FLUORIDE

Quarterly Journal of The International Society for Fluoride Research Inc.

Bioefficacy of Fipronil 5% SC and Entomopathogenic Fungi against Spiralling Whitefly, *Aleurodicus Dispersus* Russell (Aleyrodidae: Hemiptera) infesting Guava Trees Under Open Field Conditions

Unique digital address (Digital object identifier [DOI] equivalent):
https://www.fluorideresearch.online/epub/files/304.pdf

E KAVIYA[1], V AMBETHGAR[1*], R CHANDRALEKA[1], A ANNAMALAI[2] VP SANTHI[3], S GEETHANJALI[4], P YASODHA[5], A.KALYANASUNDARAM[1]

[1] Department of Entomology, Anbil Dharmalingam Agricultural College and Research Institute, Tamil Nadu Agricultural University, Tiruchirappalli-620 027, India

[2] Department of Entomology, Nalanda College of Agriculture, Tamil Nadu Agricultural University, Tiruchirappalli-, India,

[3]Department of Horticulture, Anbil Dharmalingam Agricultural College and Research Institute, Tamil Nadu Agricultural University, Tiruchirappalli-620 027, India

[4] Department of Crop Physiology and Biochemistry, Anbil Dharmalingam Agricultural College and Research Institute, Tamil Nadu Agricultural University, Tiruchirappalli-620 027, India

[5] Department of Crop Protection, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Tiruchirappalli-620 027, India

***Corresponding author:**

Dr. V. Ambethgar
Professor and Head,
Department of Entomology
Anbil Dharmalingam Agricultural College and Research Institute, Tamil Nadu Agricultural University, Tiruchirappalli, Tamil Nadu, India
Phone: (+91) 9442875303
E-mail: drva1965@gmail.com

Accepted: 2024 Nov 23
Published: 2024 Nov 25

ABSTRACT

Purpose: The spiralling whitefly, *Aleurodicus dispersus* Russell (Homoptera: Aleyurodidae) is an exotic pest which have reported to caused havoc on a wide range of crops including guava. The present study was to evaluate the effectiveness of Fipronil 5% SC, a fluoride-based insecticide and two entomopathogenic fungi (*Beauveria bassiana, Metarhizium anisopliae*) both individually and in combination treatments for the control of spiralling whitefly, *Aleurodicus dispersus* in guava orchards under open field condition.

Methods: The study was conducted in a 10-year-old guava orchard at the Horticultural College and Research Institute, Tiruchirappalli using a Randomized Block Design with seven treatments each replicated three times. Treatments included Fipronil 5% SC, *Beauveria bassiana* ($1*10^9$cfu), *Metarhizium anisopliae* ($1*10^9$cfu) and their combinations. Pre- and post-treatment assessments were made on spiralling whitefly populations at 1, 3, 5, 7 and 10 days after spraying. Data were analyzed using ANOVA with square root and angular transformations. Efficacy was measured by percent reduction in pest population.

Results: Foliar sprays of Fipronil 5% SC reduced spiralling whitefly populations by 100% at 10 days after spraying (DAS), while *Beauveria bassiana* ($1*10^9$cfu) and *Metarhizium anisopliae* ($1*10^9$cfu) achieved 84% and 80.68% reductions respectively. Combining these fungi with sublethal doses of Fipronil enhanced control reaching up to 95.32% reduction. The study demonstrates the potential for integrating chemical insecticide and biological agents with synergistic action in managing spiralling whitefly.

Conclusions: Using Fluoride based insecticide-Fipronil 5% SC as synergists of *Beauveria bassiana* ($1*10^9$cfu) and *Metarhizium anisopliae* ($1*10^9$cfu) could provide effective control of insect populations by increasing the effectiveness of the pathogen while simultaneously reducing insecticide inputs and helping to prolong their usefulness for the sustainable management of spiralling whitefly infestations in guava ecosystem.

Key-words: *Fipronil; Beauveria bassiana; Metarhizium anisopliae;*

Aleurodicus dispersus; Synergistic action, Sustainable pest management.

INTRODUCTION

The spiralling whitefly, *Aleurodicus dispersus* Russell (Hemiptera: Aleyrodidae) is a major pest infesting tropical and subtropical regions around the world causing significant damage to a wide range of host plants [1,2]. These insects feed on plant sap leading to chlorosis, leaf drop and decreased plant vigour [3,4]. The spiralling whitefly also secretes honeydew promoting sooty mould development which further impairs photosynthesis and market value of fruits [5,6]. Management of spiralling whitefly populations in open field conditions is challenging task due to their ubiquitous behaviour, polyphagous nature, high reproductive rate, short generation time, rapid evolution of resistance to insecticides and the relatively protected location of the individuals on the underside of the leaves contribute to its survival and dominance in the agroecosystem [7]. According to the principles of Integrated Pest Management (IPM), pesticides should be considered a last resort for farmers to be used only when all other pest control methods have proven ineffective in managing crop infestation [8]. In recent decades, numerous new fluoride-containing insecticides and other pesticides have been developed, driven by advancements in fluoro-organic chemistry and the growing need to combat metabolic resistance [9]. Fluoride-containing compounds are at the forefront of advancements in the life science industry with a growing number of selectively fluorinated molecules achieving commercial success as crop protection products due to their significantly enhanced potency compared to non-fluorinated analogs [10]. Traditional, regular and repeated use of chemical control methods often lead to resistance development in target pests, environmental concerns and public health associated risks [11]. To address this, we attempt on the testing of a fluoride-based insecticide- Fipronil 5% SC, a phenyl-pyrazole compound operates by disrupting neural transmission in the central nervous system of invertebrates has been reported to be effective against sucking pests like whitefly in cotton [12] and the use of entomopathogenic fungi (EPF) such as (*Beauveria bassiana*, *Metarhizium anisopliae*) offers several benefits including improved pest control effectiveness, a reduction in the need for insecticide applications, minimizing environmental contamination risks and lowering the chances of pests developing resistance [13]. Certain chemical insecticides that are compatible with entomopathogenic fungi and other biological control agents can be applied in various combinations to offer safe and effective insect pest management [14,15]. Joint application of insecticides and fungal biological agents have gained interest for their potential in integrated pest management approaches. The present study aimed to evaluate the effectiveness of fluoride-based insecticide- Fipronil 5% SC- and two selected entomopathogenic fungi- *Beauveria bassiana* and *Metarhizium anisopliae,* both individually and in combination treatments for the control of spiralling whitefly in guava orchards.

MATERIAL AND METHODS

Study area and experimental design

The experiment was conducted in a 10 year old guava orchard planted with variety Arka Kiran located at the Horticultural College and Research Institute, Tiruchirappalli (10.7554ºN, 78.6054ºE, 279'(85m) above mean sea level), Tamil Nadu, India. In Tiruchirappalli, winter is cold and summer is extremely hot, with an average annual maximum and minimum temperature of about 39.8ºC and 26.5ºC respectively. Mean annual precipitation is about 452.6 mm, which is received from October to December. The soil at the experimental field is non-saline sodic nature (clay 24.5%, silt 7.4% and sand 66.7%) having field capacity of 1/3 of 15 bars and bulk density of 1.28mg m^{-3}.

The orchard had a high natural infestation of spiralling whitefly, *Aleurodicus dispersus* Russell (Hemiptera: Aleyrodidae). The study was laid out in a Randomized Block Design (RBD) with seven treatments, each replicated three times.

Treatment details

The treatments included Fluoride-based insecticide (Fipronil 5% SC- (Regent)) @ 2ml/L; EPF - *Beauveria bassiana* ($1*10^9$cfu) @ 5ml/L; EPF - *Metarhizium anisopliae* ($1*10^9$cfu) @ 5ml/L; *Beauveria bassiana* + Sublethal dose of Fipronil @ (5ml + 0.2 ml/L); *Metarhizium anisopliae* + Sublethal dose of Fipronil
(5 ml + 0.2 ml/L); Treated control and untreated

control. One plant was selected for each treatment and each treatment was replicated thrice. The plants were tagged with waxed labels. Hand operated high volume hydraulic sprayer was used for imposing the treatments.

Spray schedule and pest population assessment

Pre-treatment population counts were taken by examining six randomly selected leaves from each tree for spiralling whitefly adults. Post-treatment assessments were made 1, 3, 5, 7 and 10 days after application. The efficacy of treatments was evaluated based on the reduction in spiralling whitefly populations. Mortality rates were recorded and percent population reduction was calculated using the formula:

$$\text{Percent (\%) Reduction} = \frac{\text{Pre-treatment count} - \text{Post treatment count} \times 100}{\text{Pre-treatment count}}$$

Statistical Analysis

The data recorded on the pest population was tabulated and subjected to the square root transformation by applying the formula SQRT (X +0.5) where "X" denotes the individual pest population under observation. The data recorded on the effect of different treatments was subjected to angular transformation and presented in percent (%) reduction. Then the transformed values were subjected to the statistical analysis of variance (ANOVA). 'F' test was used to determine the significance between the mean values and critical difference (CD) as described by Gomez and Gomez [16].

RESULTS

Results from Table 1 outlines the pre-treatment and post-treatment counts with mean number of surviving populations and percent reduction of spiralling whitefly adults on guava at 1, 3, 5, 7 and 10 days after spraying (DAS) for different treatments.

Effectiveness of Fluoride-Based Insecticide

The fluoride-based insecticide Fipronil 5% SC demonstrated the highest efficacy in reducing the spiralling whitefly population. The number of surviving adults significantly decreased from 35.00 at 1 DAS (Day After Spraying) to 0.00 at 10 DAS, with a mean of 15.87 surviving adults, indicating the most rapid control among all treatments. Additionally, the percent reduction increased from 24.28% at 1 DAS to 100% at 10 DAS, with a mean percent reduction of 65.71% across the observation period. These results underscore Fipronil's superior efficacy over other treatments in effectively controlling spiralling whitefly infestations providing rapid and sustained pest reduction.

Effectiveness of Entomopathogenic Fungi

Beauveria bassiana (1×10^9 cfu) demonstrated moderate efficacy in reducing the spiralling whitefly population with the number of surviving adults decreasing from 38.00 at 1 DAS to 7.33 at 10 DAS and a mean of 21.07 surviving adults. The percent reduction steadily increased from 16.34% at 1 DAS to 84.00% at 10 DAS, with a mean percent reduction of 53.69%, indicating moderate effectiveness. Similarly, *Metarhizium anisopliae* (1×10^9 cfu) showed comparable efficacy, reducing the population from 38.33 at 1 DAS to 9.00 at 10 DAS, with a mean of 22.27 surviving adults. The percent reduction ranged from 17.39% at 1 DAS to 80.68% at 10 DAS, with a mean percent reduction of 52.13% demonstrating a similar level of effectiveness as *Beauveria bassiana*. Both fungal treatments provided a slower but steady reduction in the spiralling whitefly population compared to Fipronil.

Combined Effects of Fluoride-Based Insecticide and Entomopathogenic Fungi

The combination treatments of *Beauveria bassiana* + Sublethal dose of Fipronil and *Metarhizium anisopliae* + Sublethal dose of Fipronil showed significantly better control compared to the fungi alone. For *Beauveria bassiana* + Fipronil, the surviving adult population decreased from 36.00 at 1 DAS to 3.00 at 10 DAS, with a mean of 18.73 surviving adults. The percent reduction increased from 23.42% at 1 DAS to 93.52% at 10 DAS, with a mean percent reduction of 60.00%, indicating a notable improvement over *Beauveria* alone. Similarly, *Metarhizium anisopliae* + Fipronil also demonstrated high efficacy reducing the population from 34.00 at 1 DAS to 2.00 at 10 DAS, with a mean of 17.40 surviving adults. The percent reduction ranged from 21.99% at 1 DAS to 95.32% at 10 DAS, with a mean percent reduction of 59.98% which was comparable to the *Beauveria* combination. These results highlight the strong synergistic effect of combining entomopathogenic fungi with Fipronil, leading to enhanced pest control efficacy.

Comparison with treated and untreated control

The treated control showed consistently high numbers of surviving spiralling whitefly adults, decreasing from 40.67 at 1 DAS to 17.67 at 10 DAS, with a mean of 29.87 surviving adults. The percent reduction was the least among all treatments, starting at 11.62% at 1 DAS and increasing to 61.59% at 10 DAS, with a mean percent reduction of 35.09% which was much lower than Fipronil and fungal treatments.

In contrast, the untreated control showed minimal reduction, starting at 43.33 at 1 DAS and ending at 39.67 at 10 DAS, with a mean of 41.33 surviving adults. The percent reduction ranged from only 2.26% at 1 DAS to 10.58% at 10 DAS with a mean percent reduction of 6.73% indicating that the spiralling whitefly

population remained largely unaffected without treatment. These results emphasize the necessity of active pest management interventions. The above all results are illustrated visually in Figure 1. which provides a clear representation of the efficacy of different treatments on the surviving population and percent reduction after application of treatments.

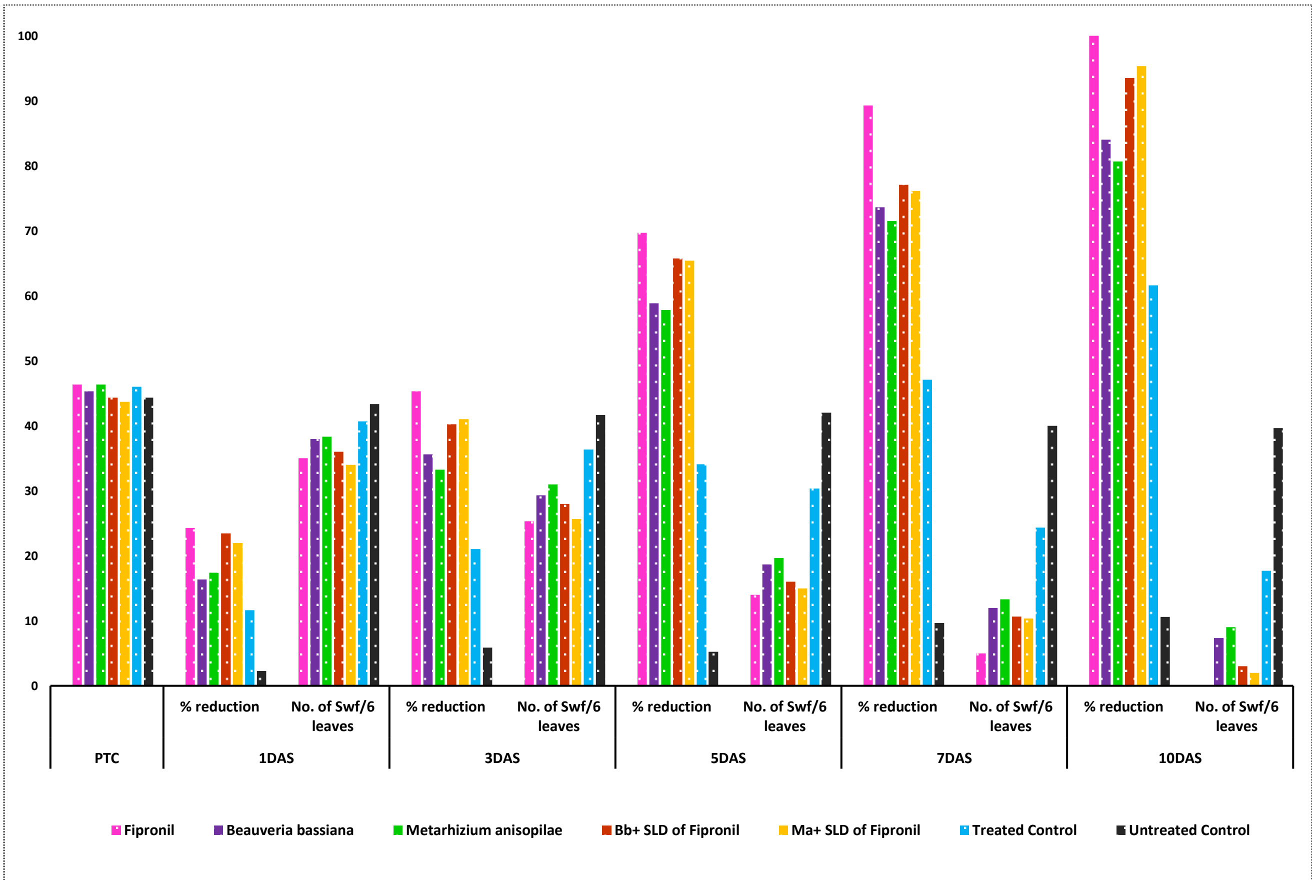

Figure 1. Efficacy of different treatments against guava spiralling whitefly, *Aleurodicus dispersus.*

Table 1. Efficacy of different treatments against guava spiralling whitefly, *Aleurodicus dispersus*

T. No.	Treatments	Pre-treatment count/ 6leaves	1DAS		3DAS		5DAS		7DAS		10DAS		MEAN	
			Surviving no. of adults/ 6leaves	Percent reduction	Surviving no. of adults/ 6leaves	Percent reduction	Surviving no. of adults/ 6leaves	Percent reduction	Surviving no. of adults/ 6leaves	Percent reduction	Surviving no. of adults/ 6leaves	Percent reduction	Surviving no. of adults/ 6leaves	Percent reduction
1.	Fipronil 5% SC @ 2ml/lit	46.33 (6.84)	35.00 (5.96) ^{a}	24.28 (29.52) ^{a}	25.33 (5.08) ^{a}	45.29 (42.29) ^{a}	14.00 (3.81) ^{a}	69.68 (56.58) ^{a}	5.00 (2.35) ^{a}	89.28 (70.89) ^{a}	0.00 (0.71) ^{a}	100.00 (90.00) ^{a}	**15.87**	**65.71**
2.	*B. bassiana* (1*10^{9}cfu) @ 5ml/lit	45.33 (6.77)	38.00 (6.20) ^{b}	16.34 (23.84) ^{b}	29.33 (5.46) ^{b}	35.63 (36.65) ^{b}	18.67 (4.38) ^{b}	58.83 (50.08) ^{b}	12.00 (3.54) ^{b}	73.64 (59.11) ^{b}	7.33 (2.80) ^{b}	84.00 (66.42) ^{c}	**21.07**	**53.69**
3.	*M.anisopliae* (1*10^{9}cfu) @ 5ml/lit	46.33 (6.84)	38.33 (6.23) ^{b}	17.39 (24.64) ^{b}	31.00 (5.61) ^{b}	33.23 (35.20) ^{b}	19.67 (4.49) ^{b}	57.81 (49.49) ^{b}	13.33 (3.72) ^{b}	71.49 (57.73) ^{b}	9.00 (3.08) ^{b}	80.68 (63.92) ^{c}	**22.27**	**52.13**
4.	*Bb* + SLD of Fipronil @ (5+ 0.2 ml/L)	44.00 (6.67)	36.00 (6.04) ^{a}	23.42 (28.94) ^{a}	28.00 (5.34) ^{b}	40.21 (39.35) ^{a}	16.00 (4.06) ^{a}	65.72 (54.16) ^{a}	10.67 (3.34) ^{b}	77.08 (61.39) ^{b}	3.00 (1.87) ^{a}	93.52 (75.25) ^{b}	**18.73**	**60.00**
5.	*Ma* + SLD of Fipronil @ (5+ 0.2 ml/L)	44.33 (6.70)	34.00 (5.87) ^{a}	21.99 (27.96) ^{a}	25.67 (5.12) ^{a}	41.02 (39.83) ^{a}	15.00 (3.94) ^{a}	65.41 (53.97) ^{a}	10.33 (3.29) ^{b}	76.14 (60.76) ^{b}	2.00 (1.58) ^{a}	95.32 (77.50) ^{b}	**17.40**	**59.98**
6.	Treated control	46.00 (6.82)	40.67 (6.42) ^{c}	11.62 (19.93) ^{c}	36.33 (6.07) ^{c}	21.05 (27.31) ^{c}	33.33 (5.55) ^{c}	34.08 (35.71) ^{c}	24.33 (4.98) ^{c}	47.09 (43.33) ^{c}	17.67 (4.26) ^{c}	61.59 (51.70) ^{c}	**29.87**	**35.09**
7.	Untreated control	44.33 (6.70)	43.33 (6.62) ^{d}	2.26 (8.65) ^{d}	41.66 (6.49) ^{d}	5.88 (14.04) ^{d}	42.00 (6.52) ^{d}	5.24 (13.24) ^{d}	40.00 (6.36) ^{d}	9.68 (18.13) ^{d}	39.67 (6.34) ^{d}	10.58 (18.98) ^{d}	**41.33**	**6.73**
	Mean	**45.19**	**37.90**	**16.07**	**31.04**	**31.25**	**22.23**	**50.70**	**16.52**	**63.32**	**11.23**	**75.06**	-	-
	SEd	**2.24**	**2.44**	**3.92**	**2.91**	**5.34**	**2.10**	**3.70**	**1.89**	**3.46**	**1.74**	**2.85**	-	-
	CD (P=0.05)	**NS**	**5.32**	**8.54**	**6.35**	**11.65**	**4.59**	**8.07**	**4.12**	**7.54**	**3.81**	**6.21**	-	-

DAS - Days after spraying

Data on surviving no. of adults are mean values and those in parenthesis are $\sqrt{x+0.5}$ transformed values

Data on the percent reduction are mean values and those in parenthesis are angular transformed values

Figures followed by same letters are on par

NS: Non-significant at 5% level of significance

DISCUSSION

The fluoride-based insecticide Fipronil 5% SC demonstrated a rapid knockdown effect on spiralling whitefly populations by blocking GABA-gated chloride channels in the central nervous system, disrupting neural transmission and leading to quick immobilization and death of the pest [17,18]. Previous studies have similarly highlighted the efficacy of Fipronil against various sucking pests. Fipronil 5% SC at 100 g ai/ha effectively controlled aphids in cotton [19], while Patil et al. [20] that fipronil 5% SC at 800 g ai/ha significantly reduced thrip populations in cotton. Additionally, Singh et al. [21] and Sinha et al. [22] demonstrated that fipronil at 50 g ai/ha applied fortnightly was the most effective treatment for managing leafhoppers in both cotton and okra. Sreekanth and Reddy [23] confirmed fipronil's effectiveness against thrips in cotton, further supporting its broad-spectrum action. Nasruddin et al. [24] also reported fipronil's efficacy in suppressing both nymphal and adult populations of *Aleurodicus dispersus* under both laboratory and field conditions, which aligns with the present findings on spiralling whitefly management.

The application of entomopathogenic fungi also resulted in a notable reduction in spiralling whitefly populations though at a slower rate compared to the fluoride-based insecticide. These fungal pathogens infected the whiteflies causing mycoses and eventual death over time, contributing to sustained pest control. Islam et al. [25] evaluated the pathogenicity of six *Metarhizium anisopliae* isolates against the Q biotype of *Bemisia tabaci* with all six isolates causing over 50% mortality. Prithiva et al. [26] examined the effectiveness of three *Beauveria bassiana* formulations - oil, talc and crude against *B. tabaci* on tomatoes under microplot conditions, reporting that all formulations significantly reduced the pest population with the oil formulation being the most effective. In line with these results, Singh [27] demonstrated the efficacy of various entomopathogenic fungal formulations, including *B. bassiana*, *Lecanicillium lecanii* and *M. anisopliae* in managing whitefly populations on capsicum under protected cultivation conditions.

This combination presents a significant advantage, as insecticide- entomopathogenic fungi (EPF) mixtures introduce multiple mortality mechanisms against the target pest. Field observations showed that the insecticide Fipronil 5% SC weakens the pest's physiology making it more susceptible to fungal infections, while also helping to delay resistance development to new insecticides [28]. Similarly, Akbar et al. [29] suggest that combining insecticides at sublethal doses with entomopathogenic fungi can produce a synergistic effect increasing pest mortality. Generally, it is thought that the insecticide acts as a physiological stressor to the insect or modifies its behaviour, which leads to increased fungal infection (Boucias et al. 1996; Inglis et al 2001). I

This strategy is particularly beneficial as it reduces the required insecticide dosage, lowers environmental contamination and minimizes the risk of resistance development. Furlong and Groden [30] observed that larvae of the Colorado potato beetle (*Leptinotarsa decemlineata*) experienced starvation stress following exposure to sublethal doses of imidacloprid, which in turn heightened their susceptibility to *Beauveria bassiana* infection. Wakil et al. [31] demonstrated that the combined toxicity of Fipronil and *Metarhizium anisopliae* enhanced mortality rates in American cockroaches. Similarly, Kassab et al. [32] found that the combination of *M. anisopliae* with thiamethoxam effectively reduced spittle bug (*Mahanarva fimbriolata*) infestations in sugarcane. Yii et al. [33] further showed that incorporating a low concentration of Fipronil with *M. anisopliae* in bait created a synergistic effect against the termite (*Coptotermes curvignathus*) significantly increasing mortality. In this context, Ambethgar [34] reported that the mechanisms by which insecticides synergize entomopathogenic fungi are not well understood. In later reports, Ambethgar [35] indicated that the insecticide acts as a physiological stressor to target insects or modifies their behaviour after combination treatments. It is further reported that joint action of insecticide and entomopathogenic fungi leads to increased fungal infection in larval population of rice leaf folder (RLF), *Cnaphalocrocis medinalis* that experienced starvation stress after treatment with sublethal doses of different insecticides, leading to their increased susceptibility to *B. bassiana* based on the observations of Ambethgar et al. [36] and consequent report of Ambethgar [37]. The present study combining fluoride-based insecticide-Fipronil 5% SC as synergistic agent of entomopathogenic fungi could provide effective suppression of spiralling whitefly populations by stimulating the virulence of fungal pathogens while simultaneously reducing quantity of insecticide and extending to prolong their usefulness. In this direction, commercial formulations of mycoinsecticides should be investigated for synergistic interactions before progressing to field trial, in order to determine appropriate field doses and to confirm the results of this study.

CONCLUSIONS

The results indicate that fungal infection in spiralling whitefly population can be synergised by fluoride-based insecticide Fipronil 5% SC at sub-leathal concentration. The success of this research prompts consideration of other insecticide classes that could be investigated for potential synergistic interactions with entomopathogenic fungi against spiralling whitefly (*Aleurodicus dispersus*) infestations in guava orchards. The fluoride-based insecticide Fipronil provided rapid knockdown of pest populations, while *Beauveria bassiana* and *Metarhizium anisopliae* delivered longer-term control through sustained infection cycles. The synergistic combination of these approaches enhanced overall efficacy, reducing spiralling whitefly populations more effectively than individual fungal treatments. This research supports integrating chemical and biological control agents into IPM strategy for sustainable whitefly management.

Combining fluoride based insecticides as synergists of fungi could provide effective control of insect populations by increasing the effectiveness of the entomopathogenic fungi while simultaneously reducing insecticide inputs and helping to prolong their usefulness. Furthermore, commercial formulations of mycoinsecticides should be investigated for synergistic interactions before progressing to field trial, to determine appropriate field doses and to confirm the results in this study. Future research should focus on optimizing the dosage and timing of application of insecticides and entomopathogenic fungi as two-in-one tank mix strategy to enhance long-term pest control and exploring the compatibility of combination treatments with other IPM components could further improve sustainable management of spiralling whitefly under open field conditions.

ACKNOWLEDGEMENTS

The authors would like to thank to the Director, ICAR-National Burea of Agriculturally Important Insect Resources (NBAIR), Bengaluru, Karnataka for supplying the fungal cultures, and sparing the services of Dr.K.Selvaraj, Senior Scientist (Entomology), Germplasm Conservation and Utilization, ICAR-NBAIR, Bengaluru, Karnataka, India for identifying the whitefly species. The authors are also highly indebted to the Dean, Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirappalli, Tamil Nadu, India for providing the necessary facilities and support to carry out the present study.

FUNDING

This research was supported by Food Machinery Corporation (FMC) Limited, Chennai Unit in Tamil Nadu, India, funded to the Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India, through the Products Bio-efficacy Testing Scheme (F37AOM) awarded to corresponding author and PG Fellowship awarded to first author to carry out this research work.

CONFLICT OF INTERESTS

The Authors declare that there is no conflict of interest.

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