FORSCIENCE
ISSN: 2318-6356

DOI: 10.29069/forscience.2026v14n2.e1427
Recebido em: 16/10/2025
Aprovado em: 10/07/2026
Publicado em: 12/11/2026

# REDUÇÃO DA ADUBAÇÃO FOSFATADA COM ESTRATÉGIAS BIOLÓGICAS MANTÉM A PRODUTIVIDADE DO TOMATEIRO[1]

**Diogo Aparecido de Carvalho**
**Rodrigo de Souza Almeida**
**Marcelo Loran de Oliveira Freitas**
**Neimar Freitas Duarte**
**Ricardo Sousa Cavalcanti**
**Fernanda Morcatti Coura[2]**

## RESUMO

O cultivo de tomate (*Solanum lycopersicum* L.) requer altos aportes de nutrientes, principalmente fósforo (P), devido à sua baixa disponibilidade em solos tropicais. Nesse contexto, inoculantes microbianos solubilizadores de fósforo têm surgido como uma alternativa sustentável para melhorar a eficiência do uso de nutrientes. Este estudo teve como objetivo avaliar os efeitos do BiomaPhos® associado à redução da adubação fosfatada sobre o crescimento vegetativo, a produtividade, a qualidade dos frutos e os atributos do solo. O experimento foi conduzido em casa de vegetação, utilizando um delineamento experimental de blocos casualizados com cinco tratamentos e quatro repetições. Os tratamentos consistiram em combinações de adubação fosfatada (100%, 50% e 0% da dose recomendada) e aplicação de BiomaPhos® (0%, 50% e 100%). Foram avaliados o crescimento vegetativo, os componentes da produtividade, a qualidade dos frutos e os atributos biológicos e químicos do solo. Os resultados mostraram que os tratamentos com BiomaPhos® associado a 50% da adubação fosfatada mantiveram o crescimento vegetativo, a produtividade e a qualidade dos frutos em níveis equivalentes à adubação completa. Em contraste, os tratamentos sem fertilização fosfatada apresentaram reduções significativas em todos os parâmetros avaliados. O inoculante também reduziu a incidência de podridão apical, sugerindo um melhor equilíbrio nutricional. Além disso, foram observadas melhorias nos indicadores de qualidade do solo, particularmente aqueles relacionados à atividade biológica e à ciclagem de nutrientes. Esses resultados indicam que o BiomaPhos® é uma estratégia promissora para aumentar a eficiência do uso de fósforo e reduzir a dependência de fertilizantes minerais em sistemas de produção de tomate.

**Palavras-chave:** *Solanum lycopersicum*. Solo. Fósforo. Bioinoculante. BioAS.

# REDUCED PHOSPHORUS FERTILIZATION WITH BIOLOGICAL STRATEGIES MAINTAINS TOMATO PRODUCTIVITY

[1]**Como citar este trabalho**: CARVALHO, Diogo Aparecido de; ALMEIDA, Rodrigo de Souza; FREITAS, Marcelo Loran de Oliveira; DUARTE, Neimar Freitas; CAVALCANTI, Ricardo Sousa; COURA, Fernanda Morcatti. Redução da adubação fosfatada com estratégias biológicas mantém a produtividade do tomateiro. **ForScience**, Formiga, v. 14, n. 2, e01427, jul./dez. 2026. DOI: 10.29069/forscience.2026v14n2.e1427.
[2]**Autor correspondente:** Fernanda Morcatti Coura, e-mail: fernanda.coura@ifmg.edu.br.

## ABSTRACT

Tomato (*Solanum lycopersicum* L.) cultivation requires high nutrient inputs, particularly phosphorus (P), due to its low availability in tropical soils. In this context, phosphorus-solubilizing microbial inoculants have emerged as a sustainable alternative to improve nutrient use efficiency. This study aimed to evaluate the effects of BiomaPhos® associated with reduced phosphate fertilization on plant growth, yield, fruit quality, and soil attributes. The experiment was conducted under greenhouse conditions using a randomized complete block design with five treatments and four replications. Treatments consisted of combinations of phosphate fertilization (100%, 50%, and 0% of the recommended dose) and BiomaPhos® application (0%, 50%, and 100%). Vegetative growth, yield components, fruit quality, and soil biological and chemical attributes were evaluated. The results showed that treatments with BiomaPhos® associated with 50% of phosphate fertilization maintained plant growth, yield, and fruit quality at levels equivalent to full fertilization. In contrast, treatments without phosphate fertilization showed significant reductions in all evaluated parameters. The inoculant also reduced the incidence of blossom-end rot, suggesting improved nutritional balance. Additionally, improvements in soil quality indicators, particularly those related to biological activity and nutrient cycling, were observed. These findings indicate that BiomaPhos® is a promising strategy to increase phosphorus use efficiency and reduce the dependence on mineral fertilizers in tomato production systems.

**Keywords**: *Solanum lycopersicum*. Soil. Phosphorus. Bioinoculant. BioAS.

## 1 INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetable crops in Brazil, with high socioeconomic relevance due to its complex production chain and strong market demand. Data from the Brazilian Institute of Geography and Statistics (IBGE) indicate that national production reached approximately 4.7 million tons in 2026, with an average yield of 75,104 kg $ha^{-1}$. These values place Brazil among the world's leading tomato producers. Maintaining this level of productivity requires high technological input, particularly in the management of plant nutritional and phytosanitary requirements.

Tomato cultivation has high nutritional demands and depends on adequate soil fertility conditions. The incorporation of organic fertilizers and other sources of organic matter improves soil chemical and biological properties, increasing the availability of nutrients such as nitrogen, potassium, and phosphorus, as well as enhancing microbial activity and crop productivity (FAN et al., 2024). In this context, phosphorus (P) plays a

central role in plant metabolism, participating in ATP formation, membrane phospholipid composition, root development, and carbohydrate synthesis (TAIZ; ZEIGER, 2013).

However, in commercial production systems, phosphorus application rates often exceed the actual demand of plants. This practice is associated with the low agronomic efficiency of this nutrient in highly weathered tropical soils, where phosphorus is rapidly adsorbed by iron and aluminum oxides and clay particles, forming less labile fractions and reducing its availability in the soil solution. As a result, the use of high doses of phosphate fertilizers is common to ensure adequate nutrient availability for plant uptake (HANYABUI et al., 2019).

Given the depletion of natural phosphorus sources and the low agronomic efficiency of phosphate fertilizers in tropical soils, the development of technologies that not only enhance phosphorus solubilization but also improve soil biological dynamics and overall soil quality has become necessary. In this context, phosphorus-solubilizing microbial inoculants have been investigated as sustainable alternatives, capable of releasing less available forms of the nutrient, stimulating microbial activity, and promoting the cycling of other nutrients.

BiomaPhos® is a biological technology developed for this purpose, containing phosphorus-solubilizing microorganisms such as *Bacillus subtilis* (CNPMS B2084 – BRM034840) and *Bacillus megaterium* (CNPMS B119 – BRM033112). These microorganisms act through the production of organic acids and other metabolites that assist in phosphate solubilization and the mobilization of other nutrients in the soil, potentially contributing to the biological conditioning of the rhizosphere. Studies conducted in crops such as maize, soybean, and sorghum have demonstrated positive results in both productivity and reduced costs associated with phosphate fertilizers (OLIVEIRA-PAIVA et al., 2020).

Considering the high nutritional demands of tomato plants and the importance of sustainable soil fertility management, it is relevant to evaluate the efficiency of BiomaPhos® in this crop. Therefore, the present study aimed to evaluate the effects of BiomaPhos® associated with reduced phosphate fertilization on plant growth, productivity, fruit quality, and soil attributes.

## 2 MATERIAL AND METHODS

The experiment was conducted in a greenhouse in the Olericulture sector of the Federal Institute of Minas Gerais – Bambuí Campus, located in the municipality of Bambuí, Minas Gerais, Brazil (20°02'15.76" S; 46°00'31.0" W), at an altitude of 681 m.

Eighty tomato plants were grown in pots with a capacity of 20 L, with an upper diameter of 33 cm, a height of 28.5 cm, and a lower diameter of 28 cm. The pots were filled with Red Latosol collected from a slope, naturally low in phosphorus, according to the initial soil chemical analysis presented in Table 1.

**Table 1** - Values obtained in the initial soil chemical analysis.

| Soil Chemical Parameter | Values |
|---|---|
| pH | 4.8 |
| P (mg/dm³) | 2.00 |
| K(mg/dm³) | 45.35 |
| Ca (cmolc/dm³) | 0.9 |
| Mg (cmolc/dm³) | 0.2 |
| Al (cmolc/dm³) | 3.1 |
| Al+H (cmolc/dm³) | 7.4 |
| SOM (g/mg³) | 8.0 |
| T (cmolc/dm³) | 8.6 |

**Source:** Author (2026).

The soil was previously sieved to standardize its texture and remove coarse residues. Subsequently, liming was carried out to correct soil acidity, reduce toxic aluminum, and increase base saturation, according to technical recommendations based on soil analysis. The resulting values are presented in Table 2.

**Table 2** - Nutrient contents in the soil after liming performed prior to tomato transplanting.

| Soil Chemical Parameter | Values |
|---|---|
| pH | 7.1 |
| P (mg/dm³) | 2.0 |
| K (mg/dm³) | 45.35 |
| Ca (cmolc/dm³) | 5.4 |
| Mg (cmolc/dm³) | 1.5 |

| | |
|---|---|
| Al (cmolc/dm³) | 0 |
| Al+H | 1.6 |
| SOM (g/dm³) | 8.0 |
| T (cmolc/dm³) | 8.6 |

**Source:** Author (2026).

Nitrogen, potassium, and micronutrient fertilization were carried out according to the recommendations for tomato cultivation established by Embrapa, considering the results of the soil chemical analysis. After preparation, the pots were filled and arranged with a spacing of 50 cm between them.

Weed control was performed manually through hoeing whenever necessary. Phytosanitary management consisted of the preventive application of pesticides, following technical recommendations for the crop and label instructions of the products used. Pruning was carried out until the emission of the first productive cluster, and thereafter desirable shoots were maintained according to the training system recommended for determinate cultivars intended for the fresh market. Staking was performed vertically to ensure adequate support of productive stems throughout the crop cycle.

Irrigation management was conducted using a drip system, aiming to maintain soil moisture close to field capacity and reduce conditions favorable to disease development. Irrigation requirements were monitored daily, considering soil moisture in the pots and environmental conditions inside the greenhouse.

The hybrid cultivar ‘Caeté’ (Blueseeds) was used, a saladette-type tomato with a determinate growth habit, an early cycle, and fruits with an average weight of 200–220 g, showing tolerance to *Verticillium* race 1, *Fusarium* races 1 and 2, Tobacco mosaic virus (TMV), Tomato spotted wilt virus (TSWV), and Tomato yellow leaf curl virus (TYLCV).

During the experimental period, climatic data were obtained from the National Institute of Meteorology (INMET). The average temperature was 24.5 °C, with an absolute maximum of 39.1 °C and an absolute minimum of 15.1 °C recorded during the period.

The experimental design was a randomized complete block design (RCBD), with four blocks and five treatments, each consisting of sixteen plants randomly distributed in

the experimental area. The treatments consisted of different combinations of phosphorus doses and BiomaPhos®, as described in Table 3.

**Table 3** - Levels of phosphate fertilization and BiomaPhos® doses in the experimental treatments.

| Treatments | $P_2O_5$ fertilization (%) | BiomaPhos® (%) |
|---|---|---|
| 1 (Control) | 100 | 0 |
| 2 | 50 | 100 |
| 3 | 0 | 100 |
| 4 | 0 | 50 |
| 5 | 50 | 50 |

**Source:** Author (2026).

Phosphate fertilization was carried out based on the fertilization plan for fresh-market tomatoes provided by Embrapa (de Ávila, [n.d.]). For the treatment corresponding to 100% of $P_2O_5$, 18.21 g of the 8-28-16 formulated fertilizer were applied per pot. For the treatment with 50% of $P_2O_5$, 9.1 g of the same fertilizer were applied at the time of transplanting.

For the application of BiomaPhos®, a solution containing 1 L of water and 3 mL of the inoculant was prepared for treatments with 100% of the recommended dose. The seedling roots were immersed in the solution immediately before transplanting. For treatments with 50% of the recommended dose, a solution containing 1 L of water and 1.5 mL of the inoculant was used. The dosages followed the manufacturer's recommendations for application via seedling immersion.

Vegetative evaluations included plant height at 30, 60, and 90 days after transplanting, measured with a measuring tape; stem diameter, evaluated every 30 days using a digital caliper; and total number of leaves per plant.

The productive parameters evaluated were the number of clusters per plant, the number of fruits per plant, and yield per plant (kg). The number of clusters was recorded from the appearance of the first cluster until the end of the experiment. Harvesting began at the ripening of the first fruits and extended for 31 days. During this period, harvesting was performed manually, and fruits from each plant were immediately counted and individually weighed on a scale to determine the average yield per plant.

Fruit size was classified based on transverse diameter as follows: large (Ø > 60 mm), medium (50 < Ø < 60 mm), and small (40 < Ø < 50 mm), according to Fernandes, Corá, and Braz (2007). The incidence of blossom-end rot was also evaluated.

Before transplanting, physical, chemical, and biological soil analyses were performed, including BioAS parameters. At the end of the experiment, soil samples were collected at a depth of 0–10 cm from all pots, separated by treatment, and sent for physical, chemical, and BioAS analyses. The BioAS technology, developed by Embrapa, evaluates arylsulfatase and beta-glucosidase enzymes as bioindicators of soil quality.

The analyzed variables included arylsulfatase activity (Aryl), beta-glucosidase activity (Beta), soil organic matter (SOM), clay content, and soil quality and nutrient cycling indices. Initial and final BioAS results were compared, along with the chemical and physical analyses of the treatments.

The assumptions of analysis of variance (ANOVA) were previously verified. When the F-test was significant ($p \leq 0.05$), means were compared using the Scott-Knott test at a 5% probability level, using R® software (R Core Team, version 4.5.2, 2025).

## 3 RESULTS

The results of the vegetative growth analyses are presented in Table 4, including plant height, stem diameter, and total number of leaves per plant. Treatments 2 and 5 showed results similar to Treatment 1 (Control) across all evaluations. In contrast, Treatments 3 and 4 were also similar to each other but presented lower values compared to the other treatments, as shown in Table 4.

**Table 4** - Vegetative growth of tomato plants under different phosphorus and BiomaPhos® treatments.

| | T1 (100% $P_2O_5$ + 0% BiomaPhos®) | T2 (50% $P_2O_5$ +100% BiomaPhos®) | T3 (0% $P_2O_5$ + 100% BiomaPhos®) | T4 (0% $P_2O_5$ + 50%BiomaPhos®) | T5 (50% $P_20_5$ + 50%BiomaPhos®) |
|---|---|---|---|---|---|
| Plant height (cm) | 87.7a | 88.1a | 60.6b | 59.8b | 87.8a |
| Stem diameter (cm) | 10.0a | 9.9a | 8.0b | 6.9b | 11.3a |

| | | | | | |
|---|---|---|---|---|---|
| Leaves per plant | 14.3a | 14.6a | 11.9b | 12.1b | 14.6a |

**Source**: Author (2026).
Means followed by the same letter do not differ significantly from each other, according to the Scott-Knott test at a 5% probability level.

The results of the productivity analyses of tomato plants are presented in Table 5. Treatments 2 and 5 were similar to Treatment 1 in all evaluations related to productivity. Treatment 3 was similar to Treatment 4, and both showed lower productivity in all evaluations compared to the other treatments in this study.

**Table 5** - Productivity of tomato plants (*Solanum lycopersicum*) under different phosphorus and BiomaPhos® treatments.

| | T1 (100% $P_2O_5$ + 0% BiomaPhos®) | T2 (50% $P_2O_5$ +100% BiomaPhos®) | T3 (0% $P_2O_5$ + 100% BiomaPhos®) | T4 (0% $P_2O_5$ + 50%BiomaPhos®) | T5 (50% $P_2O_5$ + 50%BiomaPhos®) |
|---|---|---|---|---|---|
| Clusters per plant | 4.5a | 4.8a | 2.7b | 2.6b | 4.7a |
| Fruits per plant | 13.5a | 15.8a | 3.7b | 3.6b | 14.7a |
| Fruit yield per plant (kg) | 1.27a | 1.39a | 0.14b | 0.13b | 1.32a |

**Source:** Author (2026).
Means followed by the same letter do not differ significantly from each other, according to the Scott-Knott test at a 5% probability level.

The results of the qualitative analysis of tomato plants are presented in Table 6. This table illustrates the effects of BiomaPhos® on fruit size. In the evaluation of the percentages of small and large fruits, Treatments 2 and 5 showed results similar to Treatment 1. In the same evaluation, Treatments 3 and 4 were similar to each other, with lower average values compared to the other treatments.

In the evaluation of the percentage of fruits with blossom-end rot, Treatments 2, 3, and 4 showed similar results, indicating lower incidence of this disorder, as presented in Table 6. Treatment 5 was similar to Treatment 1, showing the highest incidence rates of this disorder.

**Table 6** - Qualitative analysis of tomato fruit characteristics (*Solanum lycopersicum*) harvested under different treatments and BiomaPhos® doses.

| | T1 (100% $P_2O_5$ + 0% BiomaPhos®) | T2 (50% $P_2O_5$ +100% BiomaPhos®) | T3 (0% $P_2O_5$ + 100% BiomaPhos®) | T4 (0% $P_2O_5$ + 50%BiomaPhos®) | T5 (50% $P_2O_5$ + 50%BiomaPhos®) |
|---|---|---|---|---|---|
| Small fruits per plant (%) | 12.7a | 7.9a | 57.2b | 23.9b | 8.3a |
| Large fruits per plant (%) | 63.1a | 62.3a | 21.6b | 29.1b | 62.0a |
| Fruits with blossom-end rot per plant (%) | 13.4b | 4.2a | 4.1a | 0a | 12.9b |

**Source:** Author (2026).
Means followed by the same letter do not differ significantly from each other, according to the Scott-Knott test at a 5% probability level.

In the evaluation of soil organic matter (SOM) content performed using the BioAS analysis, Treatments 2 and 5 showed superior performance compared to the others, presenting the highest average values (Table 7). Treatments 1, 3, and 4 were comparable to each other, showing the lowest averages. Notably, in the initial analysis (Initial Analysis), conducted before any fertilization or microbial inoculation, organic matter levels were higher than those observed in Treatments 1, 3, and 4, as shown in Table 7.

**Table 7** - Soil organic matter (SOM) content and base sum of the treatments, determined by BioAS technology.

| **Treatments** | **Soil Organic Matter (g/dm³)** | **Base Sum (BS) (cmolc/dm³)** |
|---|---|---|
| Initial.Analysis | 8.0 b | 1.21 c |
| Treatment 1 (Control) | 6.25 c | 9.6 a |
| Treatment 2 | 9.5 a | 10.1 a |
| Treatment 3 | 6.75 c | 8.65 b |
| Treatment 4 | 6.5 c | 8.7 b |
| Treatment 5 | 9.5 a | 10 a |

**Source:** Author (2026).
Means followed by the same letter do not differ significantly from each other, according to the Scott-Knott test at a 5% probability level.

Base sum (BS) indices showed that T1, T2, and T5 presented similar results. In contrast, Treatments 3 (T3) and 4 (T4) showed lower averages, with comparable values between them, as shown in Table 7.

The results of the BioAS analyses are presented in Table 8. In the BioSoil Quality Index (IQS BioSolo) and Nutrient Cycling evaluations, Treatment 2 was the only one that showed superiority over all other treatments in the study. The other treatments were similar to each other and did not differ from the initial analysis of the experiment. In the IQS Fertbio and IQS Chemical evaluations, T1, T2, and T5 were equivalent and showed higher indices compared to the other treatments. Treatment 3 showed superiority only in relation to T4, which had the lowest index in both evaluations.

In the Nutrient Storage evaluation, all treatments showed improvement in soil quality compared to the initial analysis. Similar results were observed among T1, T2, and T5, which presented the highest indices in this study. Treatment 4 was considered equivalent to T5 but inferior to the other treatments.

The Nutrient Supply evaluation highlighted Treatment 1 as having the highest average. Treatments 2, 3, and 5 were similar and superior to Treatment 4. In this evaluation, all treatments showed improvement in soil conditions compared to the initial analysis.

**Table 8** - Means of the BioAS analysis: initial soil conditions (day 0) and treatment results at the end of the experiment

| | Initial Analyses | T1 (100% $P_2O_5$ + 0% BiomaPhos®) | T2 (50% $P_2O_5$ + 100% BiomaPhos®) | T3 (0% $P_2O_5$ + 100% BiomaPhos®) | T4 (0% $P_2O_5$ + 50% BiomaPhos®) | T5 (50% $P_2O_5$ + 50% BiomaPhos®) |
|---|---|---|---|---|---|---|
| IQS BioSolo | 0.18b | 0.195b | 0.23a | 0.1725b | 0.175b | 0.195b |
| Nutrient Cycling | 0.18b | 0.195b | 0.23a | 0.1725b | 0.175b | 0.195b |
| IQS Fertbio | 0.24d | 0.48a | 0.4475a | 0.38c | 0.3375b | 0.445a |
| IQS Químico | 0.28d | 0.6225a | 0.56a | 0.485b | 0.415c | 0.57a |
| Nutrient Storage | 0.11c | 0.4a | 0.3925a | 0.33b | 0.29b | 0.4075a |
| Nutrient Supply | 0.44d | 0.845a | 0.7275b | 0.6425b | 0.5425c | 0.7325b |

**Source:** Author (2026).
Means followed by the same letter do not differ significantly from each other, according to the Scott-Knott test at a 5% probability level.

## 4 DISCUSSION

In a study conducted on tomato by Passos et al. (2023), the effects of *Azospirillum brasilense* and *Bacillus aryabhattai*, microorganisms capable of solubilizing phosphorus in the soil similarly to *Bacillus megaterium* and *Bacillus subtilis* present in BiomaPhos®, were investigated. Passos observed average plant heights of 79.79 cm in treatments with *Azospirillum brasilense* and 70.93 cm with *Bacillus aryabhattai*. Additionally, average values of 14.43 leaves per plant were recorded with *Azospirillum brasilense* and 10.71 leaves with *Bacillus aryabhattai*, which are lower than those obtained in treatments with BiomaPhos® associated with reduced fertilization (Treatments 2 and 5) in the present study. These results suggest that the combination of *Bacillus megaterium* and *Bacillus subtilis* may present high efficiency in phosphorus availability and stimulation of vegetative growth, indicating a possible complementary effect between the microorganisms when associated with reduced fertilization.

Recent studies involving inoculation with phosphorus-solubilizing bacteria have demonstrated positive effects on tomato vegetative growth and productivity by increasing P availability in the rhizosphere and stimulating physiological mechanisms associated with fruit production (HAILE; TESFAYE; ASSEFA, 2025). These findings corroborate the responses observed in treatments with BiomaPhos®, indicating that phosphorus-solubilizing microorganisms can contribute to maintaining productivity even under partial fertilization reduction or when cultivated in low-fertility soils.

Souza (2023), in a study conducted on wheat, observed that the use of microorganisms such as *Bacillus subtilis* and *Bacillus megaterium* was effective in increasing spike length in two evaluated cultivars. Although this is a different crop, the results reinforce the potential of these microorganisms to improve plant nutritional efficiency. In the present study, treatments with BiomaPhos® associated with a 50% reduction in phosphate fertilization resulted in fruit size similar to that obtained with conventional fertilization, indicating that inoculation may contribute to maintaining commercial fruit standards under reduced mineral P input.

Recent studies indicate that nutritional imbalances, especially related to calcium, may cause physiological disorders in tomato fruits, such as blossom-end rot (KARLSONS et al., 2023). In the present study, the reduction in the incidence of this disorder in treatments with BiomaPhos® suggests that the inoculant may have promoted

better nutritional balance in the soil–plant system. Greater efficiency was observed in treatments with higher inoculant doses, with Treatment 2 (100% BiomaPhos® + 50% $P_2O_5$) being superior to Treatment 5, indicating a possible dose-dependent response of the inoculant.

The evaluation of base sum (BS), which reflects the concentration of $Ca^{2+}$, $Mg^{2+}$, and $K^+$ cations in the soil, showed that inoculated treatments presented behavior similar to the control, even under partial reduction of initial potassium fertilization. Considering that calcium and magnesium were uniformly applied through liming, the results suggest that BiomaPhos® may have contributed to greater efficiency in the dynamics of cation availability in the soil, although further studies are needed to elucidate the mechanisms involved.

In this context, the use of the inoculant promoted an increase in soil organic matter content when associated with phosphate fertilization. This interaction may be related to microbial activity stimulated by the inoculant, favoring mineralization processes and nutrient cycling (AGUILERA et al., 2020). Thus, in treatments combining BiomaPhos® and phosphate fertilization, greater nutrient availability was observed, possibly associated with increased soil biological activity.

In the BioAS analysis, a gradual improvement in soil quality indicators was observed, especially in indices related to biological fertility. The levels ranged from very low to medium, indicating that the effects of the inoculant on soil quality may be progressive and tend to intensify with continuous use over successive cropping cycles. Therefore, a longer evaluation period associated with inoculation is necessary to better elucidate the effects and underlying mechanisms.

## 5 CONCLUSION

BiomaPhos® was associated with a 50% reduction in phosphate fertilization and maintained plant growth, yield, and fruit quality at levels equivalent to full phosphate fertilization. The inoculant reduced the incidence of blossom-end rot, suggesting improved nutritional balance in the soil–plant system.

The combined use of BiomaPhos® and phosphate fertilization improved soil quality indicators, particularly those related to biological fertility and nutrient cycling. These results indicate that BiomaPhos® is a promising strategy to increase phosphorus

use efficiency and reduce dependence on mineral fertilizers in tomato production systems. Further studies under different environmental conditions and cropping systems are necessary to better understand the long-term effects and mechanisms involved in phosphorus solubilization by the inoculant.

## REFERENCES

OLIVEIRA-PAIVA, C. A. et al. Recomendação agronômica de cepas de *Bacillus subtilis* (CNPMS B2084) e *Bacillus megaterium* (CNPMS B119) na cultura do milho. 2020. Disponível em: http://www.infoteca.cnptia.embrapa.br/infoteca/handle/doc/1120362. Acesso em: 05 jan. 2026.

FAN, H. et al. Effects of organic fertilizer supply on soil properties, tomato yield, and fruit quality: a global meta-analysis. **Sustainability**, v. 15, n. 3, art. 2556, 2023. DOI: https://doi.org/10.3390/su15032556.

FERNANDES, C.; CORÁ, J. E.; BRAZ, L. T. Classification of cherry tomatoes based on size and weight of the fruits. **Horticultura Brasileira**, v. 25, p. 275-278, 2007.

HAILE, D.; TESFAYE, B.; ASSEFA, F. Selected phosphate-solubilizing bacteria from tomato rhizosphere as plant growth promoter to improve tomato's growth and production. **International Journal of Agronomy**, art. 6746599, 2025. DOI: https://doi.org/10.1155/ioa/6746599. Acesso em: 27 abr. 2026.

HANYABUI, E. et al. Effect of pineapple waste biochar and compost application on the growth and yield of pineapple varieties in Ghana. **Frontiers in Agronomy**, v. 6, 2024. DOI: https://doi.org/10.3389/fagro.2024.1331377.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE). **Levantamento sistemático da produção agrícola**. Rio de Janeiro: IBGE, 2026. Disponível em: https://www.ibge.gov.br/estatisticas/economicas/agricultura-e-pecuaria/9201-levantamento-sistematico-da-producao-agricola.html. Acesso em: 08 jan. 2026.

KARLSSON, P. E. et al. Deposition of phosphorus to open land and forests in Sweden. **Atmospheric Environment X**, v. 26, art. 100327, 2025. DOI: https://doi.org/10.1016/j.aeaoa.2025.100327.

PASSOS, E. G. C. et al. Use of inoculants in tomatoes to evaluate reduction of nitrogen and potassium fertilizers. **Latin American Journal of Environment and Health**, v. 5, n. 3, edição especial, p. 294-300, 2023.

SOUZA, R. V. **Uso de Bacillus megaterium e Bacillus subtilis na cultura do trigo**. Cerro Largo, 2023.

TAIZ, L.; ZEIGER, E. **Fisiologia vegetal**. 5. ed. Porto Alegre: Artmed, 2013.

**Pesquisas agrárias e ambientais: volume XVIII**. [S. l.]: Pantanal Editora, 2023. 81 p.

AGUILERA, J. G. et al. Respostas de componentes produtivos de soja à inoculação de biológicos em campo. **Ensaios e Ciência**, v. 24, n. 5, edição especial, p. 576-583, 2020.

**DADOS DOS AUTORES:**

**Diogo Aparecido de Carvalho**
**E-mail:** diogoapcarvalho4@gmail.com
**Curriculum Lattes:** http://lattes.cnpq.br/6538868790728463
Engenheiro Agrônomo e mestrando em Fitopatologia pela Universidade Federal de Lavras (UFLA), com atuação em interação planta-patógeno, fisiologia do parasitismo e indução de resistência em cafeeiro. Possui experiência em análises bioquímicas relacionadas à defesa vegetal (PAL, POX, glucanases, quitinases, compostos fenólicos e lignina), microscopia eletrônica de varredura, avaliação de fungicidas e desenvolvimento de protocolos experimentais em campo e laboratório. Atua como consultor agrícola e produtor rural, integrando pesquisa aplicada ao manejo de doenças nas culturas de café, soja e milho. Tem interesse em desenvolvimento tecnológico, validação de produtos e inovação em fitossanidade.

**Rodrigo de Souza Almeida**
**E-mail:** rodrigoodesouzaalmeida@gmail.com
**Curriculum Lattes:** http://lattes.cnpq.br/4607280996495386
Possui graduação em Agronomia pelo Instituto Federal Minas Gerais(2025). Tem experiência na área de Agronomia, com ênfase em Fitotecnia.

**Marcelo Loran de Oliveira Freitas**
**E-mail:** marcelo.freitas@ifmg.edu.br
**Curriculum Lattes:** http://lattes.cnpq.br/7337655297437956
Possui graduação em agronomia pela Universidade Federal de Lavras (2012), mestrado em Agronomia (Fitopatologia) pela Universidade Federal de Lavras (2014) e doutorado em Agronomia (Fitopatologia) pela Universidade Federal de Lavras (2017). Atualmente sou professor de Fitopatologia, Defesa Fitossanitária no IFMG Campus Bambuí.

**Neimar Freitas Duarte**
**E-mail:** neimar@ifmg.edu.br
**Curriculum Lattes:** http://lattes.cnpq.br/3416823923702282
Possui graduação em Agronomia pela Universidade Federal de Viçosa (1995), mestrado em Agronomia (Fitotecnia) pela Universidade Federal de Lavras (2000) e doutorado em Biologia Vegetal pela Universidade Federal de Minas Gerais (2005). Professor titular do

IFMG. Foi diretor de Pesquisa no CEFET Bambuí de 2006 a 2008. Foi coordenador de Pós-graduação de 2009 a 2011, diretor de Pós-graduação de 2011 a 2014, foi Pró-Reitor de Pesquisa, Inovação e Pós-Graduação do Instituto Federal de Minas Gerais no período de 2015 a 2019. Foi docente nos cursos de Agronomia, Engenharia de Alimentos, Zootecnia e Administração nas disciplinas de microbiologia, fitopatologia, tratamento de efluentes, plantas daninhas e outras. Hoje atua no curso de Mestrado em Sustentabilidade e Tecnologia Ambiental, no curso de Engenharia civil e Técnico em Paisagismo. Tem experiência na área de Meio Ambiente e Recursos Florestais, com ênfase em Recuperação de Áreas Degradadas com uso de microrganismos, atuando principalmente nos seguintes temas: sistema agrosilvopastoril, plantas invasoras, microrganismos do solo, valoração e tratamento de resíduos.

**Ricardo Sousa Cavalcanti**
**E-mail:** ricardo.cavalcanti@ifmg.edu.br
**Curriculum Lattes:** http://lattes.cnpq.br/4521520989600993
Possui graduação em Agronomia pela Universidade Federal Rural de Pernambuco (1999), mestrado em Agronomia (Entomologia) pela Universidade Federal de Lavras (2002) e doutorado em Agronomia (Entomologia) pela Universidade Federal de Lavras (2006). Concluiu o pós-doutoramento em Agronomia/Entomologia Agrícola em março de 2007 pela Universidade Federal de Lavras. Tem experiência na área de Agronomia, com ênfase em Entomologia Agrícola, atuando principalmente nos seguintes temas: entomopatógeno, controle biológico, controle microbiano, armazenamento e compatibilidade de produtos fitossanitários com entomopatógenos. Atualmente é professor no IFMG Campus Bambuí, responsável pelas disciplinas de Entomologia Geral, Entomologia Aplicada, Acarologia e Nematologia Agrícola, Receituário Agronômico e Controle de Plantas Daninhas. Na Pós-graduação atua como professor no Mestrado Profissional Sustentabilidade e Tecnologia Ambiental do IFMG, em que é responsável pela disciplina Microbiologia Ambiental.

**Fernanda Morcatti Coura**
**E-mail:** fernanda.coura@ifmg.edu.br
**Curriculum Lattes:** http://lattes.cnpq.br/6029912380223962
Possui graduação em Medicina Veterinária pela Escola de Veterinária da UFMG, em 2009, seguida por Mestrado (2011) e Doutorado (2016) em Ciência Animal pela Escola de Veterinária da UFMG. Realizou o Doutorado Sanduíche na Universidade de Nebraska-Lincoln, EUA (2014). Além disso, possui a Licenciatura em Biologia (2021) e especialização em Pós-graduação em Docência (2020). Profissional com experiência em metodologia científica, microbiologia, doenças infectocontagiosas, sanidade animal, zoonoses, biologia molecular e celular. Professora do Departamento de Ciências Agrárias do Instituto Federal de Minas Gerais (IFMG) - Campus Bambuí de 2017 a 2024. Atualmente é professora do IFMG campus Santa Luzia. Foi Coordenadora do Mestrado Profissional em Sustentabilidade e Tecnologia Ambiental do IFMG (2020-2021) e Editora-chefe da Editora IFMG (2022-2023). É coordenadora do curso de pós graduação em Proteção e Defesa Civil (2024).