Mexican Journal of Phytopathology
ISSN: 2007-8080

Crossref Open access

Scientific Article

Sensitivity of *Colletotrichum truncatum* isolated from *Echeveria gibbiflora* plants to different biofungicides

José Terrones Salgado[1]*, Carlos David Carretillo Moctezuma[2], José Francisco Díaz Nájera[3], Sergio Ayvar Serna[3], José Luis Arispe Vázquez[4], César Flores de los Ángeles[5], Nicolás Álvarez Acevedo[1]. [1]Decanato de Ciencias de la Vida y la Salud, Escuela de Ingeniería en Agronomía, Centro de Investigación en Horticultura y Plantas Nativas, UPAEP University, 21 sur No. 1103, Puebla, Puebla, CP 72410, México. [2]Facultad de Matemáticas, Universidad Autónoma de Guerrero, Av. Lázaro Cárdenas S/N, Chilpancingo de los Bravo, Guerrero, CP 39087, México. [3]Colegio Superior Agropecuario del Estado de Guerrero, Fitotecnia, Iguala de la Independencia, Guerrero, CP 40000, México. [4]Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, Km 2.5 Carretera Iguala-Tuxpan, Colonia Centro Tuxpan, Iguala de la Independencia, Guerrero, CP 40000, México. [5]Laboratorio de Diagnóstico Molecular, UPAEP University, 21 sur No. 1103, Puebla, Puebla, CP 72410, México.

***Corresponding Author:**
José Terrones Salgado
jose.terrones@upaep.mx

Section:
Special Number

Received:
15 November 2024
Accepted:
20 March, 2025
Published:
02 April, 2025

Citation:
Terrones SJ, Carretillo MCD, Díaz NJF, Ayvar SS, Arispe VL, *et al*., 2025. Sensitivity of *Colletotrichum truncatum* isolated from *Echeveria gibbiflora* plants to different biofungicides. Mexican Journal of Phytopathology 43(4): 59. https://doi.org/10.18781/R.MEX.FIT.2024-16

ABSTRACT

Background/Objetive. *Colletotrichum truncatum* is a phytopathogenic fungus that induces the anthracnose disease in the leaves of *Echeveria gibbiflora* (Echeveria), a native Mexican species with a great ornamental value. The aim was to evaluate the sensitivity of *C. truncatum* isolated from *E. gibbiflora* plants to 11 biofungicides as an alternative for the integrated management of the disease.

Materials and Methods. Through sensitivity tests, the percentage of fungal growth inhibition was determined in PDA medium modified with each biofungicide at concentrations of 0, 1, 10, 100, 500 and 1000 mg L^{-1}. A completely randomized design with an 11 × 6 factorial arrangement (11 biofungicides × six concentrations) and four replications was used. The effective concentration of an inhibition of 50% (EC_{50}) was determined by logistic regression.

Results. *C. truncatum* isolated from *E. gibbiflora* was the most sensitive to the *Melaleuca alternifolia* oil (EC_{50} = 109.23 mg L^{-1}), extracto de *Reynoutria sachalinensis* (EC_{50} = 168.76 mg L^{-1}) y *Bacillus amyloliquefaciens* QST 713 (EC_{50}=61.07 mg L^{-1}) in *in vitro* conditions. The *Laminaria digitata* oil (EC_{50} = 19.95 mg L^{-1}), *Thymus vulgaris* and *Mentha spicata* essential oils (EC_{50} = 112.47 mg L^{-1}) and the extract of *Larrea tridentata* and *Ricinus communis* (EC_{50} = 78.51 mg L^{-1}) inhibited more than 50% of the growth of the fungus.

Conclusion. The *L. digitata* oil, *T. vulgaris* and *M. spicata* essential oils and the *L. tridentata* and *R. communis* extract have an inhibiting effect on the growth of the fungus of over 50%. These results contribute to the knowledge of the integrated management of

C. truncatum that causes leaf anthracnose in *E. gibbiflora* with the application of biofungicides.

Keywords: Biofungicides, Biocontrol, EC_{50}, Sensitivity, Fungi, Echeveria, Phytopathogens

INTRODUCTION

The *Echeveria* genus belongs to the Crassulaceae family, which corresponds to a group of plants endemic to the American continent, with succulent leaves and few agricultural requirements. Out of this genus, Mexico has 83% of the diversity of species (Reyes-Santiago *et al*., 2011a; Reyes-Santiago *et al*., 2011b; Schoch *et al*., 2020).

In this genus, *Echeveria gibbiflora* (tememetla, Echeveria, ornamental succulent) stands out as one of the native Mexican species with great potential in floriculture, due to its ability to thrive in adverse environments, the beauty of its leaves, the size of its inflorescence (1 m in length), number of batches (up to 12 per inflorescence), the attractiveness of its bright pink flowers and the continuous appearance of new buds (Reyes-Santiago *et al*., 2015). These are characteristics that make it an excellent option for their commercialization, both in pots and also as cutting flowers (Leszczyñska-Borys, 2003).

On the other hand, one of the factors that influence the quality of the *Echeveria* genus plants is the attack of diverse fungal diseases such as anthracnose induced by *Colletotrichum destructivum* (Yao *et al*., 2020), powdery mildew by *Erysiphe* sp. (Shi *et al*., 2019), stem rot by *Fusarium oxysporum* (Yao *et al*., 2021), vascular wilting by *F. oxysporum* f. sp. *echeveriae* (Ortu *et al*., 2015), fungal leaf spot (*Cladosporium tenuissimum*) (Jo *et al*., 2018), white mold (*Sclerotinia sclerotiorum*) (Terrones *et al*., 2024) and anthracnose induced by *Colletotrichum truncatum* (Apáez *et al*., 2025). It is frequent that, for the management of diseases in urban areas, chemical pesticides are inadequately applied, which implies the release of toxic residues into the environment, making it a risk for human health and the environment (Meftaul *et al*., 2020), whether directly by bioaccumulation, or indirectly by the food chain (Parra-Arroyo *et al*., 2022). This leads to a need to generate sustainable strategies for the management of diseases in ornamental plants for urban areas that help reduce the resistance of the pathogens to chemical pesticides and contribute to the reduction of contamination of soils and aquifers (Reyes *et al*., 2015). Biofungicides based on plant oils, plant extracts and antagonistic microorganisms suggest possible uses in the *in vitro* biological control of *C. truncatum* isolated from *E. gibbiflora*. Due to this, the aim of this study was to evaluate the sensitivity of *C. truncatum* that induces anthracnose in *E. gibbiflora* to 11 biofungicides as an alternative for the integrated management of the disease.

MATERIALS AND METHODS

Origin of the isolation. An isolation obtained from *E. gibbiflora* plants grown in the Research Center in Horticulture and Native Plants of UPAEP University, located in

Atlixco, Puebla, Mexico, where symptoms of anthracnose was observed in leaves, with an incidence and severity of 45 and 40%, respectively. The fungus that induced the disease was isolated (isolate CtEg2) and characterized pathogenically, culturally, morphologically, morphometrically and phylogenetically in a previous study and identified as *Colletotrichum truncatum* (GenBank. ITS: PP406307; TUB2: PP616679; GAPDH: PP616680; ACT: PP616681) (Apáez *et al*., 2025).

Preparation of modified culture media and planting of *C. truncatum*. Using the poisoned culture medium method (Barroso *et al*., 2021; Guerrero *et al*., 2007), the sensitivity of the *C. truncatum* isolation was evaluated with 11 biofungicides (Table 1). All biofungicides were tested with six concentrations, 0 (control), 1, 10, 100, 500 and 1000 mg L^{-1}. A potato dextrose agar (PDA) culture medium was used, modified with the biofungicides poured into Petri dishes (100 × 15 mm). Subsequently, a 5 mm PDA disc with an active, seven-day old *C. truncatum* growth was planted, and the dishes were incubated in the dark at 25 ± 1 °C (Iturbide *et al*., 2017).

Table 1. Effect of different biofungicides on the sensitivity of *C. truncatum* isolated from *E. gibbiflora*.

Treatment	Brand name	Active ingredient	%[y]	EC_{50} (mg L^{-1})
T1	Timorex® Gold, Syngenta	*Melaleuca alternifolia*[v]	23.8	109.23
T2	REGALIA® MAXX, FMC	*Reynoutria sachalinensis*[w]	20	168.76
T3	Serenade® ASO, Bayer	*Bacillus amyloliquefaciens* QST 713[X]	1.34[z]	61.07
T4	Vacciplant®, Arysta	*Laminaria digitata*[v]	4.5	19.95
T5	Nopath®, Koppert	*Thymus vulgaris, Mentha spicata*[v]	32	112.47
T6	OrgFung®, Gowan	*Larrea tridentata*[w]	4	99.47
T7	FungiBest control, AgriBest	*Syzygium aromaticum, Piper nigrum, Ricinus communis, Ruta graveolens*[w]	10	71.55
T8	Bio Gober Plus®, BioNutra	*Larrea tridentata, Ricinus communis*[w]	82.5	78.51
T9	Bacter F®, BioNutra	*Lippia graveolens, Cinnamumun verum, Ricinus communis*[w]	31.9	27.57
T10	Naturdai MIM®, Idainature	*Mimosa tenuiflora, Quercus robur*[w]	8.3	60.15
T11	Protector Plus®, BioNutra	Potassium salts[w]	41.9	295.7

[V] Plant oil; [W] Plant extract; [X] Antagonist; [Y] Concentration of the active ingredient in the formulation of the product; [Z] 1×10^9 UFC per gram of product formulated.

Determining the percentage of inhibition. The diameter of the colony was measured every 24 h for 12 days (time taken for the control Petri dishes to fill with fungal mycelium) in two perpendicular directions using a digital caliper (Truper®, Mexico) and using the data obtained, the percentage of growth inhibition (PGI) was calculated using Abbott's formula (1925): PGI= $\left(\frac{Dc-Dt}{Dc}\right)x\ 100$ where: PGI: Percentage of growth inhibition; Dc: Diameter of the control; Dt: Diameter of the treatment (García *et al*., 2021).

Experimental design. It was a factorial experiment, arranged in a totally randomized design, 11 × 6 [11 biofungicides with six concentrations (0, 1, 10, 100, 500 and 1000 mg L^{-1}) each] with 66 treatments, four repetitions and 264 experimental units, each consisting of one Petri dish measuring 100 × 15 mm, and two repetitions of the experiment were performed.

Data analysis. The data obtained underwent normality tests, using the Shapiro-Wilk test. Likewise, the Levene test was used for the variance homogeneity test and the level of significance used was alfa=0.05. A concentration-response analysis was performed to evaluate the biological effectiveness of 11 different biofungicides in terms of percentages of inhibition. The data were adjusted to a log-logistical model to determine the effective concentration for an inhibition of 50% (EC_{50}) for each biofungicide. An analysis of variance was carried out, along with Tukey's test to carry out multiple comparisons between the percentage of mycelial inhibition of the 11 biofungicides, with a level of significance of 5%. All statistical tests were performed in the program R, version 4.3.2.

RESULTS

The effective concentration for 50% inhibition (EC_{50}) was different for each biofungicide. For the *M. alternifolia* oil, it was 109.23 mg L^{-1}, whereas for the *R. sachalinensis* extract, it was 168.76 mg L^{-1}. In the case of *B. amyloliquefaciens* QST 713, the estimation of EC_{50} was 61.07 mg L^{-1} and in the *L. digitata* oil, EC_{50} was 19.95 mg L^{-1}. Regarding the *T. vulgaris* and *M. spicata* essential oils a EC_{50} of 112.47 mg L^{-1} was observed. In the cases of the *L. tridentata* and *R. communis* extracts, a EC_{50} of 78.51 mg L^{-1} was identified; a EC_{50} of 71.55 mg L^{-1} was found for the *S. aromaticum*, *P. nigrum*, *R. communis* and *R. graveolens* extracts. The *L. tridentata* extract obtained a value of 99.47 mg L^{-1}, the EC_{50} of the *L. graveolens*, *C. verum* and *R. communis* extracts presented a value of 27.57 mg L^{-1}, and the *M. tenuiflora* and *Q. robur* extract displayed a EC_{50} of 60.15 mg L^{-1}. Finally, the EC_{50} was determined for the fatty-acid-rich potassium salts with a value of 295.70 mg L^{-1} (Table 1, Figure 1).

The estimated values of the 50% effective concentration (standard error and t and p values) indicated that the estimation is highly significant ($p < 0.001$) for all biofungicides, except for the *T. vulgaris* and *M. spicata* essential oils, as the values suggest that the estimation is significant ($p < 0.05$) (Table 1).

The analysis of variance displayed significant differences between the percentages of inhibition of the mycelial growth of biofungicides (p-value < 2e-16***). Tukey's test was used to carry out multiple comparisons between the percentages of inhibition of the mycelial growth of the 11 biofungicides, with a level of significance of 5%. The residual variability is relatively low (MSerror = 3.94), which suggests that the model is well adjusted to the data observed. The coefficient of variation was 3.65%, which indicates that the variability of the data is relatively low in comparison to the mean observed (53.46%); Tukey's means comparison test displayed statistically different group.

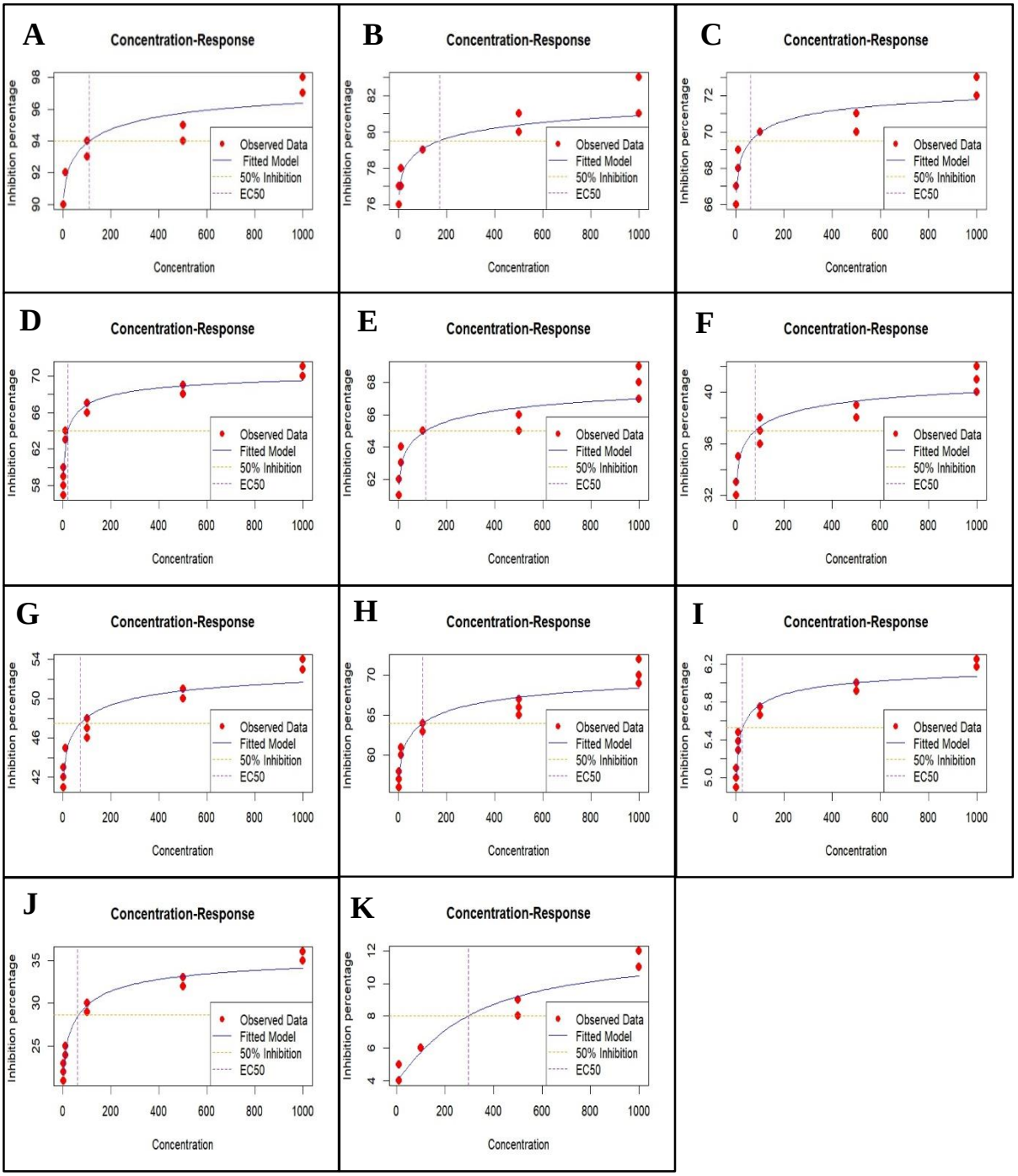

Figure 1. Concentration response and EC_{50} of 11 biofungicides against *C. truncatum* isolated from *E. gibbiflora*. A) e *M. alternifolia* oil; B) *R. sachalinensis* extract; C) *B. amyloliquefaciens* QST 713; D) *L. digitata* oil; E) ac *T. vulgaris* and *M. spicata* essential oils; F) *L. tridentata* and *R. communis* extracts; G) cinnamaldehyde, *S. aromaticum, P. nigrum, R. communis* and *R. graveolens* extracts; H) *L. tridentata* extract; I) *L. graveolens, C. verum* and *R. communis* extracts; J) *M. tenuiflora* and *Q. robur* extract; K) fatty-acid-rich potassium salts.

The treatment based on *M. alternifolia* oil was significantly different to the rest of the treatments, with the highest percentage of inhibition of the mycelial growth with a value of 93.6%, while the biofungicide made with fatty-acid-rich potassium salts was significantly different to the rest of the treatments, since it presented the lowest percentage of inhibition of the mycelial growth, with a value of 7.63%. The biofungicides composed of *R. sachalinensis* extract, *B. amyloliquefaciens* QST 713, *L. digitata* oil, *T. vulgaris* and *M. spicata* essential oils and the *L. tridentata* extract displayed percentages of inhibition above 50%, with values of 78.85, 69.5, 65.4, 64.55 and 63.4 %, respectively (Figure 2).

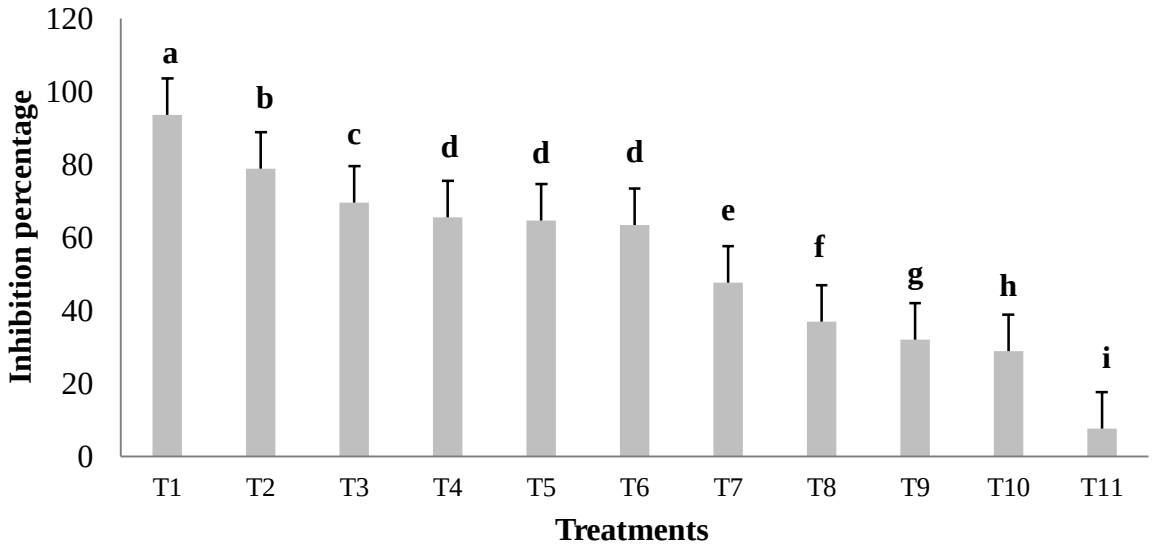

Figure 2. Percentage of inhibition of the mycelial growth of *C. truncatum* isolated from *E. gibbiflora*, evaluated *in vitro* with 11 biofungicides. The mean values followed by the same letters are statistically similar (Tukey $\alpha = 0.05$) according to Tukey's honest significant difference test. T1= *M. alternifolia* oil; T2= *R. sachalinensis* extract; T3= *B. amyloliquefaciens* QST 713; T4= *L. digitata* oil; T5= *T. vulgaris* and *M. spicata essential* oils; T6= *L. tridentata* extract; T7= cinnamaldehyde, *S. aromaticum* extracts, *P. nigrum*, *R. communis* y *R. graveolens*; T8= *L. tridentata* and *R. communis* extracts; T9= *L. graveolens*, *C. verum* and *R. communis* extracts; T10= *M. tenuiflora* and *Q. robur* extract; and T11= fatty-acid-rich potassium salts.

The percentage of inhibition of the mycelial growth of *C. truncatum* was calculated for each one of the six concentrations (0, 1, 10, 100, 500 and 1000 mg L^{-1}) of the 11 biofungicides evaluated. In concentration of 0 mg L^{-1}, the percentage of inhibition was 0% in all biofungicides. When 1 mg L^{-1} was evaluated, the percentage of inhibition varied from 0.5 to 90.0%; when the concentration of 10 mg L^{-1} was tested, the percentage of inhibition was maintained in a range of 4.8 to 92.0%, whereas when 100 mg L^{-1} was tested, a range of 6.0 to 93.8% of inhibition was identified. In the concentration of 500 mg L^{-1}, the percentage of inhibition values found were between 8.3 and 94.8%. Finally, when a concentration of 1000 mg L^{-1} was used, the percentage of inhibition was found to range between 11.5 and 97.5. In all concentrations used, the fatty-acid-based potassium

salt treatment presented the lowest percentage values, whereas the *M. alternifolia* oil-based treatment displayed the highest values (Table 2). Additionally, in all the biofungicides evaluated, the percentage of inhibition grew as the concentration increased. For example, in the case of *M. alternifolia* oil, when concentrations of 1, 10, 100, 500 and 1000 mg L^{-1} were evaluated, percentages of inhibition were identified in the *C. truncatum* mycelial growth of 90.0, 92.0, 93.8, 94.8 and 97.5 respectively. The biofungicides composed of *L. tridentata* plant extract, *T. vulgaris* and *M. spicata* oils, *L. digitata plant* oil, *B. amyloliquefaciens* QST 71 antagonist, *R. sachalinensis* plant extract and de *M. alternifolia* oil presented percentages of mycelial growth inhibition higher than 50% (Table 2).

Table 2. Effect of different biofungicides on the percentage of inhibition of the mycelial growth of the *C. truncatum* isolated from *E. gibbiflora*.

Treatment	Brand name	Active ingredient	%[y]	Concentration (mg L^{-1}) / percentage of inhibition of the mycelial growth				
				1	10	100	500	1000
T1	Timorex® Gold, Syngenta	*Melaleuca alternifolia*[v]	23.8	90.0	92.0	93.8	94.8	97.5
T2	REGALIA® MAXX, FMC	*Reynoutria sachalinensis*[w]	20	76.3	77.8	79.0	80.3	81.0
T3	Serenade® ASO, Bayer	*Bacillus amyloliquefaciens* QST 713[x]	1.34[z]	66.3	68.3	70.0	70.5	72.5
T4	Vacciplant®, Arysta	*Laminaria digitata*[v]	4.5	58.5	63.8	66.3	68.3	70.3
T5	Nopath®, Koppert	*Thymus vulgaris, Mentha spicata*[v]	32	61.3	63.3	65.0	65.3	68.0
T6	OrgFung®, Gowan	*Larrea tridentata*[w]	4	57.0	60.5	63.3	66.0	70.3
T7	FungiBest control, AgriBest	*Syzygium aromaticum, Piper nigrum, Ricinus communis, Ruta graveolens*[w]	10	42.0	45.0	47.0	50.3	53.3
T8	Bio Gober Plus®, BioNutra	*Larrea tridentata, Ricinus communis*[w]	82.5	32.5	32.5	37.0	38.8	40.8
T9	Bacter F®, BioNutra	*Lippia graveolens, Cinnamumun verum, Ricinus communis*[w]	31.9	25.0	29.0	32.3	35.3	38.8
T10	Naturdai MIM®, Idainature	*Mimosa tenuiflora, Quercus robur*[w]	8.3	21.8	24.8	29.5	32.3	35.5
T11	Protector Plus®, BioNutra	Potassium salts[w]	41.9	0.5	4.8	6.0	8.3	11.5

[V] Plant oil; [W] Plant extract; [X] Antagonist; [Y] Concentration of the active ingredient in the formulation of the product; [Z] 1×10^9 UFC per gram of product formulated

DISCUSSION

Calculating the EC_{50} of each product helped identify that seven biofungicides (64%) were effective at concentrations lower than 100 mg L^{-1} and 4 of them (36%), at

concentrations between 101 and 300 mg L^{-1}, whereas the most efficient biofungicides in the control of *C. truncatum* were the *M. alternifolia* oil, the *R. sachalinensis* extract and the *B. amyloliquefaciens* QST 713, effective in the control at relatively low concentrations of 109.23, 168.76 and 61.07 mg L^{-1}, respectively.

According to Quyen and Quoc (2024), the essential oils of the *M. alternifolia* extract contain 45 compounds, of which the main compound is terpinen-4-ol (44.55%), associated to antioxidant and antimicrobial activity. Likewise, the action mechanism of this essential oil in *Penicillium expansum* has been documented to be on the plasmid membrane of the fungus, although whether this is due to the alteration in the structure of the membrane or a change in its permeability is unknown. However, the exposure of the fungus for 4 hours to the vapor phase of the *M. alternifolia* essential oil caused a loss in DNA, protein and glucose, as well as lipid damage (da Rocha *et al*., 2019).

Regarding the control of some *Colletotrichum* species, do Nascimento *et al*. (2019) found that with a concentration of 25 µL of *M. alternifolia* essential oil, the germination of spores from *Colletotrichum gloeosporioides* isolated from bell pepper (*Capsicum annuum*) plants becomes inhibited by 100%. In turn, da Costa *et al.* (2023) reported that the EC_{100} on the mycelial growth of *C. musae* in *in vitro* plantations achieved this with a concentration of 2.15 µg mL^{-1} of *M. alternifolia* essential oil, whereas treatments with banana fruits with aqueous emulsions of the essential oil reduce the severity of anthracnose induced by *C. musae* by more than 80% without any phytotoxic effects. These data coincide with the results presented in this investigation, unlike a study by Kiranmayee *et al.* (2020) that evaluated the effect of eight essential oils on the *in vitro* growth of *C. gloeosporioides* isolated from pommegranate (*Punica granatum*) stems and roots, and showed that *M. alternifolia* essential oil had a lower effect on concentrations of 0.5, 1.0 and 2.0%, in comparison with thyme (*T. vulgaris*) and clove (*S. aromaticum*) oils, which were the most effective biofungicides for the inhibition of mycelial growth, which suggests that, in order to evaluate the fungicidal effect of *M. alternifolia*, several factors must be taken into account, such as the species of the pathogen, the host from which it was isolated, the concentration of the biofungicide and the environment.

On the other hand, *M. alternifolia* has been proven to have an effect on the growth of other phytopathogenic fungal species, as indicated in an investigation by Rani and Tripathi (2022), where it was reported that with a dose of 0.02% of *M. alternifolia* essential oil, inhibited the germination of *Botrytis cinerea* spores isolated from chili pepper (*C. annuum*) fruits by 100%. Likewise, the authors indicate that the application of this oil as a fumigant and in submersion treatments for fruits increases the shelf life of the chili pepper. The sensitivity of the *Alternaria alternata* fungus to the essential oil of *M. alternifolia* was also evaluated, with 11 concentrations that ranged between 0.0125 and 1.0%, and found that the concentration in which full inhibition was reached was 0.2%. Meanwhile, evaluating *in vivo* by treatments of the cowpea bean (*Vigna unguiculata*) seed with the essential oil did not reduce the percentage of incidence of the pathogen (de Figuerêdo *et al.*, 2019), which indicates that, alongside the *in vitro* tests of sensitivity of *C. truncatum* to the *M. alternifolia* essential oil, it is necessary to carry out *in vivo* tests on *E. gibbiflora* plants to determine the optimum dose on the field.

In addition to the antifungal effect, there are reports indicating that *M. alternifolia* has an inhibiting effect on the pathogenic bacteria of humans and some fungi that produce mycotoxins. Quyen and Quoc (2024) calculated the EC_{50} of the *M. alternifolia* essential

oils for the inhibition of the growth of *Bacillus cereus* (ATCC 11778), *Staphylococcus aureus* (ATCC 25923), *Salmonella enterica* (ATCC 13076) and *Escherichia coli* (ATCC 25922) and reported that the 50% inhibition of bacterial growth was at a concentration of 360 mg mL^{-1}. Another similar study, carried out by Zhang *et al.* (2018) shows that the *M. alternifolia* essential oil has an antimicrobial effect, not only on the growth of bacteria such as *E. coli*, *S. aureus* and *Pseudomonas aeruginosa*, but also of fungi such as *Penicillium italicum* and *P. digitatum* with a EC_{50} of 48.35 µg mL^{-1}. This is an advantage in the use of the *M. alternifolia* essential oil since *E. gibbiflora* is commonly used in plants, where these plants can come into contact with children and pets. Therefore, should there be any contamination of the water or organic residues used for the cultivation of this plant, the oil could contribute to minimizing the risks of contamination, although further study on this is necessary.

The *R. sachalinensis* extract was the biofungicide with the second highest inhibition in the growth of *C. truncatum*. According to Margaritopoulou *et al.* (2020), in a study on the control of powdery mildew induced by *Podosphaera xanthii* in zucchini, the *R. sachalinensis* extract works as an elicitor or inducer of the plant defense mechanisms, since it triggers several reactions, such as the formation of callose, the accumulation of hydrogen peroxide and the increase in the production of salicylic, p-coumaric and caffeic acids, which significantly reduced the germination of conidia and the severity of the disease. Santos-Esteban *et al.* (2021) reported that the *R. sachalinensis* extract inhibited the growth of *Fusarium oxysporum* isolated from the bean plant (*Phaseolus vulgaris*) by 100%, whereas Baysal-Gurel and Bika (2021) reported the foliar applications of this same extract at a concentration of 0.5 mL L^{-1} reduced the severity of powdery mildew (*Podosphaera physocarpi*) on the ornamental tree ninebark (*Physocarpus opulifolius*) grown in a shade house.

On the other hand, *B. amyloliquefaciens* QST 713 had a significantly greater effect than the rest of the treatments after the *M. alternifolia* essential oil and the *R. sachalinensis* extract. *B. amyloliquefaciens* QST 713 has been reported to have an effect on the regulation of genes related to the activation of transcription factors of the WRKY family and NAC, related to the defense mechanisms against stress factors and LRR-RLK receptors, which intervene in the recognition of the pathogen and the transduction of signals, through transcriptomic studies on peach fruits treated with *B. amyloliquefaciens* QST 713 for the control of *Monilinia fructicola*, where it is also pointed out that the biofungicide inhibited the *in vitro* growth of the fungus in the culture and reduced the severity of the symptoms of the disease (Tsalgatidou *et al.*, 2014). In turn, Pérez-Moreno *et al.* (2015) found that *B. amyloliquefaciens* QST 713 inhibited the *in vitr*o culture growth of *Sclerotinia minor* isolated from symptomatic lettuce (*Lactuca sativa*) plants with an average radial mycelial growth of 1.9 cm. Another study, carried out by Solano-Báez *et al.* (2021) indicates that *B. amyloliquefaciens* QST 713, at a concentration of 6×10^{7} UFC mL^{-1} reduced by 81.7% the incidence of drowning of zucchini plants produced by a complex made up of *Phytophthora capsici*, *Rhizoctonia solani* and *F. oxysporum*.

Finally, the biopesticides used to control fungal diseases have diverse advantages, since they have multiple action mechanisms due to the amount of phytochemicals they contain, leading them to generate no resistance, being ecological, easy to produce, effective and inexpensive, they produce no waste and have a low toxicity on organisms

that are not their target, including humans, making risks on human health reduced (Deresa and Diriba, 2023; Suteu *et al.*, 2020). It is worth mentioning that for the management of plant diseases in gardens, parks and public areas, where *E. gibbiflora* is appreciated, it is crucial to use fungicides that generate no residuality, are eco-friendly and low-risk for humans and fauna, due to the constant contact of users with this type of environments.

Due to the above, this investigation represents a contribution for the integrated management of diseases in *E. gibbiflora* in urban areas. However, Lecomte *et al.* (2016) indicate that once the biofungicide with efficiency in the control of phytopathogens in ornamental plants is identified, it is necessary to standardize the doses, formulation and application method, making it a guideline to continue with research.

CONCLUSIONS

C. truncatum, which induces anthracnose in *E. gibbiflora* leaves is more sensitive to biofungicides composed of *M. alternifolia* oil (109.23 mg L^{-1}), *R. sachalinensis* extract (168.76 mg L^{-1}) and *B. amyloliquefaciens* QST 713 (61.07 mg L^{-1}) in *in vitro* conditions. E *L. digitata* oil (19.95 mg L^{-1}), *T. vulgaris* and *M. spicata* essential oils (112.47 mg L^{-1}) and the *L. tridentata* and *R. communis* extract (78.51 mg L^{-1}) have an inhibiting effect on the growth of the fungus of over 50% (which vary between 63.4 and 93.6%) and represent an alternative for the integrated management of the disease. The logistic regression has a good adjustment and helps model percentages with significant biological predictions, in addition to helping calculate the EC_{50} of biofungicides.

LIMITATIONS

Not applicable.

CONFLICT OF INTEREST

All authors declare having no conflict of interest in relation to this study.

FUNDING

This investigation was partially financed by the Universidad Popular del Estado de Puebla (UPAEP University).

CONTRIBUTIONS BY AUTHORS

Idea, José Terrones Salgado; conceptualization, José Terrones Salgado and Nicolás Álvarez Acevedo; methodology, José Terrones Salgado, Cesar Flores de los Ángeles, José Francisco Díaz Nájera, Sergio Ayvar Serna; Software, José Terrones Salgado and Carlos David Carretillo Moctezuma; validation, José Terrones Salgado, José Francisco Díaz Nájera, José Luis Arispe Vázquez and César Flores de los Ángeles; formal analysis, José Terrones Salgado, Carlos David Carretillo Moctezuma, José Francisco Díaz Najera and Segio Ayvar Serna; investigation, José Terrones Salgado, Carlos David Carretillo Moctezuma, José Francisco Díaz Nájera, Segio Ayvar Serna, José Luis Arispe Vázquez, César Flores de los Ángeles, Nicolás Álvarez Acevedo; resources, José Terrones Salgado; data collection, José Terrones Salgado, Nicolás Álvarez Acevedo and José Francisco Díaz Nájera; writing (preparation of the original manuscript, revision and editing), José

Terrones Salgado, Carlos David Carretillo Moctezuma, José Francisco Díaz Nájera, Sergio Ayvar Serna, José Luis Arispe Vázquez, César Flores de los Ángeles, Nicolás Álvarez Acevedo; visualization, José Terrones Salgado, José Francisco Díaz Nájera and José Luis Arispe Vázquez; supervision, José Terrones Salgado; project administration, José Terrones Salgado; funding acquisition, José Terrones Salgado. All authors have read and accepted the published version of the manuscript.

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