

In vitro efficacy of fungicides for the control of *Fusarium* spp., the causal agent of root rot in common bean (*Phaseolus vulgaris* L.)

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ABSTRACT

Objective: Currently, common bean cultivation takes place in several regions with high population demand. However, production has been affected by vascular fusariosis, one of the main limiting factors. Chemical control is considered one of the primary alternatives for managing this disease.

Design/Methodology/Approach: Four fungicides at different concentrations: Verango Prime, Fungi Mix, Vibrance Beans, and Cobrethane WP were evaluated to quantify the percentage of mycelial growth inhibition (MGI) in three *Fusarium* species: *Fusarium nygamai*, *Fusarium verticillioides*, and *Fusarium falciforme* under *in vitro* conditions. A completely randomized design with a factorial arrangement and three replications was established. The effectiveness of each fungicide was evaluated based on the percentage of mycelial growth inhibition (MGI) 25 days after inoculating the strain in the culture medium.

Results: Tukey's multiple comparison test ($\alpha=0.05$) was performed.

Conclusions: The fungicide Verango Prime achieved the highest MGI for the three *Fusarium* species, with inhibition values of 67.5%, 37%, and 42.5% for *F. nygamai*, *F. verticillioides*, and *F. falciforme*, respectively.

Keywords: Chemical control, mycelial diameter, *Fusarium nygamai*, inhibition percentage.

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INTRODUCTION

The common bean (*Phaseolus vulgaris* L.) is one of the staple crops in the Mexican diet. In Mexico, it is among the most important agricultural commodities from nutritional, economic, and social perspectives. Bean production occurs throughout the Mexican territory. During the 2022-2023 agricultural cycle, 761,316.72 hectares of beans were harvested, yielding a total production of 723,642.32 tons. The state of Sinaloa ranks as the leading bean producer in the country, with a production volume of 172,161.73 tons and an average yield of 1.97 t ha⁻¹, representing 23.7% of the total national production (SIAP, 2024).

Low grain yields are attributed to both biotic factors, such as pests, weeds, and diseases, and abiotic factors, mainly water scarcity. Regarding diseases, phytopathogens including fungi, bacteria, viruses, and nematodes cause damage to the roots, stems, leaves, and



Pods of common bean, thereby affecting grain quality, germination, yield, and ultimately the profitability of the crop. One of the most recent reports for this crop describes wilt symptoms in the Culiacán Valley, Sinaloa, caused by the fungus *Fusarium nygamai*, which induces wilting and yellowing symptoms that can easily be mistaken for nutrient deficiencies or infections caused by other soilborne pathogens (Salgado *et al.*, 2013).

The *Fusarium* genus comprises a wide variety of phytopathogenic species with broad distribution and occurrence, highlighting their toxicological capacity and the problems they pose to crops of major agricultural and economic importance, such as common bean. It is essential to conduct phytosanitary inspections of crops throughout their developmental stages in order to establish accurate diagnoses and implement appropriate control measures (Salgado *et al.*, 2013).

Given this problem, it is necessary to implement appropriate measures for the control of this disease. Among these measures is the application of chemical compounds such as fungicides, which help prevent and promote the rapid recovery from fungal diseases. Chemical control is also one of the most widely used strategies, being applied in more than 90% of crops (Salgado *et al.*, 2013). The main objective of the present study was to determine the effect of chemical control using fungicides *in vitro* at different concentrations on the percentage of mycelial growth inhibition in three *Fusarium* species: *Fusarium nygamai*, *F. verticillioides*, and *F. falciforme*.

MATERIALS AND METHODS

Study location

The research was conducted in the Culiacán Valley, Sinaloa, Mexico, at the Phytoprotection Laboratory of the Faculty of Agronomy (Figure 1), Autonomous University of Sinaloa (FA-UAS), located at Carretera Culiacán-Eldorado km 17.5, Sinaloa, Mexico.



Figure 2. Research facilities of the Faculty of Agronomy.

Strain selection

The *Fusarium nygamai* strain identified as FNTL6P7CULSIN in the NCBI GenBank (access number OK491917) was selected; it was isolated from common bean plants. Additionally, *Fusarium verticillioides* FVTL6P6CULSIN (access number OK491916) and *Fusarium falciforme* FFTL6P5CULSIN (access number OK491915) were included. All strains were obtained from the Phytoprotection Laboratory of the Research Center at the Faculty of Agronomy, Autonomous University of Sinaloa. The isolation of *Fusarium nygamai* was cultured on PDA medium and previously identified both morphologically and molecularly. This isolate has been reported as the causal agent of root rot and wilt in common bean crops in Sinaloa, Mexico (Vega-Gutiérrez *et al.*, 2022).

Selection of chemical products for the *in vitro* control of *Fusarium nygamai* Four commercial chemical fungicides were selected, as shown in Table 1. These fungicides are used to combat damage caused by fungal diseases in various horticultural crops and are approved by the Federal Commission for the Protection against Sanitary Risks (COFEPRIS), the Secretariat of Environment and Natural Resources (SEMARNAT), and the Secretariat of Agriculture and Rural Development (SADER) (COFEPRIS, 2024).

Experiment setup

The isolate was subjected to an *in vitro* sensitivity test using different fungicides at concentrations of 1, 10, 100, 1,000, and 10,000 ppm on potato dextrose agar (PDA) medium (Gálvez *et al.*, 2016), following the poisoned food technique. This involved preparing the culture medium in sterilized Erlenmeyer flasks at 120 °C for 15 minutes in an autoclave. The medium was then allowed to cool to 40 °C before adding the fungicides at the corresponding concentrations in 9-cm diameter Petri dishes (Dingran & Sinclair, 1985).

The pathogen isolate was grown for 7 days at 28 °C in the dark and was then used to inoculate the different treatments by placing a 0.5 cm diameter disc. The plates were incubated at 28 °C for the first 7 days, at which point the control treatment reached 100% of the Petri dish surface (Muiño *et al.*, 2010). A control treatment without fungicide was included to compare mycelial growth against the growth observed in the fungicide-treated plates.

Experiment evaluation

The colony diameter was measured in two perpendicular directions using a digital caliper. The growth of the pathogen colonies was compared with that of the control treatment, following the methodology described by the radial colony growth method (FAO,

Table 1. Description of fungicides used.

Fungicides	Chemical group
Vibrance Beans	Pirazolánilidas
Fungi Mix	Orgánico
Verango Prime	Etil Benzamidas
Cobrethane Wp	Ditiocarbamatos

1982). The effectiveness of the treatments was evaluated using the percentage of mycelial growth inhibition (PMGI), calculated according to the formula proposed by Pandey *et al.* (1982).

$$PMGI(\%) = [(RC - RT) / RC] \times 100$$

where: *PMGI*: Percentage of mycelial growth inhibition. *RT*: Radial growth of the fungus in each treatment (mm). *RC*: Radial growth of the fungus in the control (distilled water) (mm).

Experimental design

A completely randomized design with a factorial arrangement was established, comprising 60 treatments and an untreated control without fungicide. Each treatment was replicated three times. An analysis of variance (ANOVA) and Tukey's multiple comparison test were performed on the PMGI values obtained from the fungicide treatments. This analysis was conducted separately for each *Fusarium* species. Subsequently, ANOVA and Tukey's test were carried out to evaluate the effectiveness of the fungicides using the SAS statistical software (version 9.0), considering the concentration of each fungicide and the *Fusarium* species separately.

RESULTS AND DISCUSSION

Mycelial diameter

The results of mycelial growth showed that treatments 35 and 45, which consisted of the fungicide Verango Prime, completely inhibited the mycelial growth of *Fusarium nygamai*, with a diameter of 0.000 mm. This represented a significant difference compared to the other fungicides, as shown in Figure 2. These findings are consistent with those reported by Yossen and Conles (2014), where all evaluated fungicides achieved over 94% mycelial growth inhibition, with benzimidazoles being the most effective, reaching over 99%. Similarly, Srivastava *et al.* (2011) reported that the radial growth of *F. oxysporum* was

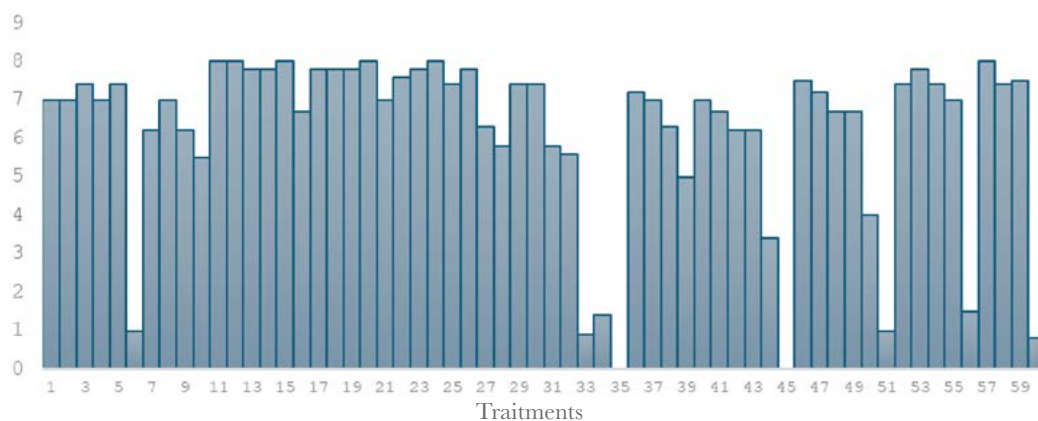


Figure 2. Mycelial diameter of *Fusarium nygamai*, *Fusarium verticillioides*, and *Fusarium falciforme* at different fungicide concentrations, expressed in millimeters (mm).

inhibited by carbendazim at different concentrations in *in vitro* assays. However, all high fungicide concentrations reduced the mycelial diameter across the three *Fusarium* species evaluated. These results indicate that the effectiveness of fungicides decreases at very high concentrations. Overall, these findings have significant social, economic, and health implications.

Percentage of mycelial growth inhibition (PMGI)

The fungicide that exhibited the highest percentage of mycelial growth inhibition for the three *Fusarium* species was Verango Prime, with values of 67.5%, 37%, and 42.5% for *F. nygamai*, *F. verticillioides*, and *F. falciforme*, respectively. Conversely, *F. falciforme* showed very low inhibition levels when treated with Vibrance Beans, with a value of 1.3% (Figure 3).

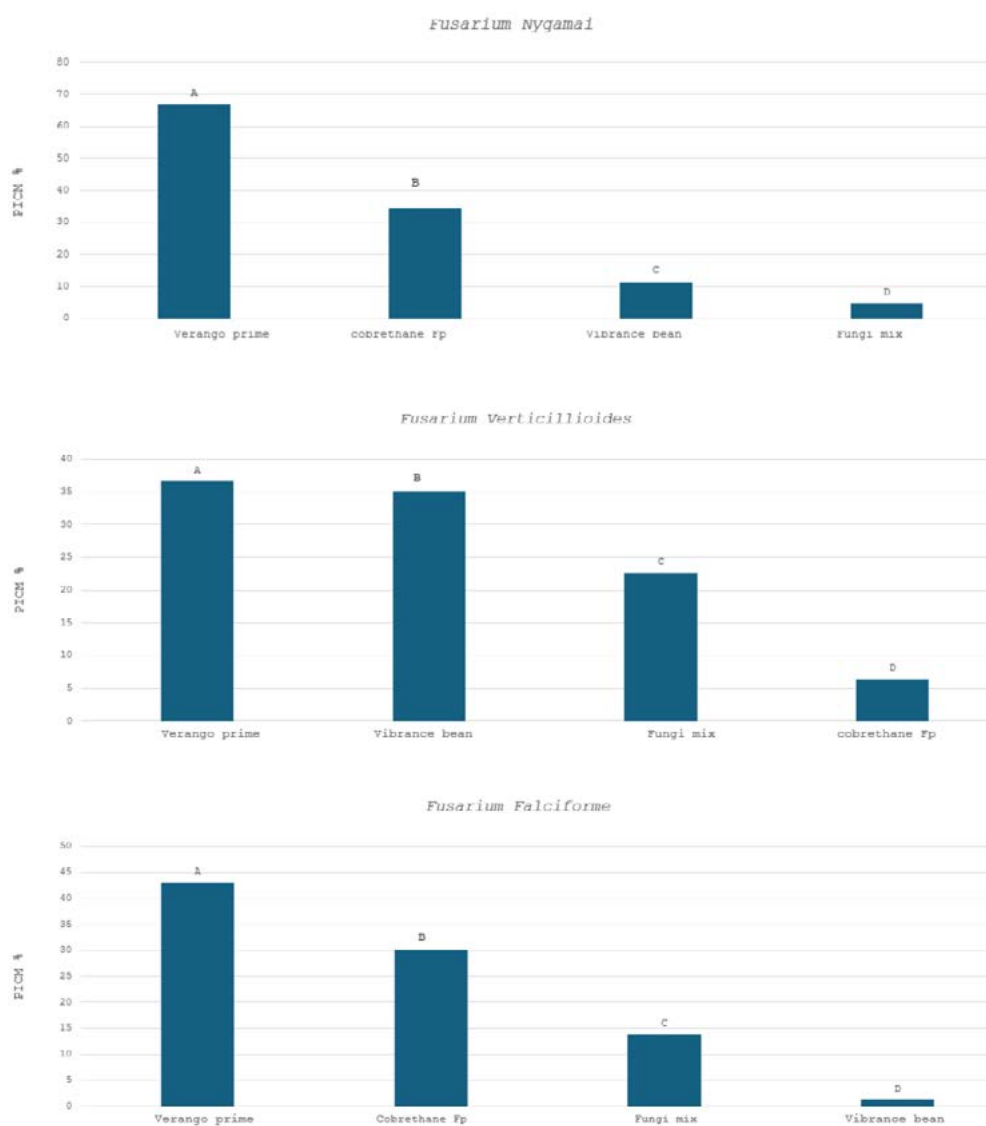


Figure 3. Percentage of mycelial growth inhibition (PMGI) in *F. nygamai*, *F. verticillioides*, and *F. falciforme*. PMGI is expressed as a percentage, and Tukey's multiple comparison test was performed ($p \leq 0.05$).

This is attributed to the fact that the fungicide Vibrance Beans is not recommended for *Fusarium* species (Syngenta Global AG, 2018). However, the product showed slightly higher inhibition percentages at a concentration of 1 ppm. The inhibition percentages reported by Ochoa *et al.* (2012) are consistent with those obtained in this study, as they evaluated *F. oxysporum*, *F. culmorum*, and *F. solani*, obtaining 43.15%, 31.81%, and 45.58%, respectively. Similarly, the values obtained in this study are in agreement with those reported by Guédez *et al.* (2012), who observed mycelial growth inhibition percentages of 80%, 72%, and 71% against the three pathogenic fungi *F. oxysporum*, *R. solani*, and *S. rolfsii*, respectively.

When evaluating the three *Fusarium* species at different fungicide concentrations, it was observed that higher fungicide concentrations tended to increase PMGI. *F. falciforme* at 10,000 ppm showed the highest PMGI, with a value of 55.6%, as shown in Figure 4. It is important to consider that high fungicide concentrations can increase pathogen resistance, production costs, and contamination of production systems (Chin *et al.*, 2001). Contact or systemic fungicides are essential in the management of fungal diseases, but they increase economic costs and environmental risks. Therefore, a resistance management program should be implemented to reduce the number of applications. In Mexico, the most commonly used fungicides are mancozeb and chlorothalonil (preventive), as well as systemic active ingredients from the benzimidazole, triazole, strobilurin, and anilopyrimidine groups (Martínez *et al.*, 2012).

Authors such as Deepak and Lal (2009) observed in their study that the fungicides thiabendazole and thiophanate-methyl showed intermediate performance, with values close to 80%, while mancozeb exhibited the lowest control efficacy among all applied treatments, with less than 60% PMGI. Tebuconazole has been reported as one of the most effective fungicides for controlling *Fusarium* spp. in cereal grains. On the other hand, carbendazim has shown a good preventive and curative effect against *F. oxysporum* in tomato crops.

Some authors agree that this fungicide, as well as other benzimidazoles, shows high efficacy in controlling various *Fusarium* species across different crops (Jahanshir and Dzhililov, 2010). Kopacki and Wagner (2006) reported that mancozeb exhibited the lowest efficacy for controlling *F. avenaceum*, with PMGI values ranging from 24% to 74%. Despite

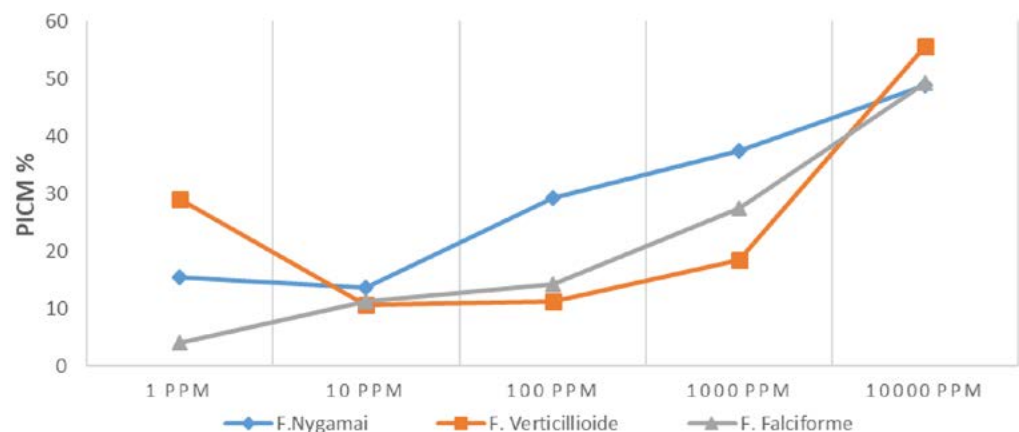


Figure 4. Percentage of mycelial growth inhibition (PMGI) at different parts-per-million concentrations in *F. nygamai*, *F. verticillioide*, and *F. falciforme*.

these results, this fungicide is considered a useful tool for reducing the development of pathogen resistance, as its mode of action affects multiple sites within fungal cells and disrupts numerous biochemical processes, significantly decreasing the likelihood that pathogens will develop resistance.

CONCLUSIONS

All the fungicides evaluated have been used to control diseases affecting the root system of common bean crops. The fungicide Verango Prime exhibited the highest mycelial growth inhibition (PMGI) value (67.5%) at a concentration of 10,000 ppm against *Fusarium nygamai*. Applying this fungicide dose is recommended to reduce the damage caused by this species in common bean cultivation. For *F. verticillioides*, Verango Prime also provided the most effective control, and the same product showed the best control of mycelial growth in *F. falciforme*.

REFERENCES

- Chin, K. M., Wirz, M. Laird, D. (2001). Sensitivity of *Mycosphaerella fijiensis* from banana to trifloxystrobin. *Plant Dis.* 85: Pp1264-1270.
- Deepak, B. and Lal, G. (2009). Integrated strategy to control wilt disease of cummin (*Cuminum cyminum* L.) caused by *Fusarium oxysporum* f. sp. *cumini* (Schlecht) Prasad. y Patel. *J. Spices and Aromatic Crops* 18(1): 13-18.
- FAO. (1982). Method for Fungicide Resistance, Plant Prot. Bull., FAO 30 (2): 38-69, Italia.
- Guédez, C., Cañizaleza, L., Castilloa, C., Rafael Olivar, R. (2012). Evaluación *in vitro* de aislamientos de *Trichoderma harzianum* para el control de *Rhizoctonia solani*, *Sclerotium rolfsii* y *Fusarium oxysporum* en plantas de tomate. *Revista de la Sociedad Venezolana de Microbiología. Venezuela.* 32: Pp. 44-49.
- Jahanshir, A., and Dzhaliyov, F. S. (2010). The effects of fungicides on *Fusarium oxysporum* f. sp. *lycopersici* associated with Fusarium wilt of tomato. *J. Plant Protect. Res.* 50(2): 172-177.
- Kopacki, M. and Wagner, A. (2006). Effect of some fungicides on mycelium growth of *Fusarium avenaceum* (Fr.) Sacc., pathogenic to chrysanthemum (*Dendranthema grandiflora* Tzvelev). *Agron. Res.* 4 (Special issue): 237-240.
- Martínez, B. L., Téliz, O. D., Rodríguez, M. J. C., Mora, A. J. A., Nieto, A. D., Cortés, F. J. I., Mejía, S. D., Nava, D. C., Silva, A. G. (2012). Resistencia a fungicidas en poblaciones de *Mycosphaerella fijiensis* del sureste de mexicano. *Revista Agrociencia.* 46(7). Pp 707-717.
- Ochoa, F. Y. M., Cerna, C. E., Landeros, F. J., Hernández, C. S., Delgado, O. J. C. (2012). Evaluación *in vitro* de la actividad antifúngica de cuatro extractos vegetales metanólicos para el control de tres especies de *Fusarium* spp. *Revista Phytos Buenos Aires. Argentina.* 82(1). Pp. 69-73.
- Pandey, D. K., Tripathi, N. N., Tripathi, R. D., Dixit, S. N. Z. (1982). Fungitoxic and phytotoxic properties of essential oil of *Hyptis suaveolens*. *Z. Pfl. Krankh. Pfl. Schutz* 89, 344-349.
- Salgado, T. S., Tinoco, R., Vázquez, D. R., Caballero, M. J., Pérez, R.E. (2013). Identification of volatile compounds produced by the bacterium *Burkholderia tropica* that inhibit the growth of fungal pathogens. London. *Journal Bioengineered.* 4: 236-243.
- SIAP. (2024). Servicio de Información Agroalimentaria y Pesquera. Consultado (05/Diciembre/2024). Disponible en: www.siap.gob.mx/
- Srivastava, S., Singh, V. P., Kumar, R., Srivastava, M., Sinha, A., Simon, S. (2011). *In vitro* evaluation of carbendazim 50% WP, antagonists and botanicals against *Fusarium oxysporum* f. sp. *psidii* associated with rhizosphere soil of guava. *Asian J. Plant Pathol.* 5: Pp. 46-53.
- Yossen, V. E., Conles, M. Y. (2014). Eficacia de fungicidas *in vitro* para el control de *Fusarium oxysporum* y *F. proliferatum*, agentes causales de marchitamiento en el cultivo de orégano en la Argentina. *Revista industrial y Agrícola de Tucuman. Argentina.* 91(1). Pp 19-25.