Effect of inoculation with mycorrhizal fungi on the production of native corn (*Zea mays* L.) in Valle de Santiago, Gto.

Efecto la inoculación con hongos micorrícicos en la producción de maíz (*Zea mays* L.) nativo en Valle de Santiago, Gto.

VARGAS-ESPINOZA, Everardo´†*, GAYTÁN-RUELAS, Marina´, CALDERÓN-RUIZ, Alberto´ and MARTÍNEZ-CAMACHO, Adriana Paola´

´Universidad Tecnológica del Suroeste de Guanajuato, Carr. Valle-Huanímaro km 1.2 Valle de Santiago, Gto. CP. 38400, Mexico.

ID 1st Author: *Everardo, Vargas-Espinoza* / **ORC ID:** 0000-0002-1238-7981, **CVU CONAHCYT ID:** 384590

ID 1st Co-author: *Marina, Gaytán-Ruelas* / **ORC ID:** 0000-0002-9714-7628 **CVU CONAHCYT ID:** 343244

ID 2nd Co-author: *Alberto, Calderón-Ruiz* / **ORC ID:** 0000-0002-1721-2953, **CVU CONAHCYT ID:** 627274

ID 3rd Co-author: *Adriana Paola, Martínez-Camacho* / **ORC ID:** 0000-0003-1970-4633, **CVU CONAHCYT ID:** 714204

DOI: 10.35429/EJE.2023.18.10.45.49 Received January 30, 2023; Accepted June 30, 2023

Abstract

The experiment was established from june-december 2022 in a randomised block design with three replications in experimental plot 1 of the Sustainable and Protected Agriculture Career of the Universidad Tecnológica del Suroeste de Guanajuato (UTSOE), located in the municipality of Valle de Santiago. The objective was to evaluate two varieties of native corn of the race harinoso de ocho (red and white) with inoculation with two commercial products containing mycorrhizal fungi (Rhizovibac® and Tec-myc®), a chemical fertilisation based on INIFAP (2015), of 80-40-00 and a fertilisation with vermicompost at a dose of approximately 100 g/mata. The experimental unit consisted of three furrows of eight metres long and 75 cm apart, where root volume - weight and yield were evaluated. Significant differences were found in Fisher's LSD ($p\leq0.05$) for the variables of root volume and weight in the white maize 128.3 cm^3 above the mean 72.1 cm^3 with chemical fertilisation; however, the criollo corn was the one that obtained the best yield. It can be identified that there is a high relationship between root volume and root weight. In the case of the treatments of the commercial products used in the white corn with Tec-myc®, the lowest root volume - weight and the lowest yield was obtained with the use of Rhizovibac® in comparison with the red corn.

***Zea mays*, Mycorrhizal fungi, Eight-flour corn**

Resumen

El experimento se estableció de junio-diciembre del 2022 en un diseño de bloques al azar con tres repeticiones en la parcela experimental 1 de la Carrera de Agricultura Sustentable y Protegida de la Universidad Tecnológica del Suroeste de Guanajuato (UTSOE), ubicada en el municipio de Valle de Santiago. El objetivo fue evaluar dos variedades de maíz nativo de la raza harinoso de ocho (colorado y blanco) con la inoculación con dos productos comerciales que contienen hongos micorrícicos (Rhizovibac® y Tec-myc®), una fertilización química con base a INIFAP (2015), de 80-40-00 y una fertilización con lombricomposta a dosis de aproximadamente 100 g/mata. La unidad experimental estuvo conformada por tres surcos de ocho metros de largo y a 75 cm de distancia entre ellos, donde se evaluaron volumen - peso de raíz y el rendimiento. Se encontraron diferencias significativas LSD de Fisher ($p\leq0.05$) para las variables de volumen y peso de raíz en el maíz blanco 128.3 cm^3 por arriba de la media 72.1 cm^3 con la fertilización química; sin embargo, el maíz criollo fue el que obtuvo el mejor rendimiento. Se logra identificar que existe una alta relación entre volumen y peso de raíz. En el caso de los tratamientos de los productos comerciales usados en el maíz blanco con Tec-myc® se obtuvo el menor volumen - peso de raíz y el rendimiento más bajo con el uso de Rhizovibac® en comparación del maíz colorado.

***Zea mays*, Hongos micorrícicos, Maíz harinoso de ocho**

Citation: VARGAS-ESPINOZA, Everardo, GAYTÁN-RUELAS, Marina, CALDERÓN-RUIZ, Alberto and MARTÍNEZ-CAMACHO, Adriana Paola. Effect of inoculation with mycorrhizal fungi on the production of native corn (*Zea mays* L.) in Valle de Santiago, Gto. ECORFAN Journal-Ecuador. 2023. 10-18:45-49.

*Correspondence to Autor (E-mail: evargase@utsoe.edu.mx)
† Researcher contributing as first author.

Introduction

Plants have developed numerous strategies since colonising terrestrial ecosystems to cope with various biotic and abiotic factors. One of the most effective is the ability of root systems to establish beneficial mutualistic symbiotic relationships with microorganisms (Camarena, 2012).

Mycorrhizal symbiosis in crops increases the absorption of nutrients and water, increasing yields by integrating its management with low and medium doses of fertilisers obtained through the inoculation of efficient strains, depending on the type of soil (Rivera *et al*., 2007).

The aim of this research was to evaluate the effect of the inoculation of two commercial products based on mycorrhizal fungi, as well as chemical fertilisation and organic fertilisation based on vermicompost, on two native maize varieties from the Bajío region of Guanajuato; the aim is to be able to recommend, especially to rainfed producers, a management alternative for this basic crop, which is currently affected by the lack of rainfall, or even if it does occur, it is concentrated in a narrow period of the agricultural cycle, affecting pollination and therefore yields, whether of grain or corn.

Literature review

Arbuscular mycorrhizae (AM) are ecologically mutualistic associations established between a select group of fungi (Glomeromycota) and the vast majority of plants. Approximately 80 % of the existing plant families have the potential to form this type of association (Trappe, 1987). AM are the type of mycorrhizae that form the majority of plants of agricultural interest. In such an association, the fungus forms arbuscules which are the structures where the exchange of carbon and phosphorus takes place between the fungus and the plant. Some mycorrhizal fungi form vesicles in the inner mycelium, which are reserve structures of the fungus.

The beneficial effects of AM are now well known and comprise increased uptake of poorly mobile elements in the soil such as phosphorus, copper and zinc by mycorrhizal plants compared to non-mycorrhizal plants (Smith and Read, 1997).

In addition, the more efficient use of soil nutrients by mycorrhizal plants saves chemical fertilisers and thus reduces pollution problems caused by excessive fertiliser use. There is also evidence that AM protect plants from pathogen attack (Newsham *et al*., 1995) and water deficit (Ruiz and Azcón, 1995).

Numerous field studies have demonstrated the benefits of mycorrhizal association in crops. Increased levels of root colonisation and hyphal density in the soil at early growth stages can increase phosphorus uptake and yield in maize (*Zea mays* L.), when the soil is deficient in this macronutrient (Deguchi *et al*., 2007).

Zulueta *et al*., (2021), found in a field study evaluating the co-inoculation of maize seeds with arbuscular mycorrhizal fungi and Azospirillum brasilense, that this microbiological interaction presented a higher percentage of mycorrhizal colonisation (62.7%), compared to the other treatments, among which chemical fertilisation reduced to 50% was also evaluated. Linked to the above, genetic richness has played an important role in Mexico, since native maize varieties are planted in regions, areas and ecological niches where improved varieties do not express their yield potential (Muñoz, 2003).

The Harinoso de Ocho race is characterised by its elongated cobs with a low number of rows and the development of large, mealy-textured kernels, with colouring ranging from pink to purple through purplish and red. It is mainly distributed in the west of the country, in Nayarit, Jalisco, Michoacán and Guanajuato (CONABIO, 2011).

Soft floury maize has white glazed kernels, which are considered to be derived from the race Harinoso de Ocho with introgression of Chapalote or Reventador (Wellhuasen *et al*. 1951).

Materials and methods

Location of the experiment

The experiment was established from July to December 2022, in the experimental plot 1 of the Sustainable and Protected Agriculture course of the Technological University of Southwest Guanajuato, in an area of approximately 500 m^2, under rainfed conditions, at the coordinates 20° 24' 01.5'' N and 101° 13' 19.5'' W.

ISSN-On line: 1390-9959

Planting material and planting density

Two varieties of native maize of the race Harinoso de Ocho, both red or "colorado" and white, which are widely used in the Valle de Santiago region to make pozole, were available. Both varieties were sown manually at the bottom of the furrow, on July 1, depositing two seeds per coup or clump, at a distance between clumps of 50 cm and in furrows 75 cm apart, to work a density of 53,000 plants per hectare, all under rainfed conditions.

Treatments and experimental design

The treatments (T) consisted of by the combination of these two varieties of native maize, with inoculation with two commercial products with mycorrhizal fungi (Rhizovibac® and Tec-myc®), a chemical fertilisation based on INIFAP (2015), of 80-40-00 and a fertilisation with vermicompost at a dose of approximately 100 g/mata, being conformed as follows: T1= white maize with chemical fertilisation; T2= white maize with vermicompost; T3= white maize with Tec-myc; T4= white maize with Rhizovibac; T5= red maize with chemical fertilisation; T6= red maize with vermicompost; T7= red maize with Tec-myc and T8= red maize with Rhizovibac. In this way, a factorial experiment was carried out with eight treatments, under a randomised complete block experimental design with three replications. The experimental unit consisted of three furrows of eight metres long and 75 cm apart, with the central furrow as the useful area.

Variables evaluated

Root volume: this was measured with the help of a graduated container, gauged with water, measuring and averaging the volume of water dislodged by three roots at the moment of submerging each one separately, previously washed to remove the water. Each one separately, previously washed to remove the soil. It was expressed in cm^3.

Root weight: measured with the aid of a digital balance, weighing and averaging three roots per replicate, previously washed to remove the soil. It was expressed in grams.

Yield: It was obtained at the end of the crop cycle, harvesting the cobs in six linear metres of the central furrow (4.5 m^2). They were shelled and the grain was weighed. It was reported in kg.

Agronomic management

During the crop cycle, two manual weeding, two applications of garlic extract for thrips control, one foliar application of Bacillus thuringiensis for Spodoptera frugiperda control and one application of foliar fertiliser at the flag leaf stage, prior to flowering, were carried out.

Data analysis

Data were analysed by analysis of variance (ANOVA) and Fisher's LSD test ($p \leq 0.05$) using Fisher's LSD test package ($p \leq 0.05$). Using the statistical package Minitab 18®.

Results and discussion

The analysis of variance showed significant differences for the variables evaluated (root volume, root weight and yield).

The LSD Fisher mean comparison test ($p \leq 0.05$) in Table 1, for treatment T1 and T8 are the treatments whose root volume and root weight were higher than the overall mean. The difference is that T1 is the treatment with chemical fertilisation and T8 is the treatment with chemical fertilisation.

Rhizovibac. This is in agreement with Tadeo et al (2017), where the use of varieties, as well as fertilisers and mycorrhizal fungi allow complementing the use of chemical fertilisers, which could increase production. It is known that, under conditions of nutrient scarcity, plants have the ability to modulate the architecture and functionality of their root system, potentially increasing nutrient uptake (Lynch, 1995). Nutrients are distributed heterogeneously in the soil and plants respond to the local concentration, allocating a higher nutrient production to their roots (Lynch, 1995). Concentration, allocating greater root production to regions of higher availability (Grossman and Rice, 2012). Possibly what happened in this experiment concentration, allocating greater root production to regions of higher availability (Grossman and Rice, 2012).

Possibly what happened in this experiment maize is related to the diversity of mycorrhizal fungi. The correlation coefficient test (table 2) was carried out for the variables evaluated. It can be seen that there is a high correlation between fresh weight and root volume.

Treatment	Root volume (cm^3)	Root weight (g)	performance (kg)
T1= maize White with chemical fertilisation	128.3 a	108.33 a	0.576 ab
T2= maize White with lombricomposta	33.33 b	53.00 ab	0.525 ab
T3= maize White with Tec- myc	25.833 b	45.667 b	0.513 ab
T4= maize White with Rhizovibac	77.5 ab	99.00 ab	0.358 b
T5= maize red maize with chemical fertilisation	53.33 ab	92.66 ab	0.595 a
T6= maize red maize withlombricomposta	83.33 ab	84.00 ab	0.435 ab
T7= maize red maize withTec-myc	43.33ab	52.00 ab	0.435 ab
T8= maize red maize with Rhizovibac	131.7a	102.667 ab	0.416 ab
Media	72.1	79.67	0.4842
LSD	44.1	27.3	0.104
Fisher's LSD (least significant difference) ($\alpha \leq 0.05$). Means that do not share a letter are significantly different.			

Table 1 Comparison of means for variables measured in the mycorrhizal fungal inoculation experiment on native maize production in Valle de Santiago,Gto.

On the other hand, the T5 treatment consisting of red maize with chemical fertilisation is the one that obtained the best yield, which suggests that mycorrhizal fungi are complementary in agricultural production. Despite their influence on plants to adapt to nutrient deficient soils by facilitating their adaptation, this may affect growth characteristics as in the case of T8.

In this experiment it was expected that maize would have the same response to the use of mycorrhizal fungi (table 1), but there are differences, possibly due to a specificity of mycorrhizal fungi to the type of maize used as observed in the work of (Sangabriel-Conde et al., 2015).

Where, the different mycorrhizal species colonised only 2-4 types of maize, suggesting that the variety of mycorrhizae colonised only 2-4 types of maize, suggesting that the variety of mycorrhizae colonised only 2-4 types of maize.

	Volume	Fresh weight
Fresh weight	0.824**	
Performance	0.07	-0.103
** Highly correlated		

Table 2 Pearson's correlation of variables measured in the inoculation experiment with mycorrhizal fungi inoculation experiment with mycorrhizal fungi in the production of native maize in Valle de Santiago, Gto.

Although plants rely on their roots to acquire nutrients, they form mutualistic symbioses with arbuscule mycorrhizal fungi regularly belonging to the phylum Glomeromycota (Smith and Read, 2008). With respect to direct nutrient delivery, mycorrhizal fungi benefit the host plant by promoting root growth (Ramírez-Flores et al., 2019), such is the case in treatment T8. Thus, plant productivity is often limited by nutrient availability. Under conditions of nutrient scarcity, plants have the ability to modulate the architecture and functionality of their root system, even when associated with the right type of mycorrhizal fungi.

Conclusions

The main treatment for most of the variables evaluated in this research was treatment T1 white maize with fertilisation 80-40-00 fertilisation, which favours root growth and weight, and in the case of red maize (T5) the best yield was obtained. On the other hand, the use of Rhizovibac® was a better result in red maize, producing 131.7 cm3 above the average of 72.1 cm3. By increasing the root volume in a plant, it is more likely to cope with biotic and abiotic changes that may occur inside the rhizosphere, so it is suggested that the use or implementation of mycorrhizal fungi is a complement to sustainable agricultural production.

References

Camarena G. G. (2012). Interacción planta-hongos micorrízicos arbusculares. Revista Chapingo. Serie Ciencias Forestales y del Ambiente, 18(3), 409-421. https://doi.org/10.5154/r.rchscfa.2011.11.093

CONABIO. (2011). Proyecto Global de Maíces Nativos. Recopilación, generación, actualización y análisis de información acerca de la diversidad genética de maíces y sus parientes silvestres en México. CONABIO. México, D.F. 75 p.

Deguchi, S.; Shimazaki, Y.; Uozumi, S.; Tawaraya, K.; Kawamoto, H. y Tanaka, O. (2007). White clover living mulch increases the yield of silage corn via arbuscular mycorrhizal fungus colonization. Plant Soil 291(1-2):291–299. DOI: 10.1007/s11104-007-9194-8.

Grossman, JD y Rice, KJ (2012). Evolución de las respuestas de plasticidad de la raíz a la variación en la distribución y concentración de nutrientes del suelo. Aplicaciones evolutivas, 5, 850–857. 10.1111/j.1752-4571.2012.00263.x

Lynch, J. P. (1995). Roto architecture and plant productivity. Plant Physiology, 109, 7–13. 10.1104/pp.109.1.7

Minitab, I. (2018). MINITAB. Obtenido de http://www.minitab.com/en-US/products/minitab/

Muñoz O. A. (2003). Centli Maíz. Colegio de Posgraduados. Montecillo, Edo. de México. 211 pp.

Newsham, K.K.; Fitter A. H.; Watkinson A.R. (1995). Arbuscular mycorrhiza protects an annual grass from root pathogenic fungi in the field. J. Ecol. 83: 991-1000. https://doi.org/10.2307/2261180 https://www.jstor.org/stable/2261180

Ramírez-Flores, M. R., Bello-Bello, E., Rellán-Álvarez, R., Sawers, R. J. H., & Olalde- Portugal, V. (2019). Inoculation with the mycorrhizal fungus Rhizophagus irregularis modulates the relationship between root growth and nutrient content in maize (Zea mays ssp. mays L.). Plant direct, 3(12), e00192. https://doi.org/10.1002/pld3.192

Rivera, R., Fernández, F., Fernández, K., Ruiz, L., Sánchez, C. & Riera, M. (2007). Advances in the management of effective arbuscular mycorrhizal symbiosis in tropical ecosystesm. En: Mycorrhizae in Crop Production (eds.) Chantal Hamel and Christian Plenchette. Haworth Press, Binghamton, NY. doi:10.1300/5425_05

Ruiz J. M.; Azcón R. (1995). Hyphal cotribution to water uptake in mycorrhizal plants as affected by the fungal species and water status. https://doi.org/10.1111/j.13993054.1995.tb00865.x Physiol. Plant. 95: 472-478.

Sangabriel-Conde W, Maldonado-Mendoza I.E, Mancera-López M.E, Cordero-Ramírez J.D, Trejo-Aguilar D, Negrete- Yankelevich S, (2015). Glomeromycota associated with Mexican native maize landraces in Los Tuxtlas, Mexico, Applied Soil Ecology, Volume 87, 63-71, https://doi.org/10.1016/j.apsoil.2014.10.017

Smith, S. E. , & Read, D. J. (2008). Mycorrhizal Symbiosis. London, UK: Academic Press. https://doi.org/10.1016/B978-0-12-370526-6.X5001-6

Smith, S.L.; Read, D. (1997). Mycorrhizal symbiosis. 2ª edición. Capítulo 1. Academic Press.

Tadeo Robledo M, J. Zavala García J, Alcántar Lugo Hugo Jesús, Ortiz Ricardo L,. Gómez Montiel N ,O, Sierra M, , Irizar G, Roberto Valdivia R, Zaragoza j, MartíneznB, López C, Espinosa A, Turrent A. (2017) Biofertilización en híbridos de maíz androestériles y fértiles para los Valles Altos de México Terra Latinoamericana.Volumen 35 número 1, DOI:https://doi.org/10.28940/terra.v35i1.242

Trappe, J.M. (1987). Phylogenetic and ecological aspects of mycotrophy in the angiosperms from an evolutionary standpoint. En Safir DG (Ed.) Ecophysiology of VA mycorrhizal plants. CRC. Boca Raton, FL, EEUU. Pp 5-25. https://doi.org/10.18946/jssm.61.1_91

Wellhausen, E. J. L. M. Roberts, E.; Hernández X. (1951). Razas de maíz en México.Suorigen, características y distribución. Oficina de Estudios Especiales-Secretaría de Agricultura y Ganadería. Folleto técnico Núm. 55. México D.F.

Zulueta, R. R.; Gómez M. F. C.; Alemán C. I.; Núñez C. M.; Lara C. L. (2021). Respuesta del cultivo de maíz a la bio-inoculación y fertilización química reducida en campo. Terra Latinoamericana. 38(3):597-612 https://doi.org/10.28940/terra.v38i3.656.