Research Article

Assessing *Beauveria Bassiana* and Orange Oil for Controlling *Bemisia Tabaci* in Greenhouse Tomatoes Compared to Neonicotinoid Insecticides

Ahmed Amin Ahmad Saleh[1]*, Eman Mohammed Fekry Arafa[1], Moshiera Ahmed Saed Ahmed[1], Said Abdel Fattah Mahmoud Amer[1] and Mohamed Farag Mahmoud Zawrah[2]

[1]Plant Protection Research Institute, Agricultural Research Center (ARC), Giza, Egypt; [2]Department of Applied Entomology, Faculty of Desert and Environmental Agriculture, Matrouh University, Fuka, Egypt.

Abstract |This study evaluated the effectiveness of various insecticides including Agriflex, Pelexam, Merland, Midore, Orange oil, and *Beauveria bassiana*(Balsamo) in controlling whiteflies in greenhouse tomatoes during 2024 and 2025. The findings showed that Merland, Midore, Agriflex, and Pelexam worked better than Orange oil and *Beauveria bassiana* at 3 days post-treatment. The treatments Merland, Midore and Agriflex significantly reduced *B. tabaci* (Gennadius) populations. On the other hand, *Beauveria bassiana* was effective at 7th and 10thday post-treatment, achieving efficacy rates of 89.64% and 97.21%, and 86.19% and 95.19% across both years, respectively. All insecticides lowered whitefly numbers significantly within a week, with *Beauveria bassiana* being the most effective, followed by Merland and Midore. Orange oil had the least impact with fewer than 70% mortality throughout the study. The effectiveness rankings for reducing infestations were: Merland, Midore, Agriflex, Pelexam, *Beauveria bassiana*, and Orange oil. The findings indicate that the insecticides evaluated may be regarded as potential options for managing whitefly in greenhouses, while posing a reduced risk to beneficial insects.

Received | Feb 13 2025; **Accepted** | Jul 4, 2025; Published | November 05, 2025
***Correspondence** | Ahmed Amin Ahmad Saleh, Plant Protection Research Institute, Agricultural Research Center (ARC), Giza, Egypt; **Email:** amin_ahmed4u@yahoo.com
Citation | Saleh, A.A.A., E.M.F. Arafa, M.A.S. Ahmed, S.A.F.M. Amer and M.F.M. Zawrah. 2025. Assessing *Beauveria bassiana* and orange oil for controlling *Bemisia tabaci* in greenhouse tomatoes compared to neonicotinoid insecticides. Sarhad Journal of Agriculture, 41(4): 1755-1762.
DOI | https://dx.doi.org/10.17582/journal.sja/2025/41.4.1755.1762
Keywords | Whitefly, Tomato, *Beauveria bassiana*, Orange oil, Neonicotinoids insecticides.

Introduction

Whitefly, or *Bemisia tabaci*, is a major threat to many crops because it can feed on a wide variety of plants and transmit over 110 viruses (Fortes *et al*., 2020). This insect feeds on plant sap, causing significant decreases in crop yield. A female whitefly can lay around 320 eggs in her lifetime (Rodríguez *et al*., 2019). In warm, controlled conditions, whiteflies can reproduce quickly throughout the year, leading to rapid population growth (Guo *et al*., 2022). Both nymphs and adults consume sap and produce sugary waste, which promotes the growth of sooty mold on plants and fruits, harming crop productivity(Abd-

Elkareim *et al*., 2019; Saleh *et al*., 2024). *B. tabaci* is particularly problematic in tomato in greenhouses in Egypt, where it significantly hampers tomato production (Ali *et al*., 2020a and b). Other effected plants include potatoes, soybeans, cassava, okra and chrysanthemums. The heavy use of chemical pesticides can create resistance in pest populations and lead to contamination of soil and water, disrupting the ecosystem (Ismail *et al*., 2024). This highlights the urgent need for effective and eco-friendly control methods for *B. tabaci*. Commonly used synthetic pesticides can negatively impact the environment, contribute to resistance, cause pest resurgence, harm pollinators and lower crop yields (Saleh *et al*., 2023; Lokma *et al*., 2023). Therefore, finding a safe and effective strategy for managing whiteflies is crucial (Abubakar *et al*., 2022). In tomatoes, the economic injury level related to *B. tabaci* is set at four nymphs per leaf and one adult per tray (Thorat *et al*., 2020). As a highly destructivepest globally, integrated pest management (IPM) is recommended to reduce the risks of synthetic insecticides (Nwezeobi *et al*., 2020). The IPM approach for *B. tabaci* includes biological control, physical methods, and careful use of selected pesticides (Sain *et al*., 2021). Certain fungi, like *B. bassiana*, have proven effective against sap-sucking insects, including *B. tabaci*. These natural enemies can assist in controlling pest numbers without the drawbacks associated with chemical miticides (Abdel-Raheem and Al-Keridis, 2017). This study will evaluate the effectiveness of the bioinsecticides *B. bassiana* and orange oil compared to neonicotinoid insecticides for controlling the tomato whitefly.

Materials and Methods

The experiments conducted during the 2024 and 2025 seasons in the Kafr Saqr district of Sharkia governorate, the research aimed to assess the effectiveness of six insecticides on tomato plants, all under greenhouse conditions. Each insecticide was applied at its recommended field rate. In the spring of 2024, the average daily temperature was recorded at 23±1°C, peaking between 21.0°C and 25.0°C, while the average relative humidity stood at 65±5%, fluctuating between 55% to 76%. By season 2025, temperatures dropped slightly to an average of 21±1°C, ranging from a low of 19.5°C to a high of 23.5°C, and average relative humidity decreased to 70±5%, with values spanning from 62% and 79%.

Field Studies

The study tested how well certain pesticides worked against whiteflies on tomato plants in a randomized block design across a 2500 m^2 area with five greenhouses. The experiment was carried out across 24 plots, with each pesticide treatment tested in four replications. Additionally, there was a control plot that did not receive any treatment at all (Table 1). Pesticides were applied starting on February 7, 2024, and January 3, 2025, when we found five nymphs per leaf. We assessed effectiveness at intervals of 1, 3, 7, and 10 days post-application. For each timing, we sampled 25 leaves from the top, middle, and bottom of the plants, noting both adult whiteflies and their natural enemies. Nymphs were identified in the lab using a binocular microscope. We sprayed pesticides with a motor sprayer at the recommended rates and calculated infestation reduction using the Henderson and Tilton, (1995) method for all insecticides, except for (*B. bassiana*), where we used Abbott's formula, (1925)for estimating whitefly numbers.

$$\text{Reduction\%} = \left(1 - \frac{\text{n in C before treatment} \times \text{n in T after treatment}}{\text{n in C after treatment} \times \text{n in T before treatment}}\right) \times 100$$

Where,

N denotes the insect population, C represents the control, and T indicates the treated.

$$\%R = \frac{Control - Treatment}{Control} \times 100$$

Statistical analysis

Statistical analysis was done using Duncan's Multiple Range Test. This helped identify differences among samples in the preference test and assess the average mortality rates of *B. tabaci* exposed to various systemic insecticides and bioinsecticides. The analysis used SPSS version 13 software from IBM Analytics in Armonk, NY.

Results and Discussion

The study evaluated the impact of several insecticides, including (*B. bassiana*), Orange oil, Agriflex, Pelexam, Merland, and Midore. , in tomatoes cultivated in greenhouses in 2024 and 2025, against the whitefly, *Bemisia tabaci* (Genn.). The results are shown in Tables 1-7.

Table1: *Tested insecticides a gainst whitefly*

Trade name	Common name	Field rate
Agriflex-18.6%SC	Thiamethoxam3.32%+ abamectin 15.24%	240 cm^3/Fadd-an
Pelexam25%WG	Thiamethoxam	20g/100Lwater
Merland20% SC	Lambadacyhaio-thrin5%+Imidacloprid 15%	75cm^3/100L-water
Mi-dore70%WDG	Imidacloprid	30g/100Lwater
Orangeoil6%SL	Prev-AM®	400ml/100L.
B. bassiana (WG2.5%X-108Is/gm1CFU)	*Beauveria bassiana*	250g/100L-water

Efficacy of tested insecticides against bemisia tabaci

Data from Tables 2-5 show that the number of whiteflies on tomato leaves before treatment in 2024 season ranged from 8.50 to 381.25 per 25 leaves, as seen in Table 2. In 2025, this number increased to between 11.0 and 412.75 per 25 leaves in 2025 season as indicated in Table 4. After treatment, nymph counts decreased significantly from initial numbers of 307.25, 202.24, and 349.75 to 8.5, 12.5, 2.0, 4.25 and 145.25 after using Agriflex, Pelexam, Merland, Midore, and Orange oil. The insecticides effectively reduced whitefly nymphs ,with Merland being the most successful and Orange oil showing the least impact. Statistical analysis revealed significant differences in Merland's effectiveness over the days following treatment (F = 323.18, df = 12, p < 0.005). After three days, nymph counts were 30.0, 32.0, 12.0,18.0,and 93.75 and by seven days ,they increased to 97.0,100.0,47.0,68.25 and 142.38.This pattern continued at ten day ,with counts of 246.5, 275.25, 106.75 ,144.50 and381.25. Overall, Merland was the most effective treatment based on average nymph counts, followed by Midore (F = 727.74, df = 12, p < 0.005) and Agriflex (F = 675.23, df = 12, p < 0.005). During the 2024 season, infestation levels ranged from 95.50 per 25 leaves for Agriflex to 190.66 for Orange oil as shown in Table 2.

Most insecticides lowered whitefly nymph numbers over time. One day after application, reductions were as follows: Agriflex (97.42%), Pelexam (95.92%), Merland (99.09%), Midore (98.33%), and Orange oil (61.31%). The percentage decreases of *B.tabaci* at three days were 92.34%, 91.24%, 95.36%, 94.18%, and 79.04% .After seven days, these values slightly rose for Agriflex, Pelexam,Merland and Midore, while Orange oil decreased to 74.92%. At ten day, the reductions were 71.14%, 65.28%, 80.99%, 78.45% and 61.63% in the first seasonTable 3.

Table 2: *Effect of the tested pesticides on B. tabaci infesting tomato plants under greenhouse conditions during season 2024.*

Pesticides	Total no. before treatment/25 leaves	Number *B.tabaci* / 25 leaves				General mean of reduction	LSD
		Oneday	3 days	7 days	10 days		
Agriflex	307a	8.5 e	30 d	97 c	246.5b	95.5	4.8682
Pelexam	285.25a	12.5 e	32 d	100 c	275.25b	104.94	4.6372
Merland	202a	2.0 e	12 d	47 c	106.75b	41.94	6.83505
Midore	244a	4.25 e	18 d	68.25c	144.50b	58.75	12.7271
Orange oil	349.75a	145.25c	93.75d	142.38c	381.25b	190.66	29.6065
Control	316.50	339.75	404.75	513.75	899.25	539.38	

Letters that differ in the same row show a significant difference (p≤0.05).

Table 3: *Reduction percentage on B. tabaci (Genn.)infesting tomato plants under greenhouse conditions during season 2024.*

Pesticides	Reduction percentage(%)				Mean of residual effect	General mean of reduction	LSD
	Oneday	3 days	7 days	10 days	(%)		
Agriflex	97.42a	92.34b	80.47c	71.14d	75.81	85.34	3.1774
Pelexam	95.92a	91.24b	78.39c	65.28d	71.84	82.71	2.8393
Merland	99.09a	95.36b	85.66c	80.99d	83.33	90.28	2.0290
Midore	98.33a	94.18b	82.83c	78.45d	80.64	88.45	2.5964
Orangeoil	61.31a	79.04 b	74.92 c	61.63 d	68.28	69.23	4.0218

Letters that differ in the same row show a significant difference (p≤0.05).

Orange oil was the least effective, with a reduction of 68.28%.Tested insecticides showed a significant decline in tomato whitefly populations at all observed intervals (1, 3, 7, and 10 days) following treatment. The average residual effect for Merland was 83.33%, followed by Midore at 80.64%, Agriflex at 75.81% and Pelexam at 71.84% (71.84%). The insecticides ranked by average residual effect are Merland, Midore, Agriflex, Pelexam and Orange oil. Over the experiment periods, the overall reduction in whitefly numbers indicated that Merland was the most effective, reducing populations by 90.28% in the 2024 season, followed by Midore at 88.45%. Agriflex (85.34%) and Pelexam (82.71%) were also effective, while Orange oil saw the least reduction at 69.23% (Table 3).

In the second season, counts of nymphs per 25 leaves decreased from initial values to significantly lower numbers after one day of treatment with each insecticide. Agriflex, Pelexam, Merland, Midore, and Orange oil showed reductions of 11.0, 17.25, 6.5, 8.75 and 169.25, respectively, with Merland being the most effective. Statistical analysis revealed no table differences in effectiveness for Merland over time. After three days, nymph counts were 32.75 for Agriflex, 45.5 for Pelexam, 20.5 for Merland, 26.5 for Midore and 108.25 for Orange oil. At seven days, counts increased to 98.75, 128.0, 79.5, 84.25 and 172.40. This trend continued with higher counts after ten days. Merland remained the top performer, followed by Midore and Agriflex, with infestations ranging from 94.69 to 215.60 per 25 leaves (Table 4).

In the 2025 season, the results mirrored the previous year. The tested insecticides again resulted in a significant reduction in whitefly populations across all time points. The average residual effect for Merland was 81.09% ($F=223.06, df=12, p<0.005$), Midore at 78.98% ($F=216.10$, $df=12$, $p <0.005$), Agriflex at 74.33%($F=115.39$, $df=12$, $p <0.005$), Pelexam at (70.04%) ($F=235.14, df=12, p<0.005$) and Orange oil at 65.99% ($F=120.03, df=12$, $p < 0.005$) Table 5. Statistical analysis confirmed significant differences in effectiveness for Orange oil on different days after treatment($F = 1323.18$, $df = 12$, $p < 0.005$).

Table 5 illustrates how much infestation was reduced. Most insecticides effectively lowered whitefly nymph numbers over time.

Table 4: *Effect of the tested pesticides on B. tabaci infesting tomato plants under greenhouse conditions during season 2025.*

Pesticides	Total no. before treatment / 25	Number *B .tabaci*/ 25 leaves				General mean of reduction	LSD
		One	3 days	7 days	10 days		
Agriflex	240.25 a	11.0 d	32.75 c	98.75 b	236.25 a	94.69	7.7635
Pelexam	280 b	17.25 e	45.5 d	128 c	331 a	130.44	27.8505
Merland	245.25 a	6.5 d	20.5 d	79.5 c	168.75 b	68.81	18.3354
Midore	228.25 a	8.75 e	26.5 d	84.25 c	172.75 b	73.06	9.1759
Orangeoil	317b	169 e	108.25 d	172.40 c	412.75 a	215.6	3.0213
Control	290.75	346.75	468	569.5	940.25	581.13	

Letters that differ in the same row show a significant difference (p≤0.05).

Table 5: *Reduction percentage on B. tabaci (Genn.) infesting tomato plants under greenhouses conditions during season 2025.*

Pesticides	Reduction percentage (%)				Mean of residual effect	General mean ofreduction	LSD
	One day	3 days	7 days	10 days	(%)		
Agriflex	96.16 a	91.53b	78.98c	69.68d	74.33	84.09	3.4569
Pelexam	94.86a	89.89b	76.63c	63.44d	70.04	81.21	2.8381
Merland	97.79a	94.79b	83.46c	78.73d	81.09	88.69	1.8767
Midore	96.78a	92.87b	81.21c	76.63d	78.92	86.87	2.0301
Orangeoil	55.30 a	78.79 b	72.23	59.74 d	65.99	66.52	4.9762

Letters that differ in the same row show a significant difference (p≤0.05).

One day after spraying, Agriflex, Pelexam, Merland, Midore and Orange oil achieved reductions of 96.16%, 94.86%, 97.79% and 96.78%, with Orange oil showing the least effect at 55.30%. After three days, these percentages changed to 91.53% ,89.89%,94.79%,92.87%,and78.79%. The reductions for Agriflex, Pelexam, Merland and Midore slightly improved to 78.98%, 76.63%, 83.46%, and 81.21%, while orange oil's effectiveness dropped to 72.23% after seven days. By ten days, the reductions were measured at 69.68%, 63.44%, 78.73%, 76.63% and 59.74%. The insecticides can be ranked based on their average residual effect: Merland (81.09%), Midore (78.92%), Agriflex (74.33%), Pelexam (70.04%) and Orange oil (65.99%). The analysis also showed that Merland was the most effective, with an 88.69% reduction in whitefly populations during the 2025 season, followed closely by Midore at 86.87%. Agriflex and Pelexam showed reductions of 84.09% and 81.21%, respectively, with significant differences between them, while Orange oil was the least effective at 66.52% Table 5. Imidacloprid showed the best results, with a control rate of 93.84% three days after application and the lowest population of whiteflies by day ten. Research has shown that imidacloprid is very effective against whiteflies, while Azadirachtin proved to be the least effective Thorat *et al.* (2020). All treatments lowered whitefly numbers compared to untreated controls, but their effectiveness differed due to the unique properties of each insecticide, such as water solubility, which impacts how toxic they are to plant-sucking pests (Nwezeobi *et al*., 2020). This a ligns with findings Zawrah *et al*., (2020) that support the effectiveness of imidacloprid and thiamethoxam against these pests. Other studies suggest that *datura alba* and *B. hystophorous* work better than imidacloprid on crops like tomato and cotton. Additionally, significant whitefly death was noted with acetamiprid in earlier reports.

The current findings align with those of Khattak *et al.* (2004) who reported that neonicotinoid insecticides such as thiamethoxam, imidacloprid, and acetamiprid can kill whiteflies. This supports Elbert *et al.* (1996) indicating that imidacloprid is especially effective against adult whiteflies in laboratory tests. Additionally, Nauen *et al*. (1996) noted that acetamiprid works well when applied to leaves. The results also show that Orange oil (Prev-AM®) effectively reduced whitefly populations during the 2024 and 2025 testing seasons. This is consistent with Mona, (2017) who found that Prev-AM® orange oil and *B. bassiana* can control whiteflies. The study reveals that treatment with Imidacloprid (Midore 70%WDG and Merland 20%SC) significantly reduces whitefly populations in two seasons. In examining tomato crops, the application of neonicotinoid insecticides resulted in varying Add this reductions in whitefly populations from the first to the second seasons, with more pronounced decreases seen in the first season. This discrepancy might stem from the higher temperatures experienced during the first season. This aligns with Kumar, 2018 who stated that imidacloprid is the most effective for keeping whitefly numbers down. Zawrah *et al.* (2020) also highlighted that imidacloprid acts quickly and has long-lasting effects. In a similar study, Thorat *et al.* (2020) found that neonicotinoids (thiamethoxam, imidacloprid, and acetamiprid) have a longer residual toxicity compared to chitin synthesis inhibitors like pyriproxyfen and novaluron against *B. tabaci*, outperforming chlorantraniliprole as well. Shinde *et al.* (2011) showed that imidacloprid effectively controls whiteflies. Similarly, Abubakar *et al.* (2022) found that both imidacloprid and thiamethoxam work well against these pests.

Table 6: *Effect of Beauveria bassiana biopesticides on B.tabaci infesting tomato plants under filed conditions during two season2024 and 2025.*

Pesticides	**Number *B .tabaci* /25 leaves**					**General mean of reduction**
		Oneday	3 days	7 days	10 days	
Beauveria bassiana (WG2.5%X108Is/gm1CFU)	2024 season					
	Number	91	70.25	34	10.65	51.48
	Control	180	216.5	328.25	381.25	276.5
	2025 season					
	Number	96	75.25	42.75	21.75	58.94
	Control	172	198.25	309.50	451.75	282.88

Table7: *Reduction Percentage on B.tabaci (Genn.) infesting plants under green house conditions during two season 2024 and 2025.*

Pesticides		Reduction percentage (%)				Meanofresidual effect	General mean of reduction	LSD
		Oneday	3 days	7 days	10 days	(%)		
2024	*Beauveria bassiana* (WG2.5%X108Is/ gm1CFU)	49.44 d	67.55 c	89.64 b	97.21 a	93.43	75.96	2.7782
2025		44.19 d	62.04 c	86.19 b	95.19 a	90.69	71.90	3.6529

Letters that differ in the same row show a significant difference (p≤0.05).

The different impacts of these insecticides on whiteflies stem from the unique traits of neonicotinoids, especially their water solubility, which affects their toxicity to pests that feed by piercing and sucking Zawrah *et al.* (2020). Similarly, Thorat *et al.* (2020) mentioned that increased temperatures can speed up the breakdown of neonicotinoids, altering their toxicity levels.

Efficacy of B. bassiana bioinsecticide against Bemisia tabaci

In the first season, The effectiveness of *B. bassiana* bioinsecticide against *B. tabaci* was no table in both seasons. In the first season, the number of nymphs per 25 leaves dropped from 180,216.5, 328.25 and 381.25 in the control group to 91.0, 70.25, 34.0 and 10.65 on days 1, 3, 7, and 10 after treatment, respectively. *B. bassiana* achieved reductions of 49.44%, 67.55%, 89.64% and 97.21% on those same days ,averaging a residual effect of 93.43% and an overall reduction of 75.96% (Table 6). In the second season, the nymph counts decreased from 172,198.25,309.50 and 451.75 in the control group to 96.0,75.25,42.75, and 21.75 after treatment. The reductions achieved were 44.19%, 62.04%, 86.19% and 95.19% with an average residual effect of 90.69% and a general reduction of 71.90% (Table 7). Overall, *B. bassiana* showed the least effectiveness in reducing whitefly populations at one and three days. In contrast, the treatments were greatest effective after seven and ten days. The highest percent mortality was observed after 10 days, while after 3 days, the mortality was the minimum. Almost similar results were reported by Loureiro *et al.* (2004) who found an increase in mortality with the increase in time and concentration Additionally, time played a significant role in influencing whitefly mortality rates. Mortality was at its lowest after three days and peaked after ten days. As the number of days progressed, there was a clear increase in mortality, indicating a direct relationship between time and mortality rates Javed *et al.*(2019).

The treatment with *B. bassiana* (WG2.5% X 10^8Is/ gm) showed significant effectiveness, reducing *B. tabaci* numbers by up to 75% in the first season and 71% in the second compared to untreated plants. Assadi *et al.* (2021) also found that the *B. bassiana* strain R444 was effective against all developmental stages of *B. tabaci* in controlled conditions. Other research confirms the effectiveness of *B. bassiana* against whiteflies. Saleh *et al.* (2023) reported that *B. bassiana* (BB-72 and BB-252) caused maximum mortality of *B. tabaci* after 12 days at various temperatures. Wari *et al.* (2020) found that *B. bassiana* strain GHA significantly reduced different life stages of *B. tabaci* in greenhouses. Zafar *et al.* (2016) demonstrated that several *B. bassiana* isolates effectively impacted reproductive rates on various host plants. Additionally, both *B. bassiana* and *M. anisopliae* led to high larval mortality rates of *B. tabaci* in greenhouse studies Sain *et al.* (2021).

Conclusions and Recommendations

The study found that five insecticides, Merland, Midore, Agriflex, Pelexam, and Orange oil had different toxicity levels against the whitefly *B. tabaci* based on how long they were applied. After treatment with all the pesticides, the average number of *B. tabaci* nymphs dropped unevenly for up to10 days. Merland was the most effective, followed by Midore and Agriflex. This insecticide can serve as a new chemical option for controlling tomato whitefly populations in heated greenhouses in Egypt. Orange oil and *B. bassiana* are excellent tools in integrated pest management (IPM) for controlling sucking insect pests, such as whiteflies, on tomato plants. Their low toxicity levels make them safe for beneficial insects, ensuring a balanced ecosystem in the fields and greenhouses .

Acknowledgements

The authors are grateful to Prof. Dr. Ahmed H. El-Heneidy from the Biological Control Department at the Agricultural Research Center in Giza, Egypt. His early contributions and thoughtful recommendations were vital to the advancement of this review article.

Novelty Statement

Orange oil and *B. bassiana* are potential chemical options for controlling tomato whitefly populations in heated greenhouses in Egypt, offering low toxicity levels for beneficial insects.

Author's Contribution

Ahmed Amin Ahmad Saleh: Conceptualization, methodology, , investigation, data curation, writing – original draf.
Eman Mohammed Fekry Atara: Writing – review & editing, resources, funding acquisition.
Moshera Ahmed: Writing – review & editing, visualization
Said Abdel Fattah Mahmoud Amer: Writing – review & editing, validation, supervision, resources
Mohamed Zawrah: Formal analysis, writing – original draft

Generative AI or AI assisted technology statement
The authors declare that no Genrative AI was used in the creation of this manuscript.

Conflict of interest
The authors have no conflict of interest.

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