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Original Article

Commercial characteristics of coffee seedlings produced with different sources of phosphorus and plant growth-promoting bacteria

Características comerciais de mudas de café produzidas com diferentes fontes de fósforo e bactérias promotoras de crescimento de plantas

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Abstract

Considered the economic engine of many countries, the coffee culture represents an important component of the agricultural chain in Brazil. The growing values of commercialization, planting areas, and crop productivity require the acquisition of quality seedlings, which must receive adequate nutritional support through efficient fertilizers. Slow and controlled-release fertilizers, such as organominerals, gain prominence when it comes to increasing efficiency in the use of phosphorus, as well as plant growth-promoting bacteria (PGPB) with phosphate solubilizing characteristics. This study aimed to evaluate the effect of different sources of mineral and organomineral fertilizers, inoculated and non-inoculated with PGPB on the quality parameters of coffee seedlings. In general, the P sources used in the experiment positively interfered with the development of coffee seedlings. This proves that there is a need for nutritional supplementation for the good development of the seedlings. Among the sources used, the organomineral in granulated form showed better performance in coffee seedlings' growth and physiological parameters, proving to be a viable alternative to commonly used fertilizers. The addition of PGPB showed a significant advantage for seedling quality variables.

Keywords: *Coffea arabica* cultivation, organomineral fertilizer, plant growth promoting bacteria, seedling production cost.

Resumo

Considerado o motor econômico de muitos países, a cultura do café representa um importante componente da cadeia agrícola no Brasil. Os crescentes valores de comercialização, das áreas de plantio e da produtividade da cultura requerem aquisição de mudas de qualidade, que devem receber adequado aporte nutricional através do uso eficiente de fertilizantes. Fertilizantes de liberação lenta e controlada, a exemplo dos organominerais, ganham destaque quando se trata de aumento da eficiência no uso do fósforo, assim como as bactérias promotoras de crescimento de plantas (BPCP) com características solubilizadoras de fosfato. Esse estudo teve como objetivo avaliar o efeito de diferentes fontes de fertilizantes mineral e organomineral, inoculados e não inoculados com BPCP, sobre parâmetros de qualidade de mudas de café. De forma geral, as fontes de P utilizadas no experimento interferiram positivamente no desenvolvimento das mudas de café. Isso comprova que existe a necessidade de complementação nutricional para um bom desenvolvimento das mudas. Dentre as fontes utilizadas, o organomineral na forma granulada apresentou melhor desempenho nos parâmetros de crescimento e fisiológicos das mudas de café, mostrando ser uma alternativa viável aos fertilizantes comumente utilizados. A adição de BPCP apresentou vantagem significativa para as variáveis de qualidade das mudas.

Palavras-chave: cultivo de *Coffea arabica*, fertilizante organomineral, bactéria promotora de crescimento de plantas, custo de produção de mudas.

1. Introduction

Coffee (*Coffea arabica*) is considered the economic motor of many countries located in the tropical zones, and represents one of the most traded products worldwide (Figueroa-Hernández et al., 2015). In Brazil, coffee farming occupies a prominent place in agribusiness, being responsible for a significant economic and social

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importance, moving about US$5.5 billion in exports (CONAB, 2022) and generating more than 8.4 million direct and indirect jobs (CNC, 2020). The expectation of coffee production in 2022 is 18.9% higher than that produced in 2021, a negative biennial year, totaling 55.7 million bags in an area 1% larger than the previous year. When compared to the 2020 harvest, a positive biennial year, the expectation for 2022 production is for lower due to climatic factors that occurred between June and September 2021 (CONAB, 2022). However, considering the historical behavior of the culture, these numbers, linked to the increasing commercialization value of the coffee bag, heat up the seedling market, since the increase in planting areas and in the productivity of the culture require the acquisition of quality seedlings.

Among the inputs necessary for the production of quality seedlings, fertilizers must provide adequate nutritional support for the best development of the plant (Dias et al., 2009). However, historically, the incorporation in Brazil of agricultural fertilization practices and technologies, which emerged in temperate countries, was inadequate to the reality of local soils that are highly weathered, with intense microbial activity and occurring in regions of high rainfall, causing large amounts of nutrients applied via fertilizers to be lost (Brasil, 2021).

Phosphorus (P) is one of the most essential elements for plant growth (Taiz et al., 2017) and a nutrient that has low efficiency of use by plants (between 15 and 50%) due to its complex dynamics in the soil, which makes it necessary to apply high amounts of phosphate fertilizers to attend the demand of crops (Figueiredo et al., 2012).

In order to increase the efficiency of phosphate fertilization for crops, one can opt for the use of slow and controlled-release fertilizers (Caione et al., 2012), as well as the addition of microorganisms known as plant growth-promoting bacteria, providing greater sustainability to the system (García et al., 2017). The introduction of new technologies related to the use and management of fertilizers has been observed in the field, with an emphasis on the use of special fertilizers (Franco, 2019). Among the outstanding reasons, we can mention the greater efficiency presented by these fertilizers, as well as improvements in the physicochemical characteristics of the soil, providing an increase in crop production (Lemos, 2017), making it essential for the protagonism of national agriculture in the aspects related to climate change and global warming (Brasil, 2021).

The organominerals category grew by 80.5% in the specialty fertilizers market between 2019 and 2020 (ABISOLO, 2021). Several scientific results demonstrate the efficiency of organomineral fertilizers in the most varied cultures, such as corn (Aguiar, 2022; Fernandes et al., 2020; Franco et al., 2020; Teixeira et al., 2011), beet (Aguiar et al., 2021), pepper (Macedo et al., 2021), strawberry (Farnezi et al., 2020), and sugar cane (Teixeira et al., 2012; Teixeira, 2013; Borges et al., 2019; Estrada-Bonilla et al., 2021).

The management of interactions between bacteria, soil, and plants has emerged as a powerful tool in the face of the biotechnological potential of these interactions, evidenced by the increase in crop productivity, reduction of production costs through the lower volume of applied fertilizers, and better conservation of environmental resources. However, to achieve the maximum of these benefits, inoculation technology based on growth-promoting bacteria must be used together with the appropriate levels of fertilization (Souza et al., 2015).

Inoculation is one of the most important sustainable practices in agriculture because microorganisms establish associations with plants and promote their growth through several beneficial characteristics (Souza et al., 2015), including the ability to solubilize inorganic phosphates that are unavailable, transforming them into available form for absorption by plants (Rodriguez et al., 2006; Sharma et al., 2013; Mendonça et al., 2020).

Scientific studies using plant growth-promoting bacteria have been published in the most diverse cultures, such as corn (Shen et al., 2021), coffee (Urgiles-Gómez et al., 2021), cucumber (Shao et al., 2015), tomato (Puri et al., 2020), wheat (Silveira et al., 2016) and cotton (Arshad et al., 2016).

The economic evaluation is as important as the technical evaluation in the quality seedling production system (Dias et al., 2011). The costs of inputs such as seeds, fertilizers, pesticides, and substrates are considerable and can add up to 28.3% of the total cost of seedling production (Hahn, 2006).

In this context, this experiment aimed to evaluate the effect of different sources of mineral and organomineral fertilizers, inoculated and not inoculated with PGPB, on quality parameters of arabica coffee seedlings, aiming at their establishment in the field and analyzing the cost of fertilization obtained in each treatment.

2. Material and Methods

The experiment was carried out in a greenhouse, at the Agronomy Department of the Federal University of Vales do Jequitinhonha and Mucuri - UFVJM, at Diamantina - MG. Seeds of arabica coffee (Catuaí Vermelho IAC 144) were sown in 11 x 22 cm plastic bags containing soil, muck, and phosphate fertilizers, in the proportion of 700 L of soil, 300 L of muck, 0.5 kg of KCl, and the equivalent of 5 kg of Simple Superphosphate, according to Ribeiro et al. (1999).

The experimental design adopted was randomized blocks, with 4 replications, arranged in a 7 x 2 factorial scheme. The effect of the source of phosphorus (P) on seedling growth was evaluated in the first factor while the association PGPB through inoculated and non-inoculated seedlings was the second factor. The fertilizers used, except Simple Superphosphate, contained P in the form of Monoammonium Phosphate (MAP), protected or not. In addition to the control treatment (without fertilization), the treatments included the pelleted organomineral (POM) 06-30-00, granulated organomineral (GOM) 05-26-00, bran organomineral (BOM) 05-26-00, coated MAP 10-50-00; conventional MAP 11-52-00 and Simple Superphosphate 00-18-00. The inoculant contained a mix of *Bacillus subtilis* and *Bacillus licheniformis*, with a minimum concentration of $1x10^9$ CFU/ml. The applied dose was equivalent to 700ml of inoculant per ton of fertilizer. The dose of phosphate fertilizers was based on Ribeiro et al. (1999)'s recommendation for the use of P in the form of Simple Superphosphate, having been converted into P_2O_5 and calculated based on the concentration of each fertilizer.

The seeds underwent treatment before sowing, which consisted of manually removing the parchment and remaining in clean water, changed daily, for seven days. The seedlings were irrigated daily and the necessary cultural treatments were carried out manually, according to the requirements of quality seedlings production.

As soon as 50% of the plants presented five pairs of definitive leaves, an indicative characteristic of the ideal point for commercialization, the growth and quality of the seedlings were evaluated by determining the following characteristics: plant height (cm), measure from the stem to the bud apical; collar diameter (mm), measured with a caliper digital; dry mass (expressed in g), determined on a precision analytical balance; ratio of shoot dry mass to root dry mass (SDM/RDM); DQI: Dickson's quality index, obtained by the formula DQI = [total dry mass/ (RHD (ratio of the height with the diameter of the collar) + RSRDM (ratio of the dry mass of the shoot with the root dry mass)] (Dickson et al., 1960) and leaf area (cm^2) following a non-destructive method (Antunes et al., 2008).

To interpret the data of the variables above, analysis of variance was used, using the F test at 5% probability. The splitting of the significant interaction was performed, adopting the Tukey test ($p < 0.05$) for the comparisons of means.

The leaves of each treatment were used as a single sample to determine leaf P content through chemical tissue analysis.

The soil not adhered to the roots was collected in each treatment, homogenized, and sampled to determine chemical attributes, specifically the phosphorus content.

Also, the commercialization prices of each fertilizer used in the treatments were raised to analyze the cost of fertilization in the production of each thousand seedlings. It was considered that the addition of plant growth-promoting bacteria did not increase the cost of fertilizers.

3. Results and Discussion

The results of the statistical analyzes indicated that Leaf Area (LA) and Dickson's Quality Index (DQI) were influenced ($p<0.05$) only by the P source effect. The ratio of shoot dry mass to root dry mass (SDM/RDM) showed significant interaction ($p<0.05$) in the relationship between phosphate sources and plant growth-promoting bacteria.

The number of leaves (NL) is an important variable in coffee seedlings as it indicates the maturation stage in which the plant is ready to go to the field. Generally, seedlings are considered suitable for sale with ten definitive leaves (five pairs) (Oliveira et al., 2012). In this experiment, plants that received P, inoculated or not, showed superior performance to the control in terms of the number of leaves, indicating the importance of phosphate fertilization in the initial growth of coffee seedlings. The seedlings of the control treatment presented an average of only 3.25 and 3.5 leaves when not inoculated and inoculated, respectively, which indicates little or no survival condition in the field (Table 1).

Leaf area is an important variable, indicative of plant productivity since photosynthesis depends on the interception of light energy by the canopy and its conversion into chemical energy (Favarin et al., 2002; Fleck et al., 2009).

All treatments that received phosphate fertilization showed an increase in leaf area, differing ($p<0.05$) to the control treatment, demonstrating that, in addition to the greater number of leaves produced, they had better development, reinforcing the importance of fertilization and response of the coffee crop to phosphorus.

Table 1. Number of leaves (NL), leaf area (LA), shoot dry mass (SDM), and root dry mass (RDM) of *Coffea arabic*a L. (Catuai Vermelho IAC 144) seedlings with and without growth-promoting bacterial (PGPB) application, fertilized with different sources of phosphate, at 180 days after sowing.

P sources	NL		LA (cm^2)		SDM (g)		RDM (g)	
	PGPB	No PGPB	PGPB	No PGPB	PGPB	No PGPB	PGPB	No PGPB
Control	3.5 bA	3.25 cA	12.66 cA	13.98 eA	0.21 dA	0.20 dA	0.09 dA	0.08 cA
POM	8.75 aA	8.5 abA	76.67 bA	73.21 cdA	0.78 bcA	0.74 bcA	0.43 cA	0.31 bB
GOM	9.5 aA	9.0 aba	91.81 aA	87.64 aA	0.94 abA	0.91 abA	0.82 aA	0.71 aB
BOM	9.5 aA	9.0 aba	76.93 bA	77.17 bcA	0.65 cA	0.63 cA	0.44 cA	0.42 bA
cMAP	10aA	9.75 abA	91.54 aA	87.13 abA	0.97 aA	0.95 aA	0.62 bA	0.59 aA
MAP	8.5 aA	8.25 bA	71.60 bA	66.55 dA	0.82 abcA	0.75 bcA	0.38 cA	0.34 bA
SimpleS	10aA	10.0 aA	97.20 aA	91.79 aA	0.98 aA	0.97 aA	0.63 bA	0.59 aA
Average	8.53	8.25	74.06*	71.07	0.76	0.74	0.49*	0.43
CV %	9.25		6.51		11.17		15.92	

Control: without fertilization; POM: pelletized organomineral 06-30-00; GOM: granulated organomineral 05-26-00; BOM: bran organomineral 05-26-00; cMAP: coated monoammonium phosphate 10-50-00; MAP: convencional monoammonium phosphate 11-52-00; SimpleS: simple superphosphate 00-18-00; PGPB: inoculated with plant growth-promoting bacteria; No PGPB: not inoculated with plant growth-promoting bacteria; CV%: coefficient of variation. Means followed by the same lowercase letter in the column and uppercase in the row do not differ from each other, by Tukey 's test at 5% probability. *Differ from each other by the F test at 5% probability.

The coffee seedling´s leaf area was positively and significantly influenced by the inoculation with PGPB, allowing an increase of 4% in the average of this variable when compared to the non-inoculated ones.

The higher values of LA and NL were observed when using Simple Superphosphate, GOM, and coated MAP, regardless of inoculation with bacteria. This result is different from that found by Machado (2019) who obtained an equivalent increase in leaf area between these fertilizers and conventional MAP. In a study carried out by Oliveira (2021), among the phosphate sources tested, the organomineral in the pelleted form was the one that presented results in leaf area superior to the others

A source of fertilization choice should be based on its efficiency in supplying P to the plants. The supply of the nutrient through slow-release fertilizers has been shown efficient in the best coffee crop´s development, providing plants with greater leaf area, greater height increments, and greater accumulation of leaf and root matter (Oliveira, 2021).

In addition to the number of leaves and their photosynthetically active area, the shoot's dry matter is another important characteristic for the evaluation of the robustness of the shooting part and the consequent coffee seedling's quality.

When the fertilizers were submitted to bacteria inoculation, the phosphate sources Simple Superphosphate, coated MAP, GOM, and conventional MAP provided higher shoot dry mass in plants, with the efficiency of phosphorus supply to culture.

By verifying canola and tomato plant development, in addition to other tree species, inoculated with different strains of growth-promoting bacteria, Puri et al. (2020) also observed significant increases in the aerial part of the plants when there was inoculation.

The inoculation with bacteria increased the root system dry mass (RDM) of coffee plants by approximately 14% in relation to the non-inoculated ones. A similar result was found by Shen et al. (2021) where the root weights of corn seedlings treated with different types of PGPB were significantly higher than the control group. The authors observed that seedlings submitted to microbial treatments developed longer, stronger roots with more lateral roots than those in the control group, without the addition of microorganisms (Shen et al., 2021). The same effects were observed by Shao et al. (2015) on the production of cucumber inoculated with *Bacillus amyloliquefaciens*.

Puri et al. (2020) observed significant increases in root growth of canola and tomato plants when inoculated with bacteria, both in root length and dry mass, results attributed to the activity of the ACC deaminase enzyme. Also Kuan et al. (2016) obtained results that indicated that variables like the dry biomass of the shoot, root, and corn cobs were significantly influenced by the inoculation of *Bacillus* sp. at different stages of plant development.

The different fertilization treatments showed the importance of phosphate fertilization in the establishment of the coffee root system, with higher averages, differing from the control. It is noted that the source of GOM fertilizer with PGPB inoculation corresponds to the highest average of root dry mass in coffee plants, evidencing the advantage and possible alternative of use as an efficient source of phosphorus supply for the crop.

Seedlings with a well-developed root system perform better after planting in the field because they have a greater root-soil interaction area, facilitating the absorption of water and nutrients (Oliveira, 2021), especially P, due to its low mobility and high adsorption in soils.

Analyzing each phosphorus source separately, the inoculation of the growth promoting bacteria interfered significantly ($p<0.05$) in the dry mass of the plants only for the root system and when granulated and pelleted organominerals were used.

The ratio between the dry mass of shoot and the roots is a quality variable that indicates the proportionality between the aerial and underground portions of the plant. The values of this ratio varied between 1.20 and 2.45, corresponding to the inoculated GOM treatment and the non-inoculated control, respectively (Table 2).

The highest values of the shoot/root ratio found for the control indicate the little development of the root system due to the scarcity of nutrients available to the plants since the treatment was not fertilized.

Similar results were found by Sardinha (2019) when testing slow-release sources in the production of coffee seedlings in tubes. The author found the highest values for the shoot/root ratio when the phosphate sources were POM, BOM, and control.

The quality of seedlings, estimated through the DQI, is a variable that integrates the growth and the allocation of plant biomass, taking into account the results of the direct variables that were previously analyzed. Dickson's quality index (DQI) = [total dry matter/(RSD+RSR)] was calculated, where RSD is the ratio between height and diameter, and RSR is the ratio between shoot and root dry matter (Dickson et al., 1960). Dickson's quality indices ranged between 0.05 and 0.10 in this experiment.

All phosphate treatments obtained significantly higher rates than the control, regardless of inoculation with PGPB. The highest value observed was for treatments with GOM, followed by coated MAP and Supersimple. The biggest difference (2 times higher) was found in favor of GOM in relation to the average DQI observed in the control.

Dickson quality indices had higher values of collar diameter, shoot and total dry mass, as found in Fonseca et al. (2002).

For Fonseca et al. (2002), the Dickson quality index is a good indicator of seedling quality, since its calculation considers the robustness and balance of the biomass distribution in the seedling, weighing the results of several important parameters used for quality assessment.

These results were possible due to the balance found in the development of seedlings fertilized with P and inoculated with bacteria, which benefited the development of both the root system and the aerial portion of the plants, providing commercial quality to the seedlings.

In addition to the physical characteristics of the seedlings described above, information about the location of the nutrient in the soil-plant system can help to analyze the effect of the different fertilizers used in this experiment, as well as the bacteria on the movement of P.

Table 2. Shoot dry matter and root dry matter ratio (SDM/RDM) and Dickson quality index (DQI) of *Coffea arabica* L. (Catuai Vermelho IAC 144) seedlings with and without growth-promoting bacterial (PGPB) application, fertilized with different sources of phosphate, at 180 days after sowing.

P sources	SDM/RDM		DQI	
	PGPB	No PGPB	PGPB	No PGPB
Control	2.19 aA	2.45 aA	0.05 dA	0.05 dA
POM	1.79 abB	2.38 aA	0.08 bcA	0.07 cA
GOM	1.20 bA	1.30 cA	0.10 aA	0.10 aA
BOM	1.49 abA	1.53 bcA	0.07 cdA	0.07 cA
cMAP	1.56 abA	1.61 bcA	0.09 abA	0.09 abA
MAP	2.13 aA	2.16 abA	0.08 bcA	0.08 bcA
SimpleS	1.55 abA	1.64 bcA	0.09 abA	0.09 abA
Average	1.87	1.7	0.08	0.08
CV %	18.13		10.36	

Control: without fertilization; POM: pelletized organomineral 06-30-00; GOM: granulated organomineral 05-26-00; BOM: bran organomineral 05-26-00; cMAP: coated monoammonium phosphate 10-50-00; MAP: convencional monoammonium phosphate 11-52-00; SimpleS: simple superphosphate 00-18-00; PGPB: inoculated with plant growth-promoting bacteria; No PGPB: not inoculated with plant growth-promoting bacteria; CV%: coefficient of variation. Means followed by the same lowercase letter in the column and uppercase in the row do not differ from each other, by Tukey's test at 5% probability.

Table 3. Means of P content in leaves (P LEAF), P content in the soil after the experiment (P SOIL) and Fertilization cost of 1000 units of *Coffea arabica* L. (Catuai Vermelho IAC 144) seedlings with and without growth-promoting bacterial (PGPB) application, fertilized with different sources of phosphate, at 180 days after sowing.

P sources	P LEAF (dag /kg)		P SOIL (mg.dm^{-3})		Cost (R$/1000 seedlings)	
	PGPB	No PGPB	PGPB	No PGPB	PGPB	No PGPB
Control	0.25	0.26	63.6	65.1	0	0
POM	0.27	0.25	371.4	398.4	30.00	30.00
GOM	0.22	0.25	338.8	368.1	35.65	35.65
BOM	0.28	0.23	603.2	637.1	33.82	33.82
cMAP	0.29	0.25	461.0	467.1	19.44	19.44
MAP	0.23	0.22	394.5	406.5	15.58	15.58
SimpleS	0.27	0.24	428.9	433.8	25.00	25.00

Control: without fertilization; POM: pelletized organomineral 06-30-00; GOM: granulated organomineral 05-26-00; BOM: bran organomineral 05-26-00; cMAP: coated monoammonium phosphate 10-50-00; MAP: convencional monoammonium phosphate 11-52-00; SimpleS: simple superphosphate 00-18-00; PGPB: inoculated with plant growth-promoting bacteria; No PGPB: not inoculated with plant growth-promoting bacteria.

The results obtained for the phosphorus content in the leaf portion of coffee seedlings were higher, on average, for treatments fertilized with coated MAP and POM (Table 3).

Observing the release of phosphorus (P) and its availability to plants from mineral and organomineral fertilizers, Teixeira (2013) found that with the passage of time and with the organomineral fertilizer, there was less soil adsorption of P, increasing up to 15% the nutrient availability for sugarcane plants, which may reflect in higher foliar content.

In general, the values found for the foliar P content were numerically higher when the treatments were submitted to inoculation with PGPB. The control and the organomineral in granulated form were the exceptions.

Estrada-Bonilla et al. (2021) observed that the use of compost from sugarcane industry residues as a source of P and co-inoculation with PGPB increased the P content in the shoot in sugarcane plants compared to the non-inoculated treatments that received only compost or other forms of soluble P.

The results of soil analyses carried out after the dismantling of the experiment showed that the levels of P remaining in the soil were lower in treatments that contained PGPB, which may have resulted from the ability of bacteria to solubilize P, making it accessible to the plant, which reflected in the foliar content of the plants. The opposite is also true for treatments without bacteria, where the remaining P contents are higher, showing that the nutrient remained in forms unavailable to the plant in a higher proportion than the other treatments.

For Oliveira (2021) the POM and BOM are alternatives to enhance coffee growth, as the positive results may reflect the efficient phosphorus use, supplied gradually, and the organic fraction present in the composition of these fertilizers, providing protection on the mineral fraction, ensuring that nutrients are less prone to losses.

Moving on to the economic issue of the use of alternative fertilizers in the production of coffee seedlings, Table 3 shows an average estimate of the cost of fertilizing one thousand seedlings, for each fertilizer, considering the average marketing value in October 2022.

It follows that the lowest cost related to fertilization would be for the conventional MAP, however, it is necessary to point out that this treatment was not among those that presented better results in the growth variables described above. Therefore, despite the economic analysis of seedling production systems being as important as the technical analysis, they must be permeated by the search for quality seedlings (Dias et al., 2011).

Among the treatments that presented the best performance in the growth variables analyzed in this study, coated MAP and Simple Superphosphate presented the lowest fertilization cost values, R$19.44 and R$25.00 per thousand seedlings, respectively.

The GOM, despite having presented the highest DQI, also presented the highest fertilization cost. This result may be related to the GOM formulation used in the experiment, which had approximately half the concentration of P when compared to coated MAP, another source characterized as a controlled release. This factor causes a greater amount of fertilizer to be demanded to supply the fertilization recommendation of the technical documents, in this case, the 5th Approximation. Probably, this cost can be reduced when the fertilizer has a higher concentration of the nutrient, which can even influence the reduction of the seedling production time since the treatment in question presented a satisfactory number of leaves (sales pattern).

4. Conclusions

In general, the P sources used in the experiment interfered positively with the development of coffee seedlings. This proves that there is a need for nutritional complementation for the good development of seedlings.

Among the sources used, GOM presented the best performance in the growth and physiological parameters of coffee seedlings, showing to be a viable alternative to commonly used fertilizers.

The addition of PGPB presented a significant advantage for the seedling quality variables.

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