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# Agronomic and Economic Assesment of *Chichen Itza* Corn with Chemical Fertilization and Biofertilizers in a *rhodic Luvisol* of Yucatan, Mexico

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## Abstract

The agronomic and economic behavior of a High Protein Quality maize named *Chichen Itza* was evaluated in a *rhodic Luvisol* intensively used for agriculture during 30 years. 12 treatments were tested as a result of combining three doses of chemical fertilization ($N-P_2O_5-K_2O$), including the Control, (30-80-00, 60-80-00, 00-00-00) with Mycorrhizal fungus, Azospirillum bacteria and both. The treatments were distributed in completely randomized block design with three replications. Agronomically speaking the three outstanding highest yields, above 6.00 $t \cdot ha^{-1}$, were: 60-80-00 + Azospirillum, 60-80-00 + Mycorrhiza and 00-00-00 + Mycorrhiza with 6.58, 6.35 and 6.16 $t \cdot ha^{-1}$ respectively while the lowest were: 00-00-00 + Azospirillum, 30-80-00 + Mycorrhiza and the control 00-00-00 with yields of 4.95, 5.20 and 5.29 $t \cdot ha^{-1}$ respectively. However, in economic terms, the treatments with the highest yields were not necessarily the most profitable ones. Even though the highest yields were obtained with the chemical fertilizer (60-80-00) (T10, T11) the highest Benefit/Cost were in those treatments where no chemical fertilizer was applied (T1, T4, T6) including the control T1 (00-00-00). This economic behavior has to do with the very high costs of chemical fertilizers as compared to those of the biofertilizers. In the case of the best treatment T4 (00-00-00 + Mycorrizae), the profit was more than 250% with a Benefit/Cost ratio of 3.57.

## Subject Areas

Agricultural Engineering

**Keywords**

High Fertilizers Cost, Low Cost Technology, Native Corn Varieties

## 1. Introduction

In the state of Yucatán, corn production is a basic activity since a little more than 103 thousand hectares are planted [1]; conventional varieties of normal grain with low yield potential and poor protein quality in the amino acids LYSINE AND TRYPTOPHAN are still traditionally used.

In areas with greater productive potential, the use of commercial hybrids with un-rational applications of high-cost chemical fertilizers is common. Due to this, producers are facing problems of low economic profitability [2].

Apparent consumption of fertilizers in Mexico has decreased and so has the production of maize. However, the volume of imports counteracted the drop in production; but the problem still remains related in a high cost of fertilizers [3].

The use of fertilizers is irrational and indiscriminate, causing deterioration of the environment, as the case of nitrate contamination [4] [5] [6].

Likewise, the low profitability of crops, such as corn, is due not only to the continuous rise in the prices of chemical fertilizers, as commented by Larqué Saavedra *et al.* (2017) [7] but also to the use of high demanding inputs varieties or hybrids.

Due to the foregoing, Cumpián Gutiérrez, *et al.* (2014) [8] and Durán Prado, *et al.* (2015) [9] mentioned the importance of having new alternatives to replace the high cost of chemical fertilizers by using biofertilizers of low-cost

Rojas Martínez, (2011) [10] comments that the use of Azospirillum brasilense and Mycorrhiza can reduce 50% of chemical fertilizers in hybrids and natives corn; and the production costs are reduced by approximately 52% with an increase in yields of 25%.

The research results, provided by different research institutions, suggest that the use of biofertilizers combined with corn genetic materials adapted (less nutrient demand) to the soils of Yucatan is a good perspective, mainly in the high productive potential soils like the arable red *rhodic Luvisols*.

There are new improved varieties with high quality protein (QPM) such as the *Chichén Itzá* variety well adapted to the local soils of Yucatan and containing over 50% of LYSINE and TRYPTOPHAN as compared to the most common and conventional maize. The yield can exceed 2.5 t·ha$^{-1}$ on stony soils and more than 5.0 t·ha$^{-1}$ on high productive arable soils [11].

Due to the foregoing, it is a compulsory task for agricultural researchers to propose new technological alternatives to enhance an agronomic culture based on the use of low, cheapest and agroecological inputs capable to maintain high corn productivity. To do this, is important to take advantage of new corn materials and the best productive potential soils.

In this work, the agronomic potential and economic behavior of the *Chichen Itza* corn were measured by using chemical fertilization and biofertilizers in a *rhodic Luvisol* of Yucatan, Mexico; with the idea of reducing the application of high cost chemical fertilizers.

## 2. Materials and Methods

### 2.1. Site Features

The experiment was established in the 2017/2017 spring-summer station under favorable weather conditions in a *rhodic Luvisol* from the INIFAP Uxmal Experimental Station located in the south of the state of Yucatan Mexico. The experimental lot has had an intensive agricultural use for more than 30 consecutive years. The chemical characteristics of the soil (**Table 1**) were compared with the Mexican Official Standards [12]. The pH is neutral, and the Electrical Conductivity (EC = 1.53 mS/cm) is classified as a Very Slightly Saline with high Sodium (Na) content.

The Organic Matter is satisfactory (2.11%) with nitrogen (N) as Nitrate ($N\text{-}NO_3$) slightly lower (17.2 ppm) than the Critical Level (20 - 40 ppm). Phosphorus (P) is in excess (80 ppm) due to past intensive fertilizer applications. Regarding potassium (K), calcium (Ca) and magnesium (Mg), all greatly exceeds the optima.

### 2.2. Phytometer, Variables and Experimental Design

As a phytometer, a native corn converted to a High Quality Protein Maize (QPM) variety named *Chichen Itza* of yellow grain and free pollination was used. 12 treatments were tested, distributed in a completely randomized block design with three replications in experimental units of 20 $m^2$ with an equivalent population of 50,000 plants·$ha^{-1}$.

The treatments (**Table 2**) were the result of combining three doses of chemical fertilization ($N\text{-}P_2O_5\text{-}K_2O$) including the Control: (30-80-00, 60-80-00, 00-00-00) each of them combined with only *Mycorrhizal* fungus, only *Azospirillum* bacteria or with the mixture of both *Mycorrhizal* + *Azospirillum*.

**Table 1.** Chemical attributes of experimental lot at the Uxmal Experimental Station. 2017/2017.

| pH | E.C. (mS/cm) | Na (ppm) | OM (%) | $N\text{-}NO_3^-$ (ppm) | P (ppm) | K (ppm) | Ca (ppm) | Mg (ppm) | CEC (meq/100gr) |
|---|---|---|---|---|---|---|---|---|---|
| 6.76 | 1.53 | 330 | 2.11 | 17.2 | 80 | 1170 | 2800 | 925 | 25.8 |
| (6.6 - 7.3)* | 1.1 - 2.0* (Very lightly saline) | 150* | (1.6 - 3.5)* | (20 - 40)* | (15 - 30)* | (117 - 234)* | (1000 - 2000)* | (156 - 360)* | (15 - 25)* |

*Critical Limits according to Official Mexican Standards.

Table 2. Treatments tested to measure the impact of chemical fertilization and biofertilizers on yield of *Chichen Itza* maize at the Uxmal Experimental Station in Yucatan Mexico. 2017/2017.

| Treatment | Chemical fertilizer ($N-P_2O_5-K_2O$) ($k\cdot ha^{-1}$) | Mycorrhizae (Fungus) | Azospirillum (Bacteria) |
|---|---|---|---|
| 1 | 00-00-00 | 0 | 0 |
| 2 | 30-80-00 | 0 | 0 |
| 3 | 60-80-00 | 0 | 0 |
| 4 | 00-00-00 | 100 | 0 |
| 5 | 00-00-00 | 0 | 100 |
| 6 | 00-00-00 | 100 | 100 |
| 7 | 30-80-00 | 100 | 0 |
| 8 | 30-80-00 | 0 | 100 |
| 9 | 30-80-00 | 100 | 100 |
| 10 | 60-80-00 | 100 | 0 |
| 11 | 60-80-00 | 0 | 100 |
| 12 | 60-80-00 | 100 | 100 |

The yield ($t\cdot ha^{-1}$) was calculated taking randomly ears from six plants complete competition. The yield was adjusted to 13.5% humidity and were subjected to an Analysis of Variance (ANOVA) ($p < 0.05$) using the Statgraphic program.

The Benefit Cost Ratio was calculated ($) considering as variables: the official sale price of corn at $6805.00 per ton (Gross Income), the current costs of UREA and TRIPLE CALCIUM SUPERPHOSPHATE, Biofertilizers and its application costs and the harvest cost of corn. Fixed expenses of other technological components such as: soil preparation, pest and weed control were added to the Total Production Cost.

## 2.3. Inoculation of Bio-Fertilizers and Chemical Fertilization

The seeds were inoculated with the INIFAP™ brand biofertilizer containing *Rhizophagus intraradices* (*Mycorrhizae* fungus) at a concentration of ≥60 spores and with another biofertilizer with *Azospirillum brasilense* (Bacterium) at a concentration of $1 \times 10^{-6}$ Colony Forming Units (CFU) $mL^{-1}$. After inoculating, the seeds were dried at room temperature for 8 hours and then planted in the experimental plots. 15 days after sowing, the chemical fertilizer was applied to the corresponding treatments. The fertilizer was buried 10 cm from the stem in the form of Urea (46% N) and Triple Calcium Superphosphate (46% $P_2O_5$) in a single application.

# 3. Results

## 3.1. Yield and Statistical Analysis

Table 3 shows the average yields of *Chichen Itza* maize, from three replications, of the 12 treatments. The three outstanding highest yields, above 6.00 t·ha$^{-1}$, were: 60-80-00 + Azospirillum, 60-80-00 + Mycorrhiza and 00-00-00 + Mycorrhiza with 6.58, 6.35 and 6.16 t·ha$^{-1}$ respectively while the lowest were: 00-00-00 + Azospirillum, 30-80-00 + Mycorrhiza and the control 00-00-00 with yields of 4.95, 5.20 and 5.29 t·ha$^{-1}$ respectively.

The absolute yields suggests that the application of Mycorrhizal fungus alone (T4) with 6.16 t·ha$^{-1}$ can increase the yield by a little more than 800 k·ha$^{-1}$ as compared to the absolute control T1 (00-00-00) with 5.29 t·ha$^{-1}$. However, this was not the case with the Azospirillum bacteria where the yield was even a little lower than the control with 4.95 t·ha$^{-1}$ (T5). There was an increase of 16%, in corn production, when seeds were inoculated with Mycorrhizae as compared to the absolute control. However, it is remarkable to mention that in addition to yields, producers are always interested in their economy

It is noteworthy that in this soil, with intensive use, the response to the combined application of Mycorrhizae and Azospirillum, with no chemical fertilizers (T6), was detrimental to yields, having 5.49 t·ha$^{-1}$, just little higher than the control (T1) with 5.29 t·ha$^{-1}$.

Regardless of the absolute yields, the Analysis of Variance (ANOVA) did not show significant statistical differences among treatments according to Table 4. This means that applying chemical fertilizers, alone or combined with biofertilizers and even, when no applying, any of them, the yields are statistically equal.

Table 3. Average maize yields (t·ha$^{-1}$) by using chemical and bio-fertilizers.

| Treatment | Average |
|---|---|
| 1) (00-00-00) | 5.29 |
| 2) (30-80-00) | 6.10 |
| 3) (60-80-00) | 6.09 |
| 4) (00-00-00 + MICO) | 6.16 |
| 5) (00-00-00 + AZO) | 4.95 |
| 6) (00-00-00 + MICO + AZO) | 5.49 |
| 7) (30-80-00 + MICO) | 5.20 |
| 8) (30-80-00 + AZO) | 5.50 |
| 9) (30-80-00 + MICO + AZO) | 5.33 |
| 10) (60-80-00 + MICO) | 6.35 |
| 11) (60-80-00 + AZO) | 6.58 |
| 12) (60-80-00 + MICO + AZO) | 5.68 |

### 3.2. Economic Analysis

Table 5 shows the Benefit/Cost ($) of the 12 treatments. As expecting, the highest yields are not necessarily the most profitable ones. All treatments with chemical fertilizers showed lower profitability as compared to those with only with biofertilizers.

The general trend is that, even though the highest yields were obtained with the chemical fertilizer (60-80-00) (T10, T11) the highest Benefit/Cost were in those treatments where no chemical fertilizer was applied (T1, T4, T6) including the control T1 (00-00-00). This economic behavior has to do with the very high costs of chemical fertilizers as compared to those of the biofertilizers.

Table 4. Mean squares of chemical and biofertilizers treatments from the Analysis of Variance.

| Source of Variation | Degree of freedom | Mean Square |
|---|---|---|
| Treatments | 11 | 0.7917 (NSD) |
| Replications | 2 | 0.8253 (NSD) |
| Error | 22 | 0.55473 |

Note: NSD = No Statistical Differences (5%).

Table 5. Economic analysis of treatments based on chemical fertilizers and biofertilizers in maize *Chichen Itza*.

| Treatment | Total, Production Cost ($) Mexican Pesos | Yield ($t \cdot ha^{-1}$) | Gross Income ($) | Benefit/Cost Ratio (B/C) |
|---|---|---|---|---|
| **1) (00-00-00)** | 11535.96 | 5.29 | 35998.45 | **3.12** |
| **2) (30-80-00)** | 15981.91 | 6.10 | 41510.50 | **2.60** |
| **3) (60-80-00)** | 16731.75 | 6.09 | 41442.45 | **2.48** |
| **4) (00-00-00 + MICO)** | 11728.00 | **6.16** | 41918.80 | **3.57** |
| **5) (00-00-00 + AZO)** | 11984.58 | 4.95 | 33684.75 | **2.81** |
| **6) (00-00-00 + MICO + AZO)** | 12176.84 | 5.49 | 37359.45 | **3.07** |
| **7) (30-80-00 + MICO)** | 16174.18 | 5.20 | 35386.00 | **2.19** |
| **8) (30-80-00 + AZO)** | 16430.53 | 5.50 | 37427.50 | **2.28** |
| **9) (30-80-00 + MICO + AZO)** | 16622.80 | 5.33 | 36270.65 | **2.18** |
| **10) (60-80-00 + MICO)** | 16924.02 | **6.35** | 43211.75 | **2.55** |
| **11) (60-80-00 + AZO)** | 16430.53 | **6.58** | 44776.9 | **2.73** |
| **12) (60-80-00 + MICO + AZO)** | 17372.64 | 5.68 | 38652.4 | **2.22** |

However, all 12 treatments showed Benefit/Cost ratios above 2.0. Indicating that for each Mexican PESO to be invested there is a minimum of one peso obtained as net income; a profit of more than 100%. In the case of the best treatment T4 (00-00-00 + Mycorrizae) the profit is more than 250% with a Benefit/Cost ratio of 3.57.

## 4. Discussion

In our case, no convincing evidence was found that the association between Mycorhhizae and Azospirillum (T4, T9, T12) be a positive one, as was suggested by other studies where positive effects of the combination on maize yields were reported [13] for similar *rhodic Luvisols*, although nostatistical differences were found, such as the results of this work. There is also other evidence showing a negative effect of the simultaneous combination on the performance of sorghum [14].

On the other hand, it seems that 60-80-00 was the best chemical treatment for both Mycorhiza and Azospirillum behavior when applied alone (T10, T11), with no combination, whilst decreasing the amount of Nitrogen (N) at half with the formula (30-80-00) (T7, T8, T9) the yields lowered. Although in some cases reducing chemical fertilization can even encourage a better association of biofertilizers [15].

The positive effect of Mycorrhizal fungus has been attributed to the improvement of corn nutrition when micelium act as extenders of the plant root system. In this way the crop increases its capacity to absorb water and nutrients, mainly phosphorus [16]. Mycorrhizae make the root system of plants more efficient, as they are able to reach, at greater distances, nutrients and water in places where the roots could not reach. This benefit is more efficient at water stress.

Mycorrhizal symbiosis is the interaction between the specialized root of a plant and a fungus. In this symbiosis, the fungus obtains a place to live and carbohydrates, while plants receive nutrients from the soil and water.

On the other hand, Azospirillum bacteria have the ability to fix atmospheric Nitrogen $\mathbf{N_2}$, which provides plants with assimilable nitrogen and also promotes the release of hormones such as Indoleacetic Acid (IAA) and Auxins stimulating root branchings and development of additional root hairs (33% - 40%). It is also involved in better mineral and water absorption by the plant and yield increment.

However, it is important to mention the complexity of the relationship existing between soil organisms since the micro activity of one can inhibit the activity of others as in our case. Although the production of hormones by Azospirillum can stimulate the activity of Mycorrhizae.

Corn yield increased between 11.5% and 19% when seeds were inoculated with Mycorhizae Glomus fungus [17]. In Chiapas, Mexico [18] higher returns (15%) of corn were found when seeds were inoculated with Azospirillum and Mycorhizae (Glomus) related to the absolute control. In that sense Pérez-Luna *et* *al.* (2012) [19] reported an increase of 68 kg·ha$^{-1}$ when using Mycorhizae.

## 5. Conclusions

This study had the objective to highlight the agronomic potential and economic behavior of the *Chichen Itza* corn by using chemical fertilization and biofertilizers in a *rhodic Luvisol* of Yucatan Mexico, in order to reduce high cost chemical fertilizers and enhance the application of low cost biofertilizers with an ecological approach. To do this, it is considered an additional advantage to use corn genetic materials more adapted to the area and soils with greater productive potential.

This study proved that high cost chemical fertilizers can be reduced or evoided maintaining satisfactory yields with good profitability.

The main findings were the following:

1) The three outstanding treatments with highest yields, above 6.00 t·ha$^{-1}$, were: 60-80-00 + Azospirillum, 60-80-00 + Mycorrhiza and 00-00-00 + Mycorrhiza with 6.58, 6.35 and 6.16 t·ha$^{-1}$ respectively while the lowest were: 00-00-00 + Azospirillum, 30-80-00 + Mycorrhiza and the control 00-00-00 with yields of 4.95, 5.20 and 5.29 t·ha$^{-1}$ respectively.

2) Any treatment with chemical fertilizer was less profitable than those consisted only with biofertilizers.

3) Even though the highest yields were obtained when the chemical fertilizer (60-80-00) was applied with the biofertilizers (T10, T11) the highest Benefit/Cost were in those treatments where no chemical fertilizer was applied (T1, T4, T6) including the control T1 (00-00-00).

4) All treatments showed Benefit/Cost ratios above 2.0 with a profitability of more than 100%.

5) The best profitable treatment with more than 250% of earning was the T4 (00-00-00 + Mycorrizae) with a Benefit/Cost ratio of 3.57.

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## Conflicts of Interest

The authors declare no conflicts of interest.

## References

[1] SIAP (2017) Resumen Nacional. Intención de Siembra 2017. Ciclo: Primavera-Verano 2017. Servicio de Información Agroalimentaria y Pesquera. http://infosiap.siap.gob.mx/opt/agricultura/intension/intencionde_siembraPV2017porcultivoR.pdf

[2] Espinoza Arellano, J.de.J., Pajarito Ravelero, A., Triana Gutiérrez, M., Ruíz Torres, J. and Gaytán Mascorro, A. (2014) Evaluación económica de la utilización de biofertilizantes en parcelas de productores de frijol de temporal en el estado de Durango, México. *Revista Mexicana de Agronegocios*, **35**, 934-945.

[3] Irizar Garza, M.B., González Molina, L., Larqué Saavedra, B.S., Martínez Trejo, G., Díaz Valasis, M. and Muñiz Reyes, E. (2015) Uso de Micorriza y Abonos Orgánicos en el Cultivo de Maíz. Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias. Centro de Investigación Regional del Centro, Campo Experimental Valle de México. Folleto Técnico Núm, 26 p. https://www.academia.edu/37427912/Uso_de_micorriza_y_abonos_org%C3%A1nicos_en_el_cultivo_de_ma%C3%ADz_2_

[4] Castellanos, J.Z. and Peña-Cabrales, J.J. (1990) Los nitratos provenientes de la agricultura: Una fuente de contaminación de los acuíferos. *Terra*, **8**, 113-126.

[5] Pacheco, J. and Cabrera, A. (1996) Efecto el uso de fertilizantes en la calidad del agua subterránea en el estado de Yucatán. *Ingeniería Hidráulica en México*, **11**, 53-60.

[6] Arévalo-Galarza, G., Hernández-Mendoza, T.M., Salcedo-Pérez, E. and Galvis-Espinola, A. (2007) Aplicación de fertilizantes sintéticos o abonos verdes y su efecto sobre la cantidad de nitrato residual en el suelo. *Revista Chapingo. Serie Ciencias Forestales y del Ambiente*, **13**, 85-90.

[7] Larqué Saavedra, B.S., Limón Ortega, A., Irizar Garza, M.G. and Díaz Valasis, M. (2017) Fertilización química del maíz, su impacto en el rendimiento y en los costos de producción. Folleto Técnico Num. 2, INIFAPInstituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias Centro de Investigación Regional Centro Campo Experimental Valle de México Coatlinchán, Texcoco, Estado de México Folleto Técnico Núm, 21-22. https://docplayer.es/82752536-Fertilizacion-quimica-del-maiz-su-impacto-en-el-rendimiento-y-en-los-costos-de-produccion.html

[8] Cumpián Gutiérrez, J., Durán Prado, A., Vásquez Hernández, A. and Aguirre-Medina, J.F. (2014) Evaluación de la Micorriza Arbuscular y bacterias en sorgo bajo condiciones de invernadero en Veracruz. *XXVI Reunión Científica Tecnológica, Forestal y Agropecuaria Tabasco* 2014, Villahermosa, 6 November 2014, 70-77.

[9] Durán, P.A., Becerra L.E.N., Vásquez, H.A., Meneses, M.I., Zetina, L.R. and Aguirre, M.J.F. (2015) Pertinencia del aprovechamiento de biofertilizantes micorrízicos como práctica agronómica para reducir la fertilización química de la soya. *XXVII Reunión Científica Tecnológica, Forestal y Agropecuaria Tabasco* 2015 *y IV Simposio Internacional de Producción Agroalimentaria Tropical*, Villahermosa, 9 November 2015, 47-52.

[10] Rojas Martínez, I. and Fernández Sosa, R. (2011) Efecto del Azospirillum brasilense y Micorriza INIFAP en el rendimiento de maíz en el estado de Tlaxcala. Desplegable para Productores No. 12. Marzo, 2011. Centro de Investigación Regional Centro. INIFAP-Tlaxcala. https://www.yumpu.com/es/document/read/46768912/efecto-del-azospirillum-brasilense-y-micorriza-inifap-en-el-

[11] Aguilar, C.G., Gómez, M.N., Torres, P.H. and Vázquez, C.G. (2010) SAC-BEH y CHICHEN ITZA: Variedades de maíz de calidad proteínica para el Sistema de Roza-Tumba-Quema de la Península de Yucatán. Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias. Campo Experimental Mocochá, Centro Regional del Sureste, 24 p. https://www.compucampo.com/tecnicos/variedades-maizcalidadprote%C3%ADnic

a-yuc.pdf

[12] Norma Oficial Mexicana (2022) Nom-021-Semarnat-2000.

[13] Uribe Valle, G. and Dzib Echeverría, R. (2006) Micorriza arbuscular (*Glomus intraradices*), *Azospirillum brasilense* y Brassinoesteroide en la producción de maíz en suelo luvisol. *Agricultura Técnica en México*, **32**, 67-76 https://www.redalyc.org/pdf/608/60832107.pdf

[14] Díaz–Franco, A., Jacques–Hernández, C. and Peña del Rio, M. A. (2008) Productividad de sorgo en campo asociada con micorriza arbuscular y Azospirillum brasilense. *Universidad y ciencia*, **24**, 229-237 https://www.scielo.org.mx/pdf/uc/v24n3/v24n3a7.pdf

[15] Yerbes, V.J.A., Santamaría, B.F., Lozano, C.M.G. and Burgos, D.J.A. (2015) Reducción de fertilizantes químicos y uso de biofertilizantes en el desarrollo de papaya (*Carica papaya* L.). *XVII Reunión Científica Tecnológica, Forestal y Agropecuaria Tabasco* 2014 *y IV Simposio Internacional de Producción Agroalimentaria Tropical*, Villahermosa, 6 November 2014, 536-540.

[16] Pérez-Luna, Y.del C., Álvarez Solís, J.D. (2021) Efecto de la aplicación de biofertilizantes sobre el rendimiento de maíz en parcelas con y sin cobertura vegetal. *Idesia*, **39**, 29-38. https://doi.org/10.4067/S0718-34292021000400029

[17] Cruz-Chávez, F.J. (2007) Transferencia de Tecnología en Biofertilizantes. Instituto Nacional de Investigaciones Forestales y Pecuarias, Centro de Investigación Regional del Pacífico Sur, Campo Experimental Centro de Chiapas, 10 p.

[18] Camas, G.R. (1999) Programa de validación de Biofertilizantes en Chiapas PV 1999 y Avances OI 99/2000. Informe anual PV 1999, Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias, Centro de Investigaciones Regionales Pacífico Sur, Campo Experimental Centro de Chiapas, 10 p.

[19] Pérez-Luna, Y.C., Álvarez-Solís, J.D., Mendoza-Vega, J., PatFernández, J.M. and Gómez-Álvarez, R. (2012) Influencia del humus de lombriz y biofertilizantes en el crecimiento y rendimiento del maíz. Gayana Botánica, 69 (número especial): 15-22 fertilizantes eficientes en el cultivo de tomate (*Lycopersicom esculentum*, Mill). *Revista Colombiana de Biotecnología*, **7**, 47-54.