Effect of endomycorrhizae (Glomus intraradices) and organic matter on the growth of cactus pear (Opuntia albicarpa) in two soil types

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Abstract
Most of the farmers who grow cactus pear (Opuntia albicarpa) use manure as a fertilizer. This practice increases the problems of pests. The use of endomycorrhizae (Glomus intraradices) is almost unknown to farmers. Therefore, the objective of this research was to study the effect of the application of organic matter (OM) and inoculation with endomycorrhizae in cactus pear. The study was conducted under greenhouse conditions at the Montecillo Campus of the Postgraduate College, Mexico. Two types of soil from San Luis Potosí, Mexico, were used: reddish coloration (xerosol) and gray coloration (lithosol). The results show that there were significant differences (p ≤ 0.05) in all the variables by inoculation with endomycorrhizae and in the majority of those by the application of OM. Both the mycorrhizae and the application of OM, as vermicompost, promoted greater growth of the stems and roots. The types of soils used did not affect the growth of the plants. Mycorrhizae can be useful to improve mineral nutrition and thus increase yields in cactus pear plantations. In addition, these fungi can increase yields and help reduce production costs. The application of 50 t ha-1 vermicompost is a better alternative to add nutrients and OM to this crop.

Keywords: endomycorrhizae fungi; xerosol; lithosol; vermicompost; mineral nutrition; pests; inoculation; stems; roots; nutrients; plants.

Resumen
La mayoría de los agricultores que cultivan nopal tunero (Opuntia albicarpa) utilizan estiércol como fertilizante. Esta práctica aumenta los problemas de plagas. El uso de la endomicorriza (Glomus intrarradices) es casi desconocido por los agricultores. Por lo tanto, el objetivo de esta investigación fue estudiar el efecto de la aplicación con materia orgánica (MO) y la inoculación con endomicorriza en nopal tunero. El estudio se realizó en condiciones de invernadero en el Campus Montecillo del Colegio de Postgraduados, México. Se utilizaron dos tipos de suelo de San Luis Potosí, México: uno de coloración rojiza (xerosol) y otro gris (lithosol). Los resultados muestran que hubo diferencias significativas (p ≤ 0.05) en todas las variables por la inoculación con endomicorriza, y en la mayoría de ellas por la aplicación de MO. Tanto la micorriza como la aplicación de MO, así como el vermicompost, promovieron un mayor crecimiento del tallo y la raíz. Los tipos de suelos utilizados no afectaron el crecimiento de las plantas. La micorriza puede ser útil para mejorar la nutrición mineral y, por lo tanto, aumentar los rendimientos en las plantaciones de nopal tunero. Además, estos hongos pueden aumentar los rendimientos y generar una reducción de los costos de producción. La aplicación de 50 t ha-1 de vermicomposta es una mejor alternativa para añadir nutrientes y MO a este cultivo.

Palabras clave: hongos endomícorrhízicos; xerosol; litosol; vermicomposta; nutrición mineral; plagas; inoculación; tallo; raíz; nutrientes; plantas.
1. Introduction

There are more than 360 species within the genus Opuntia, which have a wide distribution in the Americas (Segura et al., 2007; Caruso et al., 2010). Mexico is considered one of the two centers of origin and dissemination of this genre, but also has the largest number of species and cultivars of cactus pear (Opuntia spp.) in the world (Gallegos, & Méndez, 2000). However, the wide genetic variability of the cactus pear suggests that this plant species is native to Mexico (Luna et al., 2012). Cactus is a xerophyte plant that grows mainly in arid and semiarid areas due to its low water requirement because it has numerous adaptations that allow it to reduce its transpiration (Medina-García et al., 2021). Among them, it is important that they carry out photosynthesis through the mechanism called Crassulacean Acid Metabolism (CAM). The CAM plants open their stomata only at night and thereby reduce their transpiration. It also lacks leaves, whose functions have been replaced by flat stems called cladodes. It also has a thick and impermeable cuticle, which prevents the loss of water. However, they can achieve high dry-weight productivity (García de Cortázar, & Nobel, 1992). Opuntia species are cultivated for different purposes, but their main uses are fruit, vegetable, and forage. In 2018, a per capita consumption of 6.4 kg was recorded, with 853 495 t of production and 83 558 ha cultivated in Mexico, of which two-thirds corresponded to cactus pear (SIAP, 2019).

The price of cactus pear has remained low, which puts pressure on producers to find alternatives to keep their production costs low (Hernández et al., 2020). However, one of the main expenses is fertilization. For the application of nutrients, most producers use cow manure as fertilizer (Gardezi et al., 2007; Gardezi et al., 2008). This is applied raw, without any previous treatment, and by that, it favors the attack of soil pests such as cochineal insect (Dactylopius spp.) (Márquez-Berber et al., 2012). This practice causes problems because organic matter (OM) takes more time to decompose and immobilizes soil nitrogen in the process, which prevents its rapid utilization. In addition to the fact that its nitrogen content is low, some of it is lost for denitrification and the content of other minerals can salinize soil (García-Hernández et al., 2010).

The application of fresh or semidecomposed manure may encourage a higher incidence of pests, diseases (the most important is cladodes thickening syndrome) and shrub weeds (Mochiah et al., 2011). In addition, excessive amounts of manure, such as those used by some farmers, may lead to problems of pollution of both soil and groundwater of that region (Márquez-Berber et al., 2012). Composting manure will not only favor its use but will also help to improve soil quality, to reduce the presence of propagules of weeds, pests and diseases and to reduce soil and groundwater pollution because of leaching. Therefore, it can improve the production system and promote safer practices (Márquez-Berber et al., 2012). In addition, cactus is used like fodder in times of drought, is alternative of livestock feed in dryland areas due to the protein enrichment, which has generated the elaboration of diets based on traditional fodder and cactus enriched with proteins to feed goats and sheep’s (Flores-Hernández et al., 2017; Ramos et al., 2021).

The high cost of producing cactus pears and the low price the growers receive reduce their profitability (Hernández et al., 2020). There is a need to find alternatives to reduce their inputs. Several researchers consider mycorrhizae to be the most important organisms on earth interacting in agroenvironments (Lenoir et al., 2016; Girsowicz et al., 2019). More than 80 % of all plants in the world, including most horticultural and row crops have a symbiotic relationship with these fungi and the stimulation of plant growth can be attributed mainly to the improvement of phosphorus nutrition (Alarcón, 2008; Plenchette et al., 2005).

The nopal (Opuntia spp.) is the most commonly used plant for glucose control, since it has a high content of soluble fiber and pectins, which can favorably affect the absorption of glucose at the intestinal level, for which it is considered a hypoglycemic agent. It is traditionally used for the treatment of noninsulin-dependent diabetes. The medicinal part is the tender cladodes, from which the thorns have been removed; these are later washed and cut to finally liquefy them. This plant is free of all enzymatic inhibition; therefore, the extracts form a barrier between the enzyme complex and the substrate, thus having an antihyperglycemic mechanism of action. One more property of Opuntia spp. fruits has antioxidant capacity due to the presence of phytochemicals such as carotene, flavonoids and other phenolic compounds, vitamins C and E, or some enzymes as part of the antioxidant defense system. Red peel fruit has also been shown to contain taurine (7.7 to 11.7 mg by 100 g of fresh fruit).

On the other hand, the combination of dietary fiber associated with the phytochemicals described in nopal, together with its nutraceutical properties, allows nopal to be used as a dietary supplement and as a food ingredient,
reducing the risk of gastrointestinal problems and helping in obesity treatments (Mulík, & Ozuna, 2020). Additionally, fiber lowers the level of low-density lipoproteins and lowers blood cholesterol. It also has phenolic compounds in its fruits (prickly pear), which have been shown to have antioxidant, anticarcinogenic and antiviral capacities, among other properties (Torres-Ponce et al., 2015).

The use of endomycorrhizae (Glomus intraradices) is almost unknown to cactus pear farmers. Their use can improve mineral nutrition and reduce costs in such crops. Therefore, the objective of the present research was to study the effect of OM, such as vermicompost, and inoculation with endomycorrhizae on the growth of cactus pear (Opuntia albicarpa) in two types of soil under greenhouse conditions.

2. Methods, techniques, and instruments
This study was conducted in the spring and summer of 2013 under greenhouse conditions at the Postgraduate College in Montecillo, Mexico, located at 19° 27’ 38.90” N, -98° 54’ 14.01” W, with an altitude of 2246 m; the predominant climate was temperate sub wet C (w). Its annual mean temperature is 16.4 °C, and the annual mean rainfall is 762.7 mm (García, 1987). The greenhouse used had symmetrical flat roofs with two waters. It was built with crystal with 70% luminosity. Ventilation was performed by front and side windows and there was a heating system.

Soils from two locations were used, one of reddish coloration (xerosol) and another gray (lithosol), whose characteristics are shown in table 1. Both types of soil were collected in the community of Salinas, state of San Luis Potosí (figure 1). In the soil samples, the texture and the following characteristics were determined: the pH, electrical conductivity (EC), amount of OM, cationic exchange capacity (CEC), content of nitric nitrogen (NO₃), ammonia (NH₃), and total nitrogen (N). Additionally, the amounts of phosphorus (P), calcium (Ca), magnesium (Mg), potassium (K), manganese (Mn), sodium (Na), iron (Fe), zinc (Zn), copper (Cu), chromium (Cr) and nickel (Ni) were measured.

The soil OM was determined using the Walkey and Black method. For phosphorus, the Olsen method was utilized, and the interchangeable bases were measured with ammonium acetate 1 normal (CH₃CO₂NH₄) pH 7 and micronutrients with DTPA (diethylene-triamine-pentacetic acid).

Figure 1. Soil sampling area at Salinas, San Luis Potosi, Mexico.
The gray soil had a medium alkalinity, and the red soil had a neutral pH. Both had medium amounts of inorganic N and low amounts of K. Its contents of Fe, Mn and Zn were adequate. Lithosol, gray soil, was deficient in copper, but xerosol, red soil, had it in sufficient quantities (table 1). Both lacked salinity problems since they had a low electrical conductivity (EC). Therefore, no problems with salts were found (Castellanos et al., 2000).

Table 1. Soil analysis for the two types.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Unit of measurement</th>
<th>Xerosol (red)</th>
<th>Lithosol (gray)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP</td>
<td>-</td>
<td>28</td>
<td>34.7</td>
</tr>
<tr>
<td>EC</td>
<td>dS m⁻¹</td>
<td>0.54</td>
<td>0.65</td>
</tr>
<tr>
<td>Ph</td>
<td>1:02</td>
<td>8.3</td>
<td>7.07</td>
</tr>
<tr>
<td>OM</td>
<td>%</td>
<td>1.78</td>
<td>2.05</td>
</tr>
<tr>
<td>N inorg</td>
<td>mg kg⁻¹</td>
<td>35.27</td>
<td>28.86</td>
</tr>
<tr>
<td>P</td>
<td>mg kg⁻¹</td>
<td>0.85</td>
<td>1.07</td>
</tr>
<tr>
<td>K</td>
<td>mg kg⁻¹</td>
<td>477.04</td>
<td>453.58</td>
</tr>
<tr>
<td>Ca</td>
<td>mg kg⁻¹</td>
<td>6413.24</td>
<td>2249.79</td>
</tr>
<tr>
<td>Mg</td>
<td>mg kg⁻¹</td>
<td>110.0</td>
<td>209.6</td>
</tr>
<tr>
<td>Fe</td>
<td>mg kg⁻¹</td>
<td>12.33</td>
<td>21.96</td>
</tr>
<tr>
<td>Cu</td>
<td>mg kg⁻¹</td>
<td>0.11</td>
<td>2.81</td>
</tr>
<tr>
<td>Mn</td>
<td>mg kg⁻¹</td>
<td>19.18</td>
<td>47.96</td>
</tr>
<tr>
<td>Zn</td>
<td>mg kg⁻¹</td>
<td>1.90</td>
<td>2.28</td>
</tr>
</tbody>
</table>


The cladodes used in this experiment were collected in a commercial cactus pear plantation in Tulancingo, Hidalgo, Mexico. These cladodes were planted in pots with 3 kg of each type of soil. The plants were cultivated for nine months and irrigated with well groundwater. The evaluated variables were the number of stems, plant height, stem diameter, cladode width and fresh weight of biomass, dry weight of biomass, fresh weight of root, dry weight of root, radical volume and radical length.

The inoculant was produced under controlled conditions in sorghum (Sorghum bicolor) plants (as a trap culture) and sand as a substrate due to its low water requirements and high protein content. Prior to its use, root samples were taken from the trap plant to determine the percentage of colonization, which was 78 % colonization of Glomus intraradices (arbuscular mycorrhizae fungi (AMF) used as soil inoculum in agriculture and gardening. Also, it is found naturally in almost all types of soils especially in forest plants and grass meadows) and 1050 spores per 100 g of inert material, which was obtained through laboratory processes (figure 2). Two levels of Glomus were applied, with and without Glomus. It was inoculated with the AMF strain Glomus intraradices was inoculated at the time of transplant directly to the root, applying 5 g of inoculum per plant. Once the inoculation was done, the hole where the plant was placed was covered in such a way that no air spaces remained.
OM was applied as a vermicompost and prepared using 60 kg of bovine manure, 25 kg of melon waste and 15 kg of wheat straw (to maintain adequate hydration and provide a wide nutritional content). The mixture was subjected to the action of earthworms for a period of four months. In each 3 kg pot, 0 g, 28.86 g, 57.7 g and 86.46 g of vermicompost were mixed. This equates to 0, 25, 50 and 75 t ha⁻¹ of OM.

An experimental randomized block design with factorial arrangement with 16 treatments (4 x 2 x 2) was used with three repetitions. In addition, an analysis of variance (ANOVA) of the measured variables was carried out using SAS® ver. 9.4 statistical program (SAS Institute Inc., 2013), and the variables that resulted in significant differences, Tukey’s mean separation test was applied.

3. Results and discussion

All the factors included in this experiment had an effect on the growth of the cactus pear plants. The endomycorrhizal fungi were the most important ones. The application of OM as vermicompost also affected some important variables, and only minor differences in the effects of the soils on the plants were found because there were highly significant differences (p ≤ 0.05) in all the variables measured by inoculation with *Glomus intrarradices*. Inoculation with mycorrhizae promoted greater growth in both the aerial part and the radical one. The plants inoculated with *Glomus intrarradices* obtained 41.5 % greater fresh and 51.6 % higher dry weights of the root and a 28.1 % greater length, and 60.4 % larger volume of this one (table 2). A better radical system provides greater absorption of water and nutrients, which led to a better development of the aerial part promoted by the inoculation of mycorrhiza.

In what was reported by López *et al.*, 2018) who worked with Pearl millet with the use of *Glomus intrarradices* mycorrhizae and chemical fertilizers, he obtained differences in height with respect to the lowest height control (70 cm) with (p > 0.05). In this case, the mycorrhiza had no effect on the height of the plant, while in this work, with the use of the mycorrhiza *Glomus intrarradices*, a height of 75.62 cm was obtained in the Tuckey test and separations of means within the group a and compared to plants without inoculated 53.16 cm in group b.
Table 2. Effect of inoculation with Glomus intrarradices on the growth of cactus pear (Opuntia albicarpa).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Unit of measurement</th>
<th>Glomus intrarradices</th>
<th>Inoculated</th>
<th>Non-inoculated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cladode number</td>
<td>Piece</td>
<td>1.58554a</td>
<td>1.04736b</td>
<td></td>
</tr>
<tr>
<td>Plant height</td>
<td>cm</td>
<td>75.625a</td>
<td>53.167b</td>
<td></td>
</tr>
<tr>
<td>Stem diameter</td>
<td>cm</td>
<td>3.6625a</td>
<td>2.1875b</td>
<td></td>
</tr>
<tr>
<td>Cladode width</td>
<td>cm</td>
<td>7.2792a</td>
<td>4.8000b</td>
<td></td>
</tr>
<tr>
<td>Biomass fresh</td>
<td>g</td>
<td>597.46a</td>
<td>392.29b</td>
<td></td>
</tr>
<tr>
<td>Biomass dry</td>
<td>g</td>
<td>217.25a</td>
<td>143.54b</td>
<td></td>
</tr>
<tr>
<td>Root fresh</td>
<td>g</td>
<td>5.5417a</td>
<td>3.9167b</td>
<td></td>
</tr>
<tr>
<td>Root dry</td>
<td>g</td>
<td>2.7792a</td>
<td>1.8333b</td>
<td></td>
</tr>
<tr>
<td>Root volume</td>
<td>cm³</td>
<td>9.2917a</td>
<td>5.7917b</td>
<td></td>
</tr>
<tr>
<td>Root length</td>
<td>cm</td>
<td>26.208a</td>
<td>20.458b</td>
<td></td>
</tr>
</tbody>
</table>

Note: Means with the same letter in each column are not significantly different (Tukey p ≤ 0.05).

The inoculated plants produced 51.4% more cladodes (table 2 and figure 3), were 42.2% taller, had 67.4% thicker stems, and 51.6% wider cladodes. The *Glomus intrarradices* increased 51.5% dry and 52.3% fresh weight of the biomass (table 2 and figure 4). This is consistent with the consensus of authors who have established the important role of mycorrhizae in improving nutrition (Plenchette *et al*., 2005; Gardezi *et al*., 2015). Other similar studies have also found greater growth and yield in plants inoculated with *Glomus intrarradices* (Gardezi *et al*., 2012; Gardezi *et al*., 2013a; Gardezi *et al*., 2013b).

Another research work indicates that the mother and daughter cladodes of the plants showed a significant increase (p < 0.05) with the application of enzymes and bio stimulants; however, after four months of water stress, higher values were recorded with the treatment of Arbuscular Micorrhizal Fungi (AMF) *Glomus* sp and vermicompost (Vc) in the growth of cladiodes of (*Opuntia ficus-indica*) (Lahbouki *et al*., 2022). In a similar case to this work there was an increase in the size of the cladiodes of 2.47 cm with respect to the control, with the inoculation of *Glomus intrarradices*, for which the bio stimulation of the vegetative parts and root system is corroborated as phosphorus absorption whose agricultural use is difficult for the plant and with the help of *Glomus intraradices*, it is possible to solve the absorption of micronutrients for the benefit of the nopal plantation.
Figure 3. Effect of mycorrhizae and organic matter on cladode number of cactus pear (Opuntia albicarpa). Note: The treatments are from left to right: 0, 25, 50, and 75 t ha\(^{-1}\) of OM. GLUMUS = 0: Non-inoculated, GLUMUS = 1: Inoculated with Glomus intraradices.

Figure 4. Effect of mycorrhizae and organic matter on the shoot dry weight of cactus pear (Opuntia albicarpa). Note: The treatments are from left to right: 0, 25, 50, and 75 t ha\(^{-1}\) of OM. GLUMUS = 0: Non-inoculated, GLUMUS = 1: Inoculated with Glomus intraradices.

The application of OM as a vermicompost also improved both the growth of the stem and that of the root. All treatments resulted in significantly higher cladode (p ≤ 0.05) numbers. The best results were obtained with the application of 50 and 75 t ha\(^{-1}\). A larger amount of vermicompost produced larger stems and longer roots. However, the dry weight of the biomass and the fresh and dry weights of the root were not affected.
In comparison with the results of García et al. (2020) that observed a significant response in fresh leaf weight (FLW), fresh stem weight (FSW) and stem diameter (SD) in agave tobalá with the joint application of mycorrhizae and triple calcium superphosphate (P), it was the mycorrhizal factor that generated the greatest variation in these variables with respect to the control, the interaction generated increases of 136.5 % for (FLW), 106.2 % for (FSW) and 64.3 % for (SD) in agave tobalá. While in this research work, increases in fresh biomass of 53.30 % were found; dry biomass 51.35 %; plant height 42.32 % and stem diameter 67.68 % in favor of the use of endomycorrhizal fungi Glomus intraradices. This suggests that regardless of fertilizer or nutrient concentrations in the soil, mycorrhizal fungi are capable to provide better nutrient uptake.

In general, based on the results of this experiment, for the vegetative growth of cactus pear, the application of 50 t ha⁻¹ seems to be the best alternative. Opuntia crops are grown in subsistence agriculture (Pimienta-Barrios, 1994). Therefore, an economic analysis of the cost of inputs and harvest value will be needed to make a recommendation according to the particular circumstance of each producer.

The interaction between mycorrhizal inoculation and OM for cladode number was the only significant interaction (p ≤ 0.05). It seems that higher applications of vermicompost increase the number of cladodes in non-inoculated plants more. Only root volume was significantly different (p ≤ 0.05) between the soils (table 3 and figure 5). The Opuntia genus has several adaptive characteristics to soil and other environmental factors (Pimienta-Barrios et al., 2000).

In the work of Chenchouni et al. (2020) Tukey's tests revealed that seedlings inoculated with AMF showed significantly higher mycorrhizal response values in (Olea europaea L.) compared to control seedlings. The average height of the plant shoots varied between 77.2 cm in Glomus sp. 2 and 145.6 cm in Glomus sp.1, while the height of the control stem did not exceed 54.6 cm on average. This work obtained 3.66 cm in the Tukey mean separation test in group a compared to the inoculated and 2.18 cm in group b in non-inoculated plants.

<table>
<thead>
<tr>
<th>Table 3. Effect of the application of OM as a vermicompost on the growth of cactus pear (Opuntia albicarpa).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristic</td>
</tr>
<tr>
<td>------------------------------------------</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Cladode number</td>
</tr>
<tr>
<td>Plant height</td>
</tr>
<tr>
<td>Stem diameter</td>
</tr>
<tr>
<td>Cladode width</td>
</tr>
<tr>
<td>Biomass fresh</td>
</tr>
<tr>
<td>Biomass dry</td>
</tr>
<tr>
<td>Root fresh</td>
</tr>
<tr>
<td>Root dry</td>
</tr>
<tr>
<td>Root volume</td>
</tr>
<tr>
<td>Root length</td>
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</table>

Note: Means with the same letter in each column are not significantly different (Tukey p ≤ 0.05).
Figure 5. Effect of mycorrhizae and organic matter on root length of cactus pear (Opuntia albicarpa).

Note: The treatments are from left to right: 0, 25, 50, and 75 t ha\(^{-1}\) of OM. GLUMUS = 0: Non-inoculated, GLUMUS = 1: Inoculated with Glomus intraradices.

The mycorrhizal treatments obtained higher yields and improved the quality, quantity and health of agricultural products such as vegetables, citrus fruits and grasses according to their water potential and the absorption of micro- and macroelements from the soil to the plant (Apollon et al., 2022). This is probably because the AMF hyphae increase the area of water absorption by the roots and by an increase in the permeability of the cell membrane in the root due to the increase in the hyphal entry points and for a correlation between soil properties, carbohydrate utilization and yield (Garg, & Cheema, 2021; Matos et al., 2021). AMF improve host water relations, providing competitive advantages over nonmycorrhizal plants and thus increasing the chances of seedling survival when they are subjected to continuous water stress, such as that prevailing in arid zones (de Lemos et al., 2021).

4. Conclusions

Inoculation with mycorrhizae promoted greater radical growth in the cactus pear and contributed to better cladode development. The application of OM as a vermicompost also improved the growth of the plant. The types of soil did not affect the development of the cactus. The use of mycorrhizae can help improve their mineral nutrition. These beneficial fungi can increase yields and reduce production costs in cactus pear orchards. Vermicompost is a good source for the application of OM to this crop.

AMF are obligate symbionts and integrate with most terrestrial plants and that they cannot complete their life cycle without establishing a functional symbiosis with the host plant. Therefore, this suggests that AMF play a determining role in the establishment, water relations and development of cactus, keeping the plant hydrated when there is prolonged drought and promote its survival under conditions of water stress.

5. Supplementary information

No.

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Effect of endomycorrhizae (Glomus intraradices) and organic matter on the growth of cactus pear (Opuntia albicarpa) in two soil types

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Contribution of the authors in the development of the work
Dr. Abdul Khalil Gardezi: Responsible for the project and all technical support to the research project. Zoning of soil sampling for soil physicochemical analysis and installation of the research project, analysis of 13 micro and macro elements in two types of soil, preparation of soil for greenhouse experiment and supervision of all activities from planting to harvest and data entry in Excel.
Dr. Sergio Roberto Márquez Berber: Literature review regarding prickly pear cactus.
Dr. Héctor Flores Magdaleno: Experiment monitoring and data collection.
Dr. Hilario Flores Gallardo: Experiment monitoring and data collection.
Dr. Mario Francisco Santoyo de la Cruz: Determination of agronomic parameters.
Dr. José Abel López Buenfil: Review of article at the end of the experiment for publication.
Dr. Héctor Flores Magdaleno: Review of soil analysis, data collection during the harvest period.
Dr. Héctor García Martínez: Irrigation of the experiment and water supply.
Dr. Miguel Jorge Escalona Maurice: Determination of agronomic variables.
Dra. Nora Meraz Maldonado: Determination of agronomic parameters.
M.C. Mario Ulises Larque Saavedra: Statistical analysis, tables, figures and general analysis.
M.C. Gabriel Haro Aguilar: Assimilation model, treatment structure, weekend surveillance for water supply and irrigation, and at the end review of the article and search for bibliographic citations.

Interest conflict
The authors declare that there is no conflict of interest.

References


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