Effect of poultry manure and plant growth-promoting bacteria on melon yield and quality

Efecto de la gallinaza y bacterias promotoras del crecimiento vegetal en el rendimiento y calidad de melón

David A. Zúñiga-Gracia[1,2], Selenne Y. Márquez-Guerrero[1], Carlos J. Lozano-Cavazos[4], Erika L. López-Rodríguez[3], Juan J. Martínez-González[2], Pablo Preciado-Rangel[1*]

[1]Tecnológico Nacional de México. Campus Instituto Tecnológico de Torreón. Antigua Carretera Torreón San Pedro, km 7.5. Torreón, Coahuila, México.
[2]Universidad Politécnica de la Región Laguna, Calle Sin Nombre Sin Número. Ejido Santa Teresa, Municipio de San Pedro de las Colonias, Coahuila, México.
[3]Universidad Tecnológica de Torreón, Carretera Torreón-Matamoros, km 10. Torreón, Coahuila, México.
[4]Universidad Autónoma Agraria Antonio Narro. Calzada Antonio Narro 1923. Saltillo, Coahuila, México.

* Corresponding author: ppreciador@yahoo.com.mx

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ABSTRACT. Melon (Cucumis melo L.) production is one of the most important horticultural activities in the Comarca Lagunera region of Mexico. It contributes to the local economy and the livelihoods of rural families. However, this high productivity cannot be sustained without the use of fertilizers, especially nitrogen fertilizers. Over time, this can compromise environmental sustainability. Given this situation, the use of sustainable alternatives that maintain productivity and reduce dependence on fertilizers has become a priority. Organic amendments and plant growth-promoting bacteria (PGPB) help improve soil fertility, increase nutrient availability, and favor both crop yield and quality. This study evaluated the individual and combined effects of poultry manure and PGPB on melon fruit yield and quality. A randomized complete block design with a 5 × 2 factorial arrangement was used. Treatments included a control (conventional fertilization), four poultry manure rates (5, 10, 14, and 19 t ha^{-1}), and two inoculation conditions (with and without PGPB). Poultry manure treatments achieved yields similar to conventional fertilization. PGPB inoculation improved total soluble solids in fruits. A significant interaction between both bio-inputs was also observed for yield and total soluble solids, being more evident at the high poultry manure rate. Therefore, this organic amendment can replace nitrogen fertilization, and its combination with PGPB represents a sustainable strategy to improve melon productivity and quality.
Keywords: *Cucumis melo* L., biofertilization, organic amendments, sustainable agriculture.

RESUMEN. La producción de melón (*Cucumis melo* L.) es una de las actividades hortícolas más importantes de la Comarca Lagunera, en México. Contribuye a la economía local y al sustento de las familias rurales. Sin embargo, esta alta productividad no puede mantenerse sin el uso de fertilizantes, especialmente los nitrogenados. Con el tiempo, esto puede comprometer la sostenibilidad ambiental. Ante esta situación, el uso de alternativas sostenibles que mantengan la productividad y reduzcan la dependencia de los fertilizantes se ha convertido en una prioridad. Las enmiendas orgánicas y las bacterias promotoras del crecimiento vegetal (PGPB) ayudan a mejorar la fertilidad del suelo, aumentan la disponibilidad de nutrientes y favorecen tanto el rendimiento como la calidad de los cultivos. Este estudio evaluó los efectos individuales y combinados de la gallinaza y las PGPB sobre el rendimiento y la calidad del cultivo de melón. Se utilizó un diseño de bloques completos al azar con un arreglo factorial de 5 × 2. Los tratamientos incluyeron un control (fertilización convencional), cuatro dosis de gallinaza (5, 10, 14 y 19 t ha^{-1}) y dos condiciones de inoculación (con y sin PGPB). Los tratamientos con gallinaza lograron rendimientos similares a los de la fertilización convencional. La inoculación con PGPB mejoró el contenido de sólidos solubles totales en los frutos. También se observó una interacción significativa entre ambos bioinsumos en lo que respecta al rendimiento y al contenido de sólidos solubles totales, siendo más evidente con la dosis alta de gallinaza. Por lo tanto, esta enmienda orgánica puede sustituir la fertilización nitrogenada y su combinación con PGPB representa una estrategia sostenible para mejorar la productividad y la calidad del melón.
Palabras clave: *Cucumis melo* L., biofertilización, enmiendas orgánicas, agricultura sostenible.

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INTRODUCTION

In arid regions like northern Mexico, modern agriculture faces the dual challenge of maintaining high productivity while reducing the environmental damage caused by intensive fertilization. Conventional farming relies heavily on fertilizers, which boost yields but also degrade soils and contribute to pollution (Saldívar *et al*. 2025). Organic amendments and biological inputs offer a viable alternative (Pilla-Bardales *et al*. 2025). They help restore soil fertility, improve nutrient use efficiency, and reduce dependence on synthetic products (Vences-Martínez *et al*. 2025).

Poultry manure, a waste product from the poultry industry, is particularly useful. It is rich in macronutrients (Ortiz-Alfonso *et al*. 2025) and improves soil physical properties by increasing organic matter, improving structure, and enhancing water retention (Bedoya y Julca 2021). Unlike highly soluble synthetic fertilizers, poultry manure releases nutrients gradually, reducing leaching losses (Santiago-Juárez *et al*. 2025). It also increases microbial activity and soil biomass (Bai *et al*. 2023) and helps plants use nutrients more efficiently (Gómez-Núñez *et al*. 2025). As a result, crops tend to grow better and produce higher yields (Takata *et al*. 2025).

However, the benefits of poultry manure can be enhanced when combined with beneficial microorganisms. PGPB fix nitrogen, solubilize phosphorus, produce phytohormones, and stimulate root growth (Luna-Fletes *et al*. 2025). They also improve soil quality and increase microbial activity (Cruz-Cárdenas *et al*. 2025, Trejo-Ibarra *et al*. 2025). Organic amendments such as poultry manure provide carbon compounds that feed these bacteria, and in turn, the bacteria release nutrients for plants. This synergy increases nutrient uptake and crop productivity (Al Methyeb *et al*. 2023, Stanojković-Sebić *et al*. 2024, Muhammad *et al*. 2025) while reducing the need for fertilizers (Ruelas-Islas *et al*. 2023).

Melon (*Cucumis melo* L.) is an important cash crop in the Comarca Lagunera region, but it requires high fertilizer rates. The continuous increase in fertilizer prices is squeezing farmers’ profits, leading them to seek more agroecological options (SIAP 2023, García-López *et al*. 2022, Maraveles-Delgado *et al*. 2025). Previous studies have shown that organic amendments can reduce production costs by 15-30% without decreasing yields (Luna-Ortega *et al*. 2025). Although poultry manure and PGPB have been studied separately, it is not known how different poultry manure rates influence the effectiveness of PGPB inoculation and melon crop performance. Under this premise, the objective of the present study was to evaluate several poultry manure rates, with and without PGPB, and to quantify their individual and combined effects on melon fruit yield and quality.

MATERIALS AND METHODS

Experimental site and plant material

The research was conducted at the facilities of the Universidad Politécnica de la Región Laguna, located in San Pedro de las Colonias, Coahuila, Mexico (25°46′57.8″ LN, 103°11′30.1″ LW). The soil at the site had a clay-loam texture, electrical conductivity of 3.02 dS m^{-1}, moderately alkaline pH (7.92), and organic matter content of 1.25%. Low nitrogen (17.14 mg kg^{-1}) and phosphorus (13.82 mg kg^{-1}) contents, high base content: calcium (6594.94 mg kg^{-1}), magnesium (714.67 mg kg^{-1}), sodium (587.97 mg kg^{-1}), and potassium (535.85 mg kg^{-1}). Irrigation water had neutral pH but moderate to high salinity levels. To minimize the risk of salt accumulation in the root zone, irrigation management included the application of leaching fractions throughout the crop cycle.

The melon hybrid Cruiser (Harris Moran®) was used. Land preparation was typical for the region, including fallowing, cross-plowing, and leveling. Double-row beds were constructed, with a distance of 4 m between beds and 30 cm between plants, resulting in a density of 16,665 plants per hectare. Fertilization of the control treatment consisted of 180-60-0 (N-P_2O_5-K_2O). Gravity irrigation was applied. Before sowing, an initial irrigation depth of 0.30 m was applied, followed by a second depth of 0.25 m; subsequently, six auxiliary irrigations were applied with depths of 0.09 m each, totaling 0.74 m applied throughout the crop cycle.

Experimental design and treatments

Treatments were arranged in a 5 × 2 factorial scheme under a randomized complete block design with four replications. The factors evaluated were: a control and four poultry manure rates (5, 10, 14, and 19 t ha^{-1}), and PGPB application (with or without bacterial inoculation). Poultry manure rates were established to supply 25, 50, 75, and 100% of the nitrogen equivalent to the nitrogen fertilization rate (180 kg N ha^{-1}). The poultry manure used in the experiment had been previously characterized, with a total nitrogen content of 2.04% and a moisture content of 5%. To facilitate nutrient mineralization and reduce the possibility of phytotoxic effects during crop establishment, the manure was incorporated into the soil 30 days before sowing. Poultry manure rates were established according to the criteria proposed by López-Calderón *et al*. (2015).

PGPB inoculation

Plant growth-promoting bacteria were supplied through a commercial inoculant (Bactisoil®), which contains a microbial consortium of *Azospirillum brasilense*, *Bacillus atrophaeus*, and *Bacillus velezensis* at a concentration of 1 × 10^8 CFU mL^{-1}. Before field application, bacterial viability was confirmed by plate counting on nutrient agar following the methodology described by González-Salas *et al*. (2021). The inoculant was applied directly to the root zone 30 days after sowing using a drench (liquid soil application). Four applications were made during the crop cycle at 15-day intervals. In each application, 50 mL of inoculant was supplied per plant to ensure adequate distribution around the rhizosphere (Calero-Hurtado *et al*. 2025).

Evaluated variables

Fruits were harvested at commercial maturity, characterized by complete net formation and easy detachment from the peduncle. Immediately after harvest, the number of fruits per experimental unit was recorded, and total fruit weight was determined using a Rhino® digital scale with a maximum capacity of 40 kg. Subsequent analyses were performed on representative fruits selected from each experimental unit.

Fruit size was assessed by measuring polar and equatorial diameters using a digital caliper, and values were expressed in centimeters. Internal fruit quality was evaluated on five fruits per replicate. Total soluble solids (TSS) were measured with a Hanna® HI96801 handheld refractometer (0-32 °Brix range).

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Fruit firmness was measured with an FH20000 penetrometer (Extech®, USA) equipped with an 8-mm tip. Before each measurement, a small section of the rind was removed to expose the pulp. Fruits were placed on a flat, rigid surface, and four penetrations were performed at different points of the pulp. The average value obtained for each fruit was expressed as maximum compressive force (N).

Statistical data analysis

To satisfy ANOVA assumptions, experimental data were evaluated for normality using the Kolmogorov-Smirnov test and for homogeneity of variances using Bartlett's test. Subsequently, a two-way ANOVA was performed to examine the main effects of poultry manure, PGPB inoculation, and their interaction. For significant interactions, mean separation was achieved using Tukey's multiple range test ($p \leq 0.05$) within each factor level. In the absence of significant interactions, the main effects were interpreted independently.

RESULTS

Poultry manure and PGPB inoculation influenced melon productivity (Table 1). The maximum yield was achieved with the use of 19 t ha^{-1} of poultry manure, reaching 25.65 t ha^{-1}, while the lowest yield (18.65 t ha^{-1}) was obtained with the 5 t ha^{-1} rate. A significant interaction between poultry manure and PGPB inoculation was detected for yield. The combined application of both bio-inputs showed the highest yield, particularly at the highest poultry manure rate. This response suggests the existence of a critical threshold of organic carbon and nutrients for the development of the microbial consortium. In contrast, the lowest poultry manure rate limited the activity of the microbial consortium due to the low availability of organic carbon and nutrients, indicating that the bacterial consortium alone was insufficient to influence yield under limited organic amendment conditions (Figure 1). The equatorial diameter ranged from 11.61 to 13.48 cm, while the polar diameter ranged from 13.56 to 15.12 cm. These results indicate that poultry manure alone influenced fruit equatorial diameter. PGPB inoculation did not modify fruit morphological variables. No significant interaction was observed for fruit size, demonstrating that these attributes responded independently to the studied factors (Table 1).

Fruit firmness was not affected by the different poultry manure rates; the obtained values ranged from 19.91 to 25.97 N; the 19 t ha^{-1} rate numerically showed the highest value. PGPB inoculation did not generate significant differences in firmness. No significant interaction between poultry manure and PGPB was detected for this variable, indicating that fruit firmness was influenced independently by each factor rather than their combination (Table 1). Total soluble solids (TSS) content showed no differences attributable to the individual application of poultry manure, with values ranging from 10.12 to 10.55 °Bx. However, PGPB inoculation showed a significant increase. The interaction between poultry manure and PGPB was significant for total soluble solids, indicating that sugar accumulation in fruits is conditioned by the combination of poultry manure rate and microbial inoculation, especially with a higher poultry manure rate (Figure 2).

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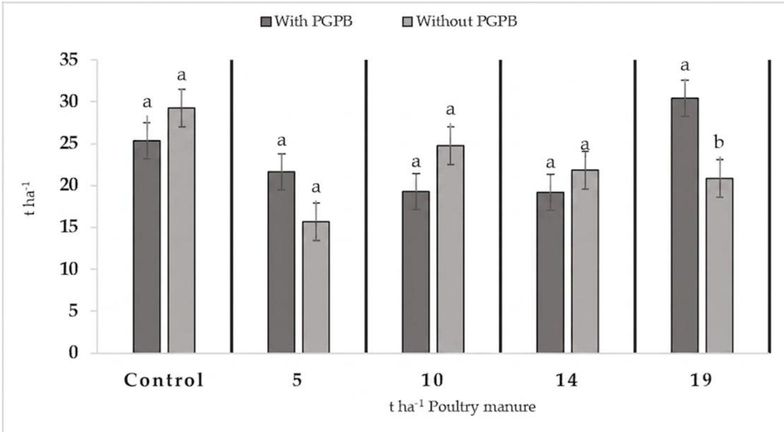

Figure 1. Interaction effects of poultry manure application levels and PGPB on melon yield. Columns associated with unique letters differ significantly (Tukey, p ≤ 0.05).

Table 1. Yield and quality attributes of melon fruits as influenced by poultry manure rates and plant growth-promoting bacteria inoculation.

Factor	Yield	Equatorial diameter	Polar diameter	Firmness	Total Soluble Solids
Poultry manure					
Control	22.82^{ab}	13.48^{a}	15.12^{a}	24.41^{a}	10.12^{a}
5	18.65^{b}	11.61^{b}	14.62^{a}	21.05^{a}	10.18^{a}
10	22.04^{ab}	12.13^{ab}	13.56a	19.91^{a}	10.37^{a}
14	22.50^{ab}	12.12^{ab}	14.69^{a}	20.03^{a}	10.37^{a}
19	25.65^{a}	12.92^{ab}	14.69^{a}	25.97^{a}	10.55^{a}
Inoculation					
Without PGPB	23.16^{a}	12.52^{a}	14.72^{a}	23.96^{a}	9.92^{b}
With PGPB	21.69^{a}	12.38^{a}	14.36^{a}	23.80^{a}	10.70^{a}
Poultry manure x PGPB	**	ns	Ns	ns	**

Values with distinct letters in the same column differ significantly based on Tukey's honest significant difference (HSD) test (p≤0.05). ns, non-significant; **, significant at p ≤ 0.01.

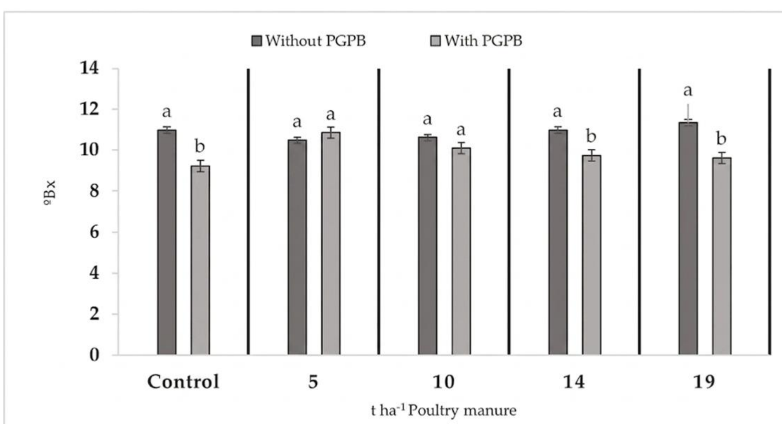

Figure 2. Interaction effects of poultry manure application levels and PGPB on total soluble solids (°Brix). Columns associated with unique letters differ significantly (Tukey, p ≤ 0.05).

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DISCUSSION

Combining poultry manure with PGPB offers an agroecological way to manage nutrients in melon crops. It maintains or increases yield while reducing the use of synthetic fertilizers, aligning with sustainable agriculture goals (Saldívar *et al*. 2025). Our results show that poultry manure functioned as an efficient nutrient source, improving both yield and some fruit physical traits. The higher yields at the highest poultry manure rates were likely due to greater nitrogen and phosphorus availability (Beltrán-Morales *et al*. 2019).

The interaction between poultry manure and PGPB was highly significant. The highest yield was obtained with 19 t ha^{-1} of poultry manure plus PGPB. This indicates that nitrogen fertilization can be replaced by poultry manure and PGPB without affecting melon crop productivity. This is probably because poultry manure supplies nitrogen, phosphorus, and organic carbon, which aid mineralization and nutrient efficiency (Ning *et al*. 2022). The addition of PGPB potentiates these effects: it solubilizes phosphorus, fixes nitrogen, and produces hormones, creating a more favorable rhizosphere for crops (Borjas-Ventura *et al*. 2020, Nicolas and Florvil 2025). A similar result has been documented by Galeote-Cid *et al.* (2022), who reported 15-25% yield increases in peppers with organic fertilizer plus *Azospirillum brasilense*. Andrade-Sifuentes *et al*. (2020) attributed such improvement to greater root activity and higher nutrient availability, which increase biomass and yield. The low yield at 5 t ha^{-1} of poultry manure shows that without sufficient organic matter and nutrients, the microbial consortium cannot function fully.

Regarding fruit size, equatorial and polar diameters showed no significant poultry manure × PGPB interaction. This suggests that genotype and environment, rather than fertilization, primarily control fruit size. In cucurbits, organic amendments tend to stimulate lateral cell division, increasing equatorial diameter, while polar diameter remains more stable because it depends more on variety genetics (Liu *et al*. 2020, Mayobre *et al*. 2025). Therefore, biofertilizers favor mesocarp expansion (flesh filling) over longitudinal growth, coinciding with Colle *et al*. (2017). The stable polar diameter reinforces that poultry manure and PGPB mainly drive lateral filling.

Fruit firmness depends on cell wall integrity and pericarp tissue, including the degradation of cellulose, hemicellulose, and pectin, as well as the availability of calcium and potassium in pectin chains (Gustani *et al*. 2025). In our study, firmness increased numerically with poultry manure rate, and inoculation had no effect. Calcium contributes to cell wall stability, but excess nitrogen or potassium can block calcium uptake, reducing fruit firmness (Amodio *et al*. 2007, D'Evoli *et al*. 2013).

Total soluble solids (TSS) responded synergistically to the poultry manure × PGPB interaction. Sugar accumulation depended not only on organic carbon and nutrients from poultry manure but also on microbial activity. A constant mineralization rate, combined with the benefits of inoculation, creates a healthier rhizosphere and photosynthetic system, which mobilizes more sugars to the fruit (Kumar *et al*. 2019). It has been documented that poultry manure improves soil properties and increases both yield and quality (Agbede 2025). In agroecological systems, poultry manure and PGPB complement each other and should be managed as an integrated package, not separately (Gabriel-Ortega *et al*. 2024).

CONCLUSIONS

These results demonstrate that poultry manure can substitute conventional nitrogen fertilization in melon systems without sacrificing yield. Beyond maintaining productivity, this organic amendment improved fruit quality, especially when combined with plant growth-promoting bacteria. The highest yield and total soluble solids were obtained with the maximum poultry manure rate combined with bacterial inoculation, evidencing a synergistic interaction between both bio-inputs. This response is likely due to the greater availability of organic substrates, which favor microbial establishment and activity in the rhizosphere. Consequently, combining poultry manure with plant growth-promoting bacteria offers a viable agroecological alternative to reduce dependence on synthetic nitrogen fertilizers while maintaining yield and quality standards in melon cultivation. However, validation of these results across multiple cycles and edaphoclimatic conditions is recommended.

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CONFLICT OF INTEREST

The authors have no competing interests to declare that are relevant to the content of this article.

STATEMENT ON THE USE OF GENERATIVE ARTIFICIAL INTELLIGENCE TOOLS

During the preparation of the manuscript, the authors used ChatGPT to improve the writing and syntax. The authors were responsible for reviewing, verifying, editing, and interpreting the information provided by ChatGPT, and they assume full responsibility for the published content.

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