Colegio de Postgraduados

Arbuscular fungi: key organisms for the symbiotic association in the genera *Agave* L. and *Opuntia* (L.) Mill

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ABSTRACT
Objective: Conduct a review of scientific literature with the aim of synthesizing current knowledge on the benefits of arbuscular mycorrhizal fungi (AMF) in *Opuntia* and *Agave* species to propose their use in the Complementary Agriculture (AgriCom) model, strengthening semi-desert production systems.
Design/methodology/approach: A systematic review (2013-2025) was conducted in databases (using keywords in English and Spanish) of studies that mentioned the role of AMF in *Opuntia* spp. and *Agave* spp.
Results: The review shows that symbiosis with AMF significantly improves biomass (increases of 35%-60% in *Opuntia*, 30%-55% in *Agave*), nutrient uptake (especially phosphorus, by 40%-70%), and drought tolerance in both genera. AMF increase water absorption in plant tissues, reduce oxidative stress, and promote more extensive root systems. Native AMF strains often showed superior benefits compared to commercial strains.
Limitations on study/implications: Most studies on Agavaceae were conducted under greenhouse conditions; therefore, further comparative field studies are required.
Findings/conclusions: Scientific evidence confirms that symbiosis with AMF is a key strategy for improving the productivity and resilience of *Opuntia* and *Agave* in adverse conditions. The use of AMF in the AgriCom model can increase crop growth.

Keywords: Arbuscular mycorrhizal fungi, *Opuntia*, *Agave*, water stress, AgriCom.

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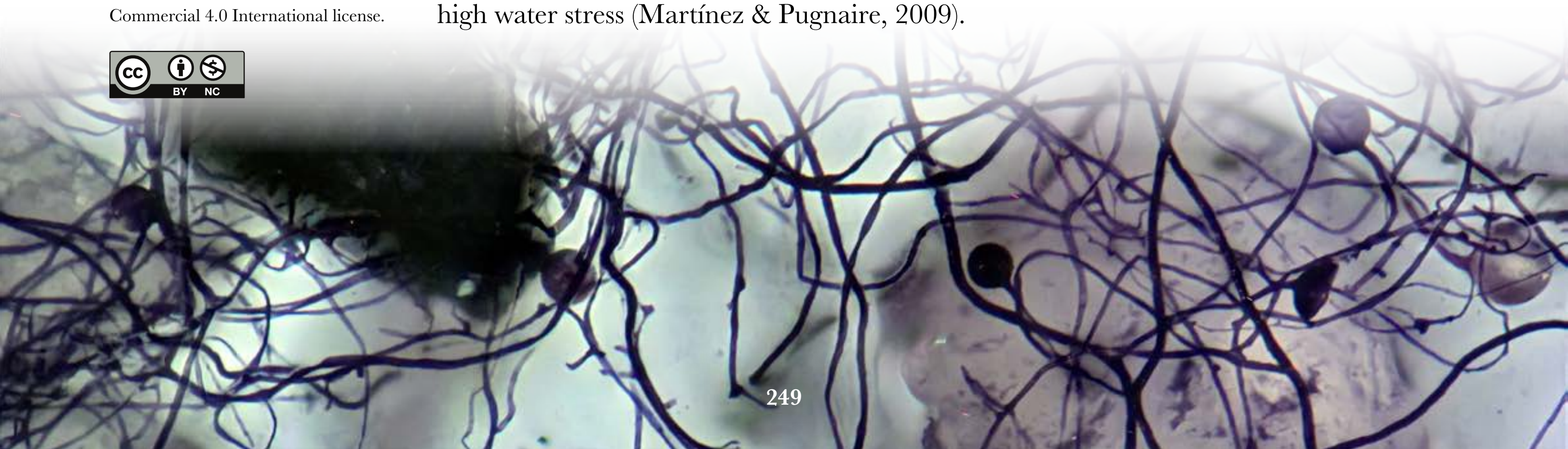
INTRODUCTION

In Mexico, the semidesert has extreme climatic conditions such as low rainfall, high temperatures, and degraded soils. These conditions cause erosion and biodiversity loss, which in turn limit soil fertility and the soil's water-retention capacity. These factors affect agricultural productivity and food security in rural communities (Cotler *et al.*, 2020). In the Potosino-Zacatecan semidesert, years with very little rainfall have been recorded (Díaz-Sánchez *et al.*, 2022), along with prolonged drought periods during which vegetation faces high water stress (Martínez & Pugnaire, 2009).



The conventional technologies used over the past few decades are no longer efficient, and conventional agriculture has generated serious social, economic, and environmental impacts. In this regard, the intensive use of agrochemicals has degraded soils, reduced biodiversity, and caused contamination of soils and water resources (Altieri & Nicholls, 2020). Furthermore, the use of monoculture systems has displaced local varieties, overlooking traditional knowledge and community identity (Sevilla Guzmán & Woodgate, 2013).

Although producers in these areas have experimented with new practices to adapt to and overcome climatic constraints, unfortunately this has not been enough (Nicholls & Altieri, 2019). Therefore, it is necessary to establish strategies to address the challenges faced by rural communities, which are highly susceptible to being affected. Agricultural diversification is a strategy to increase ecosystem resilience in order to ensure the sustainability of natural resources (Altieri & Nicholls, 2017).

Complementary Agriculture (AgriCom) is defined as small-scale agricultural and even livestock production modules whose planting, production, and harvesting times vary throughout the year, enabling rural residents to earn income at different intervals —in contrast to the seasonal harvest of a single crop— while benefiting from self-employment and avoiding or limiting migration (Díaz-Sánchez *et al.*, 2022). Currently, the AgriCom model includes 70 nopal genotypes in production and conservation modules (Díaz-Sánchez *et al.*, 2022). In the near future, the implementation of Agavaceae species is expected.

The implementation of productive systems with species such as nopal and agave can be a strategy for conserving the germplasm of these crops, benefiting food security and the economic income of rural communities. The consumption of nopalitos (young nopal pads) and their fruit (tuna) is ancestral (Reyes-Agüero *et al.*, 2005), but production has recently increased due to their nutraceutical properties. The nopal belongs to the Cactaceae family, which makes it ideal for growing in extreme temperatures and with little rainfall, as occurs in arid and semi-arid regions (Torres-Ponce *et al.*, 2015).

On the other hand, 75% of *Agave* species are found in Mexico (García-Mendoza, 2002), from which products such as mezcal, tequila, human food, and animal feed are obtained (Ramírez-Tobías *et al.*, 2014). These plants have the advantage of storing water in their tissues, allowing them to adapt to living in extreme conditions with prolonged periods of drought and high temperatures (García-Mendoza, 2007).

The inclusion of arbuscular mycorrhizal fungi (AMF) in the AgriCom model can help mitigate the effects of drought and erosion, as well as improve soil fertility and increase biodiversity in the Mexican semidesert. AMF, in the ecological context, can facilitate the recovery of soil microbial communities, thereby benefiting the restoration of disturbed areas by improving seedling survival and growth (Carrillo-Saucedo *et al.*, 2022), as well as crop productivity without reliance on chemical fertilizers, which, due to their indiscriminate use, have a negative impact on the environment (Herrera-Monroy *et al.*, 2022). These fungi have developed strategies to overcome the conditions found in these ecosystems, resulting in better use of available water and improved nutrient uptake (Martínez & Pugnaire, 2009).

Based on the above, the first objective of this study was to conduct a literature review to gain an understanding of the current knowledge regarding the various benefits of AMF in ecologically and economically important crops in the Mexican semidesert, such as *Opuntia* spp. and members of the Agavaceae family (*Agave* spp.), and to suggest their incorporation into the agricultural practices of the Complementary Agriculture (AgriCom) model to strengthen productive systems in arid and semi-arid areas.

MATERIALS AND METHODS

Information search

The information search was conducted through a systematic review (2013-2025) of scientific articles in the Web of Science (WOS) database (Page *et al.*, 2021). The search focused on studies addressing the function of AMF in *Opuntia* spp. and *Agave* spp. To narrow down the large number of publications, keyword combinations in English and Spanish were used, which were adjusted based on the results to retrieve articles (Page *et al.*, 2021). The "keyword" method (Table 1) was applied to facilitate the process of searching for information on the research topic.

The literature selection was appropriate for the scope of this review, highlighting the benefits of AMF for *Opuntia* and *Agave* species and focusing on growth and drought tolerance.

RESULTS AND DISCUSSION

Studies of cacti

Arid and semi-arid zones cover more than half of Mexico, where the vegetation is diverse (Cervantes-Ramírez, 2005). Cacti, especially the genus *Opuntia*, have held cultural significance in Mexico since the beginning of its history. The morphological and physiological characteristics of the nopal cactus enable it to store water in its tissues in order to survive drought conditions (Reyes-Terrazas *et al.*, 2020).

In rural semidesert communities, climatic conditions have intensified the drought, affecting crops (Díaz-Sánchez *et al.*, 2022). Therefore, the use of AMF allows plants to increase their tolerance to water stress and nutrient uptake through a strengthened root system and hyphae that are widely distributed in the soil (Barredo-Pool *et al.*, 1998). The symbiosis between *Opuntia* spp. and AMF favors successful establishment and productivity in arid and semi-arid zones. According to the scientific articles in this study, the genera *Glomus*, *Rhizophagus*, and *Funneliformis* are the most frequently associated with *Opuntia*, suggesting that they are preferred under stress conditions (Table 2).

Regarding nutrient uptake, all studies agree on the increase in phosphorus concentration in the plant's foliar tissues (cladodes) due to inoculation with AMF. Lahbouki *et al.* (2021)

Table 1. Keywords for information retrieval.

Keyword	*Opuntia* spp.	*Agave* spp.	AMF
Variants	Prickly pear cactus *Opuntia ficus indica* Nopal	*Agave salmiana* Otto ex Salm-Dyck *Agave americana* L. *Agave potatorum* Zucc.	Arbuscular mycorrhizal Micorriza AM
Synonyms and related words	*Nopalea* sp. *Opuntia* species	Maguey Agavaceae	Association Drought stress Growth

Table 2. Studies on cacti (*Opuntia*) and arbuscular mycorrhizal fungi.

Reference	*Opuntia* species/variety	AMF	Greenhouse/ Field	Benefits for *Opuntia* spp.
Pimienta-Barrios *et al.* (2003)	*Platyopuntia* sp.	Unspecified (native AMF)	Field (without inoculation, using benomyl to inhibit AMF)	30%-50% increase in CO_2 absorption Better root development (40%) Greater water retention under drought (25%) Reduction of oxidative stress
Neffar *et al.* (2015)	*O. ficus-indica*	*Glomus* spp. *Gigaspora* sp.	Field	Colonization ranges from 40% to 80% depending on the season. 45% increase in phosphorus uptake Greater drought resilience (30%) Maximum colonization in spring/ autumn
Bashan *et al.* (2000)	*Opuntia* spp. (plántulas)	*Glomus aggregatum* (*Rhizoglomus aggregatum* (N.C. Schenck & G.S. Sm.) Sieverd., G.A. Silva & Oehl) (*Rhizophagus intraradices* N.C. Schenck & G.S. Sm) C. Walker & Schüßler)	Field Inoculation	50% greater growth under mesquite trees 90% survival in inoculated seedlings and 65% in non-inoculated plants Synergistic effect with nurse trees
Estrada-Luna & Davies (2001)	*Opuntia albicarpa* Scheinvar	*G. intraradices* (*R. intraradices*) *G. deserticola* (*Viscospora deserticola* (Trappe, Bloss & J.A-Mente) Tedersoo & Magurno, comb. nov.)	*In vitro/ex vitro* inoculation	40-60% increase in biomass Improved phosphorus absorption (70%) 25% greater water efficiency Post-transplant stress reduction
Lahbouki *et al.* (2021)	*O. ficus-indica*	*Rhizophagus irregularis* (Blaszk., Wubet, Renker & Buscot) C. Walker & A. Schüßler *Funneliformis mosseae* (T.H. Nicolson & Gerd.) C. Walker & A. Schüßler *Claroideoglomus etunicatum* (*Entrophospora etunicata* (W.N. Becker and Gerd.). Blaszk., Niezgoda, B.T. Goto, and Magurno, comb. nov.) *Glomus aggregatum* (*Rhizoglomus aggregatum* (N.C. Schenck & G.S. Sm.) Sieverd., G.A. Silva & Oehl)	Inoculation + vermicompost	Biomass increase (60% with vermicompost) Increase in phenolic compounds and antioxidants Higher relative water content in tissues (20%) 30% better water use efficiency (WUE)

Note: *Platyopuntia* is a historical taxonomic term for flat-cladode cacti now included within the genus *Opuntia*.

reported a 40% to 70% higher concentration of this nutrient in nopal. On the other hand, it has been shown that biomass increases by 35% to 60% even under water stress (Estrada-Luna & Davies, 2001; Pimienta-Barrientos *et al.*, 2003). Mention is also made of the use of AMF with amendments such as vermicompost, which, on its own, is presented as an alternative for soil recovery by improving nutrient availability (Flórez-Muriel, 2020).

AMF reduce the impact of drought through various mechanisms: a) maintaining higher water content (20%) in plant tissues (Pimienta-Barrios *et al.*, 2003); b) increasing the production of antioxidant metabolites (up to 65%), protecting nopal plants from cellular damage (Lahbouki *et al.*, 2021); and c) enhancing AMF colonization during periods of higher moisture content, thereby optimizing their activity (Neffar *et al.*, 2015). Based on the literature, the alliance between AMF and plants of the genus *Opuntia* can be confirmed, improving their growth, nutrition, and tolerance to water stress —fundamental factors in semiarid production systems with a limiting climate.

Studies of Agavaceae

Agave (also known as maguey) is found in many arid and semi-arid regions of Mexico, where its main appeal lies in the production of mezcal (Corona-Romero *et al.*, 2022). These types of ecosystems are characterized by low rainfall and prevailing high temperatures, to which the maguey must adapt (Mayagoitia-Toulet & Zamora-Gutierrez, 2024).

Agaves are important: a) ecologically, as they prevent erosion, provide refuge for various organisms, and supply resources for animals; and b) economically, since their extraction is aimed at producing food, beverages, and fibers (Mayagoitia-Toulet & Zamora-Gutiérrez, 2024). Furthermore, the popularity of their alcoholic beverages has increased interest in them, so sustainable harvesting schemes must be in place to prevent their irrational exploitation and the loss of genetic diversity (Mandujano-Bueno *et al.*, 2018).

The use of AMF can promote their conservation, diversity, and production (Trinidad-Cruz *et al.*, 2017), so a literature review on this symbiosis is essential to understand its benefits and how it can contribute to the conscious production of this vegetative resource. According to Table 3, AMF influence increased biomass, tolerance to water stress, and enhanced nutrient uptake. AMF have fundamental benefits for agave development, primarily: vegetative growth and tolerance to abiotic stress.

Table 3. Studies on agavaceous plants (*Agave*) and arbuscular mycorrhizal fungi.

Reference	Agave species/ variety	AMF	Greenhouse/Field	Benefits for Agave spp.
Carballar-Hernández *et al.* (2013)	*Agave potatorum* Zucc.	*Glomus aggregatum* (*R. aggregatum*) *G. etunicatum* (*E. etunicata*) *Acaulospora scrobiculata* Trappe +15 especies	Field	30% increase in root biomass Greater drought tolerance (80%)
Quiñones-Aguilar *et al.* (2023)	*A. tequilana* F.A.C. Weber	*R. intraradices* *Funneliformis mosseae* (T.H. Nicolson & GErd.) C. Walker & A. Schüßler	Inoculation Greenhouse	40% increase in biomass 35% increase in root length 90% drought tolerance
Quiñones-Aguilar *et al.* (2016)	*A. inaequidens* Koch	*R. intraradices* *F. mosseae* *Claroideoglomus claroideum* (*Entrophospora claroidea* (N.C. Schenk & G.S. Sm) Blaszk, NIezgoda, BT. Goto & Magurno)	Inoculation Greenhouse	50% increase in dry biomass Height increase (45%) 85% survival compared to 45% in non-inoculated plants.
Hernández-Cuevas *et al.* (2023)	*A. maximiliana* Baker	*R. aggregatus* (*R. aggregatum*) indigenous *R. intraradices* (allochthonous)	Inoculation/Comparison	38% increase in biomass. Native fungi were more efficient at promoting growth. 92% survival rate in native fungi
Moreno-Hernández *et al.* (2025)	*A. marmorata* Roezl	*R. irregularis* *F. mosseae*	Inoculation Greenhouse	55% increase in biomass 60% increase in root length 88% survival under drought conditions
Chávez-González *et al.* (2023)	*A. salmiana*	*R. irregularis* *F. mosseae* *Diversispora spurca* (C.M. Pfeiff., C. & Bloss) C. Walker & Schüßler)	Field	40% increase in biomass 75% survival rate during drought

In the case of water stress tolerance, plants inoculated with AMF exhibit more extensive and robust root systems, which increases their capacity to explore and absorb water from the soil under water-limited conditions (Quiñones-Aguilar *et al.*, 2023; Moreno-Hernández *et al.*, 2025).

Most studies conducted inoculation in a greenhouse; however, those carried out in the field demonstrate benefits from the AMF association in different *Agave* species. All studies report increased biomass and survival rates exceeding 75% in water-stressed environments (Carballar-Hernández *et al.*, 2013; Chávez-González *et al.*, 2023).

Chávez-González *et al.* (2023) mentioned that bacteria such as *Bacillus subtilis* increased mycorrhizal colonization by 60% and phosphorus solubilization by 35%. The authors conclude that the combined symbiosis of AMF and bacteria may be more effective than the independent inoculation of these microorganisms. Based on the literature, native AMF have advantages over introduced ones, such as greater adaptation to climatic conditions, and in plants they promote a more extensive and robust root system that demonstrates benefits for growth and water tolerance in *Agave*.

Implementation of arbuscular mycorrhizal fungi in the AgriCom model

The AgriCom model works by combining crops that are essential for maintaining soil fertility. Therefore, higher yields per unit area can be achieved, while also promoting biological balance and the production of diverse foods, thereby ensuring food and economic stability for rural families (Gutiérrez-Alzate, 2020). Local plant species or those adapted to the climatic conditions where the communities being served are located are used. In addition, local agrobiodiversity is preserved by including it in the planting modules, whether as a source of forage or human food (Acevedo-Osorio *et al.*, 2020).

In the AgriCom model, inoculation with AMF can be a strategy to enhance the capacity to improve the sustainability and resilience of production systems in arid zones. The scientific evidence analyzed shows that AMF increase biomass, nutrient uptake, and drought tolerance in cacti and agaves. AMF can not only promote the development of the model crops, but can also benefit soil fertility, improve biomass, and enhance tolerance to water stress.

CONCLUSIONS

The reviewed scientific evidence demonstrates that AM symbiosis benefits the productivity of *Opuntia* spp. and *Agave* spp., especially under water stress and in low-fertility soils, which are characteristic of arid and semi-arid regions. These benefits are fundamental to the semidesert's productive systems. Therefore, incorporating AMF into AgriCom can enhance crop growth and resilience in the model, as well as strengthen soil health. The implementation of these fungi can be a comprehensive solution for semidesert agri-food systems that also promotes food security and the conservation of plant resources.

REFERENCES

Barredo-Pool, F., Varela, L., Arce-Montoya, M., & Orellana, R. (1998). Estudio de la asociación micorrízica en dos cactáceas nativas de la Península de Yucatán. In Avances de la investigación micorrízica en México (1st ed., pp. 69-76). Universidad Veracruzana.

Bashan, Y., Davis, E. A., Carrillo-Garcia, A., & Linderman, R. G. (2000). Assessment of VA mycorrhizal inoculum potential in relation to the establishment of cactus seedlings under mesquite nurse-trees in the Sonoran Desert. *Applied Soil Ecology, 14*(2), 165-175. https://doi.org/10.1016/S0929-1393(00)00050-0

Carballar-Hernández, S., Palma-Cruz, F. J., Hernández-Cuevas, L., & Robles, C. (2013). Arbuscular mycorrhizal potential and mycorrhizal fungi diversity associated with *Agave potatorum* Zucc. in Oaxaca, Mexico. *Ecological Research, 28*(6), 923-934. https://doi.org/10.1007/s11284-012-1008-7

Cervantes Ramírez, M. C. (2005). Plantas de importancia económica en zonas áridas y semiáridas de México. Anais do X Encontro de Geógrafos da América Latina, 20 a 26 de março de 2005, Universidade de São Paulo. http://observatoriogeograficoamericalatina.org.mx/egal10/Procesosambientales/Usoderecursos/08.pdf

Chávez-González, J. D., Flores-Núñez, V. M., Merino-Espinoza, I. U., & Partida-Martínez, L. P. (2023). Desert plants, arbuscular mycorrhizal fungi and associated bacteria: Exploring the diversity and role of symbiosis under drought. *Environmental Microbiology Reports, 15*(4), 278-291. https://doi.org/10.1111/1758-2229.13300

Corona-Romero, N., Coronado Juárez, E., & Madrigal Gómez, J. M. (2022). Estudio espectral de diferentes variedades de agave para la creación de una librería espectral para su mapeo y monitoreo mediante percepción remota. *Investigaciones Geográficas*, 107, e60451. https://doi.org/10.14350/rig.60451

Díaz-Sánchez, F., Cadena-Iñiguez, J., Gómez-González, A., Ruiz-Vera, V. M., Morales-Flores, F. J., & Bustamante-Lara, T. I. (2022). Modelo de producción y conservación de germoplasma (AgriCom) en una comunidad rural del semidesierto mexicano. *Agro-Divulgación, 2*(6). https://doi.org/10.54767/ad.v2i6.123

Estrada-Luna, A. A., & Davies, F. T. (2001). Mycorrhizal fungi enhance growth and nutrient uptake of prickly-pear cactus (*Opuntia albicarpa* Scheinvar 'Reyna') plantlets after *ex vitro* transplantation. *Journal of Horticultural Science & Biotechnology, 76*(6), 739-745. https://doi.org/10.1080/14620316.2001.11511439

Flórez Muriel, E. (2020). El vermicompost, una alternativa para la recuperación de suelos [Tesis de grado, Universidad Militar Nueva Granada]. Repositorio UMNG. https://repository.umng.edu.co/server/api/core/bitstreams/9e68aef1-25d4-4359-82cc-244593bea79e/content

García-Mendoza A. 2002. Distribution of Agave (Agavaceae) in Mexico. *Cactus and Succulent Journal* 74:177-187

García-Mendoza, A. J. (2007). Los agaves de México. *Ciencias*, 87, 14-23. https://www.redalyc.org/pdf/644/64408704.pdf

Gutiérrez Alzate, F. (2020). Práctica tradicional de agricultura: Los policultivos como estrategia de sustento económico y conservación de los recursos naturales in situ en el corregimiento de Santa Cecilia - Pueblo Rico. Universidad Católica de Pereira. http://hdl.handle.net/10785/7154

Hernández-Cuevas, L. V., Salinas-Escobar, L. A., Segura-Castruita, M. Á., Palmeros-Suárez, P. A., & Gómez-Leyva, J. F. (2023). Physiological responses of *Agave maximiliana* to inoculation with autochthonous and allochthonous arbuscular mycorrhizal fungi. *Plants, 12*(3), 535. https://doi.org/10.3390/plants12030535

Quiñones-Aguilar, E. E., Montoya-Martínez, A. C., Rincón-Enríquez, G., Lobit, P., & López-Pérez, L. (2016). Effectiveness of native arbuscular mycorrhizal consortia on the growth of *Agave inaequidens*. *Chilean Journal of Agricultural Research, 76*(3), 267-274. http://dx.doi.org/10.4067/S0718-95162016005000077

Quiñones-Aguilar, E. E., Montoya-Martínez, A. C., Rincón-Enríquez, G., & López-Pérez, L. (2023). Inoculación de bulbilos de *Agave tequilana* con hongos micorrízicos arbusculares: efecto en el crecimiento y biocontrol contra *Fusarium oxysporum*. *Revista Colombiana de Ciencias Agrícolas, 24*(1), Artículo 3043. https://doi.org/10.21930/rcta.vol24_num1_art:3043

Lahbouki, S., Anli, M., El Gabardi, S., Ait-ElMokhtar, M., Ben-Laouane, R., Boutasknit, A., ... & Meddich, A. (2021). Evaluation of arbuscular mycorrhizal fungi and vermicompost supplementation on growth, phenolic content and antioxidant activity of prickly pear cactus (*Opuntia ficus-indica*). *Plant Biosystems, 155*(6), 1228-1238. https://doi.org/10.1080/11263504.2021.1947408

Mayagoitia-Toulet, D. J., & Zamora-Gutierrez, V. (2024). Flores de agave, centros de interacción del semidesierto. *Therya Ixmana, 3*(3), 101-103. https://doi.org/10.12933/therya_ixmana-24-512

Moreno-Hernández, M. R., López-Buenfil, J. A., Serrano-Fuentes, M. K., Contreras-Oliva, A., & Bello-Bello, J. J. (2025). Arbuscular mycorrhizal fungi improve the growth, nutrient uptake and survival of micropropagated agave (*Agave marmorata* Roezl) plantlets during acclimatization. *Journal of Arid Environments*, 224, 105330. https://doi.org/10.1016/j.jaridenv.2025.105330

Neffar, S., Beddiar, A., & Chenchouni, H. (2015). Effects of soil chemical properties and seasonality on mycorrhizal status of prickly pear (*Opuntia ficus-indica*) planted in hot arid steppe rangelands. *Sains Malaysiana, 44*(5), 683-691. https://doi.org/10.17576/jsm-2015-4405-05

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., ... & Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *Systematic Reviews, 10*(1), 89. https://doi.org/10.1186/s13643-021-01626-4

Pimienta-Barrios, E., González del Castillo-Aranda, M. E., Muñoz-Urias, A., & Nobel, P. S. (2003). Effects of Benomyl and Drought on the Mycorrhizal Development and Daily Net CO_2 Uptake of a Wild Platyopuntia in a Rocky Semi-arid Environment. *Annals of Botany, 92*(2), 317-324. https://doi.org/10.1093/aob/mcg133

Ramírez-Tobías, H. M., Peña-Valdivia, C. B., & Aguirre, J. R. (2014). Respuestas bioquímico-fisiológicas de especies de Agave a la restricción de humedad. *Botanical Sciences, 92*(1). https://doi.org/10.17129/botsci.11

Reyes-Agüero, J. A., J. R. Aguirre R., and H. M. Hernández. 2005. Systematic notes and a detailed description of *Opuntia ficus-indica* (L.) Mill. (Cactaceae). *Agrociencia* 39: 395-408.

Reyes Terrazas, A. S., Flores-Sánchez, D., Navarro-Garza, H., Pérez-Olvera, M. A., & Almaguer-Vargas, G. (2020). Importancia, sentido de pertenencia y continuidad del sistema cultivo nopal verdura (*Opuntia ficus indica* L.) en Cuautlacingo, Otumba, Estado de México. *RA XIMHAI, 16*(4), 229-250. https://doi.org/10.35197/rx.16.04.2020.11.ar

Torres-Ponce, R. L., Morales-Corral, D., Ballinas-Casarrubias, M. L., & Nevárez-Moorillón, G. V. (2015). El nopal: planta del semidesierto con aplicaciones en farmacia, alimentos y nutrición animal. *Revista Mexicana de Ciencias Agrícolas, 6*(5). https://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S2007-09342015000500018

Trinidad-Cruz, J. R., Quiñones-Aguilar, E. E., Hernández-Cuevas, L. V., López-Pérez, L., & Rincón-Enríquez, G. (2017). Hongos micorrízicos arbusculares asociados a la rizosfera de *Agave cupreata* en regiones mezcaleras del estado de Michoacán, México. *Revista Mexicana de Micología*, 45, 13-25. https://www.redalyc.org/pdf/883/88352759003.pdf

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