http://journal.unoeste.br/index.php/ca/index
DOI: 10.5747/ca. 2023.v19.h509
ISSN on-line 1809-8215

Colloquium Agrariae

Submetido: 24/05/2022 Revisado: 28/11/2022 Aceito: 01/02/2023

PHOSPHORUS SOURCES IN THE GROWTH AND QUALITY OF ARABICA COFFEE SEEDLINGS PRODUCED IN TUBES

Levy Tadin Sardinha[1], Andre Cabral França[1], Caroline Maira Miranda Machado[1], Brendo Oliveira Ferreira[1], Leandro Alves Macedo[2], Rafaele Sousa Cruz[1], Samuel Dias Moreira[1], Fausto Henrique Vieira Araújo[1]

[1]Universidade Federal dos Vales do Jequitinhonha e Mucuri – UFVJM, MG. [2]Universidade Federal de Viçosa – UFV. E-mail: levy.tadin@yahoo.com.br

Abstract

The objective of this study was to evaluate the growth and quality of arabica coffee seedlings produced in tubes under different sources of phosphorus (P). The experiment was conducted in a greenhouse in a randomized block design with ten treatments (control, Osmocote®, three doses of pelleted organomineral, three doses of mashed organomineral, MAP, coated MAP) and four replications, three plants per plot. The dose of organomineral, MAP, and MAP coated was based on the recommendation of P_2O_5 for the formation of coffee seedlings. For Osmocote®, the manufacturer's recommendation was used depending on the amount, in dm^3, of substrate. After 180 days of transplanting, the growth characteristics of the plants (leaf dry matter, stem, and roots) were evaluated, and the aerial part and root system ratio and Dickson's quality index were calculated, as well as regression equations were adjusted for the evaluated parameters. For the growth and quality of seedlings, it was observed that in fertilizations with pelleted and branched organomineral, coated MAP and Osmocote®, the highest averages were obtained for the contents of dry matter, height, diameter of the collection and quality indexes, when compared to the other sources of P_2O_5. The dose that provides the maximum growth and quality of coffee seedlings for the treatments with organomineral was calculated, this being equal to 6 g/dm^3 of P_2O_5 for bran and pelleted organomineral. According to the results, the sources that promoted the formation of a vigorous seedling, with an adequate supply of nutrients and a good quality standard are pelleted organonineral fertilization and MAP, reducing the risk of losses and consequently the need to discard the seedlings in the nursery.

Keywords: *Coffea arabica* L.; fertilization management; nursery; slow release of nutrients.

FONTES DE FÓSFORO NO CRESCIMENTO E QUALIDADE DE MUDAS DE CAFÉ ARÁBICA PRODUZIDAS EM TUBETES

Resumo

O objetivo deste estudo foi avaliar o crescimento e a qualidade de mudas de café arábica produzidas em tubetes sob diferentes fontes de fósforo (P). O experimento foi conduzido em casa de vegetação em delineamento de blocos casualizados com dez tratamentos (controle, Osmocote®, três doses de organomineral peletizado, três doses de organomineral farelado, MAP, MAP revestido) e quatro repetições, três plantas por parcela. A dose de organomineral, MAP e MAP revestido foi baseada na recomendação de P_2O_5 para a formação de mudas de café. Para Osmocote®, foi utilizada a recomendação do fabricante em função da quantidade, em dm³, de substrato. Após 180 dias do transplante, foram avaliadas as características de crescimento das plantas (matéria seca de folhas, caule e raízes), calculadas a razão parte aérea e sistema radicular e o índice de qualidade de Dickson, bem como ajustadas equações de regressão para os parâmetros avaliados. Para o crescimento e qualidade das mudas, observou-se que nas adubações com organomineral peletizado e farelado, MAP revestido e Osmocote®, as maiores médias para os teores de matéria seca, altura, diâmetro da coleta e índices de qualidade, quando comparados as outras fontes de P_2O_5. Foi possível identificar a dose que proporciona o máximo crescimento e qualidade de mudas de café para os tratamentos com organomineral, sendo esta igual a 6 g/dm³ de P_2O_5 para o organomineral farelado e peletizado. De acordo com os resultados, as fontes que promoveram a formação de uma muda vigorosa, com aporte adequado de nutrientes e um bom padrão de qualidade são a adubação organomineral peletizada e MAP, reduzindo o risco de perdas e consequentemente a necessidade de descarte das mudas no viveiro.

Palavras-chave: *Coffea arabica* L.; liberação lenta de nutrients; manejo de adubação; viveiro.

Introduction

Coffee is one of the main products traded worldwide, with sales hovering around ninety billion dollars, with Brazil being the world's largest producer (VILELA *et al.*, 2017; SANTOS *et al.*, 2022). Therefore, when it comes to nutrients in coffee, from seedling production to high yielding plantations, experiments targeting fertilizer doses at each stage of production are scarce (SOBREIRA *et al.*, 2011).

In the production of quality coffee seedlings, we have as a limiting factor the fertilization of the substrate (OLIVEIRA *et al.*, 2019), necessary to maximize the development of coffee seedlings, influencing seedling quality and survival under field conditions (SANTOS *et al.*, 2019). Among the essential elements in seedling production, phosphorus stands out for its participation in the physiological processes of the plant and manifests a key role in ATP production reactions for plants (TAIZ *et al.*, 2017).

For fertilizer recommendations, the nutritional demand of the plants for vegetative and reproductive growth is evaluated, considering the efficiency of use of the fertilizers applied (LAVIOLA *et al.*, 2007). Thus, for adequate availability of phosphorus to the plants, the correct management of phosphate fertilization must be considered, evaluating the source used and the most suitable mode of application for the substrate (CORRÊA *et al.*, 2005).

Aimed at producing seedlings at low cost and increasing the efficiency of phosphate fertilizer use, ensuring the adequate development of coffee seedlings, we have the use of slow release technologies, which differ due to their solubility, chemical composition, granulometry, reactivity and release rate (LEMOS *et al.*, 2015; CAIONE *et al.*, 2012). In this way, the objective of this study was to determine the effect of growth and quality of Arabica coffee seedlings produced in tubes, submitted to different sources of P.

Material and Methods

The experiment was conducted in a plant propagation room and greenhouse at the Department of Agronomy of the Federal University of the Valleys of Jequitinhonha and Mucuri - UFVJM, Diamantina, MG, located in the Alto Jequitinhonha region, with an average altitude of 1400 meters, latitude 18°14'17' 'and longitude 43° 36' 40".

A randomized block design (DBC) was used with ten treatments and four replications, three plants per plot, with the Arabica coffee cultivar Mundo Novo IAC 379/19. The commercial substrate used is composed of sphagnum peat, coconut fiber, rice husks, pine husks, and vermiculite.

The tubes (100 mL), used in this work, were washed and sterilized with 2% sodium hypochlorite. The dose of organomineral, MAP, and MAP coated was based on the recommendation of P_2O_5 for the formation of coffee seedlings (MELO *et al.*, 2006). For Osmocote®, a manufacturer's recommendation of 4 g/dm³ of substrate was used. In pelleted and mashed organomineral fertilization, the doses of P_2O_5 used for the experiment were 4, 8, and 12 g/dm³ of a substrate. For the fertilization with MAP and coated MAP, the dose of P_2O_5 used was 5 g/dm³ of substrate. For the control, no fertilization was used.

Seeds of the Arabica coffee cultivar were placed in sandboxes, remained in the growth room, with a temperature of 30 °C and controlled humidity until they reached the stage of “matchstick”. Then, the seedlings were transplanted into the tubes filled with commercial substrate, where the phosphate fertilizers described above were applied. Irrigation was performed daily (water depth of 7 mm/day).

After 180 days of transplanting, when half of the coffee seedlings reached five pairs of fully expanded leaves, seedling growth and quality were assessed by determining the following characteristics: **1)** leaf area, expressed in cm^2, by the non-destructive method (ANTUNES *et al.*, 2008); **2)** height of the aerial part, expressed in cm, measured with a millimeter ruler, from the collection to the apical bud; **3)** stem diameter, expressed in mm, measured with a digital caliper; **4)** leaf dry matter, stem dry matter and root dry matter, expressed in grams, determined on a precision analytical balance; **5)** relationship between shoot dry matter and root dry matter (RPAR); **6)** IQD: Dickson's quality index, obtained by the formula IQD = [total dry matter/(RAD (relationship of height to the stem diameter) + RPAR (relationship between shoot dry matter and root dry matter)] (DICKSON *et al.*, 1960).

The data obtained were submitted to analysis of variance ($p \leq 0,05$), unfolding the significant interaction, using the Tukey test at 5% probability for comparisons between treatments. Regression analysis was also performed depending on the doses of pelleted and mashed organomineral fertilization.

Results and Discussion

The height, stem diameter, and leaf area of the coffee seedlings were affected by the dose and source of P used (Table 1). The highest height was observed in pelleted and mashed organomineral fertilization, at a dose of 4 g/dm³, Osmocote®, and the coated MAP, in which the height was more than ten centimeters. At the highest doses of pelleted and mashed organomineral (12 g/dm³), seedlings had low values for this variable, with averages below seven centimeters in height.

Evaluating the height in isolation, it is not a good characteristic to express the quality of seedlings, because very tall coffee seedlings, with a characteristic of etiolation, may be due to a physiological adjustment in search of light to avoid low irradiance from the environment (DARDENGO *et al.*, 2013). In this study, the greater heights found are justified by the supply of P, in an appropriate dose, causing cell elongation so that the plants invested in growth in height (ARAÚJO, 2009).

The stem diameter of Arabica coffee seedlings was higher in treatments with Osmocote®, pelleted organomineral at a dose of 4 g/dm³, and the coated MAP, obtaining values close to and greater than three millimeters (Table 1). The stem diameter is a characteristic considered less affected by factors such as shading and type of production container (DARDENGO *et al.*, 2013), the diameter of the stem is one of the fundamental characteristics when deciding whether the seedling is ready for planting (MENEGHELLI *et al.*, 2017). According to Santos *et al.* (2010), the larger diameter of the stem can demonstrate more vigorous plants. Coffee seedlings produced in 120 mL tubes with Osmocote® 15-10-10 reached a height of 16.96 cm and a diameter of 2.82 mm (VALLONE *et al.*, 2010).

The highest averages for leaf area were observed in treatments with Osmocote®, pelleted organomineral at a dose of 4 g/dm³ and coated MAP, with average values above 83 cm² (Table 1). This shows that the photosynthetic processes of the coffee seedling, through the supply of P in an adequate amount, allow the seedling to invest in leaf expansion to capture solar radiation. It is important to note that, in absolute values, the highest value obtained in fertilization with pelleted organomineral at a dose of 4 g/dm³, followed by coated MAP and Osmocote®.

The lowest values for leaf area were found in the highest doses of pelleted and mashed organomineral (12 g/dm³), with an average corresponding to approximately half of the maximum values found (Table 1). The evaluation of coffee seedlings considering the leaf area is a relevant characteristic because it interferes with the photosynthetic rate of the plant through the capture of solar energy and in the fixation of CO_2 which results in greater production of photoassimilates with a subsequent location in other organs of the plant (DARDENGO *et al.*, 2013; FERRARI *et al.*, 2015).

Table 1. Height (ALT), stem diameter (DC) e leaf area (AF) of Arabica coffee seedlings produced in tubes and submitted to different sources of P.

Fertilizing	ALT (cm)	DC (mm)	AF (cm²)
Control	5,68 e	1,92 e	11,01 f
Osmocote®	12,31 a	3,05 a	83,67 ab
OMP 4	12,37 a	3,03 ab	87,82 a
OMP 8	10,94 b	2,44 c	75,60 c
OMP 12	6,85 e	2,02 de	42,27 e
OMF 4	11,72 ab	2,80 b	79,52 bc
OMF 8	9,62 cd	2,27 c	61,65 d
OMF 12	6,72 e	1,95 e	45,40 e
MAP	10,85 bc	2,42 c	75,33 c
MAP R.	12,05 ab	2,93 ab	86,25 ab
Overall Average	9,81	2,45	63,4
CV (%)	*9,72*	*7,39*	*9,15*

MAP: Monoammoniumphosphate (09-48-00); MAP R.: MAP coated (10-50-00); OMP: pelleted organomineral (07-30-00); OMF: mashed organomineral (07-30-00); 4, 8, 12: doses de P_2O_5 in g/dm³. Means followed by equal letters in the column do not differ by Tukey's test at 5% probability.

Fertilization with pelleted and mashed organomineral at a dose of 4 g/dm³, Osmocote®, and the coated MAP showed the highest mean dry matter of leaves, with values greater than 0.60 g.

At the highest doses of mashed and pelleted organominerals (12 g/dm³) and the treatment without fertilization, low production of drymatter of the leaves was observed, with values below 0.36 g (Table 2).

An increase in the dry matter content of leaves and roots represents an improvement in the production of coffee seedlings (COGO *et al.*, 2011), this pattern of seedlings should be recommended to the producer in order to reduce their youth (BALIZA *et al.*, 2013). The dry matter of the aerial part is also related to the development of the stem and leaf area because the leaves are responsible for photosynthesis (CARMO *et al.*, 2016).

The highest average dry matter of the stem (Table 2) of Arabica coffee seedlings was above 0.20 g, in treatments fertilized with pelleted and mashed organomineral at a dose of 4 g/dm³, coated MAPand Osmocote®. At the dose of 12 g/dm³ of pelleted and branched organomineral, and in the control, we obtained the lowest averages, with values below 0.1 g.

For root dry matter (Table 2) difference was observed between treatments, where Osmocote®, pelleted and mashed organomineral at a dose of 4 g/dm³ and coated MAP obtained the highest averages, with values close to or above 0.60 g. At the highest doses of organomineral, low production of dry matter from roots is observed, which can infer the effect of salinity on the substrate, predisposing the plant to an environment not conducive to the good development of the root system.

The root dry matter characterizes coffee seedlings, as deep, branched and well-distributed roots that promote good seedling development, being responsible for extracting water, substrates, and anchoring the plant in the soil (PEREIRA *et al.*, 2017). Small, weak vigorous and little branched roots result in smaller plants, delaying their phenological development and consequently the productive response of the coffee crop, leading to the extension of the seedlings' youth fulness and consequent delay at the beginning of production (BALIZA *et al.*, 2013).

The greater development of coffee seedlings in treatments with pelletized organomineral, coated MAP and Osmocote® demonstrate good availability of P in the substrate, stimulating the growth of the roots, and as a consequence the absorption of water and nutrient, promoting a good growth of the seedling. It is important to highlight that the treatments with higher averages for the dry matter content of the seedling also obtained a larger leaf area, allowing the production of adequate dry matter in response to the capture of incident solar radiation by the leaves, this process being a direct reflection of the liquid photosynthetic production added to the good availability of nutrients.

Possibly, the lowest values for leaf, stem, and root dry matter occurred due to the burning of roots resulting from the salinity of the substrate, caused by the excess nutrients inside the tube, affecting the growth of roots, and aerial part, preventing the proper growth of the seedling. The study of biometric characteristics is relevant to obtain information on the production of better-quality seedlings in commercial substrate, using slow-release fertilizers.

Similar results were found for Eucalyptus urograndis seedlings as a function of alternative substrates fertilized with Osmocote®, observing an average of 0.69 g of root dry matter in substrate with coconut fiber, carbonized rice husk and vermiculite (SILVA *et al.*, 2012). According to Sousa *et al.* (2021) studying the use of organominerals in the development of Leucena obtained higher root dry mass and robustness index averages by using organomineral fertilizer. In other words, alternative sources of P to Osmocote® allow satisfactory root growth.

Quantitative assessments are commonly used and are good indicators of coffee seedling growth. However, they can lead to errors when used alone. Situations where excess nitrogen occurs, or leaf growth to the detriment of the root system, cause the use of wrong growth rates. With this in this study, we use relations between these growth indexes, calculated the ratio of the dry matter of the aerial part to the dry matter of roots (RPAR), and Dickson's Quality Score (IQD).

For the aerial part/root system relationship (RPAR), the control treatments, pelleted and mashed organomineral at a dose of 12 g/dm³ were similar and presented higher averages (Table 2). This can be explained by the negative influence of the lack of nutrients and the salinization caused by organomineral fertilization inside the tube, promoting low growth of the root system.

The highest averages for the Dickson Quality Index were in the treatments with Osmocote®, mashed and pelleted organomineral at a dose of 4 g/dm³, and the MAP coated (Table 2). And the lowest averages in those with the highest doses of pelleted and branched organomineral and the most soluble sources of P with values between 0.17 and 0.05, resulting in low-quality of seedlings.

The highest averages for the Dickson Quality Index observed are a consequence of the highest values found for the dry matter content of leaf, stem, and roots, of the height and diameter of the collection, providing the balance of dry matter distribution to the seedling, resulting in the production of quality seedlings, in addition to characterizing a positive correlation with a direct and favorable effect with the main variable under study (IQD) (SILVA *et al.*, 2010). The Dickson quality index was established with an average of 0.24 (LEMOS *et al.*, 2015) and 0.62 (SILVA *et al.*, 2010) for Arabica coffee seedlings. In leucena, seedlings treated with organomineral and mineral fertilizer were found Dickson quality indices of 0.18 and 0.17, respectively (SOUSA *et al.*, 2021).

Table 2. Leaf dry matter (MSF), stem dry matter (MSC), root dry matter (MSR), shoot/root system relationship (RPAR) e Dickson's quality score (IQD) of coffee seedlings produced in tubes and submitted to different sources of P.

Fertilizing	MSF (g)	MSC (g)	MSR (g)	RPAR	IQD
Control	0,14 f	0,05 d	0,09 c	2,31 ab	0,05 c
Osmocote®	0,64 ab	0,21 a	0,57 a	1,55 c	0,25 a
OMP 4	0,66 a	0,23 a	0,60 a	1,50 c	0,27 a
OMP 8	0,52 c	0,19 ab	0,39 b	1,87 bc	0,17 b
OMP 12	0,30 e	0,09 d	0,14 c	2,86 a	0,08 c
OMF 4	0,61 abc	0,20 ab	0,54 a	1,55 c	0,26 a
OMF 8	0,49 cd	0,16 bc	0,36 b	1,62 bc	0,16 b
OMF 12	0,29 e	0,08 d	0,14 c	2,78 a	0,08 c
MAP	0,55 bcd	0,15 c	0,40 b	1,79 bc	0,17 b
MAP R.	0,61 abc	0,22 a	0,57 a	1,48 c	0,25 a
Overall average	0,47	0,16	0,37	1,93	0,17
CV (%)	*16,47*	*18,1*	*20,64*	*23,48*	*18,49*

MAP: Monoammoniumphosphate (09-48-00); MAP R.: MAP coated (10-50-00); OMP: pelleted organomineral (07-30-00); OMF: bran organomineral (07-30-00); 4, 8, 12: doses de P_2O_5 in g/dm³. Means followed by equal letters in the column do not differ by Tukey's test at 5% probability.

From the regression study of the doses of pelleted and mashed organomineral, there was a significant effect on height, stem diameter, leaf dry matter, stem dry matter, root dry matter, aerial part/root system ratio, and quality index from Dickson. For the leaf area, there were differences between doses and between pelleted and mashed organomineral fertilization (Figure 1).

The height and diameter of the stem (Figure 1A and 1B) showed quadratic behavior, with higher values at the dose of 4 g/dm³ of P. At higher doses, there was a drop in the seedling growth curve. The seedlings showed a late response to the dose of 8 g/dm³ of P, showing values close to the treatment with half of this dose. This indicates that the saline environment formed reduced the formation and growth of the seedling.

It is also noted that the maximum point of this curve, which corresponds to a value where the height and diameter of the stem are maximized, corresponds to 6.23 and 5.77 g/dm³, respectively. Regarding the leaf area (Figure 1C), a parameter that is influenced by phosphate fertilization (SOUZA *et al.*, 2014) we observed that for treatments fertilized with organomineral, the pelletized material stood out from the bran, presenting higher averages in the doses of 4 and 8 g/dm³ of P, demonstrating the importance of using controlled release fertilizers for the ideal development of the leaf area of the seedlings. The dose of 6.58 g/dm³ for the pelleted organomineral and 6.81 g/dm³ for the bran organomineral are the doses in which the leaf area is at its maximum value, according to each equation generated.

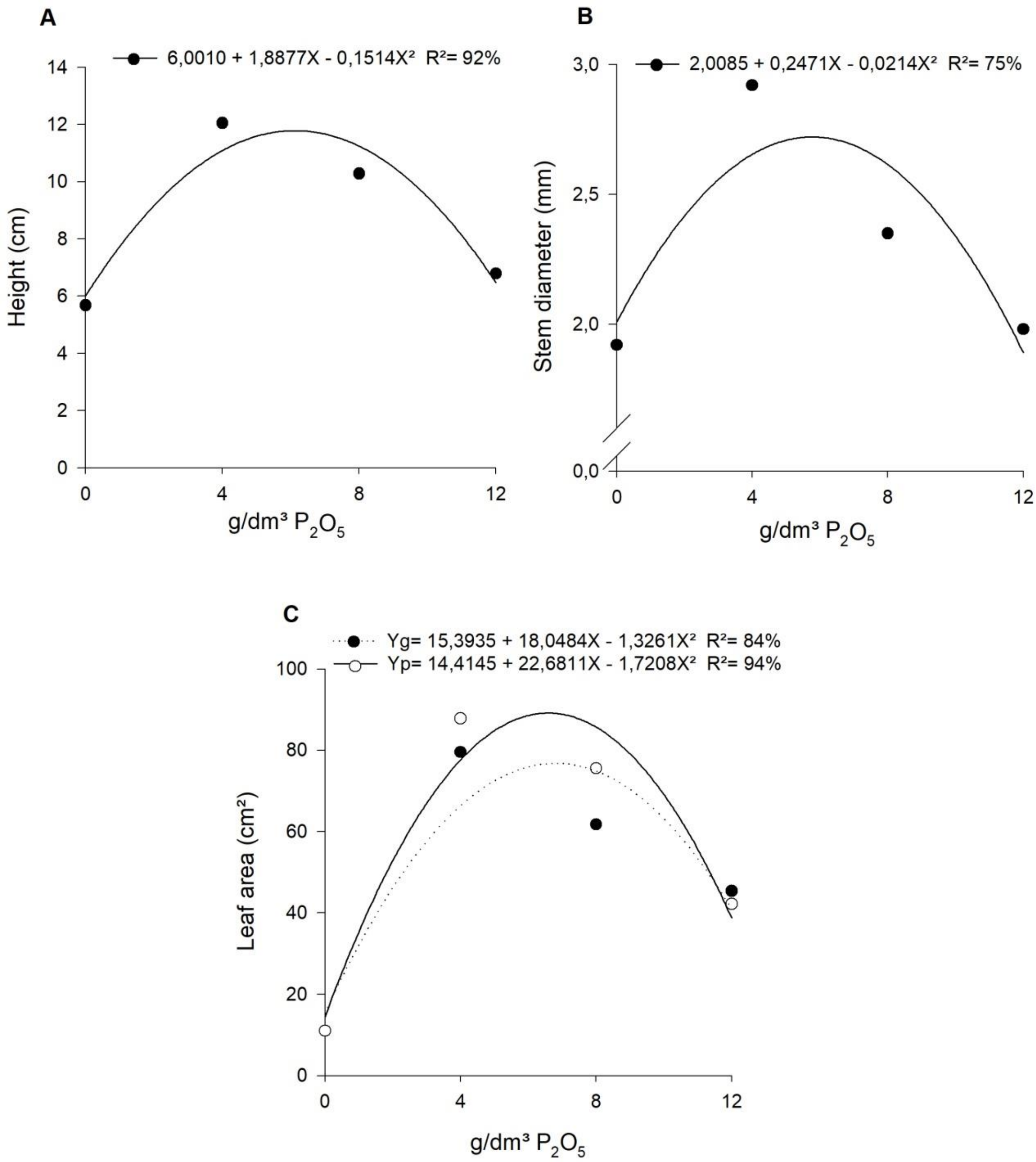

Figure 1. Height growth (ALT), stem diameter (DC), and leaf area (AF) of Arabica coffee seedlings produced in tubes as a function of P doses.

According to the polynomial models adjusted for the dry matter of the leaves, stem and, roots of coffee seedlings (Figure 2), we have that the doses of P that maximize the production of dry matter of leaves, stem and, roots are respectively 6.33, 6.13 and 5.94 g/dm³.

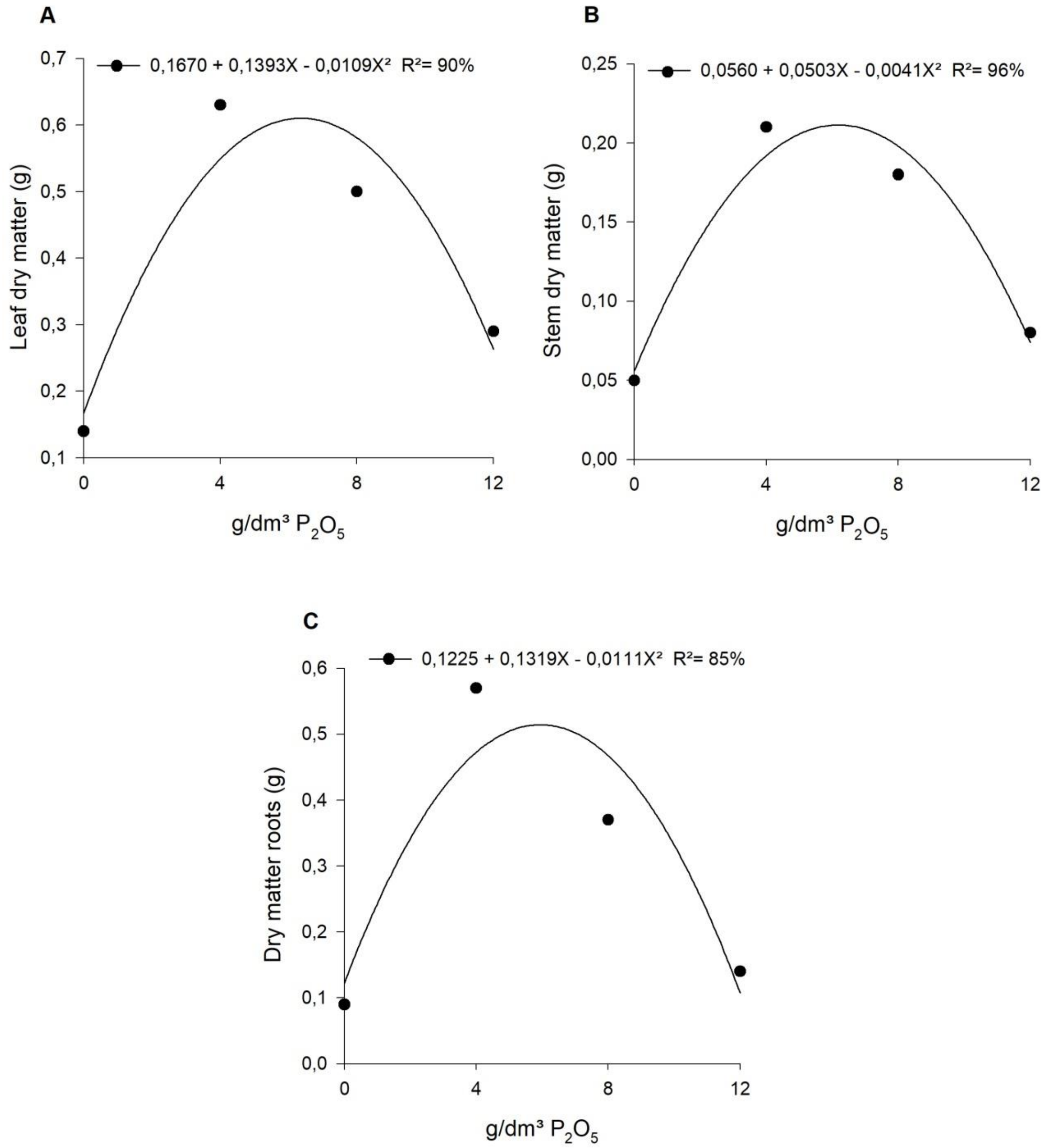

Figure 2. Leaf dry matter production (MSF), stem dry matter (MSC), root dry matter (MSR) of Arabica coffee seedlings produced in tubes as a function of P doses.

The effect of doses on the relationship between the aerial part/root system of coffee seedlings and Dickson's quality index is shown through a quadratic polynomial model, but with different behaviors (Figure 3). For Dickson's quality index (Figure 3B), there was a quadratic behavior, where the dose that provides the maximum quality index corresponds to 5.92 g/dm³.

Evaluating different doses of Osmocote® (14-14-14), Kato *et al.* (2018) observed the response in growth and development of yellow passion fruit seedlings as a function of increasing the dose, with 8.33 kg/m^3 being the best dose. For the production of Australian cedar seedlings, similar results were found with maximum growth in dry mass of the aerial part, height, and diameter of the neck at doses 6 to 8 kg/m³ of Osmocote®, the same average dose obtained in the present study for organomineral fertilization (SOMAVILLA *et al.*, 2014).

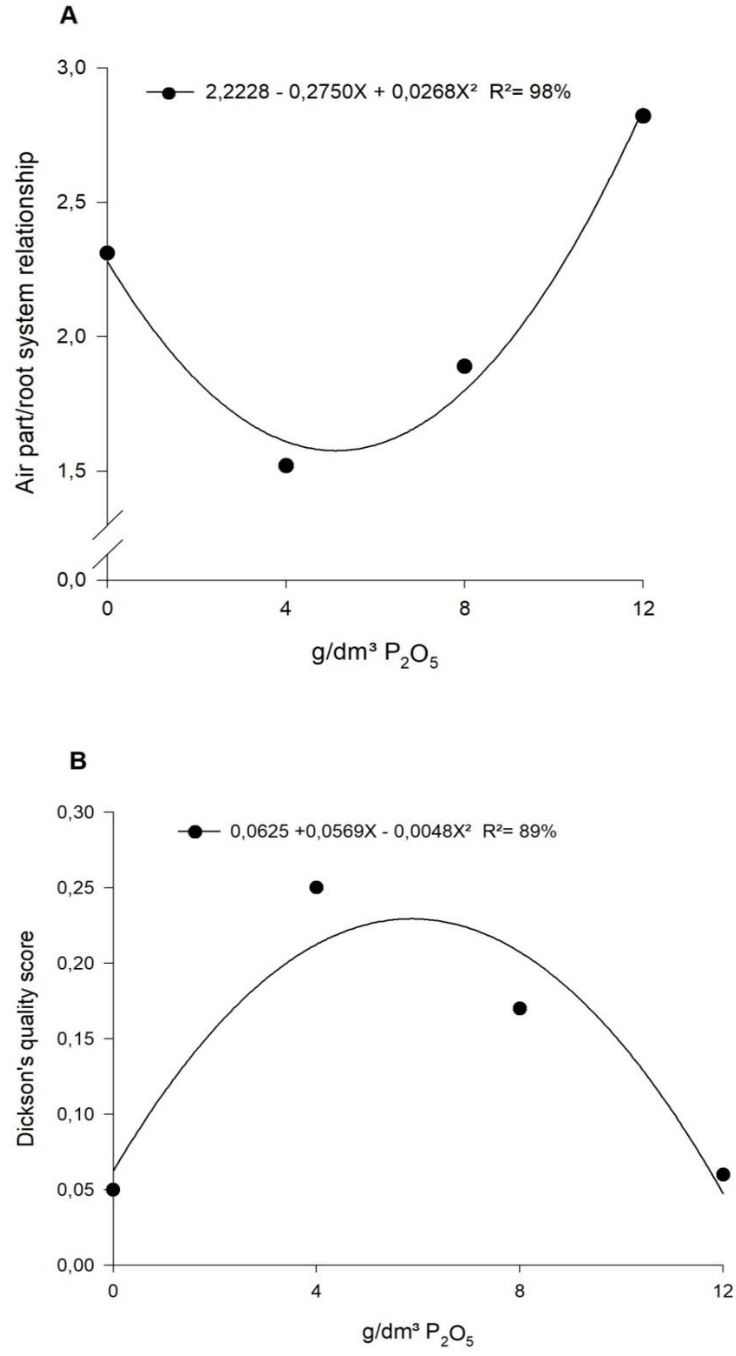

Figure 3. Shoot/root system relationship (RPAR) and Dickson Quality Score (IQD) of Arabica coffee seedlings produced in tubes as a function of P doses.

Conclusion

From the present study, we can verify the viability of alternative fertilizers in the production of coffee seedlings in tubes when using Osmocote®, since it is expensive and has a high market value. This statement is based on the fact that sources such as coated MAP, organomineral pelletized and bran at a dose of 4 g/dm³ showed the highest values for height, stem diameter, leaf area and, dry matter content of leaf, stem and, roots when compared to the other sources studied. According to the regression study, the dose that provides the maximum values for the growth and quality variables is equal to 6 g/dm³ of P_2O_5.

Acknowledgments

The authors would like to thank the Research Support Foundation of the State of Minas Gerais (FAPEMIG), for granting the scholarship to the first author.

Authors Contribution

All authors contributed from the idealization of the study to the writing of this manuscript, participatingdirectly in the experimental planning, assembly and conduct of the experiment, data analysis, writing and correction of the manuscript. In addition, all authors approved the final version of the manuscript.

References

ANTUNES, W. C.; POMPELLI, M. F.; CERRETERO, D. M.; DAMATTA, F. M. Allometric models for non-destructive leaf area estimation in coffee (*Coffea arabica* and *Coffea canephora*). **Annals of Applied Biology**, v.153, p.33-40, 2008. https://doi.org/10.1111/j.1744-7348.2008.00235.x

ARAÚJO, D. D. **Crescimento de mudas de jatobá (*Hymenaea courbaril* L.) sob quatro níveis de sombreamento.** 2009. 72 f. Dissertação (Mestrado) - Universidade Federal Rural da Amazônia, Belém, 2009.

BALIZA, D. P.; ALEXANDRINO, A. L.; DIAS, R. A.; GUIMARÃES, R. J.; BARBOSA, C. R. Anticipation of the production and development of the coffee crop implanted with different types of seedlings. **Coffee Science,** v.8, n.1, p.61-68, 2013.

CAIONE, G.; FERNANDES, F. M.; BERGASMACHINE, A. M.; DALCHIAVON, F. C.; SILVA, A. F. Produtividade e valor nutricional de variedades de cana-de-açúcar sob diferentes fontes de fósforo. **Semina: Ciências Agrárias**, v.33, p.2813-2824, 2012**.** https://doi.org/10.5433/1679-0359.2012v33n6Supl1p2813

CARMO, E. R.; SILVA, C. F.; FREITAS, M. S. M.; LIMA, K. B.; MARTINS, M. A. Production of australian cedar seedlings inoculated with arbuscular mycorrhizal fungi in different types of containers. **Revista Árvore**, v.40, n.2, p.269-278, 2016. https://doi.org/10.1590/0100-67622016000200009

COGO, F. D.; ALMEIDA, S. L. S.; VIEIRA, R. J.; LOPES, F. A. B.; CAMPOS, K. A.; RAMALHO, A. Crescimento de mudas de diferentes cultivares de cafeeiro em função da fertilização orgânica do substrato. **Enciclopédia Biosfera**, v.7, n.12, p.1-9, 2011.

CORRÊA, R. M.; NASCIMENTO, C. W. A. D.; SOUZA, S. K. D. S.; FREIRE, F. J.; SILVA, G. B. D. Gafsa rock phosphate and triple superphosphate for dry matter production and P uptake by corn. **Scientia Agricola**, n.2, v.62, p.159–164, 2005. https://doi.org/10.1590/S0103-90162005000200011

DARDENGO, M. C. J. D.; SOUSA, E. F.; REIS, E. F.; GRAVINA, G. A. Crescimento e qualidade de mudas de café conilon produzidas diferentes recipientes e níveis de sombreamento. **Coffee Science**, v.8, n.4, p.500-509, 2013.

DICKSON, A.; LEAF, A. L.; HOSNER, J. F. Quality appraisal of white spruce and white pine seedling stock in nurseries. **Forest Chronicle,** v.36, p.10-13, 1960. https://doi.org/10.5558/tfc36010-1

FERRARI, E.; PAZ, A.; SILVA, A. C. Déficit hídrico no metabolismo da soja em semeaduras antecipadas no Mato Grosso. **Nativa**, v.3, n.1, p.67-77, 2015. http://dx.doi.org/10.14583/2318-7670.v03n01a12

KATO, D. S.; SILVA, C. M.; HIGUCHI, M. T.; BAUCHROWITZ, I. M.; NETO, J. S.; SHIMIZU, G. D.; OLIVEIRA, A. F. Produção de mudas de maracujá amarelo submetidas a doses crescentes de adubação de liberação lenta. **Revista Terra e Cultura: Cadernos de Ensino e Pesquisa**, v.34, p.310-320, 2018.

LAVIOLA, B. G.; MARTINEZ, H. E. P.; SOUZA, R. B. D.; ALVAREZ V, V. H. Dinâmica de cálcio em folhas e frutos de cafeeiro arábico em três níveis de adubação. **Revista Brasileira de Ciência do Solo**, v.31, p.319-329, 2007. https://doi.org/10.1590/S0100-06832007000200014

LEMOS, V. T.; FRANÇA, A. C.; SILVA, E. B.; MARINHO, R. L. S.; FRANCO, M. H. R.; AVELLAR, M.; FREITAS, A. F.; REIS, L. A. C.; CORRÊA, J. M.; CARVALHO, G. R. Ácido cítrico e fósforo no desenvolvimento e estado nutricional de mudas de café. **Coffee Science**, v.10, n.3, p.298-308, 2015.

MELO, B.; MENDES, A. N. G.; GUIMARÃES, P. T. G.; DIAS, F. P. Substratos, fontes e doses de P2O5 na produção de mudas de café (*Coffea arabica* L.) em tubetes. **Bioscience Journal**, v.19, n.2, p.35-44, 2006.

MENEGHELLI, L. A. M.; MONACO, P. A. V.; HADDADE, I. R.; MENEGHELLI, C. M.; KRAUSE, M. R.; VIEIRA, G. H. S. Produção de mudas de café arábica em substrato composto por resíduo da secagem dos grãos. **Coffee Science**, v.12, n.3, p.381-388, 2017. https://doi.org/10.25186/cs.v12i3.1312

OLIVEIRA, M.C.; SANTOS, J.R.; COSTA, D.F. *et al.* Mudas de tomateiro produzidas à base de pó de coco e esterco bovino curtido. **Revista Brasileira de Agropecuária Sustentável**, v.9, n.3, p.87-95, 2019. https://doi.org/10.21206/rbas.v9i3.8660

PEREIRA, I. S.; LIMA, K. C. C.; MELO JUNIOR, H. B. M. Substratos orgânicos na produção de mudas de cafeeiro em tubetes. **Revista de Agricultura Neotropical**, v.4, n.2, p.17-26, 2017. https://doi.org/10.32404/rean.v4i2.1254

SANTOS, M. R.; SEDIYAMA, M. A. N.; SALGADO, L. T.; VIDIGAL, S. M.; REIGADO, F. R. Produção de mudas de pimentão em substratos à base de vermicomposto. **Bioscience Journal**, v.26, n.4, p.572-578, 2010.

SANTOS, L. C. S.; COSTA, J. P.; VALE, V. S.; DIAS NETO, O. C. Resposta de espécies arbóreas nativas de Cerrado à fertilização com diferentes substratos. **Advances in Forestry Science**, v.6, n.1, p.487-493, 2019. https://doi.org/10.34062/afs.v6i1.5532

SANTOS, T. B.; SILVA FERREIRA, M. F.; MARQUES, I.; OLIVEIRA, S. C.; ZAIDAN, I. R.; OLIVEIRA, M. G.; RODRIGUES, W. P.; RIBAS, A. F.; GUYOT, R.; RAMALHO, J. C.; RIBEIRO-BARROS, A. I.; PEREIRA, L. F. P.; PARTELLI, F. L. Current challenges and genomic advances towards the development resilient coffee genotypes to abiotic stresses. **Genomic Designing for Abiotic Stress Resistant Technical Crops,** p.41-69, 2022. https://doi.org/10.1007/978-3-031-05706-9_3

SILVA, J. I.; VIEIRA, H. D.; VIANA, A. P.; BARROSO, D. G. development of *Coffea canephora* Pierre ex A. Froehner transplants cultivated in different substrates and containers**. Coffee Science**, v.5, n.1, p.38-48, 2010.

SILVA, R. B. G.; SIMÕES, D.; SILVA, M. R. Qualidade de mudas clonais de *Eucalyptus urophylla* x *E. grandis* em função do substrato. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v.16, n.3, p.297-302, 2012. https://doi.org/10.1590/S1415-43662012000300010

SOBREIRA, F. M.; GUIMARÃES, R. J.; COLOMBO, A.; SCALCO, M. S.; CARVALHO, J. G. Adubação nitrogenada e potássica de cafeeiro fertirrigado na fase de formação, em plantio adensado. **Pesquisa Agropecuária Brasileira**, v.46, p.9-16, 2011. https://doi.org/10.1590/S0100-204X2011000100002

SOMAVILLA, A.; CANTARELLI, E. B.; MARIANO, L. G.; ORTIGARA, C.; LUZ, F. B. Avaliações morfológicas de mudas de Cedro australiano submetidas a diferentes doses do fertilizante Osmocote plus®. **Comunicata Scientiae**, v.5, n.4, p.493-498, 2014. https://doi.org/10.14295/cs.v5i4.305

SOUSA, A.; RATKE, R. F.; VIERA, J. W. P.; DE SOUZA, F. V.; ZUFFO, A. M.; AGUILERA, J. G. Produção de mudas de *Leucaena leucocephala* com uso de fertilizante mineral e organomineral. Research, Society and Development, v.10, n.2, 2021. https://doi.org/10.33448/rsd-v10i2.12095

SOUZA, A. J. J.; GUIMARÃES, R. J.; DOMINGHETTI, A. W.; SCALCO, M. S.; COLOMBO, A. Doses de fósforo no desenvolvimento inicial de cafeeiros em solos com diferentes texturas. **Coffee Science**, v.9, n.2, p.284-288, 2014.

TAIZ, L.; ZEIGER, E.; MOLLER, I. M.; MURPHY, A. **Fisiologia e desenvolvimento vegetal**. Artmed, 2017.

VALLONE, H. S.; GUIMARÃES, R. J., MENDES, A. N. G.; SOUZA, C. A. S.; CUNHA, R. L.; DIAS, F. P. Diferentes recipientes e substratos na produção de mudas de cafeeiros. **Ciência e Agrotecnologia**, v.34, n.1, p 55-60, 2010. https://doi.org/10.1590/S1413-70542010000100006

VILELA, D. J. M.; CARVALHO, G. R.; BOTELHO, C. E.; CARVALHO, A. M.; PRAXEDES, M. A.; SANTOS, M. C.; FERNANDES, F. C. Crescimento inicial de cultivares de cafeeiro com diferentes doses de nitrogênio, fósforo e potássio. **Coffee Science**, v.12, n.4, p.552-561, out./dez. 2017. https://doi.org/10.25186/cs.v12i4.1370