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Potential of phosphorus-solubilizing bacteria as growth promoters in corn plants.

Potential of phosphorus-solubilizing bacteria as growth promoters for corn plants

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Summary

Intensive management and reliance on phosphate fertilizers in agricultural systems, such as corn, have significantly increased production costs. As an alternative, the use of phosphorus-solubilizing microorganisms has emerged as a sustainable biotechnological strategy, aiming to optimize phosphorus bioavailability in the soil. Thus, this study aimed to evaluate the effect of inoculation with previously selected bacteria with phosphorus solubilization capacity on the growth promotion of corn plants. The experiment was conducted in a greenhouse at the UNIVAG Experimental Field, in a completely randomized design, with 11 treatments: nine bacterial isolates (VG09, VG27, VG42, VG46, VG47, VG68, VG82, VG89, VG91), fertilization (NPK), no phosphate fertilization (NK), and a control without fertilization, with five replications. Forty days after emergence, the following parameters were evaluated: root length (cm), plant height (cm), stem diameter (mm), fresh and dry weight of the aerial part and roots (g). Isolate VG09 and the NPK treatment showed the best performance in six of the seven parameters evaluated, followed by isolates VG27 and VG91, which stood out in five parameters. The results demonstrate that the application of technologies based on beneficial microorganisms is a promising route for modern agriculture. The use of phosphorus-solubilizing bacteria not only enables increased corn productivity but also offers a means of reducing dependence on chemical inputs, fostering the adoption of more stable, efficient, and competitive production systems.

Keywords: phosphatases, *Bacillus,* inoculants

Abstract

Intensive management and dependence on phosphate fertilizers in agricultural systems, such as corn, have significantly increased production costs. As an alternative, the use of phosphorus-solubilizing microorganisms has emerged as a sustainable biotechnological strategy, aiming to optimize phosphorus bioavailability in the soil. Therefore, this study aimed to evaluate the effect of inoculating previously selected bacteria with phosphorus-solubilizing capacity on promoting corn plant growth.

The experiment was conducted in a greenhouse at the UNIVAG Experimental Field, in a completely randomized design, with 11 treatments: nine bacterial isolates (VG09, VG27, VG42, VG46, VG47, VG68, VG82, VG89, and VG91), NPK fertilization, and a control without fertilization, with five replicates. Forty days after emergence, the following parameters were evaluated: root length (cm), plant height (cm), stem diameter (mm), and fresh and dry weight of shoots and roots (g). Isolate VG09 and the NPK treatment performed best in six of the seven parameters evaluated, followed by isolates VG27 and VG91, which excelled in five. The results demonstrate that the application of technologies based on beneficial microorganisms is a promising path for modern agriculture. The use of phosphorus-solubilizing bacteria not only increases corn productivity but also offers a means to reduce dependence on chemical inputs, encouraging the adoption of more stable, efficient, and

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INTRODUCTION

Corn *(Zea mays* L.) cultivation is of great importance worldwide because multiple uses, serving as a food source for humans and animals, and as raw material. raw material for various manufactured products (OKUMURA; MARIANO; ZACCHEO, 2011). The The United States, China, and Brazil are the world's largest producers of corn. In Brazil, this cereal is... Considered one of the most important agricultural products, with a production of 298.41 million. tons in the 2023/2024 crop season (CONAB, 2024).

In order to meet the demand for corn, the production system depends on replenishment of nutrient reserves that are removed for maintenance or even Increased productivity. Currently, this supply is achieved through the addition of Chemical fertilizers. Among chemical fertilizers, nitrogen and phosphate fertilizers stand out for... Their intensive use. However, these fertilizers have low utilization efficiency. by plants, resulting in high application rates and consequent environmental degradation. (MOTES, 2010).

Given the above, there is a great demand for agricultural systems that advocate for... Sustainability and adding value to their products. Among the alternatives to meet this The demand highlights the use of biological products. The adoption of these inputs makes it possible to... Partial replacement of mineral chemical fertilizers, directly impacting cost reversal. of production. Among the biological inputs, the use of microorganisms that promote growth stands out. plant growth regulator (MPCP) (BHATTACHARYYA and JHA, 2012).

After nitrogen, phosphorus (P) is the most limiting nutrient for plant development (BARROTI and NAHAS, 2000). It is an essential element for the establishment and development, as it improves the entire root system and, consequently, the aerial part. (GONÇALVES et al., 2000). Its deficiency causes reduced growth and production, lower tillering, impaired flowering and grain filling of the ears, and delayed maturation. (NAHAS, 1991).

OP is a macronutrient of great importance for plant growth. playing a fundamental role in metabolic processes, such as photosynthesis and the formation of of energy molecules (ATP). However, most of this element is present in Brazilian soils It is found adsorbed, that is, adhered to clay and Fe and Al oxides (SOUZA and LOBATO, 2004). Therefore, to guarantee crop production, high doses of fertilizers must be applied. Soluble phosphates, which increase production costs, in addition to promoting dependence on Importation of phosphate mineral fertilizers (OLIVEIRA PAIVA et al., 2021).

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Pavinato and colleagues (2020) report that excessive fertilizer applications
Soluble phosphates have provided an accumulation of P in the soil, less labile forms, that is, not readily available to plants. An alternative strategy to make this residual P available. For plants, the use of phosphate-solubilizing microorganisms is employed; these are capable of... to form associations with plant roots and solubilize the less labile forms of P in the soil, A strategy that can reduce the demand for mineral fertilizers (PAVINATO et al., 2021).

The solubilization of phosphorus in the soil through the use of solubilizing bacteria occurs by through different biochemical mechanisms. These microorganisms are able to secrete acids. organic compounds, such as citric acid, oxalic acid, and acetic acid, have the ability to solubilize insoluble phosphates present in the soil, transforming them into soluble forms that can be assimilated by plants (RODRÍGUEZ; FRAGA, 1999). Furthermore, phosphate-solubilizing bacteria also... They can release phosphatase enzymes, which catalyze the hydrolysis of phosphate bonds in compounds. organic and inorganic compounds, increasing the availability of phosphorus for plants (RICHARDSON; SIMPSON, 2011).

However, despite the promising potential of these microorganisms, there are challenges to be overcome. These challenges have been overcome for their practical application in corn cultivation in Brazil. These challenges include selection... of microorganisms effective for the different edaphoclimatic conditions of the country, the formulation of viable inoculants and an understanding of the complex interactions between these bacteria, corn, and soil (SANTOS et al., 2020). Although there is evidence demonstrating the benefits of bacteria phosphorus solubilizers in different crops, scientific knowledge about the ideal way of Research on the application, dosage, and specific impacts on corn crops is still limited. In-depth studies are essential to fill these gaps and provide practical guidance for the farmers

In an increasingly competitive agricultural environment, farmers need to adopt Practices that optimize production yields and costs; understanding how to apply them. The effective metabolism of phosphorus-solubilizing bacteria can contribute to competitiveness and sustainability of agricultural operations. Thus, the objective of this study was to evaluate the effect of inoculation of pre-selected bacteria with the ability to solubilize phosphorus in the promotion of growth of corn plants.

MATERIALS AND METHODS

The experiment was conducted in a greenhouse located at the Experimental Field of University Center of Várzea Grande (UNIVAG). First, a soil analysis was carried out by Through composite samples, the levels of available nutrients in the soil were verified. through chemical analysis, to determine the soil condition and to make the necessary corrections accordingly.

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analysis (Table 1).

Table 1. Chemical analysis of experimental soil from the University Center of Várzea Grande–
UNIVAG, at a depth of 0 to 20 cm. Várzea Grande, MT, 2025.

Prof.	pH	pH	mg dm-3	cmolc dm-3			g dm-3	g kg-1	
0 to 20 cm	H2O	CaCl2	PK	Ca	Mg	Al	HH + Al	MO	Sand	Silt	Clay
	6.5	5.8	30.5	60.8	1.07	0.59	0.0	0.9	0.9	Cu			4.71	826	66	108
Zn				Faith		Mn		B		S	
mg dm-3											
3.90		1.30		93.10		27.58		0.36		9.42	

Planting was carried out in 20-liter pots containing soil from the experimental field.
Corn seeds with 3 seeds per pot of the AG7088PRO variety, which were microbiolized.
for 30 minutes with suspensions (OD600=0.5) of pre-selected bacterial isolates by
to solubilize phosphorus (SOUZA JUNIOR et al., 2024), namely: VG09, VG27, VG42, VG46, VG47,
VG68, VG82, VG89, VG91, in addition to a control group with phosphate fertilization (NPK), and another without.
Phosphate fertilization (NK) and a control without fertilization. The experimental design used
It was a completely randomized design with 12 treatments and five replicates per treatment.

After germination, only one plant was left per pot. All weeding was carried out.
The irrigation was done manually throughout the days, and then automatically by the sprinklers.
from the greenhouse.

The assessments were carried out 40 days after the emergency, and the following were evaluated.
Growth parameters: root length (cm), measured using a ruler, height
Plant height (cm) measured with a ruler, calculated from the ground level to the leaf apex of the plant.
last expanded leaf (cm), stem diameter (mm) obtained using a caliper taking-
if measured from the base of the plant to the second internode, fresh weight of the roots (g) and of the part
aerial part (g), measured on an analytical balance and dry weight of roots and aerial part (g) for this, the
Samples were placed in paper bags and placed in an oven at 65 ºC for 72 hours.
Subsequently, the samples were also weighed on an analytical balance. The data obtained were
submitted to analysis of variance (ANOVA) using the SASM-AGRI statistical program, being the
Comparison between means, performed using the Scott-Knott test ($p<0.05$) (CANTERI et al., 2001).

RESULTS AND DISCUSSION

According to the results for evaluating the promotion of plant growth of
In corn, it was found that for all plant growth parameters analyzed there was...
significant difference between treatments (Table 1).

Table 1. Evaluation of growth promotion of corn plants in a greenhouse.
based on growth parameters such as root length (RL) (cm), height (HT) (cm), fresh weight

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of the root (PFRA), Dry weight of the root (PSRA) (g), Fresh weight of the aerial part (PFPA) (g), Dry weight of the part aerial (PSPA) (g) and stem diameter (DC) (mm). Várzea Grande, MT, 2025.

Treatments	CR (cm)	PFRA (g)	PSRA (g)	ALT (cm)	A.D (mm)	PFPA (g)	PSPA (g)
Without fertilization	37.8 c	184.2 b	57.54 b	125.4 c	22.44 c	220 c	44.94 b
NK	55.36 b	39.6 a	209.8 a	40.2 a	40.6 c	311.0 a	89.86 a
NPK	154.4 a	22.82 c	260 b	39.2 c	196.0 b	80.08 a	152.4 a
VG09	23.72 b	270 b	38.8 c	264.2 a	62.14 a	79.96 a	154.0 a
VG24	24.50 b	320 a	7.42	27.6	4.24	11.25	64.38 a
VG27							52.76 b
VG68							66.82 a
VG82							58.28 b
VG89							55.22 b
VG91							56.32 b
CV(%)			19.22	5.03			69.38 a
							13.94

Regarding the root length parameter, it is observed that the treatment with the The VG09 bacteria showed the highest average value, reaching 56 cm, followed by the treatment with Fertilization with NPK, with an average of 47 cm, the other treatments did not differ from each other. The isolated The bacterial strain VG09 provided increases of 48% and 19% in root length, respectively. to the treatments without fertilization and the treatment without phosphate fertilization, respectively.

Souza Júnior and colleagues (2024a), while working with soybeans, found that the The isolates VG09, VG27, VG68, VG89, and VG91 showed increases in root length. which corroborates the results found in this study. Regarding cotton cultivation, noteworthy factors include... VG24, VG27, VG42, VG47, VG68, and VG82 isolates provided greater root lengths (SOUZA JÚNIOR et al., 2024b). It is observed that a more complex interaction may be occurring. specific differences exist between the isolates and the plant species tested; however, root colonization tests... Studies with different plant species and bacterial isolates should be conducted to better understanding.

Saharan and Nehra (2011) observed that *Bacillus* species contributed to the improvement of different root parameters, such as rooting, root length and dry matter content, and that inoculation with IAA (indoleacetic acid) producing isolates increased the absorption of certain nutrients, promoting the growth of sweet potatoes and better root development in seedlings. eucalyptus.

According to Cassán et al. (2009), plant growth promotion by bacteria This occurs due to stimuli that trigger the production of plant hormones, resulting in changes in... root system changes such as an increase in either root volume or size. Possibly isolated

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This study showed that those that produced larger root sizes also produce these hormones; however, Further tests should be carried out to confirm this characteristic.

For the PFRA parameter, it is observed that the highest average values were recorded in treatments VG27, VG09, VG82, NPK, VG68 and VG91. These treatments on average presented increases of 67% and 46.65% compared to the control without fertilization and the treatment without fertilization. Phosphated, respectively. The bacterial isolates VG09, VG27, VG68, VG89 and VG91 provided greater fresh root weight when tested on soybean plants (SOUZA JÚNIOR et al. al., 2024), which corroborates the results found in this study. Furthermore, in the culture of In cotton, the bacterial isolates VG24, VG27, VG68, and VG82 also stood out for presenting higher fresh root weights (SOUZA JÚNIOR et al., 2025).

In evaluating the results for PSRA, obtained after oven drying and weighing, It was observed that the bacterial treatments VG82, VG27, VG89, VG68, VG91 and the treatments with NPK and NK fertilization resulted in the highest weights, with an average of 87 g, with the increase in The PSR provided by this group, in relation to the control, was 51%. The bacterial isolates VG27 and VG91 also stood out for this parameter when evaluated in soybean plants (SOUZA JÚNIOR et al., 2024). In cotton cultivation, similar results to this study were found when using isolates VG27, VG68, and VG82 (SOUZA JÚNIOR et al., 2025).

According to the data for the plant height parameter, it was observed that the treatments VG09, VG24, VG27, VG68, VG82, VG89, VG91 and NPK obtained the highest averages, not They differed from each other, resulting in an average value of 153.9 cm. When compared to the control group, this was the average value of 153.9 cm. (without fertilization) and the treatment without phosphate fertilization, an increase of 23% and 9.8% was observed. at the height of the plants, respectively at the stem.

This result was similar to that found by Lobo (2018) in which inoculation with different endophytic bacteria of the genus *Bacillus* have been shown to be effective in promoting Growth of corn plants both in greenhouses and in field conditions. & Glick (1996) suggest that the additional input of microbial AIA may modify auxin. endogenous growth to or above optimal levels, resulting in the induction or inhibition of growth of plant. The auxin response depends on the stage of root development of the plant, which influences in the composition and quantity of exudates released by the root (PILET et al., 1979).

For the PFPA, it was found that treatments VG09, VG24, VG27, VG68, VG91 and fertilization with NPK, they showed the highest average weights, with an average of 310 g. In comparison with the Control treatments without fertilization and without phosphate fertilization showed increases of 41% and 15%, respectively. For PSPA, the treatments VG09, VG27, VG91 and fertilization with NPK showed the highest averages, with an average increase of 46% and 18.6% compared to The control group received no fertilizer and no phosphate fertilizer, respectively.

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Guerra and colleagues (2024) observed that *B. subtilis* via seed + an application via
Soil in corn at 90 DAE stood out for the MSPA variable (mean of the squares of the treatments).
when compared to the other treatments tested, providing a greater increase in dry mass.
of the aerial part. According to Machado et al. (2020), when applying *B. subtilis* to plants of
In corn, there was a significant increase in root system growth and in the accumulation and partitioning of
biomass produced by the plant. This increase can be attributed to the production of certain hormones.
by these bacteria, such as indoleacetic acid (IAA), responsible for regulating
plant growth and development and indolebutyric acid (IBA), responsible for stimulating the formation
of secondary roots.

For the stem diameter parameter, resulting in a large difference compared to the others.
parameters. More clearly, the NPK and VG09 treatments yielded the best results with
average of 25.84 mm, making it on average 12.43% higher than the treatments with the lowest averages.
(Without fertilization and VG82), compared to the other treatments, they were 6.96% higher.

The data obtained in this study on DC are supported by those presented by Inagaki et al.
al. (2015) and Cecatto Júnior et al. (2019), who mentioned favorable increases in plant stems
corn inoculated with *Azospirillum brasilense* and *Herbaspirillum seropedicae.* These authors
They attributed this increase to the supply of plant hormones, resulting in greater capacity.
improved nutrient absorption and reserve accumulation, and consequently, better development of
stem, which contributes to reducing breakage and lodging and increasing storage of
photoassimilates.

Generally, when evaluating all the growth parameters of corn plants, it is observed-
It is noted that the VG09 isolate and the NPK treatment stood out for providing higher averages.
for six of the seven growth parameters evaluated, followed by isolates VG27 and VG91, which stood out for five of the
seven parameters evaluated. It is important to emphasize that for many
The average parameters were similar to or higher than those of the NPK treatment. Furthermore, these three isolates
showed fungicidal activity against the fungus *Sclerotinia sclerotiorum* (SOUZA JÚNIOR,
2024).

Santos et al. (2017) indicate that *B. aryabhattai* is a beneficial microorganism capable of
to increase root biomass in maize and sugarcane genotypes. According to
Vieira (2017), plant growth-promoting bacteria can contribute to the
plant development is aided by both N2 fixation and increased solubilization of
phosphate, control of phytopathogens and production of phytohormones that promote development and
root growth, primarily auxin, increasing the absorption of water and nutrients.
Consequently, the plant becomes more resistant to stressful situations such as deficiency.
water supply.

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The results indicate that certain bacteria were able to promote increases in corn plant growth parameters comparable to or exceeding those observed in treatment with NPK fertilizer. This performance highlights their potential as promoters of plant growth and potential biocontrol agents. These findings reinforce the importance of Further studies are needed to elucidate the mechanisms involved and to develop strategies. more sustainable management practices.

Based on the results obtained, the use of phosphorus-solubilizing bacteria It showed a promising effect in promoting the growth of corn plants, promoting improvements. significant in parameters such as root length, fresh and dry root mass, height of plant, stem diameter and shoot mass. The bacterial isolates VG09, VG27 and VG91 are They stood out in different variables, even surpassing the NPK fertilizer treatment in some areas. These cases highlight the potential of these microorganisms as biostimulants in corn cultivation. These results reinforce the idea that the use of microbial inoculants can be a sustainable alternative. and economically viable compared to conventional phosphate fertilization, especially in soils with low availability of phosphorus.

FINAL CONSIDERATIONS

The VG09 isolate and the NPK treatment stood out among the treatments because providing higher averages for six of the seven growth parameters evaluated, followed by VG27 and VG91 isolates stood out for five of the seven parameters evaluated.

Despite the promising results, it is important to highlight the need for further studies. especially under field conditions and with long-term productivity analyses, so that can safely recommend the use of these microorganisms in the nutritional management of the crop. corn.

Finally, the data obtained contribute to the advancement of knowledge about practices. more sustainable and efficient agricultural practices, aligned with the principles of sustainable agriculture and Low environmental impact. The adoption of technologies based on beneficial microorganisms represents a promising path to increasing productivity and reducing costs with chemical inputs, promoting more resilient and competitive agricultural systems.

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