Cultivos Tropicales, Vol. 43, No. 4, October-December 2022, e-ISSN: 1819-4087, p-ISSN: 0258-5936, https://ediciones.inca.edu.cu

Cu-ID: https://cu-id.com/2050/v43n4e05

Original article

Effect of rhizobia on growth and yield of maize (*Zea mays* L.) cultivar P-79-28

Efecto de rizobios en el crecimiento y rendimiento del cultivar de maíz (*Zea mays* L.) P-79-28

Saray Márquez-Cruz*, Michel Martínez-Cruz †, Rosa Acosta-Roca

Instituto Nacional de Ciencias Agrícolas (INCA), carretera San José-Tapaste, km 3½, Gaveta Postal 1, San José de las Lajas, Mayabeque, Cuba. CP 32 700

ABSTRACT: Maize is one of the most important cereals in the world and a strategic crop for food sovereignty and security. The use of bioproducts based on rhizobia in this crop, represents an alternative to decrease chemicals application in their development. The present research was carried out on the "El Mulato" farm, CCS "Orlando Cuellar Peñalver", San José de las Lajas municipality. Developed from December 2018 to April 2019, four strains of *Rhizobium* sp. were inoculated, with the objective of determining their effect on the growth and yield characters in the P-79-28 maize variety. It was obtained that the different evaluated stains showed positive effects on yield characters. The treatment that obtained the best results in terms of growth characteristics was the one that was inoculated with the C1 strain of *Rhizobium sp*.

Key words: treatment, bioproduct, microbial inoculants, diastrophic bacteria.

RESUMEN: El maíz es uno de los cereales más importantes del mundo y un cultivo estratégico para la soberanía y seguridad alimentaria en sus distintas formas de usos. El empleo de bioproductos a base de rizobios en este cultivo, representa una alternativa en la disminución de la aplicación de productos químicos durante su desarrollo. La presente investigación se llevó a cabo en la finca "El Mulato", perteneciente a la CCS "Orlando Cuellar Peñalver", del municipio San José de las Lajas; durante los meses de diciembre 2018 hasta abril 2019. Cuatro cepas de *Rhizobium* sp fueron inoculadas, con el objetivo de determinar su efecto sobre los caracteres de crecimiento y rendimiento, en el cultivar de maíz P-79-28. Se constató que las diferentes cepas evaluadas mostraron efectos positivos en los caracteres de crecimiento, no siendo así en los caracteres de rendimiento. El tratamiento con mejores resultados en cuanto a características de crecimiento fue el que se inoculó con la cepa C1, de *Rhizobium* sp.

Palabras clave: tratamiento, bacterias diazotróficas, *Rhizobium*, seguridad alimentaria.

INTRODUCTION

Corn is a vital species in the food and culture of Central America, and it is considered a strategic crop for food sovereignty and security in its different forms of use (1). It is estimated that during the 2020-2021 season, world production of this crop will reach 1,133.89 million tons (2). For its optimal development, this crop requires large amounts of fertilizers to achieve acceptable yields, but, at the same time, the irrational and excessive use of fertilizers is the main cause of soil fertility loss, as well as a significant increase in the pollution of water resources and the atmosphere (3).

Under these conditions, the alternative is to use technologies compatible with microbiological activity to favor plant nutrition. The application of microbial inoculants is an emerging alternative and a component of integrated plant nutrition management (4). The use of bioproducts is not intended to eliminate the use of mineral inputs, but to reduce the doses applied to crops and, therefore, their negative effects (5). The application of biofertilizers based on 'Plant Growth Promoting Rhizobacteria' (PGPR) constitutes an economic and environmentally friendly alternative that allows increasing agricultural yields and reducing production costs (6).

*Author for correspondence: saray@inca.edu.cu

Received: 12/04/2021

Accepted: 25/08/2021

Rhizobia are diazotrophic soil bacteria that establish a symbiotic relationship with leguminous plants. The isolation of these microorganisms from the rhizosphere and as endophytes of grasses (7) and the presence of mechanisms related to the promotion of plant growth have allowed them being included within the PGPR group (6). Therefore, the objective of this research is to evaluate the effect of rhizobial strains on growth and yield traits in the maize cultivar P-79-28.

MATERIALS AND METHODS

The work was developed in the farm "El Mulato", belonging to the CCS "Orlando Cuellar Peñalver"; during the months of December 2018 to April 2019. This is located in San José-Tapaste road, 5½, Mayabeque, Cuba which presents a Ferrallitic Red Lixiviated Ferrallitic soil, eutric (8).

The method of sowing two seeds per nest was used, of the corn cultivar P-79-28, at a distance of 50 cm, with a planting frame of 0.70 m x 0.40 m and was developed on plots of four furrows with 5 m long. Treatments were arranged in a randomized block design with three replications (Table 1).

Different rhizobial strains used in the treatments were obtained from the Department of Plant Physiology of the National Institute of Agricultural Sciences (INCA), and they were isolated from corn plants (9). Strains with the C nomenclature were isolated from the rhizoplane of the maize cultivar Canilla and in the case of the R nomenclature they were isolated from the rhizoplane of the cultivar Raul.

In the established plots, soil preparation was carried out with animal traction, using a moldboard plow for the breaking work; subsequently, furrowing was carried out. No chemical fertilizers were applied at any stage of cultivation.

Seeds were inoculated with the different strains of rhizobia just before sowing, using a dose of 1 mL of pure product per 250 g of seed (equivalent to 1000 grains for this cultivar). Inoculation was carried out in sterilized trays, applying the inoculum directly on corn seeds.

During crop development, evaluations of 10 morphoagronomic characters (Table 2) were carried out on a sample of 10 plants per treatment; evaluations were carried out according to the Graphic Manual for the Varietal Description of Maize (*Zea mays* L.) (10). Evaluations were carried out by selecting plants from the two furrows in the center of each plot, to avoid the edge effect.

Hand harvesting was carried out 96 days after sowing (December 28, 2018 - April 2, 2019).

A simple rank analysis of variance was performed on the 10 quantitative traits evaluated (SD, HUC, PH, NGR, LC, MCD, NGM, M100G, TMG, MDT) of the different treatments, through the statistical program Stagraphics Plus version 5.1 for Windows.

RESULTS AND DISCUSSION

Effect of rhizobia on maize growth traits

During the course of the experiment, three characters related to the growth stage of the crop (PH, HUC and SD) were evaluated.

As shown in Figure 1, treatments 2 and 4 showed the best results for the PH trait, in which strains C1 and C8, respectively were used. Treatments 1 and 3 differed significantly from these (Control and C4), although treatment 5 (strain R10) showed statistically shared values among all treatments.

Regarding HUC, treatment 2 (C1) was significantly superior to the rest of the treatments, where the one with

Table 1. Description of treatments

Treatments	Description
T1	Absolute control (treatment without product application)
T2	Seeds inoculated with the strain *Rhizobium* sp. (C1)
T3	Seeds inoculated with Rhizobium sp. strain (C4)
T4	Seed inoculated with *Rhizobium* sp. strain (C8)
T5	Seeds inoculated with strain *Rhizobium* sp.(R10)

Table 2. Traits evaluated, unit of measurement and stage of evaluation of rhizobium-inoculated plants of maize cultivar P-79-28

No.	Characteres assessed	Unit of measurement	Stage of assessment
1	Stem diameter (SD) (cm)	(cm)	Grain filling
2	Height to the upper cob (HUC) (m)	(m)	Grain filling
3	Height of plant (HP)	(m)	Grain filling
4	Number of grains per row (NGR)	Unit	Post-harvest
5	Cob length (CL)	(cm)	Post-harvest
6	Mean cob diameter (MCD)	(cm)	Post-harvest
7	Number of grains per cob (NGM)	Unit	Post-harvest
8	Mass of 100 kernels (M100G)	(g)	Post-harvest
9	Total mass of grains per cob (TMG)	(g)	Post-harvest
10	Mean diameter of the cob (MDC)	(cm)	Post-harvest

the lowest height to the upper cob (HUC) was treatment 1 (Control).

When analyzing these results and what was proposed in 2003 (11), where the author refers to the existence of a positive correlation between PH and HUC, this fact can be considered as the factor that contributed to the behavior shown by treatment 2 with respect to the HUC character.

However, it is important to highlight the behavior for the HUC trait between treatments 4 and 5. In this regard, it is important to consider for both traits (PH and HUC), values obtained in treatments 2, 4 and 5, which would allow estimating the effectiveness of strains C1, C8 and R10.

For the SD trait (Figure 2), there were no significant differences among treatments analyzed, so inoculation of the maize plants with *Rhizobium* sp. showed no effect.

In general, the treatment that showed the best results for most of the traits evaluated was number 2, which was inoculated with *Rhizobium* sp. strain C1.

From the results obtained for the characters evaluated above, it is evident that the rhizobial strains used in the treatments show a superior effect on the growth phase of the crop, since the treatments inoculated with the strains showed better results compared to the control.

There are investigations that demonstrate the possibility of rhizobia to colonize and enhance growth in corn and other cultivars not belonging to the legume family, such as lettuce, bell pepper and tomato (12, 13). However, there are no previous reports on the effects of the strains analyzed in the present study on the growth-related traits: PH, HUC and SD, an element that undoubtedly refers to new contributions of these strains in the cultivation of maize.

Effect of rhizobia on maize yield traits

Figure 3 shows the analysis of the effect of the inoculated strains on the MCD, LC and MDC traits. For MCD and LM, treatments 1, 2, 3 and 4 showed similar results while in MDC there were no significant differences among treatments.

For NGH and NGR traits, there were no significant differences between treatments (Figure 4); this was not the case for the M100G and TMG traits, where the treatment with the best result was treatment 1 (Figure 5).

Once the different growth and yield traits were analyzed, it can be observed that the different rhizobium strains showed positive effects during the growth stage, but not with the yield variables evaluated.

In this research, the *Rhizobium* strains were applied to the seeds before sowing, and they were not applied to the crop in other stages of development, which could have determined the lack of influence of the strains evaluated on the yield traits analyzed. In general, it is proposed that Rhizobium sp. strains form nodules on legumes, providing fixed nitrogen to their hosts. However, it has also been shown that rhizobia are able to colonize the roots of non-legumes as efficiently as they colonize their legume hosts (9).

In an experiment conducted on maize (14), inoculations of different native strains showed statistically superior data

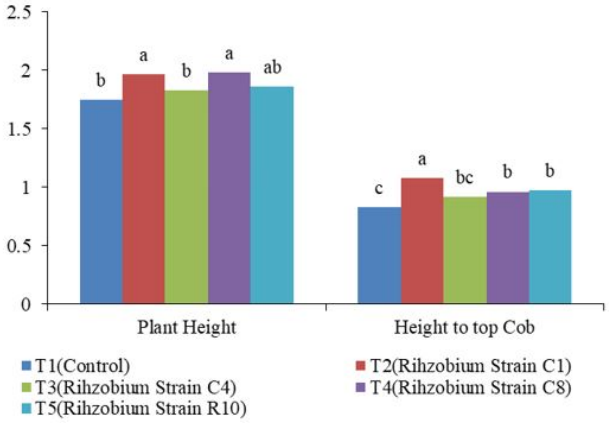

Figure 1. Mean and statistical significance of growth-related traits: Plant Height (PH) (m) and Height to Upper Cob (HUC) (m)

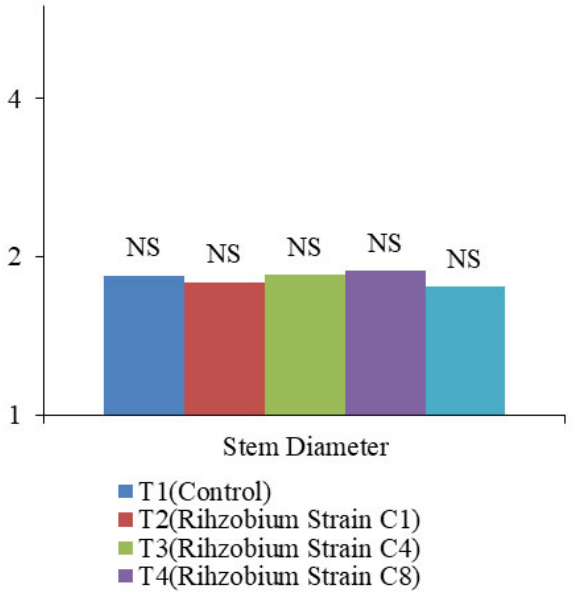

Figure 2. Mean and statistical significance of growth-related trait: Stem diameter (SD) (cm)

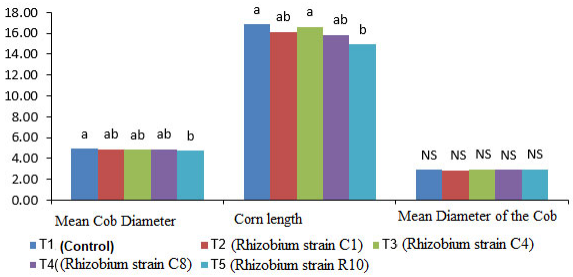

Figure 3. Mean and statistical significance of yield traits: Mean Diameter of the Cob (MDC), Length of the Cob (LC) and Mean Diameter of the Cob (MDC) (cm)

to the control, which could be because rhizobia produce phytohormones that favor a greater extraction of nutrients from the soil, promoting plant growth and, possibly, increased yields. In the same year, in another investigation,

these authors obtained similar results when applying rhizobia strains from livestock ecosystems of Sancti Spíritus, Cuba.

The rhizobia effect on growth was demonstrated in other research, where a stimulus in plant height was reported in corn grown in pots, after the application of nine isolates of rhizobia, in comparison with the non-inoculated control (15). These authors report an effect on plant height of 3.23 and 23.44 % over the non-inoculated control, demonstrating that inoculation with the strains studied improved the growth and yield parameters of corn, both in pots and in the field.

On the other hand, it has been revealed that the effectiveness of rhizobial isolates varies among different species against a common host (16), and from one site to another where the experiments are carried out (15).

However, these values were higher than the found ones by other scientists in an experiment (17), where corn was inoculated with commercial strains of *Bradyrhizobium japonicum*, in which they obtained increases in the aerial dry mass of the plant, from 6.7 to 8.7%, with respect to the absolute control. Other authors found that strain E11 of *Rhizobium leguminosarum* bv. trifolii was able to stimulate growth in corn under field conditions (18).

In this sense, when considering the similarity in the origin of the strains used in this research, it could have contributed to the results obtained, where no significant differences were obtained among the strains for the yield traits evaluated (MCD, LC, MDC, NGR and NGC). The inoculation of the strains was carried out under the same experimental conditions on the same host, which may have contributed to the similarity found in the behavior of the strains on the yield traits evaluated.

Although it was not possible to prove the efficiency of the strains studied on the corn traits related to yield, the results shown for the case of Treatment 2 (strain C1 of *Rhizobium* sp.) on PH, HUC and SD are distinctive, arguments in favor of the use of this strain in corn cultivation.

CONCLUSIONS

- Rhizobia inoculated on maize seeds showed superior effects on the plant, during the growth stage of the crop, which did not occur for yield traits.
- Treatment 2 showed the best result for most of the parameters evaluated, which demonstrated the efficiency of *Rhizobium* sp. strain C1 evaluated.

RECOMMENDATIONS

Based on the results obtained in the present study and, taking into account the reference evidence of the literature consulted, it is proposed to evaluate the effect of the rhizobial strains studied on other morphoagronomic characters of the crop and other maize cultivars, in order to assess their effectiveness.

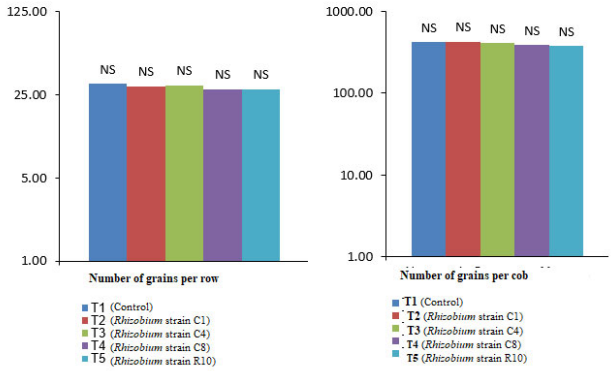

Figure 4. Mean and statistical significance of yield traits Number of Grains per Row (NGR) and Number of Grains per Cob (NGC) (units)

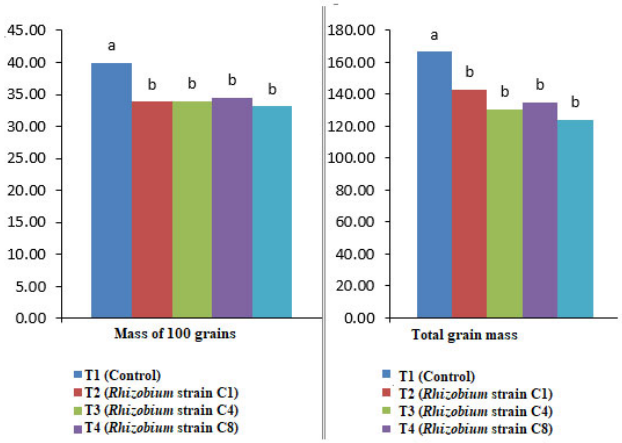

Figure 5. Mean and statistical significance of yield traits: Mass of 100 Grains (M100G) (g) and Total Grain Mass (TGM) (g)

BIBLIOGRAPHY

1. González-Cortés N, Silos-Espino H, Estrada Cabral JC, Chávez-Muñoz JA, Tejero Jiménez L. Características y propiedades del maíz (*Zea mays* L.) criollo cultivado en Aguascalientes, México. Revista mexicana de ciencias agrícolas. 2016;7(3):669-80.
2. Produccion Agricola Mundial.com. Producción Mundial de Maíz 2020/2021 [Internet]. 2021 [cited 01/03/2021]. Available from: http://www.produccionagricolamundial.com/cultivos/maiz.aspx
3. Rodríguez JHV, Landin WEC, Carreño D de los ÁC, Galarza FAE, Herrera GMI, Cárdenas A del RB, et al. Efecto de 3 formas de fertilización en cultivo de Maíz variedad DAS 3383, La Troncal-Ecuador. Revista Colombiana de Ciencia Animal - RECIA. 2020;12(1):e750-e750. doi:10.24188/recia.v12.n1.2020.750
4. Nehra V, Saharan BS, Choudhary M. Evaluation of *Brevibacillus brevis* as a potential plant growth promoting rhizobacteria for cotton (*Gossypium hirsutum*) crop.

SpringerPlus. 2016;5(1):1-10. doi:10.1186/s40064-016-2584-8

5. Calero-Hurtado A, Pérez-Díaz Y, González-Pardo Hurtado Y, Olivera-Viciedo D, Peña-Calzada K, Castro-Lizazo I, et al. Aplicación complementaria de dos bioproductos incrementan la productividad del frijol común. Cultivos Tropicales [Internet]. 2020 [cited 30/03/2021];41(3). Available from: http://scielo.sld.cu/scielo.php?script=sci_abstract&pid=S0258-59362020000300007&lng=es&nrm=iso&tlng=es
6. Moreno Reséndez A, García Mendoza V, Reyes Carrillo JL, Vásquez Arroyo J, Cano Ríos P. Rizobacterias promotoras del crecimiento vegetal: una alternativa de biofertilización para la agricultura sustentable. Revista Colombiana de Biotecnología. 2018;20(1):68-83. doi:10.15446/rev.colomb.biote.v20n1.73707
7. Hernández Forte I, García N, Caridad M. Rizobios residentes en la rizosfera de plantas de arroz (*Oryza sativa* L.) cultivar INCA LP-5. Cultivos Tropicales. 2017;38(1):39-49.
8. Jiménez H, Infante B, Jiménez P, Speck C. Clasificación de los suelos de Cuba [Internet]. 1.ª ed. Instituto Nacional de Ciencia Agrícolas; 2015 [cited 2/03/2021]. Available from: https://isbn.cloud/9789597023777/clasificacion-de-los-suelos-de-cuba-2015/
9. Pérez Reneé. Aislamiento y caracterización de posibles rizobios asociados a la rizosfera de plantas de maíz (*Zea mays*) L. Efecto en el crecimiento del cultivo. [Facultad de Biología, Universidad de la Habana]: Universidad de La Habana; 2017. 35-38 p. https://www.researchgate.net/profile/Renee-Perez-Perez
10. Carballo A, Ramírez M, Coronado H, Andrade A, Sánchez S, Valdés M, et al. Guía Técnica para la Descripción Varietal [Internet]. 2014 [cited 01/03/2021]. Available from: https://www.researchgate.net/publication/313793274_Guia_Tecnica_para_la_Descripcion_Varietal_de_Maiz
11. Martínez M, Ortiz R, Ríos H. Caracterización y evaluación participativa de maíz colectado en la localidad de Catalina de Güines, la Habana. Cultivos Tropicales. 2003; 24(4): 69-75.
12. Blanco EL, Castro Y, Olivo A, Skwierinski R, Barrios FM. Germinación y crecimiento de plántulas de pimentón y lechuga inoculadas con rizobios e identificación molecular de las cepas. Bioagro. 2018;30(3):207-18.
13. Marquina ME, Ramírez Y, Castro Y. Efecto de bacterias rizosféricas en la germinación y crecimiento del pimentón *Capsicumannuum* L. var. Cacique Gigante. Bioagro. 2018;30(1):3-16.
14. Bécquer CJ, Salas B. Selección de rizobios adaptados a ecosistemas ganaderos de Alberta, Canadá, inoculados en maíz (*Zea mays*, L.). Fase I: invernadero. Pastos y Forrajes. 2008;31(3):229-46.
15. Mehboob I, Zahir ZA, Arshad M, Tanveer A, Khalid M. Comparative effectiveness of different *Rhizobium* sp. for improving growth and yield of maize (*Zea mays* L.). Soil and Environment. 2012;31(1):37-46.
16. Hafeez FY, Safdar ME, Chaudhry AU, Malik KA. Rhizobial inoculation improves seedling emergence, nutrient uptake and growth of cotton. Australian Journal of Experimental Agriculture. 2004;44(6):617-22. doi:10.1071/ea03074
17. Prévost D, Saddiki S, Antoun H. Growth and mineral nutrition of corn inoculated with effective strains of *Bradyrhizobium japonicum*. En: Proceedings of the 5th International PGPR Workshop. Villa Carlos Paz, Córdoba, Argentina; 2000.
18. Yanni YG, Rizk RY, El-Fattah FKA, Squartini A, Corich V, Giacomini A, et al. The beneficial plant growth-promoting association of *Rhizobium leguminosarum* bv. trifolii with rice roots. FunctionalPlantBiology. 2001;28(9):845-70. doi:10.1071/pp01069