.7 %) + pymetrozine (40 %) WG against *S. furcifera* (August – December 2019)

Tr.no.	Treatments	Number of white-backed planthopper per hill* (First application)					Number of white-backed planthopper per hill* (Second application)				Pooled mean	Percent reduction over control
		PTC	3 DAT	7 DAT	10 DAT	14 DAT	3 DAT	7 DAT	10 DAT	14 DAT		
T1	Ethiprole (10.7 %) + pymetrozine (40 %) WG @ 36.91 + 138	11.33 (3.83)	8.33 $(3.05)^{e}$	6.33 $(2.71)^{de}$	4.67 $(2.38)^{cd}$	5.00 $(2.45)^{bcd}$	3.67 $(2.16)^{cde}$	3.00 $(2.00)^{de}$	2.33 $(1.82)^{cde}$	1.67 $(1.63)^{de}$	4.38	67.65
T2	Ethiprole (10.7 %) + pymetrozine (40 %) WG @ 40.13 + 150	10.67 (3.83)	5.33 $(2.52)^{ab}$	3.67 $(2.16)^{b}$	2.33 $(1.82)^{a}$	3.00 $(2.00)^{a}$	1.67 $(1.63)^{ab}$	1.33 $(1.52)^{ab}$	0.67 $(1.28)^{ab}$	0.33 $(1.14)^{ab}$	2.29	83.09
T3	Ethiprole (10.7 %) + pymetrozine (40 %) WG @ 45.47 + 170	11.00 (3.65)	4.67 $(2.38)^{a}$	2.67 $(1.91)^{a}$	2.00 $(1.73)^{b}$	2.33 $(1.82)^{ab}$	1.33 $(1.52)^{a}$	1.00 $(1.41)^{a}$	0.33 $(1.14)^{a}$	0.00 $(1.00)^{a}$	1.79	86.78
T4	Market Std. Check Pymetrozine (50 %) WG @ 150 g a.i ha^{-1}	11.67 (3.78)	6.33 $(2.70)^{bc}$	4.67 $(2.38)^{bc}$	3.33 $(2.08)^{bc}$	3.67 $(2.16)^{abc}$	2.67 $(1.91)^{bc}$	1.67 $(1.63)^{abc}$	1.33 $(1.52)^{bc}$	1.00 $(1.41)^{c}$	3.08	77.25
T5	Market Std. Check Buprofezin (25 %) SC @ 200 g a.i ha^{-1}	11.33 (3.74)	8.67 $(3.11)^{ef}$	6.67 $(2.77)^{ef}$	5.00 $(2.44)^{cde}$	5.33 $(2.52)^{cde}$	4.33 $(2.31)^{def}$	3.33 $(2.08)^{def}$	2.67 $(1.91)^{def}$	2.33 $(1.82)^{de}$	4.79	64.62
T6	Market Std. Check Ethiprole (40 %) + imidacloprid (40 %) WG @ 50 + 50 g a.i ha^{-1}	10.67 (3.70)	6.67 $(2.77)^{cd}$	5.33 $(2.52)^{cd}$	3.67 $(2.16)^{cdef}$	4.00 $(2.24)^{cdef}$	3.33 $(2.08)^{cd}$	2.67 $(1.91)^{de}$	1.67 $(1.63)^{cd}$	1.33 $(1.52)^{cd}$	3.58	73.56
T7	Un treated control	11.00 (3.79)	11.67 $(3.56)^{g}$	12.00 $(3.60)^{g}$	12.67 $(3.70)^{g}$	13.33 $(3.79)^{g}$	14.00 $(3.87)^{g}$	14.33 $(3.91)^{g}$	15.00 $(4.00)^{g}$	15.33 $(4.04)^{f}$	13.54	-
	SE(d)	0.09	0.11	0.11	0.12	0.16	0.13	0.11	0.15	0.11	-	-
	CD (P=0.05)	NS	0.24	0.23	0.26	0.34	0.28	0.25	0.34	0.25	-	-

*Mean of three replications; Values in parenthesis are angular transformed values; In a column means followed by a common letter are not significantly different by DMRT(P=0.05); SE(d) - Standard error of difference; CD - Critical difference; NS - Non significant; DAT - Days after treatment; PTC – Pretreatment count

Table 5. Field efficacy of ethiprole (10.7 %) + pymetrozine (40 %) WG on spiders in rice eco system (August – December 2018)

Tr.no	Treatments	Spiders population / 10 plants (First application)			Spiders population / 10 plants (Second application)		Mean
		PTC	7 DAT	14 DAT	7 DAT	14 DAT	
T_1	Ethiprole (10.7 %) + pymetrozine (40 %) WG @ 36.91 + 138 g a.i ha^{-1}	7.33 (2.89)	6.67 (2.77)	7.00 (2.83)	6.67 (2.77)	7.67 (2.94)	7.00
T_2	Ethiprole (10.7 %) + pymetrozine (40 %) WG @ 40.13 + 150 g a.i ha^{-1}	6.67 (2.77)	6.33 (2.70)	6.67 (2.77)	6.00 (2.65)	7.00 (2.83)	6.50
T_3	Ethiprole (10.7 %) + pymetrozine (40 %) WG @ 45.47 + 170 g a.i ha^{-1}	7.33 (2.87)	6.00 (2.64)	6.33 (2.71)	5.67 (2.58)	6.67 (2.77)	6.17
T_4	Market Std. Check Pymetrozine (50 %) WG @ 150 g a.i ha^{-1}	6.33 (2.70)	5.67 (2.58)	6.00 (2.64)	5.33 (2.52)	6.33 (2.71)	5.83
T_5	Market Std. Check Buprofezin (25 %) SC @ 200 g a.i ha^{-1}	7.00 (2.83)	4.67 (2.37)	5.00 (2.44)	4.33 (2.31)	5.33 (2.52)	4.83
T_6	Market Std. Check Ethiprole 40 %+ Imidacloprid 40 % WG @ 50 + 50 g a.i ha^{-1}	6.67 (2.76)	5.00 (2.44)	5.67 (2.58)	5.00 (2.44)	6.00 (2.64)	5.42
T_7	Control	6.67 (2.76)	7.00 (2.83)	7.33 (2.89)	7.67 (2.94)	8.00 (3.00)	7.50
	SE(d)	0.18	0.16	0.12	0.10	0.10	-
	CD (P=0.05)	NS	NS	0.25	0.23	0.22	-

*Mean of three replications; Values in parenthesis are angular transformed values; In a column means followed by a common letter are not significantly different by DMRT(P=0.05); SE(d) - Standard error of difference, CD - Critical difference, NS- Non significant, DAT - Days after treatment, PTC – Pretreatment count

Table 6. Field efficacy of ethiprole (10.7 %) + pymetrozine (40 %) WG on spiders in rice eco system (August – December 2019)

Tr.no	Treatments	Spiders population / 10 plants (First application)			Spiders population / 10 plants (Second application)		Mean
		PTC	7 DAT	14 DAT	7 DAT	14 DAT	
T_1	Ethiprole (10.7 %) + pymetrozine (40 %) WG @ 36.91 + 138 g a.i ha^{-1}	4.67 (2.38)	3.33 (2.08)	4.33 (2.31)	4.00 (2.24)	5.00 (2.44)	4.17
T_2	Ethiprole (10.7 %) + pymetrozine (40 %) WG @ 40.13 + 150 g a.i ha^{-1}	4.00 (2.23)	2.67 (1.91)	4.00 (2.24)	3.67 (2.16)	4.67 (2.38)	3.75
T_3	Ethiprole (10.7 %) + pymetrozine (40 %) WG @ 45.47 + 170 g a.i ha^{-1}	4.33 (2.31)	2.00 (1.73)	3.33 (2.08)	3.00 (2.00)	4.33 (2.31)	3.17
T_4	Market Std. Check Pymetrozine (50 %) WG @ 150 g a.i ha^{-1}	4.33 (2.31)	1.67 (1.63)	3.00 (2.00)	2.67 (1.91)	4.00 (2.24)	2.84
T_5	Market Std. Check Buprofezin (25 %) SC @ 200 g a.i ha^{-1}	4.67 (2.38)	1.00 (1.41)	2.33 (1.82)	2.00 (1.72)	3.33 (2.08)	2.17
T_6	Market Std. Check Ethiprole 40 %+ Imidacloprid 40 % WG @ 50 + 50 g a.i ha^{-1}	4.33 (2.30)	1.33 (1.52)	2.67 (1.91)	2.33 (1.82)	3.67 (2.16)	2.50
T_7	Control	4.33 (2.31)	4.67 (2.38)	5.00 (2.44)	5.33 (2.52)	5.67 (2.58)	5.17
	SE(d)	0.14	0.12	0.12	0.12	0.11	-
	CD (P=0.05)	NS	0.25	0.26	0.27	0.24	-

*Mean of three replications; Values in parenthesis are angular transformed values; In a column means followed by a common letter are not significantly different by DMRT(P=0.05); SE(d) - Standard error of difference, CD - Critical difference, NS - Non significant, DAT - Days after treatment, PTC – Pretreatment count

Table 7. Field Efficacy of ethiprole (10.7 %) + pymetrozine (40 %) WG on mirid bugs in rice eco system (August – December 2018)

Tr.no	Treatments	Number of mirid bugs / 10 hill (First application)			Number of mirid bugs / 10 hill (Second application)		Mean
		PTC	7 DAT	14 DAT	7 DAT	14 DAT	
T_1	Ethiprole (10.7 %) + pymetrozine (40 %) WG @ 36.91 + 138 g a.i ha^{-1}	4.33 (2.31)	3.67 (2.16)	4.00 (2.23)	3.33 (2.08)	4.67 (2.38)	3.92
T_2	Ethiprole (10.7 %) + pymetrozine (40 %) WG @ 40.13 + 150 g a.i ha^{-1}	4.00 (2.23)	3.33 (2.08)	3.67 (2.16)	3.00 (2.00)	4.33 (2.31)	3.58
T_3	Ethiprole (10.7 %) + pymetrozine (40 %) WG @ 45.47 + 170 g a.i ha^{-1}	4.33 (2.29)	3.00 (2.00)	3.33 (2.08)	2.67 (1.91)	4.00 (2.24)	3.25
T_4	Market Std. Check Pymetrozine (50 %) WG @ 150 g a.i ha^{-1}	4.33 (2.31)	2.67 (1.91)	3.00 (2.00)	2.33 (1.82)	3.67 (2.16)	2.92
T_5	Market Std. Check Buprofezin (25 %) SC @ 200 g a.i ha^{-1}	4.00 (2.23)	2.00 (1.72)	2.33 (1.82)	1.67 (1.63)	3.00 (2.00)	2.25
T_6	Market Std. Check Ethiprole 40 %+ Imidacloprid 40 % WG @ 50 + 50 g a.i ha^{-1}	4.33 (2.29)	2.33 (1.82)	2.67 (1.91)	2.00 (1.73)	3.33 (2.08)	2.58
T_7	Control	4.00 (2.22)	4.33 (2.31)	4.67 (2.38)	5.00 (2.44)	5.33 (2.52)	4.83
	SE(d)	0.20	0.12	0.12	0.12	0.09	-
	CD (P=0.05)	NS	0.27	0.27	0.27	0.21	-

*Mean of three replications; Values in parenthesis are angular transformed values; In a column means followed by a common letter are not significantly different by DMRT(P=0.05); SE(d) - Standard error of difference; CD - Critical difference; NS - Non significant; DAT - Days after treatment; PTC – Pretreatment count

Table 8. Field Efficacy of ethiprole (10.7 %) + pymetrozine (40 %) WG on mirid bugs in rice eco system (August – December 2019)

Tr. no	Treatments	Number of mirid bugs / 10 hill (First application)			Number of mirid bugs / 10 hill (Second application)		Mean
		PTC	7 DAT	14 DAT	7 DAT	14 DAT	
T_1	Ethiprole (10.7 %) + pymetrozine (40 %) WG @ 36.91 + 138 g a.i ha^{-1}	3.33 (2.08)	2.67 (1.91)	3.00 (2.00)	2.33 (1.82)	3.67 (2.16)	2.92
T_2	Ethiprole (10.7 %) + pymetrozine (40 %) WG @ 40.13 + 150 g a.i ha^{-1}	3.00 (1.99)	2.33 (1.82)	2.67 (1.91)	2.00 (1.73)	3.33 (2.08)	2.58
T_3	Ethiprole (10.7 %) + pymetrozine (40 %) WG@ 45.47 + 170 g a.i ha^{-1}	3.33 (2.08)	2.00 (1.73)	2.33 (1.82)	1.67 (1.63)	3.00 (2.00)	2.25
T_4	Market Std. Check Pymetrozine (50 %) WG @ 150 g a.i ha^{-1}	2.67 (1.91)	1.67 (1.63)	2.00 (1.73)	1.33 (1.52)	2.67 (1.91)	1.92
T_5	Market Std. Check Buprofezin (25 %) SC @ 200 g a.i ha^{-1}	3.33 (2.08)	1.00 (1.41)	1.33 (1.52)	0.67 (1.28)	2.00 (1.73)	1.25
T_6	Market Std. Check Ethiprole 40 %+ Imidacloprid 40 % WG @ 50 + 50 g a.i ha^{-1}	2.67 (1.91)	1.33 (1.52)	1.67 (1.63)	1.00 (1.41)	2.33 (1.82)	1.58
T_7	Control	3.00 (1.99)	3.33 (2.08)	3.67 (2.16)	4.00 (2.24)	4.67 (2.38)	3.92
	SE(d)	0.16	0.08	0.12	0.13	0.10	-
	CD (P=0.05)	NS	0.18	0.26	0.28	0.23	-

*Mean of three replications; Values in parenthesis are angular transformed values; In a column means followed by a common letter are not significantly different by DMRT(P=0.05); SE(d) - Standard error of difference; CD - Critical difference; NS - Non significant; DAT - Days after treatment; PTC – Pretreatment count

Table 9. Effect of ethiprole (10.7 %) + pymetrozine (40 %) WG on rice yield

Tr.no	Treatments	Yield kg ha^{-1}	
		Season I (Aug – Dec 2018)	**Season II (Aug – Dec 2019)**
T_1	Ethiprole (10.7 %) + pymetrozine (40 %) WG @ 36.91 + 138 g a.i ha^{-1}	3066.67 (55.37)^{c}	2883.33 (53.69)^{d}
T_2	Ethiprole (10.7 %) + pymetrozine (40 %) WG @ 40.13 + 150 g a.i ha^{-1}	4000.00 (63.22)^{b}	3918.00 (62.60)^{b}
T_3	Ethiprole (10.7 %) + pymetrozine (40 %) WG @ 45.47 + 170 g a.i ha^{-1}	4123.33 (64.17)^{a}	4000.67 (63.24)^{a}
T_4	Market Std. Check Pymetrozine (50 %) WG @ 150 g a.i ha^{-1}	2800.00 (52.85)^{d}	3183.33 (56.40)^{c}
T_5	Market Std. Check Buprofezin (25 %) SC @ 200 g a.i ha^{-1}	2033.33 (44.99)^{f}	2070.00 (45.49)^{f}
T_6	Market Std. Check Ethiprole 40 %+ Imidacloprid 40 % WG @ 50 + 50 g a.i ha^{-1}	2426.67 (49.16)^{e}	2516.67 (50.14)^{e}
T_7	Control	1500.00 (38.61)^{g}	1400.00 (37.39)^{g}
	SE(d)	2.75	1.55
	CD (P=0.05)	6.06	3.42

Mean of three replications; Values in parentheses are square root transformed values; In a column means followed by a common letter are not significantly different by DMRT (P=0.05); SE(d) - Standard error of difference, CD - Critical difference

bugs were in accordance with earlier workers where ethiprole10SC@ 25 g a.i. ha^{-1} was found to be the least toxic to *C. lividipennis* (Kumaran *et al*., 2009). Jhansi Lakshmi *et al.* (2010) reported that pymetrozine@125 g a.i. ha-1 exhibited less toxicity to mirid bugs and pymetrozine@ 400 g a.i. ha^{-1} has fewer adverse effects on mirid bugs (Murali *et al*., 2009). Pymetrozine 50WG and ethiprole 10SC as a seperate product doesn't have an adverse effect on the natural enemies. Likewise, the combination of ethiprole and pymetrozine also proved to be safer for the miridbugs in the rice ecosystems.

Yield

The highest yields of 4123.33 and 4000.67 kg ha^{-1} were recorded in T3 and T2 treated plots at 4000.00 and 3918.00 kg ha^{-1} in season I and season II respectively (Table 9).

The results were in line with the previous studies where pymetrozine 50WG@ 0.5g/l recorded highest yield of paddy (BPT 5204) (Deekshita and Ramarao, 2018). Ranjith Kumar *et al.,* 2017 reported that pymetrozine 50WG@ 400g/ha resulted in higher grain yield.

Conclusion

The present investigation revealed that the combination of ethiprole (10.7 %) + pymetrozine (40 %) WG is a new potential insecticide and is effective against white-backed planthoppers (*S. furcifera*) in rice (ADT–46). So, we hope that this compound can be included in the spray schedule of rice to manage the white-backed planthopper.

ACKNOWLEDGEMENTS

The authors are grateful to the Department of Entomology, Faculty of Agriculture, Annamalai University, Chidambaram., Tamil Nadu, India for providing facilities to conduct this experiment and Crystal Crop Company for providing financial assistance.

Conflicts of interest

The authors declare that they have no conflicts of interests.

REFERENCES

1. Bambawale, O.M., Venkateswaralu, B. & Virktamath, B.C. (2011). Surviellance plan and procedure, Manual for Rice Pest Suveillance, 49 pp.
2. Bhanu, K.V. (2015). Bioefficacy of Pymetrozine 50 WG against Brown Planthopper, *Nilaparvata lugens* and white-backed planthopper, *Sogatella furcifera* in rice, *Journal of Rice Research*, 8(2), 64-70.
3. Cheng, X.N., Wu, J.C. & Ma, F. (2003). Research and prevention of the brown planthopper. Chinese Agricultural Press, Beijing, China, p. 52-55.
4. Deekshita, K. & Rama Rao, C.V. (2018). Pymetrozine: A Pyridine Azomethine insecticide for management of rice brown planthopper in India, *Chemical Science Review and Letters*,7(25), 335-339.
5. Deekshita, K., Rama Rao, C.V., Sandhya Rani, C. & Prasanna Kumari, V. (2017). Effect of new insecticide molecules on predators of rice ecosystem, *Journal of Entomology and Zoology Studies,* 5(4), 1617-1620.
6. Dhaliwal, G.S., Jindal, V. & Dhawan, A.K. (2010). Insect

pest problems and crop losses: changing trends, *Indian Journal of Ecology*, 37(1), 1-7.
7. Duncan, D.B. (1951). A significance test for differences between ranked treatment means in an analysis of variance. *The Virginia Journal of Science*, 2, 171-189.
8. European patent application (2012). Retrieved from https://patentimages.storage.googleapis.com/29/df/90/69be13ae58088d/EP2422620A1.pdf.
9. Fishel, F.M. (2007). Pesticide Use Trends in the U.S.: Global Comparison; Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida: Gainesville, FL, USA, 3 pp.
10. Fluckiger, C.R., Kristinsson, H., Senn, R., Rindlisbacher, A., Buholzer, H. & Voss, G. (1992a). CGA 215–944 - a novel agent to control aphids and whiteflies. Proceedings 1992 Brighton Crop Protectioin Conference - Pests and diseases, 1, 43–50.
11. Fluckiger, C.R., Senn, R. & Buholzer, H. (1992b) CGA 215–944-opportunities for use in vegetables. Proceedings 1992 Brighton Crop Protection Conference - Pests and diseases, 3, 1187–1192.
12. Food Safety Commission (2004), Pesticides Expert Committee. Retrieved from https://www.fsc.go.jp/english/ethiprole_fullreport.pdf.
13. Gomez, A. A. & Gomez, K. A. (1984). Statistical procedures for agricultural research. Statistical Procedures for Agricultural Research, 6, 680 pp.
14. Henderson, C.F. & Tilton, E.W. (1955). Tests with acaricides against the brown wheat mite, *Pterobia lateens* (Muller), *Journal of Economic Entomology*, 48(2), 157-161.
15. Hu, G., Lu, M., Tuan, H., Liu, W., Xie, M., McInerney, C. & Zhai, B. (2017). Population dynamics of rice planthoppers, Nilaparvata lugens and Sogatella furcifera (Hemiptera, Delphacidae) in Central Vietnam and its effects on their spring migration to China, *Bulletin of Entomological Research*, 107(3), 369-381. doi:10.1017/S00074853 1600 1024.
16. Jhansi Lakshmi, V., Krishnaiah, N.V. & Katti, G.R. (2010). Potential toxicity of selected insecticides to rice leafhoppers and planthoppers and their important natural enemies, *Journal of Biological Control*, 24(3), 244–252.
17. Karunaratnel, S.H.P.P., Weerakoon, K.C., Nugaliyadda, L. & Manuweera. G.K. (2007). Susceptibility of rice insect pests and their natural enemies, *Journal of Natural Science and Foundation*, 35(2), 97-102.
18. Kulshreshtha, J.P. (1974). Field problems in 1974. 2. White-backed planthopper epidemic in Kerala (India), *Rice Entomological Newsletter*, 1, 3-4.
19. Kumaran, N., Vinoth Kumar, B., Boomathi, N., Kuttala, S. & Gunasekaran K. (2009). Nontarget effect of ethiprole 10 SC to predators of rice planthoppers, *Madras Agricultural Journal*, 96(1-6), 208-212.
20. Kumaran, N., Vinothkumar, B., Srinivasan, T. & Kuttalam, S. (2007) Bioefficacy of ethiprole 10 EC to brown planthopper, *Nilaparvata lugens* (Stal) (Homoptera: Delphacidae) in rice, *Pestology*, 31(11), 22-25.
21. Mahmood, I., Imadi, S., Shazadi, K., Gul, A. & Hakeem, K. (2015). Effects of Pesticides on Environment in Plant, Soil and Microbes, Springer International Publishing, Switzerland. Doi:10.1007/978-3-319-27455-3_13.
22. Misra, H.P. (2008). Field evaluation of some newer molecules against the white-backed planthopper, *Sogatella furcifera* (Horvath), *Oryza*, 45(4), 339- 341.
23. Murali, B.R.K., Suresh, K., Rajavel, D.S. & Palanisamy, N. (2009). Field efficacy of pymetrozine 50 WG against rice brown planthopper, *Nilaparvata lugens* (Homoptera: Delphacidae), *Pestology*, 33(5), 20-21.
24. Panse, V.G. & Sukkatme, P.V. (1957), Statistical Methods for agricultural workers, I.C.A.R, New Delhi. 361 pp.
25. Patel, S.K., Rajeswari, B. & Krishnaveni, D. (2018). Efficacy of insecticides against rice tungro disease and its vector (*Nephotettix virescens*) under glasshouse conditions, *Agricultural Science Digest*, 38(3), 225-227. DOI: 10.18805/ag.D-4728.
26. Rama Gopala Varma, N., Zaheruddeen, S.M., Bhavani, B. & Rao, P.R.M. (2003). Efficacy of certain new insecticides against rice planthoppers under field conditions, *Indian Journal of Plant Protection*, 31(2), 31-33.
27. Ranjith Kumar, E., Guruprasad, G.S., Arun Kumar Hosamani, Srinivas, A.G. and Pramesh D. (2017). Bioefficacy of novel insecticides against planthoppers in direct seeded rice, *Plant Archives*, 17(2), 1047-1051.
28. Sandeep Kumar, Lakhi Ram, Ankit Kumar, Yadav, S.S., Banvir Singh & Deepika Kalkal. (2015). Biology of white-backed plant hopper, *Sogatella furcifera* on basmati rice under agroclimatic condition of Haryana, *Agricultural Science Digest*, 35(2), 142-145. Doi: 10.5958/0976-0547.2015.00026.9
29. Sardar, M., Khatun, R., Shariful Islam, K., Haque, T. & Jahan M. (2019). Time oriented mortality of brown planthopper, nilaparvata lugens by some new chemistry insecticides, *International Journal of Entomology Research*, 4(5), 54-57.
30. Schreinemachers, P., Chen, H., Nguyen, T., Buntong, B., Bouapaoe, L., Gautam, S., Le, N., Pinn, T., Vilaysone, P. & Srinivasan, R. (2017). Too much to handle? Pesticide dependence of smallholder vegetable farmers in Southeast Asia, *Science of the Total Environment*, 593–594,470 -477.Doi:http://dx.doi.org/10.1016/j.scitotenv.2017.03.1 81
31. Seni, A. & Naik, B.S. (2017). Evaluation of some insecticides against brown plant hopper, *Nilaparvata lugens* (Stal) in rice, *Oryza sativa* L. *International Journal of Bioresource and Stress Management*, 8(2), 268-271. Doi: http://dx.doi.org/10.23910/IJBSM/2017.8.2.1685
32. Singh, R., Kumari, N., Paul, V. & Kumar, S. (2018). Bioefficacy of novel insecticides and pymetrozine (50 %) WG against insect pest of paddy, *International Journal of Plant Protection*, 11(1), 23-29. Doi:10.15740/HAS/IJPP/11.1/23-29.
33. Zainab, S. & Singh, R.N. (2016). Bioefficacy of combination insecticides against brown plant hopper, *Nilaparvata lugens* (stal) and rice gundhibug, *Leptocorisa varicornis* (fabr) in rice, *International Journal of Agricultural and Statistical Science*, 12(1), 29-33.