Dijlah Journal of Agricultural Sciences
Journal homage: https://djas.uowasit.edu.iq/index.php/djas/en

Research article

Evaluation of the efficiency of some plant extracts and biological agents againt whitefly *Bemisia tabaci* on eggplant plant *Solanum melongena*

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A R T I C L E I N F O

Keywords:
Bemisia tabaci,
plant extract,
Beauveria bassiana,
Solanum melongena

Article history:
Received: 8 May 2026
Accepted: 24 May 2026
Online: 30 Jun 2026

A B S T R A C T

This study was carried out to evaluate the efficiency of some aqueous extracts of the plant's sweet basil Ocimum basilicum, shrubby Lantana camara, and Eucalyptus camaldulensis, and the two biological fungi Beauveria bassiana and Trichoderma viride against the whitefly insect Bemisia tabaci. This experiment was implemented at the Agricultural Research and Experimental Station associated with the College of Agriculture, University of Basrah. The results of the laboratory experiment showed the superiority of the aqueous extract of O.basilium, as it achieved a mortality percentage of 45.36%, followed by the aqueous extract of shrubby L.camara with a mortality percentage of 41.38%, while the aqueous extract of E.camaldulensis achieved a mortality percentage of 37.36%. As for the biological fungi, the fungus B.bassiana achieved the highest mortality percentage, which reached 47.68%, and it was significantly superior to the biological fungus T.viride, as the mortality percentage reached 42.71%. As for the field experiment, the aqueous extract of sweet basil achieved a relative efficiency of 41.66%, which was superior to the extracts of shrubby lantana and eucalyptus, as the relative efficiency on nymphs reached 36.18 and 33.42%, respectively. As for the biological fungi, the biological fungus B. bassiana achieved a relative efficiency of 36.77%, which differed significantly from the biological fungus T. viride, as it achieved a relative efficiency of 31.86%.

1. Introduction

Eggplant plant Solanum melongena L is one of the leading crops in herbaceous annual vegetables solanaceae family. It is cultivated globally, particularly in tropical and subtropical regions. It is rich in proteins and dietary fibers, and plays a crucial role in the biosynthesis of diverse secondary metabolites, which increases its chemical diversity (Subramanian et al.,2025) .

Secondary metabolites, such as phenols, terpenoids, glycoalkaloids, flavonoids, and antioxidants, act as stress regulators (Subramaniam and Kumar, 2023). Many insect pests, including the shoot and fruit borer Leucinodes orbonalis, the leafhopper insect Amrasca biguttula, the cotton aphid insect Aphis gossypii, and the whitefly Bemisia tabaci (Venkatesh et al., 2025), infect eggplant crop.

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The whitefly insect B. tabaci is a global pest that causes direct damage through feeding on plant sap, and indirect damage by transmitting numerous plant viruses. Its high reproduction rate and wide host range contribute to large losses in crops across many plant hosts, including legumes, cucurbits, and solanaceous crops (Kavallieratos et al., 2024; Indriyani et al., 2025). The whitefly insect B. tabaci also causes severe damage to tropical and subtropical agricultural systems due to its behavior in sucking plant sap, and it enables the transmission of over 350 plant viruses, resulting in significant yield losses in crops including tomato, potato, cabbage, and cotton., soybean, and others. Traditional control strategies depend greatly on synthetic insecticides; however, their intensive use has led to the appearance of insecticide resistance in whitefly strains, environmental deterioration, and harmful effects on non-target organisms (Jalloh et al., 2025; Saleh et al., 2023).

Plant extracts are considered a form of environmentally friendly natural pesticides, as insecticides of plant origin are materials produced naturally or products simply derived from these plant materials. Secondary metabolic compounds are produced inside the plant as secondary products of the main biochemical pathways. Chemically, they include alkaloids, terpenoids, and phenols, in addition to a number of other compounds, as they prevent feeding and egg laying on plants, and disrupt insect behavior and physiology in different ways, in addition to their toxicity to the different growth stages of many sucking insect pests (Routray et al., 2021).

Many species of entomopathogenic fungi have been used as bioinsecticides against different insect pests (Sun et al., 2020). Intizar et al. (2025) also showed that the use of the fungus B. bassiana on whitefly achieved a mortality percentage of 72.0% on cucumber plant. Biopesticides, made from natural sources such as plant extracts, microbes, and their metabolites, are considered a sustainable and effective alternative to chemical pesticides (Ayilara et al., 2023).

Insecticides of plant origin provide a great advantage represented by their compatibility with biological agents such as entomopathogenic fungi, predators, and parasitoids, which can be integrated into integrated pest management programs (Ghosh et al., 2021). The study aimed to assess the biological effect of plant extracts and compare them with fungal suspensions and to know their effect in controlling whitefly under laboratory and field conditions in order to find a sustainable agricultural environment free from environmental pollution.

2. Materials and methods

2.1 Preparation of whitefly insect rearing under laboratory conditions

For the purpose of rearing the whitefly insect, plastic pots with a capacity of 3 kg containing loamy soil mixed with peat moss at a ratio of 2:1 were used. Eggplant saplings were planted in October, on 15/10/2025, and placed inside cages covered with muslin cloth. A group of whitefly adults, which had been collected from an infected eggplant field using an aspirator device, was introduced. They were maintained to serve as a source of whitefly for conducting laboratory studies and obtaining the different stages.

2.2 Preparation of aqueous plant extracts

The leaves of *O. basilicum*, *L. camara* and *E. camaldulensis* were collected from the Agricultural Research Station / Agriculture College / University of Basrah and taxonomically classified by Dr. Taha Yasin al-Idani, prof of taxonomy at plant protection department. Leaves were dried at 40 °C for 72 hrs and then ground to a fine powder. To prepare aqueous extract of leaves powder, 10 gm of powder homogenized with 100 ml of distilled water and incubated overnight to obtaining a good extraction for the active component. The extract was filtrated and centrifuged at 3000 rpm for 10 min. The supernatant used either as a high concertation (100 %) or a stock solution to prepare diluted concentrations (25, 50, 75) % in further experiments (Shaba,2011).

Table (1). Names of the plants used to measure the effect of their extracts in controlling whitefly nymphs

Scientific names of plants	Family	Part used from the plant
Lantana camara	Verbenaceae	Leaves
Ocimum basilicum	Lamiaceae	Leaves
Eucalyptus camaldulensis	Myrtaceae	Leaves

Preparation of the spore suspension of the two fungi B. bassiana and *T. viride*

The fungus *T. viride* was obtained from Kadhim *et al*. (2025), and the fungus *B. bassiana* was obtained from a previous study of the Diseases Laboratory in the Department of Plant Protection / Dr. Yahya Ashour identified College of Agriculture – University of Basrah, and it. The two fungi were cultured in Petri dishes containing PDA culture medium, each separately. The dishes were placed in an incubator at a temperature of 28 ± 2 °C and left for one week, until the radial growth reached the edge of the dish. After that, the dishes were transferred to the refrigerator and left until use. The spore suspension of the two fungi was prepared by taking a disc with a diameter of 0.5 cm using a cork borer from the fungal colony grown on sterile PDA culture medium at the age of 7 days. The disc was placed in sterile test tubes containing 9 ml of sterile water, and the tube was shaken for 3 minutes to remove the spores from the disc containing the fungal colony. Then, the dilutions were prepared, which were 1×10^{-6}, 1×10^{-5}, and 1×10^{-4}.

2.3 Laboratory experiment

Leaves were collected from infected eggplant plants that had been reared in the laboratory. The plant extracts and bioinsecticides were used separately on the nymphal stage. Ten individuals of the nymphal stage, close in age, were placed inside each Petri dish with a capacity of 9 cm, after placing a moistened cotton piece inside the dish. Then, a piece of eggplant leaf with a length of 7 cm was placed to feed the insect, with 3 replicates for each treatment. The concentrations were 100, 75, 50, and 25%. The dishes were then sprayed with the extracts at a rate of 1 ml for each dish, while the control was sprayed only with distilled water. The dishes were placed in an incubator at a temperature of 27°C, relative humidity of 50-60%, and a photoperiod of 16:8 hours (light : dark).. Readings were taken after 24, 48, 72, and 96 hours. As for the biological fungi, the same method used for the extracts was used, and the dilutions 1×10^{-4}, 1×10^{-5}, and 1×10^{-6} were used. The mortality percentage was calculated after 24, 48, 72, and 98 hours from treatment, then corrected using the Orell and Schneider equation.

$$\text{Mortality \%} = \frac{\text{Mortality \% in treatment} - \text{Mortality \% in control}}{\text{Mortality \% in control}} x100$$

2.4 Field experiment

The trial was implemented at the Agricultural Research Station belonging to the College of Agriculture after preparing the field, represented by plowing and softening the soil. The plastic house was divided into three furrows. The distance between plants was 40 cm, and between treatments 1 m. Saplings were planted on 5/10/2025, and drippers were used in the irrigation process. Crop service operations, including fertilization and weed removal, were carried out. A randomized complete block design (RCBD) was followed, as each treatment was sprayed at a concentration of 100%, while the control was sprayed with distilled water only after sprayer calibration. Spraying was carried out in the evening using a backpack sprayer with a capacity of 2 liters. The numbers of nymphs on each plant were calculated one day before spraying, and then the numbers of nymphs were calculated after 1, 3, 7, and 10 days from treatment. As for the biological fungi, each treatment was sprayed with 3 dilutions for each fungus with three replicates. The equation of Tilton and Henderson (1955) was used to calculate the relative efficiency of the pesticides in the field.

$$\text{RE}\ \% = \left(1 - \frac{\text{No. of pests after treatment } \times \text{No. of pests in control before treatment}}{\text{No. of pests before treatment } \times \text{ No. of pests in control after treatment}}\right) x\ 100$$

2.5 Statistical analysis

The study was designed using the completely randomized design C.R.D. at a probability level of 0.01 under laboratory conditions, while the field trial were implemented using RCBD at a probability level of 0.05, using the least significant difference LSD to compare the means of the treatments. The GenStat Procedure Library Release PL18.2 program was used in the statistical analysis.

3. Results and discussion

3.1 Effect of plant extracts and fungi on whitefly nymphs under laboratory conditions

The results shown in Table (2), at a significance level of 0.01, indicated the superiority of the plant extract of *O. basilicum* over the extracts of *E. camaldulensis* and shrubby *L. camara* under laboratory conditions, as it achieved a mortality percentage of 45.36%. It was followed by the plant extract of shrubby *L. camara*, which achieved a mortality percentage of 41.38%, and which differed significantly from the plant extract of *E. camaldulensis*, as the mortality percentage of whitefly nymphs reached 37.36%. As for the concentrations, the concentration of 100% was superior, as the mortality percentage reached 60.89%, and it differed significantly from the concentrations 75, 50, and 25%. It was followed by the concentration of 75%, as the mortality percentage of the nymphs reached 53.18%, and it differed from the concentrations 50 and 25%, in which the mortality percentages reached 33.20 and 18.39%, respectively. As for the time periods, the highest mortality percentage reached 53.23% on the fourth day after treatment, and it differed significantly from the first, second, and third days, which achieved mortality percentages of 26.46, 37.00, and 48.76 % respectively.

The reason for the superiority of the methanolic extract of basil *O. basilicum* may be attributed to its content of phenolic compounds, alkaloids, terpenoids, flavonoids, saponins, and steroids. Ouko *et al*. (2017) mentioned that the concentrations 25, 50, 75, and 100% caused mortality percentages of 32.05, 73.08, 89.74, and 100% after 96 hours from treating the insect *Sitophilus zeamais*. Yousif and

Satti (2012) also showed that the use of the aqueous extract of sweet basil and shrubby lantana proved an effective effect on the khapra beetle *Trogoderma granarium* under laboratory conditions, and that sweet basil was more effective than shrubby lantana. The plant *Lantana camara* L. contains active components of alkaloid compounds, lantanin, flavonoids, and triterpenoids, and the concentration of 15% achieved a mortality percentage of 90% after 72 hours from treating the whitefly *B. tabaci* under laboratory conditions (Ikhsanu and Prastowo, 2022). The importance of discovering new active substances that are environmentally friendly, agriculturally sustainable, and of plant origin is increasing compared with chemical pesticides. The toxicity of aqueous extracts of the leaves of *E. camaldulensis* and *L. camara* plants was determined under laboratory conditions on the aphid insect *Aphis gossypii* Glover, as the concentration of 20% of the extracts of eucalyptus and sweet basil achieved 54 and 60.8%, respectively, after 72 hours in the laboratory. The reason for their efficiency may be attributed to their effect on the enzyme acetylcholinesterase (AChE) and the enzyme carboxylesterase (Ulusoy *et al*., 2019).

Many researchers, Amina *et al*. (2026) and Rizwan *et al*. (2022), indicated that the aqueous extract of eucalyptus leaves contains many secondary compounds, represented by alkaloids, flavonoids, phenols, and saponins, which achieved mortality percentages on the mealybug *Drosicha ma*ngifera reaching 66.67% under laboratory conditions.

Table (2). Effect of some studied aqueous extracts on the mortality of whitefly nymphs under laboratory conditions.

Extract type	Dilution	Corrected mortality percentage after (hour)				Mean effect of concentration	Mean effect of extract
		24	48	72	96		
O. basilicum	100	45.79	56.05	75.86	86.14	60.89	45.36
	75	37.25	52.63	68.93	73.95	53.18	
	50	25.35	35.49	39.66	44.73	33.20	
	25	13.42	15.29	25.87	29.29	18.39	
L. camara	100	40.61	54.12	70.70	77.54		41.38
	75	33.77	44.03	67.17	67.19		
	50	20.26	33.92	37.89	38.63		
	25	11.75	15.26	20.61	27.54		
E. camaldulensis	100	35.44	49.12	66.25	71.61		37.36
	75	27.02	42.28	60.35	63.59		
	50	16.75	32.25	34.56	37.89		
	25	10.09	13.59	17.28	20.70		
Mean effect of time period		26.46	37.00	48.76	53.23		
L.S.D.0.01: time = 3.66; dilution = 3.66; extract = 3.16; interaction = 6.33							

The results of Table (3), at a significance level of 0.05, also showed that the fungus *B. bassiana* achieved a mortality percentage of 47.68%, which was significantly superior to the fungus *T. viride*, which achieved a mortality percentage of 42.71%. As for the dilution1×10^{-4}, it achieved a mortality percentage of 53.66%, which differed significantly from the dilution 1×10^{-5}, which achieved a mortality percentage of 44.79%, and which differed significantly from the dilution 1×10^{-6}, which achieved a mortality percentage of 37.14%. As for the time periods, the highest mortality percentage reached 76.58% on the fourth day after treatment, followed by the third day, as the mortality percentage reached 57.77%, while the first and second days recorded mortality percentages of 17.69 and 36.74%, respectively.

The use of the biological fungus *B. bassiana* on second-instar nymphs of the whitefly *Bemisia tabaci* at a concentration of 1×10^{7} spores ml^{-1} achieved a mortality percentage of 100% after eight days from treatment (Sandoval *et al*., 2025). Treating nymphs of the aphid insect Myzus persicae with the biological fungus *T. viride* achieved a mortality percentage of 82% after three days from treatment under laboratory conditions (Mahdi *et al*., 2025).

Chitinolytic enzymes extracted from the fungus *T. viride* affect the plasma membrane of the silkworm, which belongs to Lepidoptera. It was found that these enzymes secreted by the fungus have noticeable effects on the structure and permeability of the plasma membrane of the insect *Bombyx mori*. When the insect is orally fed, they cause changes in the plasma membrane, which leads to the cessation of larval growth and development, negatively affects pupal weight, and may cause its mortality (Berini *et al*., 2016). Several studies have confirmed the effect of the fungus *Trichoderma* in controlling harmful insects through parasitism, production of secondary metabolites inhibitory to insects, and antifeedant compounds (Poveda, 2021).

Table (3). Effect of the two biological fungi *T. viride* and *B. bassiana* on whitefly nymphs under laboratory conditions.

Type of fungus	Dilution	Corrected mortality percentage after (hour)				Mean effect of concentration	Mean effect of fungus
		24	48	72	96		
B. bassiana	1×10^{-4}	23.59	46.57	70.17	82.00	**53.16**	**47.68**
	1×10^{-5}	20.26	37.89	63.15	71.44	**44.79**	
	1×10^{-6}	11.75	30.96	54.38	59.96	**37.13**	
T. viride	1×10^{-4}	20.26	43.15	64.91	74.65		**42.38**
	1×10^{-5}	16.84	32.63	54.38	61.69		
	1×10^{-6}	13.42	29.21	45.61	51.75		
Mean effect of time period		**17.69**	**36.74**	**58.77**	**66.92**		
L.S.D. 0.05	Time = 4.87; dilution = 3.22; fungus = 3.44; interaction = 6.89						

Effect of plant extracts and fungi on whitefly nymphs under field conditions

The results shown in Table (4), at a significance level of 0.05, indicated that the plant extract of *O. basilicum* achieved a relative efficiency of 41.66%, which was significantly superior to the extracts of shrubby *lantana* and *eucalyptus*. It was followed by the aqueous extract of shrubby *L. camara*, which achieved a mortality percentage of 36.18%, while the aqueous extract of *E. camaldulensis* achieved a mortality percentage of 33.42%.

Plant extracts usually contain a complex mixture of secondary metabolites that act through multiple pathways for penetration through the cuticle (contact), entry into the respiratory system (fumigation), or ingestion after systemic translocation (Padial *et al*., 2025). Sweet basil contains many metabolites, including terpenoids, flavonoids, alkaloids, and others (Kacaniova *et al*., 2022).

Hussein *et al*. (2025) proved that the use of sweet basil oil was effective against whitefly, as it contains anethole and estragole, Estragole and E-anethole, which act as repellents or toxicants. When tomato plants were sprayed with basil oil, it reduced whitefly density, as it reached 2.20 flies / plant compared with the control treatment, which reached 9.13 flies / plant. Basil leaf extract succeeded in reducing the severity of infection with whitefly, as basil extract had a positive effect on fruit yield and caused an increase in fruit weight (Diputra and Setiawan, 2024). Plant extracts are among the most prominent methods for protecting crops and their products from infection with insect pests, as the extract of shrubby lantana plant *L. camara* affects growth, behavior modification, and killing in many pests (Mandakini *et al*., 2021). Baidoo *et al*. (2017) showed that the use of the ethanolic extract of the leaves of shrubby lantana plant was effective in reducing the numbers of whitefly on okra plant, as it reached 1.42 insects / leaf compared with the control treatment, which reached 3.72 insects / leaf.

Table (4). Effect of some studied aqueous extracts on the mortality of whitefly nymphs under field conditions.

Extract	Days				Mean Extract
	1	3	7	10	
O. basilicum	28.22	39.37	52.60	46.49	**41.66**
L. camara	22.29	34.15	46.65	41.69	**36.18**
E. camaldulensis	21.61	31.21	42.96	37.92	**33.42**
Mean effect of time period	24.03	**34.91**	**47.38**	**42.03**	
L.S.D. 0.05	Time = 1.96 Extract=1.96 Interaction=3.39				

The results shown in Table (5), at a significance level of 0.05, also indicated that the fungus *B. bassiana* achieved a relative efficiency of 36.77%, which was significantly superior to the fungus *T. viride*, as it achieved a relative efficiency of 31.861%. As for the dilutions, the dilution 1×10^{-4} was superior, as it achieved a relative efficiency of 40.39%, which differed significantly from the dilution 1×10^{-5}, which achieved a relative efficiency of 33.91%, and which differed significantly from the dilution 1×10^{-6}, which achieved a relative efficiency of 28.65%. As for the time periods, the highest mortality percentage reached 55.54% on the fourth day after treatment, followed by the tenth day after treatment, as the mortality percentage reached 47.43%, while the first and third days recorded mortality percentages of 5.61 and 28.54%, respectively.

The effectiveness of the fungus *B. bassiana* against whitefly nymphs may be attributed to its secretion of some extracellular enzymes. This is what Ito *et al*. (2007) mentioned, as they indicated the ability of the fungus *B. bassiana* to secrete the enzymes chitinase and protease in liquid media, where the fungus gave a mortality percentage ranging between 58 and 91% after seven days from treatment against the insect *Aphis craccivora*. Saleh *et al*. (2002) referred to the role of the spore suspension of the fungus *B. bassiana* against nymphs and adults of the dubas bug of date palm, and the killing percentage increases with increasing exposure duration to the fungus. Meanwhile, the effectiveness of the fungus *T. viride* on the plasma membrane of the silkworm may be due to its ability to secrete the enzyme chitinase, and thus the fungus has the ability to penetrate inside the insect body, as it was found that these enzymes have effects on the structure and permeability of the plasma membrane of this insect, leading to the cessation of larval growth and development, and may cause their death (Berini *et al*., 2016).

In a study conducted by Saleh *et al*. (2025a) using the fungus *B. bassiana* on whitefly in greenhouses, it achieved a mortality percentage of 89.64%. Saleh *et al*. (2025b) also showed that the fungus *B. bassiana* achieved a mortality percentage on the aphid insect *Aphis gossypii* reaching 86.59% after ten days from treatment under field conditions.

The implementation of pest and disease management strategies that minimize environmental impact is crucial for the advancement of sustainable agriculture. Microbial biopesticides are considered an effective approach due to their low environmental impact and the low risk of resistance appearance against them (Komagata *et al*., 2024). Entomopathogenic fungi are considered safe and highly effective against many pests, and the fungus *B. bassiana* achieved a mortality percentage on whitefly reaching 85.90% (Bohata et al., 2024). Erol *et al*. (2020) also showed that the fungus *T. viride* achieved a killing percentage of 93.33% after seven days from treatment of nymphs of the aphid insect *Aphis gossypii*.

Table (5). Effect of the two biological fungi *B. bassiana* and *T. viride* on whitefly nymphs under field conditions.

Fungi	Dilution	Time (days)				Mean	Mean fungi effect
		1	3	7	10		
B.bassiana	1×10^{-4}	10.22	34.28	56.00	70.73	**40.39**	**36.77**
	$10^{-5}\times1$	7.61	30.89	49.11	58.19	**33.91**	
	$^{6-}101\times$	3.95	24.99	43.33	51.97	**28.65**	
T. viride	1×10^{-4}	5.11	31.91	53.01	61.84		**31.86**
	^{5} $^{-}101\times$	4.12	27.58	43.87	49.93		
	$^{6-}101\times$	2.67	21.59	38.90	41.79		
Mean effect of time period		**5.61**	**28.54**	**47.37**	**55.54**		
L.S.D 0.05	Time = 2.51 Dilution 1.77 Fungi=2.17 Interaction=3.45						

Conclusion

The results of this study demonstrated that the aqueous extract of sweet basil was the most efficient plant extract in increasing the mortality of *Bemisia tabaci* nymphs under laboratory and field conditions compared with the aqueous extracts of shrubby lantana and eucalyptus. The biological fungus *Beauveria bassiana* also showed higher effectiveness than *Trichoderma viride* in reducing whitefly nymph populations. These findings indicate that sweet basil aqueous extract and *B. bassiana* may represent promising, environmentally safe alternatives that can be used within integrated pest management programs for whitefly control on eggplant.

Acknowledgment

The authors express their sincere thanks and appreciation to the College of Agriculture, University of Basrah, and the Agricultural Research and Experimental Station for providing the facilities and support required to conduct this study. The authors also thank all staff members who contributed to the completion of the laboratory and field work.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this research.

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