



COMPARISON OF TWO METHODS OF INOCULATION OF TERRESTRIAL AND MARINE MICROORGANISMS ON MORPHOLOGICAL PARAMETERS AND PRODUCTIVITY OF WAX CHILI PLANTS (*Capsicum pubescens* R. & P.) IN WINTERMILLS

Roberto Gregorio Chiquito-Contreras¹
César Josué Chiquito-Contreras²
Luis Guillermo Hernández-Montiel³
Doris Guadalupe Castillo-Rocha⁴
Angel Rosario Ceballos-Chávez⁵
Nayelli Ayatzol Vidal-Martínez⁶

ABSTRACT

Objective: The objective of this study was to evaluate two methods of inoculation of terrestrial and marine microorganisms on morphological parameters and productivity of wax chili plants in greenhouses.

Theoretical Framework: Currently, meeting the demand for food requires the excessive use of inorganic fertilizers, causing health problems and environmental pollution. An alternative for agricultural production is beneficial microorganisms, capable of fixing atmospheric nitrogen, solubilizing phosphorus, and performing other metabolic activities.

Method: Wax pepper plants inoculated with alginate capsules and immersion in liquid suspension were used. The microorganisms evaluated were *Trichoderma harzianum*, *Debaryomyces hansenii* and *Stenotrophomonas rhizophila*. The experiment was conducted with a randomized block arrangement with ten treatments and ten replications. The variables evaluated were: height, stem diameter, root length and volume, dry biomass weight of plant, root and stem, and fruit yield. The data were analyzed to obtain the variance and comparison of means with the Duncan test ($p \leq 0.05$) in the SAS statistical program for Windows.

Results and Discussion: The *Trichoderma harzianum* strain inoculated with liquid showed better results in stem height and root dryness variables; in contrast, *Trichoderma harzianum* in alginate capsules performed better in stem diameter. According to the results, inoculating wax pepper plants with beneficial terrestrial and marine microorganisms represents an ecologically viable alternative for consideration in sustainable production schemes.

Originality/Value: This study contributes to the literature by reporting the ability of microorganisms isolated from extreme environments to enhance agricultural production and minimize the impact of chemical use.

Keywords: *Trichoderma harzianum*, *Stenotrophomonas rhizophila*, *Debaryomyces hansenii*, Beneficial Microorganisms.

¹Facultad de Ciencias Agrícolas. Universidad Veracruzana. Xalapa, Veracruz, México. E-mail: rchiquito@uv.mx
Orcid: <https://orcid.org/0000-0001-8381-7507>

²Facultad de Ciencias Agrícolas. Universidad Veracruzana. Xalapa, Veracruz, México. E-mail: cchiquito@uv.mx
Orcid: <https://orcid.org/0000-0002-9522-0828>

³Centro de Investigaciones Biológicas del Noroeste, La Paz, Baja California Sur, México.
E-mail: lhernandez@cibnor.mx Orcid: <https://orcid.org/0000-0002-8236-1074>

⁴Facultad de Ciencias Agrícolas. Universidad Veracruzana. Xalapa, Veracruz, México. E-mail: dcastillo@uv.mx

⁵Universidad Tecnológica de la Tarahumara. Guachochi, Chihuahua, México.
E-mail: aceballos@uttarahumara.edu.mx Orcid: <https://orcid.org/0000-0002-8332-0389>

⁶Facultad de Ciencias Agrícolas. Universidad Veracruzana. Xalapa, Veracruz, México. E-mail: nvidal@uv.mx
Orcid: <https://orcid.org/0000-0001-7205-150X>



COMPARAÇÃO DE DOIS MÉTODOS DE INOCULAÇÃO DE MICRORGANISMOS TERRESTRES E MARINHOS EM PARÂMETROS MORFOLÓGICOS E NA PRODUTIVIDADE DE PLANTAS DE PIMENTA (*Capsicum pubescens* R. & P.) EM ESTUFA

RESUMO

Objetivo: O objetivo deste estudo foi avaliar dois métodos de inoculação de microrganismos terrestres e marinhos sobre parâmetros morfológicos e produtividade de plantas de wax chili em estufas.

Referencial Teórico: Atualmente, o atendimento à demanda por alimentos requer o uso excessivo de fertilizantes inorgânicos, causando problemas de saúde e poluição ambiental. Uma alternativa para a produção agrícola são os microrganismos benéficos, capazes de fixar nitrogênio atmosférico, solubilizar fósforo e realizar outras atividades metabólicas.

Método: Foram utilizadas plantas de wax pepper inoculadas com cápsulas de alginato e imersão em suspensão líquida. Os microrganismos avaliados foram *Trichoderma harzianum*, *Debaryomyces hansenii* e *Stenotrophomonas rhizophila*. O experimento foi conduzido em blocos casualizados com dez tratamentos e dez repetições. As variáveis avaliadas foram: altura, diâmetro do caule, comprimento e volume da raiz, peso da biomassa seca da planta, raiz e caule e produção de frutos. Os dados foram analisados para obtenção da variância e comparação de médias com o teste de Duncan ($p \leq 0,05$) no programa estatístico SAS para Windows.

Resultados e Discussão: A cepa *Trichoderma harzianum* inoculada com líquido apresentou melhores resultados nas variáveis altura do caule e secar da raiz; em contraste, *Trichoderma harzianum* em cápsulas de alginato apresentou melhor desempenho no diâmetro do caule. De acordo com os resultados, a inoculação de plantas de pimenta cera com microrganismos terrestres e marinhos benéficos representa uma alternativa ecologicamente viável para consideração em esquemas de produção sustentável.

Originalidade/Valor: Este estudo contribui para a literatura ao relatar a capacidade de microrganismos isolados de ambientes extremos de aumentar a produção agrícola e minimizar o impacto do uso de produtos químicos.

Palavras-chave: *Trichoderma harzianum*, *Stenotrophomonas rhizophila*, *Debaryomyces hansenii*, microrganismos benéficos.

COMPARACIÓN DE DOS MÉTODOS DE INOCULACIÓN DE MICROORGANISMOS TERRESTRES Y MARINOS SOBRE PARÁMETROS MORFOLÓGICOS Y PRODUCTIVIDAD DE PLANTAS DE CHILE DE CERA (*Capsicum pubescens* R. & P.) EN INVERNADERO

RESUMEN

Objetivo: El objetivo de este estudio fue evaluar dos métodos de inoculación de microorganismos terrestres y marinos sobre parámetros morfológicos y productividad de plantas chile de cera en invernadero.

Marco Teórico: Actualmente para solventar la demanda de alimentos, conlleva el uso excesivo de fertilizantes inorgánicos, ocasionando problemas de salud y contaminación ambiental. Una alternativa para la producción agrícola son los microorganismos benéficos, capaces de fijar nitrógeno atmosférico, solubilizar fósforo, entre otras actividades metabólicas.

Método: Se utilizaron plantas de chile de cera inoculadas con cápsulas de alginato y por inmersión en suspensión líquida. Los microorganismos evaluados fueron *Trichoderma harzianum*, *Debaryomyces hansenii* y *Stenotrophomonas rhizophila*. El experimento se realizó con un arreglo de bloques al azar con diez tratamientos y diez repeticiones. Las variables evaluadas fueron: altura, diámetro de tallo, longitud y volumen de la raíz, peso de biomasa seca de planta, raíz y tallo y rendimiento de fruto. Los datos fueron analizados para obtener la varianza y comparación de medias con la prueba Duncan ($p \leq 0.05$) en el programa estadístico SAS para Windows.

Resultados y Discusión: La cepa de *Trichoderma harzianum* en inoculación líquida presentó mejores resultados en las variables altura de tallo y seca de raíz; en contraste *Trichoderma harzianum* en cápsulas de alginato presentó mejor respuesta en la variable de diámetro de tallo. De acuerdo con los resultados, la inoculación de plantas de chile de cera con microorganismos benéficos terrestres y marinos representa una alternativa ecológicamente viable para su consideración en el esquema de producción sustentable.



Originalidad/Valor: Este estudio contribuye a la literatura al reportar la capacidad de microorganismos aislados de ambientes extremos que presentan mecanismos para potencializar la producción agrícola y que a su vez permitan minimizar el impacto del uso de productos químicos.

Palabras clave: *Trichoderma harzianum*, *Stenotrophomonas rhizophila*, *Debaryomyces hansenii*, microorganismos benéficos.

RGSA adota a Licença de Atribuição CC BY do Creative Commons (<https://creativecommons.org/licenses/by/4.0/>).



1 INTRODUCTION

The wax chile is the only chile found in the region, with altitudes between 1,700 and 2,599 meters above sea level. This type of chile varies greatly in terms of fruit color, shape, and size; yellow varieties are generally preferred over red and orange varieties. In Mexico, production of this crop is characterized by seasonality, which concentrates the harvest from July to December, with a complete shortage from January to June (Gasca-Peña, 2011).

Currently, the implementation of sustainable and environmentally friendly practices has gained importance, one of the alternatives that has been investigated is the use of microorganisms, which allows the reduction of the use of synthetic fertilizers (Cruz-Cardenas et al., 2021). Among the benefits that stand out the use of beneficial microorganisms are the fixation, solubilization of phosphorus, biological control, weed control, among other mechanisms (Samaniego-Gaxiola, 2021). The use of biofertilizers represents a viable and reliable alternative in the production of foods free of chemical agents, which add numerous advantages not only in the generation of fruits and vegetables, but also in the germination and establishment of seeds and seedlings, the increase in the supplies of essential nutrients for plants, as well as the improvement of soil structure, without forgetting the zero damage it generates to the environment (Grageda et al., 2012).

2 THEORETICAL FRAMEWORK

Among the biofertilizers for agricultural use we can find some compounds by *Trichoderma*, which is an anaerobic fungus that naturally inhabits the soil, characterized by saprophytic or parasitic behavior, the most notable species are *T. harzianum*, *T. viride*, *T. koningii*, and *T. hamatum* (INTAGRI, 2015); we can also find *Debaryomyces hansenii*, a marine yeast of the hemiascomycetals class, it is unicellular, uninucleate, haploid and easy to



grow in the laboratory (Arroyo-González, 2009). It has been mainly used in the food and medical industries, also helping as antagonists to other fungi of agricultural importance, inhibiting their effects and controlling their growth in the host (Hernández-Montiel et al., 2010). And last but not least, we can find a bacterium that presents mechanisms as a stimulant of vegetative growth by eliminating harmful rhizospheric organisms, we are talking about *Stenotrophomona rhizophila* (Stephan-Schmidt, 2012).

It is important to keep in mind that the success of the application of biofertilizers will depend on the knowledge of their nutritional and environmental requirements, as well as their interaction with other microorganisms, including their ability to coexist in mixed cultures with other microorganisms, both before and after their application to the soil (INTAGRI, 2013).

3 METHODOLOGY

3.1 GEOGRAPHICAL LOCATION OF THE EXPERIMENT

The research work was carried out at the facilities of the Faculty of Agricultural Sciences, Xalapa Campus, Universidad Veracruzana, located in the city of Xalapa, Veracruz, Mexico with a north latitude of 19°30'58.85" and west longitude of 96°55'6.26" and a height of 1417 meters above sea level.

3.2 VEGETATIVE MATERIAL

Wax chili pepper seeds with a physiologically ripe, yellow-orange color were used. The fruits were purchased from the Tatahuicapan ranch, located in the town of Micoxtla, Municipality of Xico, in the state of Veracruz.

3.3 OBTAINING AND PROPAGATION OF BENEFICIAL MICROORGANISMS

two strains of *Trichoderma* were evaluated, one native to the state of Veracruz catalogued as LCBTH01 and a commercial strain of *T. harzianum* (Tricoder MS), which is freely sold in Mexico by the company MS. The selected bacteria was *Stenotrophomonas rhizophila* (strain KM02) and the selected yeast was *Debaryomyces hansenii* (strain ECP04), both types of microorganisms were originally isolated from the hyperhaline lagoon "Ojo de



Liebre”, located between 27°35' and 27°52' latitude north and 113° 58' and 114° 0' west latitude in the municipality of Mulegé, Baja California Sur Southern California, Mexico.

Based on the nutritional requirements of the different beneficial microorganisms, they were propagated in specific liquid culture media. For the *Trichoderma* and yeast (ECP04) strains, Potato Dextrose (PD) medium was used. For propagation of both microorganisms, the flasks were shaken at 180 rpm for 48 hours at 28°C.

Finally, the concentration was adjusted for yeasts to 10^6 cells mL⁻¹ and for *Trichoderma* to 10^6 spores mL⁻¹. In the case of marine bacteria, the liquid culture medium Soya Trypticaseina (CST) was used having the same incubation methodology as the microorganisms mentioned above, finally the concentration of bacteria was adjusted to 10^6 cells mL⁻¹.

3.4 PREPARATION OF ALGINATE CAPSULES WITH BENEFICIAL MICROORGANISMS

From the cultures of beneficial microorganisms previously grown in PDy CTS media, 50 mL of each strain were taken and mixed with 1.5 g of sodium alginate. The mixture was shaken for 20 min at 350 rpm. The alginate capsules of the beneficial microorganisms were individually prepared by forming drops with a polyethylene Pasteur pipette. These drops were placed in a sterile 0.1 M CaCl₂ solution and shaken for 30 min at 100 rpm to promote gelation of the capsules. The capsules were removed from the CaCl₂ solution and washed twice with sterile 0.85% (w/v) NaCl saline solution.

Finally, the alginate capsules of approximately 4 mm in diameter were preserved in sterile 0.1 M CaCl₂ solution at room temperature for 72 hours until used for inoculation of the wax chili plants.

3.5 TRANSPLANTATION AND INOCULATION OF ALGINATE CAPSULES AND LIQUID CULTURE OF BENEFICIAL MICROORGANISMS

Prior to transplanting, the roots of the wax pepper seedlings were washed with running water. After transplanting the seedlings into polyethylene bags, 50 capsules of sodium alginate (equivalent to 5 mL of liquid culture) were applied to the roots and covered with the substrate. Another group of seedlings, separately, had their roots submerged in the broth of beneficial microorganisms contained in beakers for a period of 20 minutes, to ensure coverage of the entire root system of the plants. After the application of the liquid culture, the roots were covered with



the substrate. At the end of the transplant and inoculation process, all plants were watered thoroughly with running water .

The wax chili plants were grown in a semi-hydroponic system and fertilized with nutrient solution, using commercially available, highly soluble fertilizers as raw materials and implementing the necessary cultural practices and care during the experimental stage in the greenhouse.

3.6 VARIABLES EVALUATED

At the conclusion of the experimental phase the determination was made of the morphological variables which were: plant height (cm), stem diameter (mm), root volume (cm³), root length (cm), dry weight of foliage, root and stem (g) and fruit yield (g).

3.7 EXPERIMENTAL DESIGN

Trichoderma strains , marine yeasts and bacteria, the experiment was established with a randomized block design with 10 treatments and 5 blocks with 10 plants as repetition for each treatment (Table 1). The data obtained were analyzed by analysis of variance and comparison of Duncan means ($p = 0.05$) in the SAS statistical program for Windows version 9.1.

Table 1

Description of the treatments implemented in wax chili plants in a greenhouse.

Treatment No.	Treatment
1	<i>Trichoderma harzianum</i> (C)
2	<i>Trichoderma harzianum</i> (L)
3	<i>Trichoderma</i> sp. cepa LCBTH01 (C)
4	<i>Trichoderma</i> sp. cepa LCBTH01 (L)
5	ECP04 (C) lift
6	ECP04 Lift (L)
7	KM02 battery (C)
8	KM02 battery (L)
9	Testigo (C)
10	Testigo (L)

C= Capsules

L= Liquid Cultivation



4 RESULTS AND DISCUSSIONS

The results obtained show that the wax pepper plants, after seven months in the greenhouse, showed a positive response to the inoculation of beneficial microorganisms. Statistically significant differences were obtained in the stem height variable (Figure 1), with the T1L treatment with *Trichoderma harzianum* (commercial strain MS Agros) which presented the best results with an average height of 189.35 cm, surpassing the control treatments T5C (alginate capsules) and T5L (liquid application) by 8.40% and 10.85% respectively. Although the effectiveness of beneficial microorganisms depends on the metabolic activity and the type of reaction in the host, the *Trichoderma* genus has been shown to have rapid growth, with the ability to grow in a variety of substrates, act as a biocontrol agent and promote growth by improving the efficiency of photosynthesis, the synthesis of phytohormones and phyto regulators (Tyśkiewicz et al., 2022).

On the other hand, although it has been shown that the colonization of *Stenotrophomonas maltophilia* favors the germination rate in seeds and the growth of plants, in wax chili plants no significant values were presented (Xuliang et al., 2023). For stem diameter there were significant statistical differences (Figure 2), with treatment T1C being the one that presented the best results with an average stem diameter of 16.98 cm, surpassing the control treatments T5C and T5L by 23.94 % and 13.5 % respectively.

Figure 1

Stem height of wax pepper plants inoculated with terrestrial and marine microorganisms by liquid immersion of root (L) and alginate capsules (C). T1 (L- C) = commercial *Trichoderma harzianum*; T2 (LC) = *Trichoderma* sp. (Native); T3 (LC) *Debaryomyces hansenii*; T4 (LC) *Stenotrophomonas rhizophila*; T5 (LC) Control. Different letters above the bars indicate significant differences between treatments according to Duncan's test ($p \leq 0.05$).

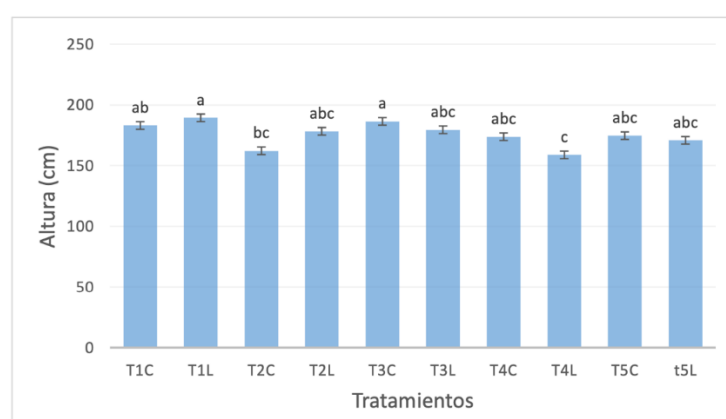
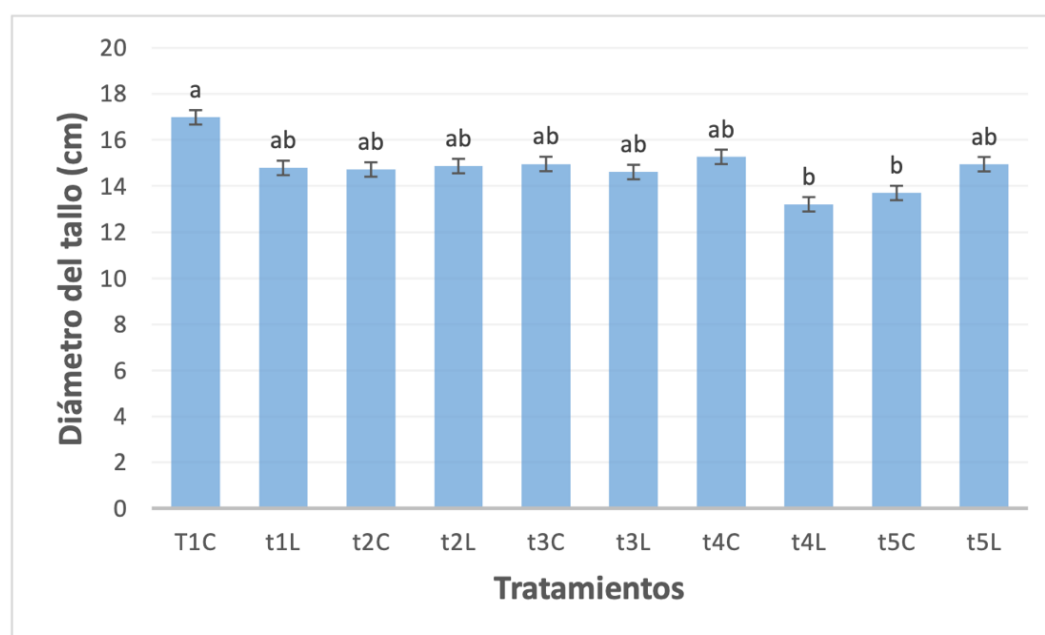




Figure 2

Stem diameter of wax pepper plants inoculated with terrestrial and marine microorganisms by liquid immersion of root (L) and alginate capsules (C). T1 (LC) = commercial *Trichoderma harzianum*; T2 (LC) = *Trichoderma* sp. (Native); T3 (LC) *Debaryomyces hansenii*; T4 (LC) *Stenotrophomonas rhizophila*; T5 (LC) Control. Different letters above the bars show significant differences between treatments according to Duncan's test ($p \leq 0.05$).

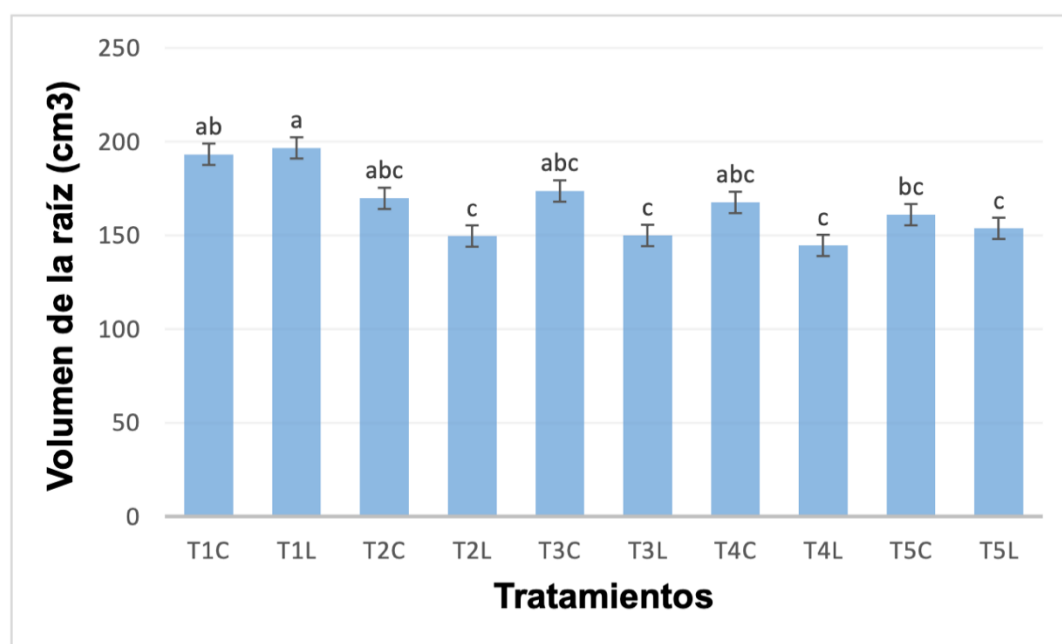


In the root volume variable there were significant statistical differences (Figure 3), with the T1L treatment with *Trichoderma being the most harzianum* (commercial strain MS Agros) in direct liquid inoculation to the roots of the plants, which presented better results with an average root volume of 193.3 cm^3 , surpassing the control treatments T5C (alginate capsules) and T5L (liquid application of water) by 19.98% and 25.6% respectively. The above validates the criterion of Stewart and Hill (2014), when making references that the increase in root and / or aerial biomass in tomato plants is the most common expression of growth promotion by *Trichoderma* spp., although changes in plant morphology and development are also reported.



Figure 3

Root volume of wax pepper plants inoculated with terrestrial and marine microorganisms by liquid immersion of root (L) and alginate capsules (C). T1 (LC) = commercial *Trichoderma harzianum*; T2 (LC) = *Trichoderma* sp. (Native); T3 (LC) *Debaryomyces hansenii*; T4 (LC) *Stenotrophomonas rhizophila*; T5 (LC) Control. Different letters above the bars show significant differences between treatments according to Duncan's test ($p \leq 0.05$).



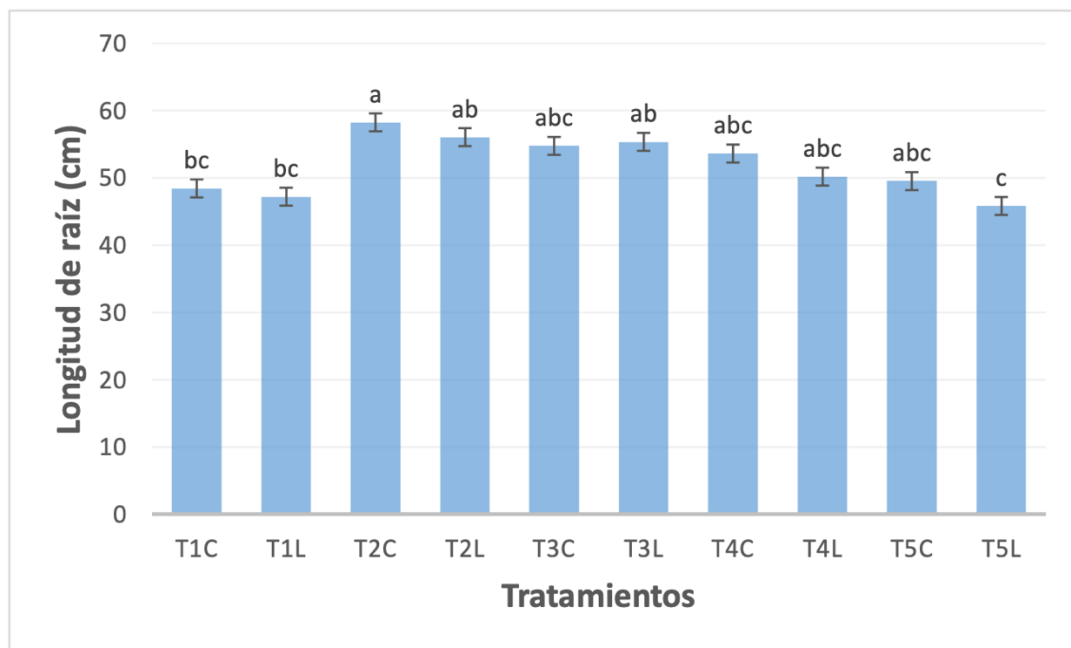
The treatments presented significant differences in the variable root length (Figure 4). Significant statistical differences can be observed, with treatment T2C standing out from the rest with an average of 58.27 cm of root length, surpassing T5C and T5 L by 17.64% and 27.08% respectively.

Regarding the total dry biomass variable, significant differences were obtained (Figure 5), with treatment T3C with *D. hansenii* inoculated with alginate capsules, with an average weight of total dry biomass of 223.78 g, surpassing the control treatments T5C (alginate capsules) and T5L by 35.15% and 35.79% respectively. Sevillano-Caño *et al.* (2024) highlight the capacity of *D. hansenii* to absorb nutrients, favoring plant growth, as well as a microorganism that presents biocontrol mechanisms such as ethylene biosynthesis and induced resistance.



Figure 4

Root length of wax pepper plants inoculated with terrestrial and marine microorganisms by liquid immersion of root (L) and alginate capsules (C). T1 (LC) = commercial *Trichoderma harzianum*; T2 (LC) = *Trichoderma* sp. (Native); T3 (LC) *Debaryomyces hansenii*; T4 (LC) *Stenotrophomonas rhizophila*; T5 (LC) Control. Different letters above the bars show significant differences between treatments according to Duncan's test ($p \leq 0.05$).



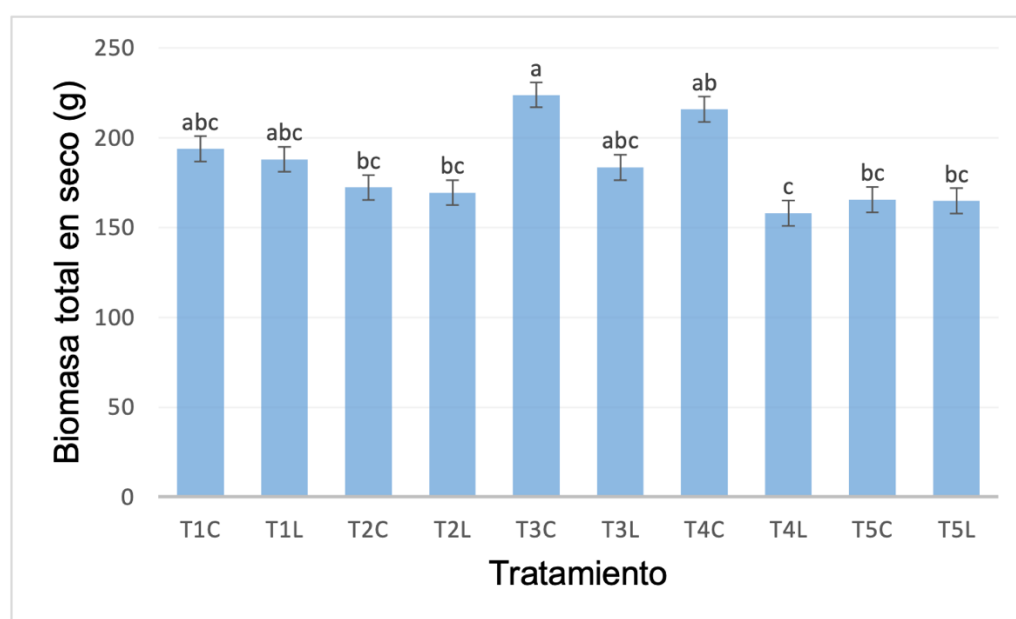
Soto *et al.* (2018), emphasize that the application of marine yeast As a biological control agent in lemon fruits against phytopathogens, such as *P. digitatum*, *P. italicum*, *P. citricarpa*, and *G. citri-aurantii*, it promotes control without causing damage to the quality of the fruit during its application.

Trichoderma inoculation in *C. annuum* plants, it is reported that the observed benefits were the increase in leaf and root biomass and stem diameter; in turn, the increase in lipids and proteins in the obtained fruits is reported. These effects associated with the capacity of *Trichoderma* in the production of indole-3-acetic acid, a plant phytohormone that stimulates plant growth (Basto-Pool *et al.*, 2023).



Figure 5

Total dry biomass of wax pepper plants inoculated with terrestrial and marine microorganisms by liquid immersion of root (L) and alginate capsules (C). T1 (LC) = commercial *Trichoderma harzianum*; T2 (LC) = *Trichoderma* sp. (Native); T3 (LC) *Debaryomyces hansenii*; T4 (LC) *Stenotrophomonas rhizophila*; T5 (LC) Control. Different letters above the bars show significant differences between treatments according to Duncan's test ($p \leq 0.05$).

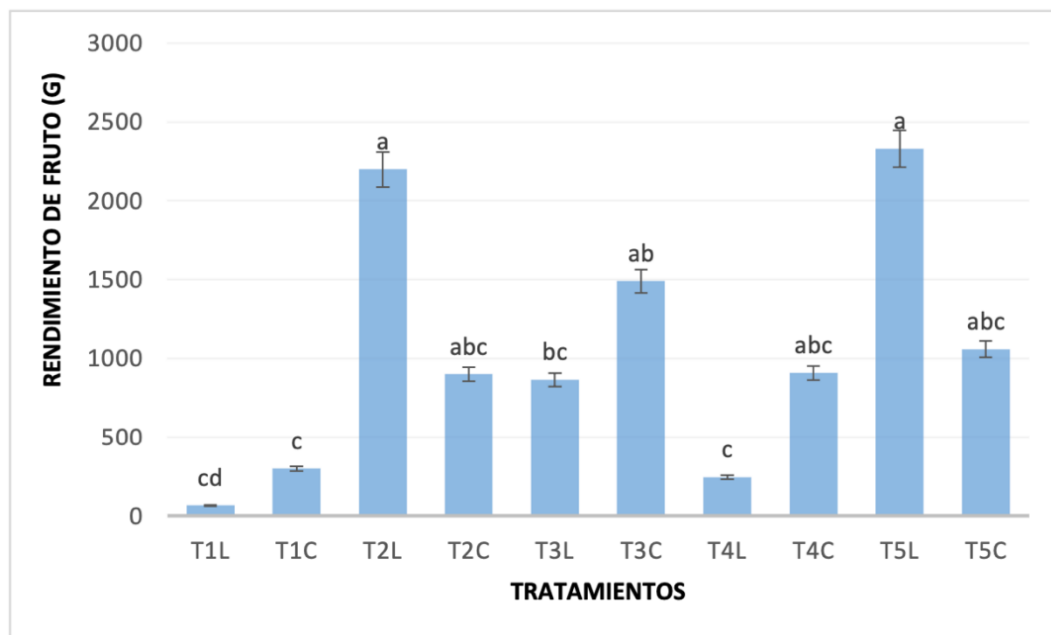


Regarding the yield variable, significant statistical differences were obtained (Figure 6), with the T5L treatment (control of the experiment) showing the best results with an approximate fruit yield weight of 2329.9 g. Currently, there are no published studies on the productivity of wax chili; however, Espinosa-Torres and Ramírez-Abarca (2016) found an acceptable profitability on the production of wax chili (Var. Chapingo) in the Texcoco Valley, in the State of Mexico.



Figure 6

Yield of wax chili plants inoculated with terrestrial and marine microorganisms by liquid immersion of root (L) and alginate capsules (C). T1 (LC) = commercial *Trichoderma harzianum*; T2 (LC) = *Trichoderma* sp. (Native); T3 (LC) *Debaryomyces hansenii*; T4 (LC) *Stenotrophomonas rhizophila*; T5 (LC) Control. Different letters above the bars show significant differences between treatments according to Duncan's test ($p \leq 0.05$).



5 CONCLUSION

Terrestrial and marine microorganisms applied via sodium alginate capsules and liquid culture to the roots of wax pepper plants promoted vegetative growth and productivity in a semi-hydroponic greenhouse system. The use of the yeast *Debaryomyces hansenii* and the fungus *Trichoderma harzianum* represent a viable alternative for use in the cultivation of wax pepper plants, since they stimulate plant growth and yield through a semi-hydroponic greenhouse production system.

REFERENCES

Arroyo-González, N (2009). Perfil de expresión del genoma de *debaryomyces hansenii* en respuesta a la osmoadaptación. San Nicolás de los Garz. Universidad Autónoma de Nuevo León.



- Basto-Pool, C., Zavala-León, M., Cristóbal-Alejo, J., Herrera-Parra, E (2023). Efecto de Trichoderma en el crecimiento de chile Catiknifap (*Capsicum annuum* L.) y en el control de *Meloidogyne incognita*. Avances en Investigación Agropecuaria. 27:175-186.
- Cruz-Cardenas, C.I., Zalaya. M.L., Sandoval, C.G.; de los Santos, V.S., Rojas, A.E., Chávez, D.I., Ruíz, R.S (2021). Utilización de microorganismos para una agricultura sostenible en México: consideraciones y retos. Rev. Mex. Cienc. Agri. 12(5).
- Espinosa-Torres, L., & Ramírez-Abarca, O (2016). Rentabilidad de chile manzano (*Capsicum pubescens* R Y P) producido en invernadero en Texcoco, Estado de México. Revista Mexicana de Ciencias Agrícolas. 7(2). Doi: <https://doi.org/10.29312/remexca.v7i2.347>
- Gasca-Peña, R. (2011). Reflectancia en hojas de chile manzano (*Capsicum pubescens* R. y P. para estimar contenido de nitrógeno. Colegio de Postgraduados, México.
- Grageda Cabrera,, O., Mora, M., Castellanos, R., Follet, R., & Peña Cabriales, J. (2003). Fertilizernitrogen recovery under different tillage treatments and cropping sequences in a vertisol central México. IAEA-TECDOC. 1354, 39-55.
- Hernandez-Montiel, L. G., Larralde-Corona, C.P., Vero, S., López-Abusto, M.G., Ochoa, J.L., Ascenso-Valle, F (2010). Caracterización de levaduras *Debaryomyces hansenii* para el control biológico de la podredumbre azul del limón mexicano. Ciencia y Tecnología Alimentaria. <https://doi.org/10.1080/19476330903080592>
- INTAGRI (2015). Thrichoderma: Control de hongos fitopatógenos. <https://www.intagri.com/articulos/fitosanidad/trichoderma-control-de-hongos-fitopatogenos>
- INTAGRI. (2013). Los Biofertilizantes en la Agricultura. Celaya. <https://www.intagri.com/articulos/agricultura-organica/biofertilizantes-en-agricultura#:~:text=Los%20biofertilizantes%20son%20insumos%20formulados,de%20n utrientes%20para%20las%20plantas.>
- Samaniego-Gaxiola, J.A (2021). Benefic organisms in agricultural crops: Towards a safety and healthy food in response COVID-19 and future syndemics. Rev. Mex. De Fitopatología. 261- 281.
- Stewart, A. y Hill R. (2014). Applications of Trichoderma in Plant Growth Promotion. Biotechnology and Biology of Trichoderma. 415–428. Doi: <https://doi.org/10.1016/B978-0-444-59576-8.00031-X>
- Sevillano-Caño J, García MJ, Córdoba-Galván C, Luque-Cruz C, Agustí-Brisach C, Lucena C, Ramos J, Pérez-Vicente R, Romera FJ. 2024. Exploring the Role of *Debaryomyces hansenii* as Biofertilizer in Iron-Deficient Environments to Enhance Plant Nutrition and Crop Production Sustainability. Int J Mol Sci. 25(11):5729. DOI: 10.3390/ijms25115729.
- Soto, F., Tramón , P., Aqueveque M., P., & de Bruijn, J (2018). Microorganismo antagonistas que inhiben el desarrollo de patógenos en post-cosecha de limones (*Citrus limon* L.). 173-184. Chilean J. Agric. Anim. Sci. 34 (2): 173-184.
- Tyskiewicz, R.; Nowak, A.; Ozimek, E.; Jaroszuk-Ściśeł, J. 2022. *Trichoderma*: The Current Status of Its Application in Agriculture for the Biocontrol of Fungal Phytopathogens and



Stimulation of Plant Growth. *Int. J. Mol. Sci.* 23: 2329. DOI: <https://doi.org/10.3390/ijms23042329>.

Xuliang, Z., Ying, L., Na, F., Zhihui, B., Jie, G. 2023. Quorum sensing improves the plant growth-promoting ability of *Stenotrophomonas rhizophila* under saline-alkaline stress by enhancing its environmental adaptability. *Frontiers in Microbiology*. 14. DOI: <https://doi.org/10.3389/fmicb.2023.1155081>.