ORIGINAL ARTICLE

Effect of a Pectic Oligosaccharide on the Root Development of Maize

Efecto de un oligosacárido pécticos en el desarrollo radical del maíz.

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Ana Elida Sáez-Cigarruista[I]*, Donaldo Morales-Guevara[II], Román Gordón-Mendoza[I], Jorge Enrique Jaén-Villarreal[I], Francisco Pablo Ramos-Manzané[I], Jorge Franco-Barrera[I]

[I]Instituto de Innovación Agropecuaria de Panamá, Ciudad del Saber, Clayton, Panamá.
[II]Instituto Nacional de Ciencias Agrícolas. San José de Las Lajas, Mayabeque, Cuba.

ABSTRACT: The objective of this research was to determine the effect of a pectic oligosaccharide on the root development of maize plants in El Ejido, Los Santos, Republic of Panama, during two research cycles in the year 2022. Two treatments were evaluated: the control and the treatment imbibed with biostimulant. A completely randomized design was used, where the data obtained were analyzed using the t-Student test for independent samples. This experiment was established in polyethylene bags of different sizes. A drip irrigation system with a venturi was used to apply fertigation to the crop. The variables evaluated were: wet and dry root weight, root number count, root length and root diameter. Variables of the aerial part of the plant such as plant height, leaf area, stem diameter and biomass were also determined. The results showed that the application of pectic oligosaccharides significantly increased the length, weight and number of roots. This increase was also reflected in greater leaf area, height and dry mass of the crop. The imbibition of maize seed with pectic oligosaccharides is beneficial for both root and aerial growth and development of the maize crop.

Keywords: Biostimulants, Growth, Imbibition, Productivity, Resistance.

RESUMEN: El objetivo de esta investigación fue determinar el efecto de un oligosacárido péctico en el desarrollo radical de plantas de maíz en El Ejido, Los Santos, República de Panamá, durante dos ciclos de investigación en el año 2022. Se evaluaron dos tratamientos el testigo y el tratamiento imbibido con bioestimulante. Se utilizó un diseño completamente al azar, donde los datos obtenidos se analizaron mediante prueba de t-Student de muestras independientes. Este experimento se estableció en bolsas de polietileno de diferentes tamaños. Se utilizó un sistema de riego por goteo con un venturi para aplicar el fertirriego al cultivo. Las variables evaluadas fueron: peso húmedo y seco de raíces, conteo del número, largo y diámetro de las raíces. También se determinaron variables de la parte aérea de la planta como: altura de la planta, área foliar, diámetro del tallo y biomasa. Los resultados mostraron que la aplicación de oligosacáridos pécticos incrementó significativamente la longitud, peso y número de raíces. Este incremento también fue relejado en mayor área foliar, altura y masa seca del cultivo. La imbibición de la semilla de maíz con oligosacáridos pécticos es beneficiosa para el crecimiento y desarrollo tanto radical como aéreo del cultivo de maíz.

Palabras clave: Bioestimulantes, crecimiento, imbibición, productividad, resistencia.

INTRODUCTION

The root system is the main anchoring and nutrient absorption medium available to plants, consuming more than half of the carbon fixed annually by plants. Despite its obvious importance, the dynamics of live roots are poorly understood due to the inaccessibility of the root system (Benítez-Vega, 2007).

Plants produce small organic molecules of variable chemical identity that influence growth and development, known as phytohormones or growth regulators (Jaillais &y Chory, 2010). Compounds that play a more direct role in modulating maize root architecture include auxins, ethylene, brassinosteroids, and gibberellins.

The maize plant's root system is fasciculated and robust, serving the functions of anchoring the plant and nutrient absorption, with the presence of adventitious roots favoring these functions Ortigoza *et al.* (2019). Within agriculture, there is a significant interest in discovering mechanisms that certain species employ to counteract the negative impacts of climate

*Author for correspondence: Ana Elida Sáez-Cigarruista, e-mail: ansacig@gmail.com

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change, particularly in the context of food production (Hunt & Elliott, 2002).

The use of biostimulants that stimulate root development is one of the best alternatives for increasing productivity because they act directly on the roots, inducing the appearance of rootlets. This translates into an improvement in the absorption capacity of nutrients available in the soil, resulting in enhanced maize production (Morales, 2021).

The use of biostimulants in agriculture is on the rise, aiming not to replace fertilization but to complement it by stimulating natural processes to improve nutrient absorption and efficiency. This has a positive impact on crop yield and quality while promoting plant development and providing resistance to various stress conditions caused by adverse weather or herbicide side effects (Van Oosten *et al.*, 2017; Samudio-Cardozo, 2020).

Pectic oligosaccharides represent a promising alternative to boost the growth and productivity of various crops. They have shown a positive effect on vegetative and root development, accelerating and improving the flowering and fruiting process. Additionally, their application offers multiple ways to effectively increase yields (Falcón-Rodríguez *et al.*, 2015; Lara-Acosta *et al.*, 2018).

This research aimed to determine the effect of a mixture of pectic oligosaccharides on the development of the root system of maize plants.

MATERIALS AND METHODS

Location

This experiment was conducted at the Experimental Station of the Agricultural Innovation Institute of Panama, located in El Ejido, Los Santos Province, Republic of Panama. This area is characterized by an average annual temperature of 27.2ºC, average annual precipitation of 900 mm/year, average relative humidity of 75%, altitude of 25 meters above sea level, soil pH of 6.20, coastal plain topography, loam-clay soil texture, and wind speed of 1.2 m/s.

Experimental setup

The research was carried out in the field using polyethylene bags of different sizes (one pound for plants evaluated at seven DAP, twenty-five pounds for plants evaluated at twenty and forty DAP, and one hundred pounds for plants evaluated at sixty DAP (Figure 1). A drip irrigation system was implemented and the necessary plant nutrition was ensured through the application of fertilizers, following the guidelines proposed by Gordon (2021). The nutrient mixture was introduced into the irrigation system through a Venturi, thus guaranteeing its adequate distribution.

FIGURE 1. Experiment established under field conditions.

Experimental Design

A completely randomized design with three replicates was used, and two treatments were evaluated:

T1: Control (seeds soaked in water for four hours)

T2: Seeds soaked in water + biostimulant (pectic oligosaccharides) 10 ml/L of water for four hours.

Sampling

Two crop cycles of hybrid maize ADV-9293 were grown. The treatments were evaluated at seven, twenty, forty, and sixty days after planting. The root system of the crop was washed to remove all substrate residues without affecting the root system (Figure 2). Aboveground plant evaluations were also performed.

FIGURE 2. Procedure to extract the roots from the growth bags.

Evaluated Variables

During the samplings, variables such as wet and dry weight of roots were measured using a digital scale, and the drying process was carried out in an oven at 75°C for forty-eight hours until reaching a constant weight. The number of roots was counted, and the length and diameter of the roots were measured using a graduated tape and a digital caliper, respectively (Figure 3).

Variables of the aerea part evaluated:

Plant height (cm): measured with a graduated ruler from the base of the stem to the last fully open leaf, and in the sixty-DAP sampling, it was measured up to the insertion of the ear.

FIGURE 3. Evaluation of the root system 40 days after planting, A: roots of corn plants treated with biostimulant, B: roots of corn plants without biostimulant.

Leaf area: determined using the equation applied by Razquin *et al.* (2017), by measuring the length and width of each leaf per plant. Three plants per treatment were measured using equation 1.

$$Leaf\ length\ X\ Leaf\ width\ X\ 0.75 \quad (1)$$

Stem diameter (cm): measured at the base of the stem using a digital caliper.

Biomass: aboveground biomass was determined by cutting and depositing the samples in labeled manila paper bags. Wet weight was measured with a scale, and then the samples were dried in an oven at 75°C for forty-eight hours to obtain dry weight.

Plant nutrition was carried out following the requirements indicated by Gordon (2021). The fertilizer solution was introduced into the irrigation system through a Venturi.

RESULTS AND DISCUSSION

The application of a bioestimulant based on pectic oligosaccharides through seed imbibition significantly influenced (P≤ 0.05) the length of the roots (Figure 4). The bioestimulant-treated group showed the highest values of root length during the four periods evaluated. This behavior may be due to the ability of pectic oligosaccharides to release auxins, which are plant hormones triggering various growth responses in plants. By promoting auxin synthesis, bioestimulants contribute to the elongation of plant roots. By increasing root length, plants can more efficiently explore and absorb soil resources, leading to greater development and resilience. Additionally, the interaction between bioestimulants and plants not only enhances root growth but can also protect plants against harmful pathogens and improve the availability of essential nutrients. These results align with those obtained by González & Fuentes (2017) in their study on the action mechanism of five plant growth-promoting microorganisms. Pectic oligosaccharides can stimulate protein synthesis in plant roots, favoring their growth and development.

The results for root weight showed statistically significant differences (P≤ 0.05) in the evaluated periods (Figure 5). This increase in root weight is

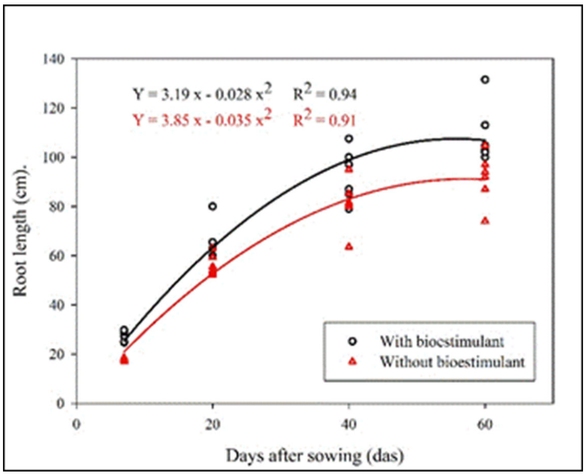

FIGURE 4. Effect of the application of pectic oligosaccharide-based bioestimulant on root length in maize cultivation.

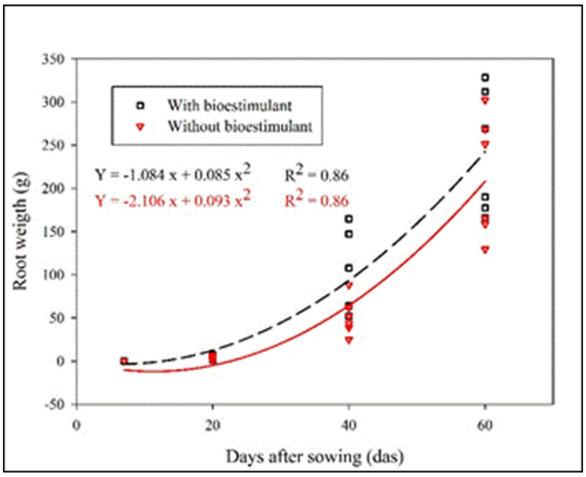

FIGURE 5. Dry weight of roots in plants treated with seed imbibition bioestimulant.

attributed to the fact that bioestimulants are growth promoters that enhance cell division and elongation, increase chlorophyll production, and improve the overall vigor of the plant. Pectic oligosaccharides can act as substitutes for auxins, plant hormones that promote root growth, resulting in increased root weight. This information is supported by the findings of Lemus-Soriano *et al.* (2021), indicating that the use of microorganisms and organic acids favors the vegetative and root growth of avocado crops. Sakthiselvan *et al.* (2014) have proposed that microorganisms can enhance plant development by exerting a beneficial impact on certain soil chemical properties. This translates into increased nutrient solubilization and greater absorption capacity by plants.

Maize plants treated with the bioestimulant differed significantly (P≤ 0.05) from untreated plants (Figure 6), exhibiting a greater number of roots in the different periods studied. In the study conducted by Posada-Pérez *et al.* (2016), a significant increase in

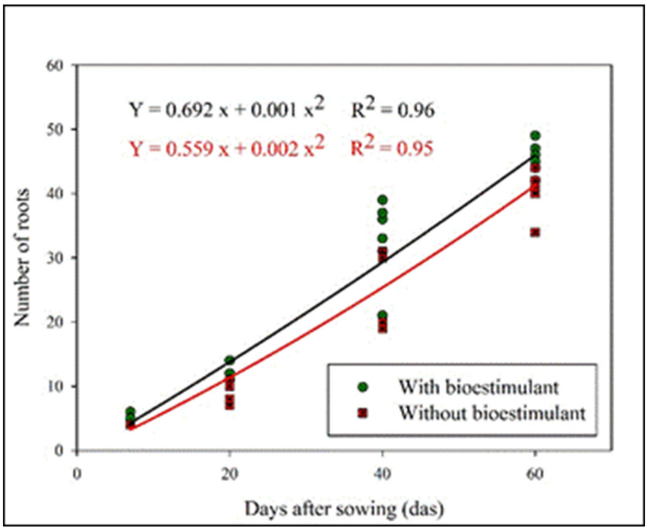

FIGURE 6. Number of roots in plants treated and untreated with pectic oligosaccharides.

the number of roots was observed in plants treated with a combination of Pectimorf® and AIB auxin (indole-3-butyric acid). This result highlighted the importance of these substances in promoting root development in plants. In general, bioestimulants stimulate natural processes that benefit nutrient utilization and increase resistance to stressful conditions, which could explain the increased number of roots in maize plants treated with bioestimulants.

The application of pectic oligosaccharides through seed imbibition had a significant impact ($P \leq 0.05$) on the increase in leaf area, plant height, and dry mass of maize crops. Plants treated with pectic oligosaccharides experienced an increase in leaf area, plant height, and dry mass due to the influence of certain hormones and their functions in the growth and development process of plants (Falcón-Rodríguez *et al.*, 2020; Pérez-Díaz *et al.*, 2023). This is attributed to the presence of certain hormones that participate in the process and contribute to the positive effects observed in plants treated with pectic oligosaccharides. Auxins are responsible for cell elongation and division, contributing to the increase in plant height; gibberellins promote stem elongation and cell division, also contributing to the increase in plant height; and cytokinins promote cell division and differentiation, contributing to the increase in leaf area (Pérez-Díaz *et al.*, 2023). These hormones work together to regulate plant growth and development, and their presence in pectic oligosaccharides contributes to the observed effects in treated plants.

The bioestimulant-treated groups showed greater development in leaf area and dry mass. During the evaluation periods, leaf areas of 7.45, 573.34, 4414.44, and 9511.85 cm² were obtained, along with dry mass weights of 0.07, 8.52, 73.36, and 195.48 g, respectively (Table 1). These results are consistent with the previous findings of Soares *et al.* (2016) and Cargua-Chávez *et al.* (2019), who also observed a significant increase in leaf area and biomass in bean and soybean plants treated with a bioestimulant.

These results indicate a significant positive impact of the pectic oligosaccharide-based bioestimulant on leaf area, plant height, and dry mass in maize cultivation.

The application of pectic oligosaccharides through seed imbibition had a significant impact ($P \leq 0.05$) on plant height. This result aligns with the findings of Barreto- Zúñiga & Pinos-Rocel (2023), who also assessed maize production performance using three bioestimulants. Additionally, Blanco-Valdes *et al.* (2022) found that treatments imbibed with Quitomax® (a naturally sourced bioestimulant) resulted in increased plant height.

TABLE 1. Effect of pectic oligosaccharide-based bioestimulant application on leaf area, plant height, and dry mass in maize cultivation. El Ejido, Los Santos, Panama 2022

Days After Sowing (DAS)	Leaf Area (cm²)		Plant Height (cm)		Dry Mass (g)	
	CB	SB	CB	SB	CB	SB
7 DAS	7.45 a	6.59 b	6.56 a	5.08 b	0.07 a	0.04 a
20 DAS	573.34 a	386.24 b	34.00a	29.2 b	8.52 a	5.74 b
40 DAS	4414.44 a	3875.87 b	118.17 a	110.33 a	73.36 a	60.58 b
60 DAS	9511.85 a	8376.97 a	223.67 a	205.17 b	195.48 a	

CB= with bioestimulant SB= without bioestimulant

CONCLUSIONS

- The application of pectic oligosaccharides through seed imbibition is beneficial for the root growth and development of maize crops, as these substances can influence the growth and development of plant tissues, increasing tolerance to abiotic stresses.
- The use of bioestimulants based on pectic oligosaccharides constitutes an effective strategy to improve the production and vigor of maize crops.

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Ana Elida Sáez-Cigarruista, Inv., Instituto de Innovación Agropecuaria de Panamá. Ciudad del Saber, Clayton, Panamá. Apartado postal 6-4391. Teléfono +507 500-0519.
Donaldo Morales-Guevara, Dr.C., Inv. Titular, Instituto Nacional de Ciencias Agrícolas. San José de Las Lajas, Mayabeque, Cuba. Código postal 32700. e-mail: dmoralesguevara48@gmail.com.
Román Gordón-Mendoza, Inv., Instituto de Innovación Agropecuaria de Panamá. Ciudad del Saber, Clayton, Panamá. Apartado postal 6-4391. Teléfono +507 500-0519. e-mail: gordon.roman@gmail.com.
Jorge Enrique Jaén-Villarreal, Inv., Instituto de Innovación Agropecuaria de Panamá. Ciudad del Saber, Clayton, Panamá. Apartado postal 6-4391. Teléfono +507 500-0519. e-mail: jorgejaen02@gmail.com.
Francisco Pablo Ramos-Manzané, Inv., Instituto de Innovación Agropecuaria de Panamá. Ciudad del Saber, Clayton, Panamá. Apartado postal 6-4391. Teléfono +507 500-0519. e-mail: franciscoramos2016@gmail.com.
Jorge Franco-Barrera, Inv., Instituto de Innovación Agropecuaria de Panamá. Ciudad del Saber, Clayton, Panamá. Apartado postal 6-4391. Teléfono +507 500-0519. e-mail: joenfra13@gmail.com.

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AUTHOR CONTRIBUTIONS: Conceptualization: A. Sáez. **Data curation:** A. Sáez, D. Morales, **Formal Analysis:** A. Sáez, D. Morales, R. Gordón. **Investigation:** A. Sáez, D. Morales, R. Gordón, J. Jaén, F. Ramos, J. Franco. **Methodology:** A. Sáez. **Supervision:** A. Sáez. D. Morales **Validation:** A. Sáez. D. Morales **Visualization:** A. Sáez. **Writing - original draft:** A. Sáez, D. Morales, R. Gordón. **Writing - review & editing:** Sáez, D. Morales, R. Gordón.