Colegio de Postgraduados

Biopesticides for the control of whitefly (*Trialeurodes vaporariorum* Westwood) in tomato (*Solanum lycopersicum* L.) in greenhouse conditions

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ABSTRACT

Objective: To evaluate the effectiveness of biopesticides against whitefly (*Trialeurodes vaporariorum* Westwood) in greenhouse tomato (*Solanum lycopersicum* L.) cultivation.
Design/methodology/approach: The treatments evaluated included *Isaria javanica*, *Beauveria bassiana*, and a commercial insecticide. Evaluations were conducted at four post-application dates (DAA): 3, 5, 7, and 14 days. A factorial design was employed in randomized complete blocks with interaction, considering two factors: Factor 1: treatments, and Factor 2: DAA (3, 5, 7, and 14). The study variables included the number of surviving adults, nymphs, eggs, and the total number of surviving whitefly organisms.
Results: No statistical differences were observed among treatments in their effectiveness against whitefly eggs and adults. However, *Isaria javanica* and the commercial insecticide demonstrated a higher control percentage for nymphs. Regarding the total number of organisms, *Beauveria bassiana* showed a statistically significant difference compared to the commercial insecticide, whereas *Isaria javanica* showed no significant difference. The interaction between biopesticides and DAA did not yield significant differences across the variables studied.
Findings/conclusions: Biopesticides were shown to be efficient or better than the commercial insecticide for whitefly control in greenhouses.

Keywords: Microbial control, Entomopathogenic fungi, *Isaria javanica*, *Beauveria bassiana*.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetables globally, with a *per capita* consumption of 20.2 kg. Mexico, recognized as the center of tomato domestication, exhibits extensive morphological diversity, making it one of the most widely cultivated crops in greenhouses (Pérez *et al.*, 2020). However, open-field tomato production faces growing challenges due to adverse environmental conditions and the prevalence of pests and diseases that significantly impact crop productivity (Carrillo *et al.*, 2003).

Conventional agriculture relies heavily on agrochemicals, including herbicides, insecticides, and fungicides, which contribute significantly to environmental pollution. A viable alternative to mitigate these impacts is sustainable agriculture (Cano *et al.*, 2004). Among the most promising strategies to reduce the environmental footprint of pest and plant disease control is the use of biological control agents (Hynes & Boyetchko, 2005).

Biological control of insect pests has emerged as one of the most effective strategies for sustainable pest management. This approach involves the use of predators, parasitoids, or pathogens to regulate insect populations. Insect pathogens, or entomopathogens, include viruses, bacteria, fungi, protists, and nematodes that infect and ultimately kill their insect hosts (Loreti *et al.*, 2020). Comparisons between entomopathogens and conventional chemical insecticides are typically centered on their efficacy and cost-effectiveness (Lacey, 2001).

The concept of biopesticides in the agrobiological industry refers to microbial biological products developed through formulation and industrial production for use in pest control. Biopesticides are effective in managing agricultural pests while minimizing environmental damage and avoiding further environmental pollution (González-Maldonado & García-Gutiérrez, 2012; Nava-Pérez *et al.*, 2012). Although the application of synthetic insecticides remains the most commonly employed method for controlling whitefly, their improper use has several drawbacks. These include increased production costs, the development of pest resistance, and heightened risks of environmental pollution, public health concerns, and food contamination (Eskenazi *et al.*, 2004; Hernández *et al.*, 2009; Pérez *et al.*, 2011). Biopesticides harness a diverse range of entomopathogenic microorganisms. Among the most commonly utilized fungal species, renowned for their broad-spectrum control capabilities, are *B. bassiana*, *M. anisopliae*, and *I. fumosorosea* (Pacheco-Hernández *et al.*, 2019; Nava-Pérez *et al.*, 2012). These fungi exhibit variations in their infection mechanisms, replication sites, viability, and pathogenic processes. Additionally, differences among strains and varieties result in varying levels of efficacy (Nava-Pérez *et al.*, 2012).

B. bassiana is widely regarded as one of the most effective biological control agents in agriculture (Castruita-Esparza *et al.*, 2020; Malpartida-Zevallos *et al.*, 2013). Similarly, *Isaria javanica*, a well-studied and extensively utilized fungal species for insect management, has shown significant potential as an efficient microbiological agent for pest control (Flores *et al.*, 2013). Whitefly is one of the primary pests affecting crops, particularly solanaceous and cucurbitaceous plants (Basso *et al.*, 2001). The most prevalent species, *Trialeurodes vaporariorum*, adversely impacts plant growth by directly feeding on sap, transmitting viruses that cause diseases, and encouraging the development of sooty mold on leaves and fruits (Scotta *et al.*, 2014). Its feeding weakens plants by depleting nutrients (Toledo, 2019), often resulting in production losses of up to 100%, especially during spring, when whitefly populations reach their peak density (Ruiz & Aquino, 1996). The use of synthetic insecticides has increased substantially over the past century. However, the lack of regulation and excessive application of these chemicals have led to severe environmental damage and health risks (Ruiz *et al.*, 2018). Biopesticides have emerged as a viable alternative, offering economically attractive and ecologically sustainable solutions for pest management (Marchese & Filippone, 2018). This study was conducted in a greenhouse at the INIFAP-

Cotaxtla Experimental Station to evaluate the effectiveness of biopesticides in controlling whitefly in tomato cultivation under greenhouse conditions.

MATERIALS AND METHODS

This study was conducted at the INIFAP-Cotaxtla Experimental Station, located at km 34.5 on the Veracruz-Córdoba Federal Highway, in the municipality of Medellín, Veracruz, at an altitude of 15 meters above sea level, with a tropical sub-humid climate. The study was carried out in a 600 m^2 greenhouse with zenithal windows, anti-aphid mesh, and white plastic covering the upper part. Seeds of the hybrid tomato Atrevido F1 from Harris Moran® were used, which were initially sown in a nursery. One month after seedling emergence, transplanting was carried out into 1 m wide by 50 m long planting beds covered with white-black plastic mulch. A staggered topological arrangement was used, with 50 cm spacing between plants.

Experimental design and treatments

For the evaluation of biopesticides, a factorial randomized complete block design with interaction was used. Two factors were considered: factor 1, pesticides; and factor 2, days after application (DAA) of the pesticides 3, 5, 7, and 14 DAA. Two biopesticides, one synthetic insecticide, and a control (water) were evaluated, with the latter used only to account for natural mortality (Table 1). The experiment was conducted on two planting beds. Each bed contained two blocks, consisting of four plots with 12 plants arranged in double rows. In each plot, three plants in double rows were identified for evaluation.

The application of biopesticides was performed using electric spray backpacks (Hyunday® brand) equipped with full-cone nozzles. To prevent cross-contamination between treatments, a separate backpack was designated for each product. The spraying system was calibrated to generate very fine droplets at high pressure, producing a mist that ensured effective coverage and adherence across the entire plant surface. Applications were directed at both the adaxial and abaxial surfaces of the tomato leaves. Transparent plastic barriers were installed to isolate the four plants in each treatment and further eliminate the risk of cross-contamination. From each experimental plot, two central plants (usable plot) were sampled, and two leaves were taken from each plant, one from the upper part and the other from the middle part of the plant. The presence of whitefly by developmental stage was recorded. The first count focused on adults present on the abaxial side of the leaf, as their high flight capability required that the plant not be disturbed during counting. For counting eggs and nymphs, a paper template with a sampling area of 1.44 cm^2 was used.

Table 1. Treatments evaluated against whitefly in tomato cultivation under protected conditions.

Treatments	Active ingredient	Concentration	Dose
Movento®[a]	Spirotetramat	15%	1.25 $mL\ L^{-1}$
Beauveria bassiana[b]	*Beauveria bassiana*	1×10^8	2.5 $mL\ L^{-1}$
Isaria javanica[b]	*Isaria javanica*	1×10^8	2.5 $mL\ L^{-1}$
Witness test	water		

[a] Bayer, [b] Biotechnology ANDREB.

This template was placed on the abaxial side of the leaf along the second vein. The first sampling was conducted in the morning before applying the biopesticides, and subsequent samplings were repeated on days 3, 5, 7, and 14 after the application (DAA). The studied variable consisted of survival counts of organisms after the applications, considering the following response variables: the number of live adults, eggs, and nymphs. For pesticide evaluation, the sampling data were transformed into efficiency (%) using the formula by Henderson and Tilton (1955).

$$\text{Efficiency } \% = \left(\frac{n \text{ in } Co \text{ before treatment} * n \text{ in } T \text{ after treatment}}{n \text{ in } Co \text{ after treatment} * n \text{ in } T \text{ before treatment}} \right) * 100$$

Where: n=number of insects, T=treated, Co=control.

For the statistical analysis, a univariate GLMM program was used with the statistical packages SPSS 20 and INFOSTAT, obtaining the analysis of variance for the independent factors and their corresponding interaction. The means test was performed using Tukey's test at 95% confidence.

RESULTS AND DISCUSSION

A statistically significant difference was observed in the efficiency of the pesticides for nymph control ($F_{2,452}$=4.10, p=0.0171) and the total number of organisms ($F_{2,642}$=2.91, p=0.0550). However, no statistical differences were observed for adults and eggs ($F_{2,468}$=0.40, p=0.6714) and ($F_{2,355}$=2.64, p=0.0725), respectively (Table 2).

A statistically significant difference was observed among the pesticides for the control of whitefly nymphs. *Isaria javanica* and Movento® exhibited the highest control percentages, with averages of 48% and 45%, respectively, both of which were statistically different from *Beauveria bassiana*. Regarding the total number of organisms, *B. bassiana* demonstrated superior efficacy, showing a statistically significant difference compared to Movento® and a similar effect to *I. javanica*. For adults and eggs, an efficiency exceeding 50% was recorded across the treatments. These findings align with those reported by Scorsetti *et al.* (2008b), who documented mortality rates ranging from 26.6% to 76.6% using entomopathogens against *T. vaporariorum*. Similarly, Quesada *et al.* (2006b) achieved mortality rates exceeding 50%, while Oreste *et al.* (2016) reported mortality rates of over 86%.

Table 2. Efficiency ($\bar{X}$±ES) of the treatments evaluated against whitefly in tomato cultivation under protected conditions.

Treatments	Adults	Nymphs	Eggs	Total organisms
Isaria javanica	69.72±3.32a	48.84±3.73 a	58.25±4.51a	48.80±2.98 ab
Beauveria bassiana	67.88±3.33a	34.00±3.85 b	65.19±4.00a	50.98±2.87a
Movento	72.16±3.46a	45.02±3.65 ab	52.35±3.90a	41.52±2.92b

Values corrected for natural mortality using the Henderson and Tilton (1955) formula.
$\bar{X}$=average. ES=Standard error. Means joined by the same letter indicate no statistical difference.

For the DAA (Days After Application) factor, no statistically significant differences were detected in the control of adults ($F_{3,468}$=2.13, p=0.0951), nymphs ($F_{3,452}$=1.06, p=0.3673), eggs ($F_{3,355}$=1.37, p=0.2513), or the total number of organisms ($F_{3,642}$=0.49, p=0.6860). Similarly, no significant differences were observed for the interaction between biopesticides and DAA across any of the variables studied: adults ($F_{6,468}$=0.59, p=0.7419), nymphs ($F_{6,452}$=0.50, p=0.8092), eggs ($F_{6,355}$=0.62, p=0.7156), or the total number of organisms ($F_{6,642}$=0.38, p=0.8939). These findings differ from those reported in other studies, which have documented significant effects on whitefly mortality at 7 DAA (Quesada *et al.*, 2006c; Oreste *et al.*, 2016b).

CONCLUSIONS

Isaria javanica and the commercial insecticide Movento® demonstrated greater efficiency in controlling whitefly nymphs compared to *Beauveria bassiana*. All evaluated treatments showed similar effectiveness in controlling whitefly eggs. Regarding the total number of organisms (sum of all developmental stages), *Beauveria bassiana* stood out as the most effective treatment, while Isaria javanica exhibited a similar level of control to Movento®.

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