

REGULAR ARTICLE

Different sources of phosphorus in coffee tree formation

Guilherme Serafini Amaral¹, Kleso Silva Franco Junior¹, Giselle Prado Brigante¹, Marcio de Souza Dias²

¹Machado Higher Education and Research Center, CEP, Machado, MG, Brazil.

²Minas Gerais State Secretary of Education, CEP, Serrania, MG, Brazil.

Regular Section

Academic Editor: Fernando Ferrari Putti

Statements and Declarations

Data availability

All data will be shared if requested.

Institutional Review Board Statement

Not applicable.

Conflicts of interest

The authors declare no conflict of interest.

Funding

This work did not have financial support.

Author contribution

GSA: experimental data collection, literature review, writing the manuscript; KSFJ: conceptualization, data custody, data analysis, writing the manuscript; GPB: literature review, writing the manuscript; MSD: manuscript review, literature review.

Abstract

Arabica coffee is one of the main crops in Brazil and requires balanced nutrition. Among the nutrients, phosphorus is essential in planting so that seedlings can be successful in the after transplanting, allowing a good development and growth. The use of quality seedlings and balanced fertilization is essential for this, however, Brazilian soils, due to their mineral origins, have the characteristic of adsorbing part of the applied phosphorus, making it unavailable to plants. Therefore, the objective of this work is to verify if the sources of phosphorus when applied to the soil can be more efficient in relation to the growth and initial development of the coffee tree. The study was carried out in randomized blocks with five treatments and five replications: T1 - formulation 02-10-00; T2 - formulation 00-15-00; T3 - formulation 10-49-00; T4 - formulation 00-19-00; T5 - control, where phosphorus was not applied. After 120 days, after planting, the characteristics of the seedlings were measured, verifying root length, plant height, fresh matter, dry matter and leaf area index. Data were submitted to analysis of variance and Scott-Knott test with 5% probability. It was concluded that the treatments T1 (02-10-00) and T3 (10-49-00) provided better coffee development, proving to be a valid option for the coffee grower aiming at a better performance of phosphorus (P), an element of great complexity in plant nutrition in tropical soils.

Keywords

Organomineral; Phosphate rock; MAP; Seedling transplantation



This article is an open access, under a Creative Commons Attribution 4.0 International License.

Introduction

Arabica coffee is one of the most cultivated crops in Brazil, spread mainly in the southeastern region of the country. Its exact origin is uncertain; however, it is believed to be originally from the high regions of Ethiopia (Abic, 2020).

In Brazil, the culture was initially introduced in the state of Pará, in the mid-eighteenth century. Nevertheless, climatic factors in the region hampered productivity, consequently leading to the migration of the culture to other states. A good adaptation was reached in the states of Minas Gerais and São Paulo due this region's climate, characterized as the largest productive areas in the country (Abic, 2020; Conab, 2021). Currently, the cultivation of arabica coffee belongs to a territorial extension of 1.7 million hectares, with an average productivity of 22.71 sc ha⁻¹ (Conab, 2021; Conab, 2021).

Belonging to the *Rubiaceae* family, its main characteristic is a reddish-colored fruit. Still, it is worth mentioning that there is a great variability regarding its morphology, which results from crosses and mutations (Alves, 2008).

The morphology of the aerial part of the coffee plant has two branches that are separated into two types: those that

develop vertically (orthotropics) and those that develop horizontally (plagiotropics), thus providing a cylindrical shape developed in a single orthotropic stem (Alves, 2008).

The leaves develop on the plagiotropic branches, and their leaf blades range from 12 to 24 cm. Flowers are present in the portion of the plagiotropic branches developed in the previous season (Alves, 2008). Coffee flowering cannot endure severe water deficit and it requires temperatures between 19 °C and 21 °C, with an annual rainfall ranging from 1,400 mm to 1,500 mm homogeneously during the spring (Alves, 2008).

According to Malavolta et al. (1993), nutrient extraction is the amount of minerals which a plant extracts from the soil and that is contained in all its parts, encompassing the entire root system and also the aerial part of the plant. It is worth mentioning that the aerial part of the plant is everything above the soil layer.

The coffee plant continuously accumulates dry matter from 6 to 78 months of age, while its nutritional requirement up to 18 months is small. However, there is a significant increase from this age onwards, mainly when fertilization should aim

* Corresponding author

E-mail address: marciodesouzadias2013@gmail.com (M.S. DIAS).

at plant maintenance and production development (Malavolta, 1993).

Phosphorus is available in the soil through two large groups, inorganic and organic, which depend on the nature of the compound to which it is bound. Yet, identification is complex due to the fact that it refers to the infinity of reactions that the element undergoes, as well as its resulting compounds (Gatiboni, 2003).

In general, phosphorus is one of the main macronutrients essential for plant development. According to Oliveira et al. (1982), it is considered as the most used element in fertilization, and the one that research has been focusing the most on. It is also worth mentioning that phosphorus promotes root formation and growth, as well as improves water absorption efficiency (Souza et al., 2007).

As for its nature, phosphate fertilizers can be classified as reactive or as having low solubility. Nevertheless, in the formation of seedlings sources, phosphate fertilizers are soluble to the high availability of phosphorus in the seedlings (Carmo et al., 2014).

In coffee culture, excessive doses are mainly used during planting, however, the absorption of the seedlings is not efficient because it provides a reduced root system. On the other hand, the remarkable response of plants to phosphate nutrition in its initial stage can be associated with the importance that phosphorus develops in protein synthesis. In addition to constituting nucleoproteins necessary for cell division and acting in the process of ionic absorption, it has great influence on the development of the root system (Malavolta, 1980).

The different sources of phosphorus have different characteristics in terms of their solubility, chemical composition, granulometry, reactivity, and also their release rate. This nutrient is also seen as a major constraint in the development and initial growth of different crops, since tropical soils have a high degree of weathering (Machado et al., 2012).

Thus, the efficiency of fertilization depends mainly on the used doses and sources, as well as the cation exchange capacity. It is important to highlight that adequate and balanced nutrition along with other factors provide and define productivity (Dias et al., 2015). On the other hand, the use of fertilizers by plants influences agronomic efficiency (AE). The fertilizer represents the amount of increment in crop production, considering the type and dose of fertilizer applied (Silva et al., 2011). Silva et al. (2011) also highlights that, due to the low values of AE, with the use of phosphorus, it is necessary to be careful and use this nutrient efficiently, making it essential to deepen studies and research aimed at the knowledge of phosphate fertilizers.

Given the above, the objective of the present study is to evaluate the efficiency of different sources of phosphorus in the initial development of the coffee plant.

Materials and methods

The experiment was carried out between February and November 2021, in the city of Machado, located in the state of

Minas Gerais, Brazil, at the following geographic coordinates: Latitude 21° 39' 40" South, Longitude 45° 55' 30" West. The city is located at an altitude of approximately 900 m and its main climatic characteristic is 'hot temperate', whose average annual temperature is 20.2 °C and the average accumulated precipitation is around 2500 mm (Climatedata-Org, 2013).

The experiment was carried out in generalized randomized block designs (GRBDs), with five treatments of different sources of phosphorus, which were as follows:

T1 – 02-10-00 source: organomineral, dosage: 500 g/pot;

T2 – 00-15-00 source: Phosphate Rock, dosage: 340 g/pot;

T3 – 10-49-00 source: protected monoammonium phosphate (MAP), dosage: 105 g/pot;

T4 – 00-19-00 source: Super single phosphate, dosage: 270 g/pot;

T5 – 00-00-00 control, source: without application, dosage: 0 g.

The treatments were based on the application of 50 g of P₂O₅ and had five replications. Nitrogen supplies were adjusted and applied equally to all treatments, preventing nitrogen variation from interfering with the results.

The adopted cultivar was *Catuá Vermelho 144*, and the planting took place in pots with a capacity of 20 kg, containing the substrate that came from ravine soil, prioritizing control of the experiment environment. In addition, the seedlings used in the experiment were acquired from an accredited nursery, having the stamp from the Brazilian National Register of Seeds and Seedlings (RenaseM/Mapa, 2020).

The transplanting of the seedlings to the experimental units took place in July 2021. After the completion, doses of phosphorus were applied, in a single dose for each treatment. After 120 days of application, the characteristics of the transplanted coffee seedlings were evaluated, taking the measurements of: root system length (cm); plant height (cm); fresh matter weight (g); dry matter weight (g), and leaf area index (LAI), as proposed by Barros et al. (1973).

Soil sampling was also carried out in each pot, using a Dutch auger, in the 0 - 20 cm layer. The sample was sent for soil analysis in order to evaluate the levels of P.

The data following the evaluation were systematically listed in a table and submitted to analysis of variance (ANOVA). The obtained averages were compared by the Scott-Knott test with 5% probability, using the SISVAR® software (Ferreira, 2014).

Results and discussion

The evaluations of the seedlings characteristics, after 120 days of the application of the treatments presented in Table 1, show that the treatments were statistically different in the evaluation of the plant height (PH), meaning T3 (10-49-00) provided larger plants. In addition, the root length (RL) showed better results for treatments T1 (02-10-00) and T3 (10-49-00).

The leaf area index (LAI) showed better results for T1 (02-10-00), which may come from the organomineral formulation.

However, it can be observed in fertilizers with higher phosphorus concentrations, that T3 (10-49-00) and T4 (00-19-00) produced lower LAI results when compared to T2 (00-15-00).

Table 1. Means of observed characteristics of coffee seedlings with the application of different phosphorus sources.

Treatment	PH		RL		LAI	
T1 02-10-00	7.66	C	9.00	A	1.32	A
T2 00-15-00	6.46	D	7.40	B	1.17	B
T3 10-49-00	10.26	A	8.60	A	1.07	C
T4 00-19-00	9.80	B	7.20	B	1.00	C
T5 00-00-00	4.72	E	6.40	C	0.87	D
CV (%)	27, 44		14.54		16.88	

PH – plant height; RL – root length; LAI – leaf area index. Means followed by the same letters in the column do not differ by the Scott-Knott mean test at 5% probability.

According to Nazareno et al. (2000), the doses of nitrogen, phosphorus, and potassium do not influence the initial growth of the aerial part of the coffee plant in relation to the LAI and plant mass. Nonetheless, the results found in the study go against these statements, due to the fact that the different sources of phosphorus ended up showing the existence of a difference in the growth of the plant among themselves, mainly because of the organomineral source.

The presence of organic matter in the composition allows the release of nutrients in a continuous and regular way, which allows for better use of the nutrients by the culture (Costa et al., 2018). This can be explained by the fact that during mineralization, organominerals form humic and fulvic acids, thus being able to be adsorbed on soil surfaces, which makes it possible to reduce P adsorption by site blocking, permitting the formation of complexes with Al, Fe, and Ca (Mkhabela; Warman, 2005).

The evaluations of aerial parts and root system fresh and dry matter weights (Table 2) showed that treatments T1 (02-10-00) and T3 (10-49-00) presented higher averages for the fresh matter weight of the aerial part (FMWAP), differing

statistically from the other treatments. Even after drying, treatment T1 (02-10-00) still showcased the best result.

The fresh matter weight of the root system (FMWRS) showed a statistical difference between treatments, with the highest average treatment being T1 (02-10-00). However, when analyzing the dry matter weight (DMWRS), there was no significant statistical difference between treatments.

The dry matter weight of the aerial part (DMWAP) showed results with statistically significant differences between the treatments, it impacted the result of the total dry matter weight, which showed a significant difference in the treatments, especially for T1 (02-10-00), the biggest weight. On the other hand, treatment T2 (00-15-00) permitted a lower mean weight referring to DMWRS, which directly reflected on the total dry matter weight (TDMW). Referring to this indicator, T2 ended up presenting a mean lower than the one observed in for the control.

After drying the aerial part matter, it was noted that T1 had the best result, statistically superior to the others.

Table 2. Average values of fresh and dry matter weight of the aerial part and root system and average of the total dry matter of coffee seedlings with different sources of phosphorus.

Treatments	FMWAP		DMWAP		FMWRS		DMWRS		TDMW	
T1 02-10-00	3.70	A	1.31	A	0.64	A	0.30	A	1.62	A
T2 00-15-00	2.15	C	0.74	D	0.44	B	0.17	A	0.91	D
T3 10-49-00	3.64	A	1.18	B	0.47	B	0.24	A	1.41	B
T4 00-19-00	2.56	B	0.91	C	0, 44	B	0.20	A	1.11	C
T5 00-00-00	1.85	C	0.77	D	0.37	B	0.24	A	1.01	C
CV (%)	29.07		24.43		22.90		32 .20		23.63	

FMWAP – fresh matter weight of the aerial part; DMWAP – dry matter weight of the aerial part; FMWRS – fresh matter weight of the root system; DMWRS – dry matter weight of the root system; TDMW – total dry matter weight (TDMW = DMWAP + DMWRS).

Means followed by the same letters in the column do not differ by the Scott-Knott test at 5% probability.

In relation to the fresh matter weight of the root system, T1 allowed for the highest weight when compared to the others, which did not show statistical difference between them. On the other hand, when analyzing dry matter weight of the root system, it was noted there was no statistically significant difference among any of the treatments.

As the dry matter weight of the aerial part showed results with statistical significance, this impacted the result of the total dry matter weight, since it was observed that, statistically, the dry matter weight of the root system showed no difference between treatments. In relation to TDMW, T1 had greater weight than the others.

Figueiredo (2018) reports that the use of superphosphate Yorin showed a tendency of mass accumulation and growth, despite not differing statistically from the control. These results differ from what was found in the present study, where there were statistical differences between treatments.

Corsini et al. (2019) concluded that the super simple phosphate resulted in the best development of coffee seedlings permanently implanted in the field, and that the increase in doses of organomineral acted proportionally to the development of the plants. Yet, since the super simple phosphate is more soluble, it provided better results. The single superphosphate phosphate fertilizer provided better initial development, while the increase in doses of organomineral phosphate fertilizer significantly influenced the development of coffee plants for most evaluated parameters.

Melo et al. (2005) worked with different sources of P, but with evaluations from 30 to 41 months after planting. Their obtained results showed that the sources did not vary in plant characteristics, a fact that can be related to the dynamics of the element in the soil.

After the assessment of the plants, an evaluation of the availability of P₂O₅ in the soil of the pots was carried out in an accredited laboratory, shown in Table 3. The highest availability of phosphorus (P) in the soils, after 120 days of application, can be observed in treatments T1 (02-10-00) and T3 (10-49-00), contrary to what was found in the soil of treatment T2 (00-15-00), with the lowest availability. This may be a result of the source availability, which may have been better used by the plant, or it may be implied that there was leaching of the nutrient.

Table 3. Mean values of P₂O₅ in the soil of the treatments.

Treatments	Availability P ₂ O ₅ (mg/dm ³)
T1 02-10-00	22.70 A
T2 00-15-00	1.14 C
T3 10-49-00	22.0 A
T4 00-19-00	6.50 B
T5 00-00-00	5.60 B
CV (%)	8.94

Means followed by the same letters in the column do not differ by the Scott-Knott test at 5% probability.

It should be noted that the soil used initially had much higher P levels than it was identified at the end of the research. For the knowledge of all the dynamics of P in the soil and its complexities, new research works are always needed to try to help coffee producers to better manage this nutrient.

Conclusions

It is concluded that treatments T1 (02-10-00) and T3 (10-49-00) provided better coffee development, proving itself to be a valid option for the coffee grower aiming at a better performance of phosphorus (P), an element of great complexity in the nutrition of plants in tropical soils.

References

- ABIC – ASSOCIAÇÃO BRASILEIRA DA INDÚSTRIA DO CAFÉ. In: Martins, A. L. (2008). *História do café*. (Editora Contexto). São Paulo, SP, Brazil.
- Alves, J. D. (2008). *Morfologia do cafeeiro*. In: Carvalho, C. H. S. et al. (2008). *Cultivares de café*. (Ed.). Varginha - MG: EMBRAPA, Brazil.
- Barros, R. S., Maestri, M., Vieira, M., Braga-Filho, L. J. (1973). Determinação da área de folhas do café (*Coffea arabica* L. cv. Bourbon Amarelo). *Revista Ceres*, 20(107), 44-52.
- Carmo, D. L., Takahashi, H. Y. U., Silva, C. A., Guimarães, P. T. G. (2014). Crescimento de mudas de cafeeiro recém-plantadas: efeito de fontes e doses de fósforo. *Coffee Science*, 9(2), 196-206.
- Climate-data.org. Clima Machado. 2013. Disponível em: <<https://pt.climate-data.org/america-do-sul/brasil/minas-gerais/poco-fundo-25005/>>. Access in: 12 June 2021
- CONAB – COMPANHIA NACIONAL DE ABASTECIMENTO. **Acompanhamento da safra brasileira – café**. CONAB, 4^o ed., 2020. Available in: <https://www.conab.gov.br/info-agro/safras/cafe>. Access in: 12 June 2021.
- CONAB – COMPANHIA NACIONAL DE ABASTECIMENTO. **Acompanhamento da safra brasileira – café**. CONAB, 1^o ed., 2021. Available in: <https://www.conab.gov.br/info-agro/safras/cafe>. Access in: 12 June 2021.
- Corsini, M., Franco Júnior, K. S., Brigante, G. P., Dias, M., de S. D., Fiorini, F. V. A. (2019). Avaliação do uso de fertilizante organomineral no desenvolvimento de mudas de *Coffea arabica* L. *Revista Cerrado Agrociências*, (10), 7-33. Available in: <https://revistas.unipam.edu.br/in dex.php/cerradoagrociencias/issue/view/157/cerrado_agrociencias_n10_2019>. Access in 14 Feb. 2022.
- Costa, F. K. D., Menezes, J. F. S., Almeida Júnior, J. J., Simon, G. A., Miranda, B. C., Lima, M. S. de, Lima, M. S. de (2018). Desempenho agrônomico da soja convencional cultivada com fertilizantes organomineral e mineral. *Nucleus*, 15(2), 301-309. <https://doi.org/10.3738/1982.2278.2902>
- Dias, K. G. L., Neto, A. E. F., Guimarães, P. T. G., Reis, T. H. P., Oliveira, C. H. C. de (2015). Coffee yield under different phosphorus sources and levels. *Ciência e Agrotecnologia*, 39(2), 110-120. Available in: <https://www.scielo.br/j/cagro/a/BjNGjYCOGKwBwf9tDxH5qXc/?lang=en&format=pdf>. Access in 14 Feb. 2022.
- Ferreira, D. F. (2014). Sisvar: um guia dos seus procedimentos de comparações múltiplas Bootstrap. *Ciência e Agrotecnologia*, 38(2), 109-112. <https://doi.org/10.1590/S1413-70542014000200001>
- Figueiredo, M. S. (2018). *Doses e fontes de P2O5 no desenvolvimento inicial do cafeeiro* (Monografia de conclusão de curso), UNICERP, Patrocínio, Brazil.
- Gatiboni, L. C. (2003). *Disponibilidade de formas de fósforo do solo às plantas* (Tese de Doutorado). UFSM, Santa Maria, Brazil.
- Machado, V. J., Souza, C. H. E. (2012). Disponibilidade de fósforo em solos com diferentes texturas após aplicação de doses crescentes de fosfato monoamônico de liberação lenta. *Bioscience Journal*, 28(1), 1-7.
- Malavolta, E. (1980). Nutrientes e nutrição mineral de plantas. *Agrônoma Ceres*. 251p.
- Malavolta, E., Vitti, G. C., Boaretto, A. E. (1993). Fertilizantes fluidos. *Potafos*, 343p.

- Melo, B., Marcuzzo, K. V., Teodoro, R. E. F., Carvalho, H. P. (2005). Fontes e doses de fósforo no desenvolvimento e produção do cafeeiro, em um solo originalmente sob vegetação de cerrado de patrocínio-MG. *Ciência & Agrotecnologia*, 29(2), 315-321. <https://doi.org/10.1590/S1413-70542005000200007>
- Mkhabela, M. S., Warman, P. R. (2005). The influence of municipal solid waste compost on yield, soil phosphorus availability and uptake by two vegetable crops grown in a Pugwash Sandy loam soil in Nova Scotia. *Agriculture, Ecosystems & Environment*, 106, 57-67. <https://doi.org/10.1016/j.agee.2004.07.014>
- Nazareno, R. B., Oliveira, C. A. S., Sanzonowicz, C., Sampaio, J. B. R., Silva, J. C. P. da, Guerra, A. F. (2003) Crescimento inicial do cafeeiro Rubi em resposta a doses de nitrogênio, fósforo e potássio e a regimes hídricos. *Pesquisa Agropecuária Brasileira*, 38, 903-910. <https://doi.org/10.1590/S0100-204X2003000800002>
- Oliveira, J. S., Miranda, J. E. C. de, Carneiro, J. C, D'Oliveira, P. S., Magalhães, V. M. A. de (2015). EMBRAPA: Como medir a matéria seca (MS%) em forragem utilizando forno micro-ondas. Comunicado Técnico 77. Available in: <https://ainfo.cnptia.embrapa.br/digital/bitstream/item/137606/1/COT-77-Teor-mat-seca.pdf>. Access in 14 Feb. 2022.
- RENASEM. REGISTRO NACIONAL DE SEMENTES E MUDAS. Ministério da Agricultura, Pecuária e Abastecimento. Available in: <http://sistemasweb.agricultura.gov.br/renasem> Access in 19 Jun. 2020.
- Silva, D. R. G., Pereira, A. F., Dourado, R. L., Silva, F. P. da, Ávila, F. W., Faquim, V. (2011). Productivity and efficiency of nitrogen fertilization in maize under different levels of urea and NBPT-treated urea. *Ciência e Agrotecnologia*, Lavras, 35 (3), 516-523. <https://doi.org/10.1590/S1413-70542011000300012>
- Souza, H. A., Pio, R., Chagas, E. A., Rodrigues, J. M., Rodrigues, H. C. A., Ramos, J. D. (2007). Doses de nitrogênio e fósforo na formação de mudas de tamarindo. *Bioscience Journal*, 23(1). Retrieved from <https://seer.ufu.br/index.php/biosciencejournal/article/view/6664>