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Research Article

Vegetative parameters and productivity of coffee crops planted with seedlings produced in bags and tubes

Parâmetros vegetativos e produtividade de lavoura cafeeira implantada com mudas produzidas em saquinhos e tubete

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ABSTRACT

The longevity of coffee plantations reflects the health of the plant material, the management of seedling production in nurseries, and the use of appropriate techniques in the establishment of coffee crops. This study focused on evaluating the effect of coffee seedlings produced in bags and tubes on the vegetative parameters and productivity of the coffee crop, cultivar IPR 100. The experiment was conducted at Fazenda Bordin, located in Monte Carmelo, Minas Gerais, using a rainfed system. A randomized block design was used, with eight blocks and three treatments, namely: T1 - Seedlings planted with polyethylene bags containing 84 holes; T2 - Seedlings planted with the removal of polyethylene bags containing 84 holes; and T3 - Seedlings produced in tubes. Assessments of plant height, stem diameter, and crown diameter were conducted monthly from May 2018 to April 2020. In June 2020, the first harvest was carried out, evaluating productivity (60 kg bags per hectare), grain classification in terms of size and shape, and percentage of ripeness. The results suggest that the packaging used in the production of IPR100 seedlings was not a decisive factor in the development, production, grain quality, and maturation for the plants' first production cycle. It is concluded that in the production of healthy seedlings in a more sustainable manner, the use of tubes should be considered. Compared to plastic bags, the tube offers important advantages such as reusability, preventing soil contamination with non-degradable plastics; reducing the risk of biological contamination with pathogens; and facilitating nursery operations, shipping, and crop planting without compromising the productivity of the first harvest of the IPR100 cultivar.

KEYWORDS: Coffee tree. Seedling production. Productivity. Growth.

RESUMO

A longevidade do cafezal é reflexo da sanidade do material vegetal, do manejo da produção de mudas em viveiro e da utilização de adequadas técnicas na implantação da lavoura cafeeira. Nesta pesquisa o destaque foi avaliar o efeito de mudas de café produzidas em saquinho e tubete nos parâmetros vegetativos e produtividade da lavoura cafeeira, cultivar IPR 100. O experimento foi conduzido na Fazenda Bordin, localizada em Monte Carmelo – Minas Gerais em sistema de sequeiro. Foi utilizado o delineamento em blocos casualizados, com oito blocos e três tratamentos, sendo: T1 - Mudas plantadas com saquinho de polietileno contendo 84 furos; T2 - Mudas plantadas com a retirada do saquinho de polietileno contendo 84 furos e T3 - Mudas produzidas em tubete. As avaliações dos parâmetros altura, diâmetro de caule e diâmetro de copa das plantas foram realizadas mensalmente no período de maio de 2018 a abril de 2020. Em junho de 2020 foi realizada a colheita referente à primeira safra da lavoura, avaliando-se a produtividade (sacas beneficiadas de 60 kg por hectare), classificação dos grãos quanto ao tamanho e formato e percentual de maturação. Os resultados permitem sugerir que a embalagem utilizada na produção das mudas da cultivar IPR100 não se apresentou como um fator decisivo para o desenvolvimento, produção, qualidade do grão e maturação para o primeiro ciclo produtivo das plantas. Conclui-se que na produção de

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mudas com sanidade e de forma mais sustentável, a utilização de tubetes deve ser considerada. Em comparação com as sacolas plásticas, o tubete oferece vantagens importantes como reutilização, evitando a contaminação do solo com plásticos não degradáveis; diminuição dos riscos de contaminação biológica com agentes patogênicos; facilita as operações em viveiro, expedição e implantação da lavoura sem comprometer a produtividade da primeira safra da cultivar IPR100.

PALAVRAS-CHAVE: Cafeeiro. Produção de mudas. Produtividade. Crescimento.

INTRODUCTION

Brazil stands out in the global production of *Coffea arabica* L. In the 2023 harvest, the area planted with this crop in the country was 2.4 million hectares, with a production of 55.1 million bags processed, with emphasis on the state of Minas Gerais, which is responsible for 52.6% of national production (CONAB 2023). Within the state, the Cerrado Mineiro region was the first in the country to receive the Denomination of Origin seal, conferring intrinsic aroma and flavor characteristics to coffees produced with high sensory quality, providing international recognition for the product (BATISTA & CRUZ 2020).

Coffee trees, being a perennial crop, require adequate planning for crop implementation. Several factors must be analyzed, such as choice of area and crop, soil preparation, and acquisition of healthy, high-quality seedlings (FERRARO et al. 2023).

Seedlings produced in polyethylene bags have the disadvantages of high substrate consumption, with a potential risk of contamination of seedlings by soil fungi and nematodes, in addition to more expensive transportation. On the other hand, seedlings produced in tubes are more sensitive to water stress, but have the advantage of eliminating root abnormalities, such as “píão torto” (crooked spinnig) characterized by the bending of the taproot, and possible problems with soil pathogens (ANDRADE et al. 2021).

The Cerrado Mineiro region has a wide diversity in the size of its productive area, with small, medium, and large properties (FALEIROS NETO & MONTI 2020), presenting extensive and flat areas that facilitated the introduction of agricultural mechanization in all phases of crop management (DUTRA et al. 2023). As a result, many producers have opted for mechanized planting, using seedlings produced in tubes or polyethylene bags.

Mechanized planting faces some operational limitations and planting yield issues, such as removing plastic from seedlings that come in plastic bags. In order to make planting operations feasible, some producers choose to use seedlings produced in bags with 84 holes and do not remove the packaging. However, the two-centimeter-thick cross-cut at the bottom of the bag remains essential to prevent the “crooked spinning” (BRANDÃO 2022).

Planting without removing the bag has some drawbacks, such as the presence of non-biodegradable residues in the soil, which hinders the free formation of the root system and can also alter the temperature and availability of water for root system development and initial crop establishment.

On the other hand, removing the seedling bag by cutting it lengthwise, if not done by a trained team at the time of planting, can cause the seedlings to become dislodged and damage the root system, which will result in poor establishment and development of the coffee crop (SENAR 2017).

Operationally, seedlings produced in tubes are a more sustainable and practical option for planting coffee trees using mechanized management. The tubes offer operational and economic gains, as they facilitate handling, reducing seedling damage after removal from the container, and can be reused in the production of other seedlings. For seedlings produced in tubes, cross-cutting the taproot is not necessary at the time of planting, preserving the integrity of the root system against mechanical damage. This management hinders the spread of diseases and soil pests via the root system, allowing for more suitable physiological and sanitary conditions to achieve better results in the vegetative and productive development of the crop being planted (FREITAS et al. 2022).

In this study, the objective was to evaluate the effect of coffee seedlings produced in bags and tubes on the vegetative parameters and productivity of the coffee crop, cultivar IPR 100.

MATERIALS AND METHODS

The experiment was conducted at Fazenda Bordin, in Monte Carmelo, Minas Gerais. The municipality is located in the mesoregion of Triângulo Mineiro and Alto Paranaíba. The area is located at an altitude of 870 m, latitude 18° 43' 29'' south and longitude 47° 29’ 55'' west. The temperature ranges from a minimum of 15.2 °C to a maximum of 32.2 °C, with average annual rainfall of 1,600 mm. The soil is classified as Red Latosol (SANTOS et al. 2018). The chemical characteristics of the soil in the experimental area are described in Table 1.

Table 1. Chemical characterization of the soil for the year 2018.

Depth	pH	P	K^+	Ca^{++}	Mg^{++}	H+Al	Total CEC	V	m	MO
	H_2O	mg dm $^{-3}$		cmolc dm $^{-3}$				%		dag kg^{-1}
0-20 cm	5.7	12.8	75.0	1.9	0.8	3.6	6.56	45.0	0.0	1.8

Extraction methods: P, K, Na = Mehlich^{-1}; S-SO_4 $^{2-}$ = [Monobasic calcium phosphate 0.01 mol L^{-1}]; Ca, Mg, Al = [KCl 1 mol L^{-1}]; H+Al = [SMP buffer solution pH 7.5]; B = [$BaCl_2$. $2H_2O$ 0.125% hot]; Cu, Fe, Mn, Zn = DTPA.

The crop was planted in February 2018, using seedlings of the IPR 100 cultivar, with a spacing of 3.70 m between rows and 0.55 m between plants. Irrigation was used only in the first 30 days after planting, with sufficient volume to cover the wet bulb, in order to ensure better seedling establishment. Subsequently, the crop was managed using rainfed farming methods.

In preparing the soil, 1,000 kg of limestone were used in the total area (dolomitic limestone – PN of 96.2% and PRNT of 80%), 1,000 kg of limestone in the furrow (dolomitic limestone – PN of 96.2% and PRNT of 80%), 890 kg of gypsum within the furrow (14% S, 17% Ca), 570 kg of reactive phosphate at a depth of 45 cm in the furrow (30% P_2O_5), and class A organic compound fertilizer at a dose of 5,470 kg ha^{-1}.

The experimental design used was randomized blocks (RBD) with eight replicates. Each plot was represented by 12 plants, with the eight central ones considered useful. The treatments used were: T1 - Seedlings planted with polyethylene bags containing 84 holes; T2 - Seedlings planted with the polyethylene bags containing 84 holes removed; and T3 - Seedlings planted with the tubes removed.

The bag measures 11 cm wide and 20 cm high, with a capacity of 654 mL. The tube can hold up to 180 mL of substrate. The treatments were arranged in four planting rows, containing two blocks per coffee row.

In all treatments, except for seedlings produced in tubes, a two-centimeter cross-cut was made at the bottom of the bag to prevent the taproot from bending or twisting.

Biometric measurements, such as plant height (measured with a ruler from ground level to the point of insertion of the terminal bud, in cm), stem diameter (measured with a caliper, 1 cm from the plant collar, in mm), and crown diameter (measured with a ruler, taking as a measurement standard the two branches between rows that are the longest, in cm) were performed monthly.

To calculate the monthly growth rate for height, stem diameter, and crown diameter, the last assessment, referring to April 2020, was subtracted from the first assessment after treatment differentiation, carried out in May 2018, divided by the number of months between the two assessments.

In June 2020, the first harvest of the experimental area was carried out, using manual stripping on cloth, of the fruits belonging to the three central plants of the plot. The volume of coffee produced by the plot was measured and a 10 L sample was subsequently taken and dried on a suspended drying floor. When the coffee reached 11% moisture content, the mass and volume of the coffee in the coconut shell were determined. Subsequently, the samples were processed and subjected to determination of grain mass, volume, and moisture content. The ratio of the initial volume of coffee beans harvested on the cloth, the volume of the 10 L sample, and the mass of the processed sample provided the yield (kg) of each plot, which was extrapolated to bags ha^{-1}.

To analyze the percentage of fruits at different stages of ripeness, a 0.3 L sample was taken from each plot to separate the fruits into the categories of unripe, green, cane green, cherry, raisin, and dry.

The classification regarding bean size and shape followed the guidelines of Normative Instruction No. 8 of June 11, 2003, of the Ministry of Agriculture, Livestock, and Supply (Ministério da Agricultura, Pecuária e Abastecimento – MAPA 2003), with a 100 g sample of processed coffee being taken from each plot and distributed across a set of sieves of different diameters and shapes (oblong and circular). After this process, the beans retained in each sieve were weighed to determine the percentage of large flat beans (sieves 19, 18, and 17), medium flat beans (sieves 16 and 15), small flat beans (sieves 14 and smaller), large moka beans (sieves 13, 12, and 11), medium moka beans (sieve 10), and small moka beans (sieve 9 and smaller).

The data were submitted to analysis of variance after meeting the assumptions of normality of residuals, homogeneity of variances, and block additivity. When significant differences between treatments were detected, the variables were compared using Scott-Knott's test at a 5% probability level.

RESULTS AND DISCUSSION

Based on the results, no significant difference was observed between treatments for the biometric evaluations of coffee trees (Figure 1). The coffee trees showed an average growth rate of 4.71 cm month^{-1}; 6.16 cm month^{-1} and 1.64 mm month^{-1}, respectively for height, crown diameter, and stem diameter.

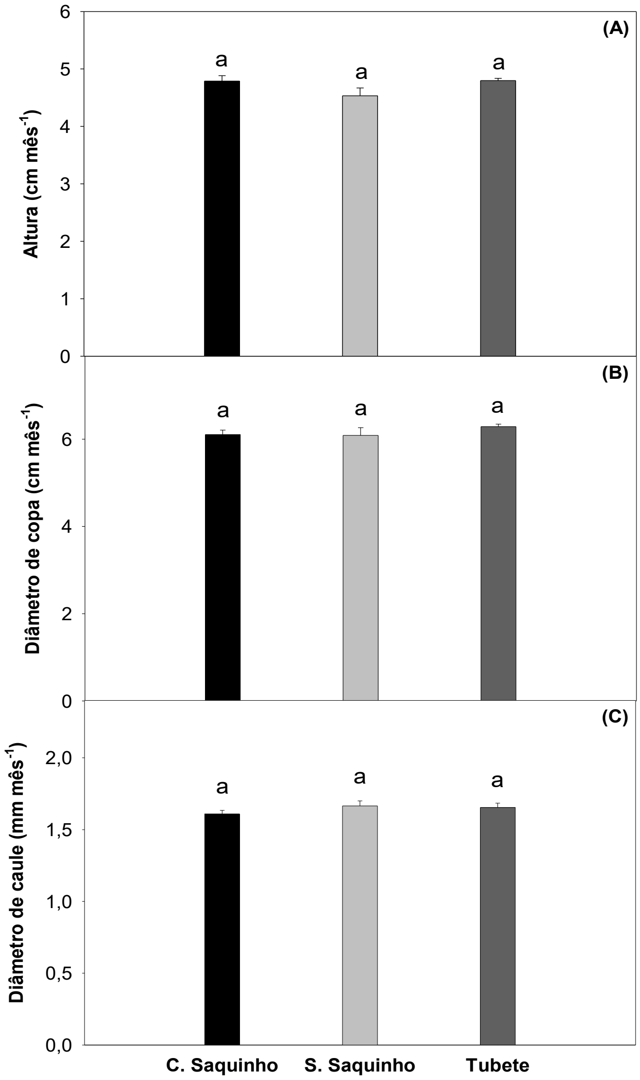

Figure 1. Average growth rate in height - cm month^{-1} (A), crown diameter - cm month^{-1} (B), and stem diameter - mm month^{-1} (C) of coffee trees depending on the use of seedlings in bags and tubes. Not significant according to the F test (p>0.05). C. Bag: with bag; S. Bag: no bag.

Planting seedlings in tubes and bags, regardless of whether the plastic was removed or not, did not interfere with the biometric parameters of the crop, which contradicts the results obtained by VERDIN FILHO et al. (2019), who found that seedlings produced in tubes accumulated higher dry mass levels than plants produced in polyethylene bags, and SERBER et al. (2020), who observed that seedlings in tubes had greater height, stem diameter, and survival in perennial crops.

The use of tubes is highly controversial because they reduce the volume of substrate and consequently increase root concentration when compared to plastic bags. SANTOS & OLIVEIRA (2021), VERDIN FILHO et al. (2021), MAGISTRALI et al. (2022), OLIVEIRA et al. (2022), COSTA et al. (2023) showed that reducing the volumetric capacity of containers restricts the root system, impacting the development of seedlings in the nursery and later when transplanted to the field of perennial crops.

LEÃO (2014) observed that the use of substrate and containers with reduced volume in seedling production causes physical changes in the root system, leading to a higher concentration of roots. It is clear that research conducted on this topic has contrasting results and highlights the need for new information that can support producers' decision-making.

As for the uniformity of fruit ripening, no significant differences were observed depending on the treatments adopted (Figure 2). On average, at harvest time, the coffee trees had 0.95% unripe, 32.9% green fruit, 21.9% green cane fruit, 38.3% cherry, 4.3% raisins, and 1.6% dry fruit.

LIMA et al. (2016) and MOTA et al. (2024) report that fruit ripening uniformity is directly related to balanced plant nutrition, which will result in greater floral retention.

The management adopted in the cultivation of the crop did not allow for significant differences in performance and production quality to be observed for seedlings in bags, regardless of whether or not the plastic and tube were removed in the classification of coffee according to the size and shape of the beans (Figure 3). The coffee trees presented on average: 57.14% large flat beans, 20.87% medium flat beans, 0.56% small flat beans, 14.85% large moka beans, 5.66% medium moka beans, and 0.91% small moka beans. It is believed that the fertilization management of the experiment was adequate and the genetic capacity of the cultivar to produce fruits with a mean sieve size of 16 (MORELLO et al. 2017) was confirmed.

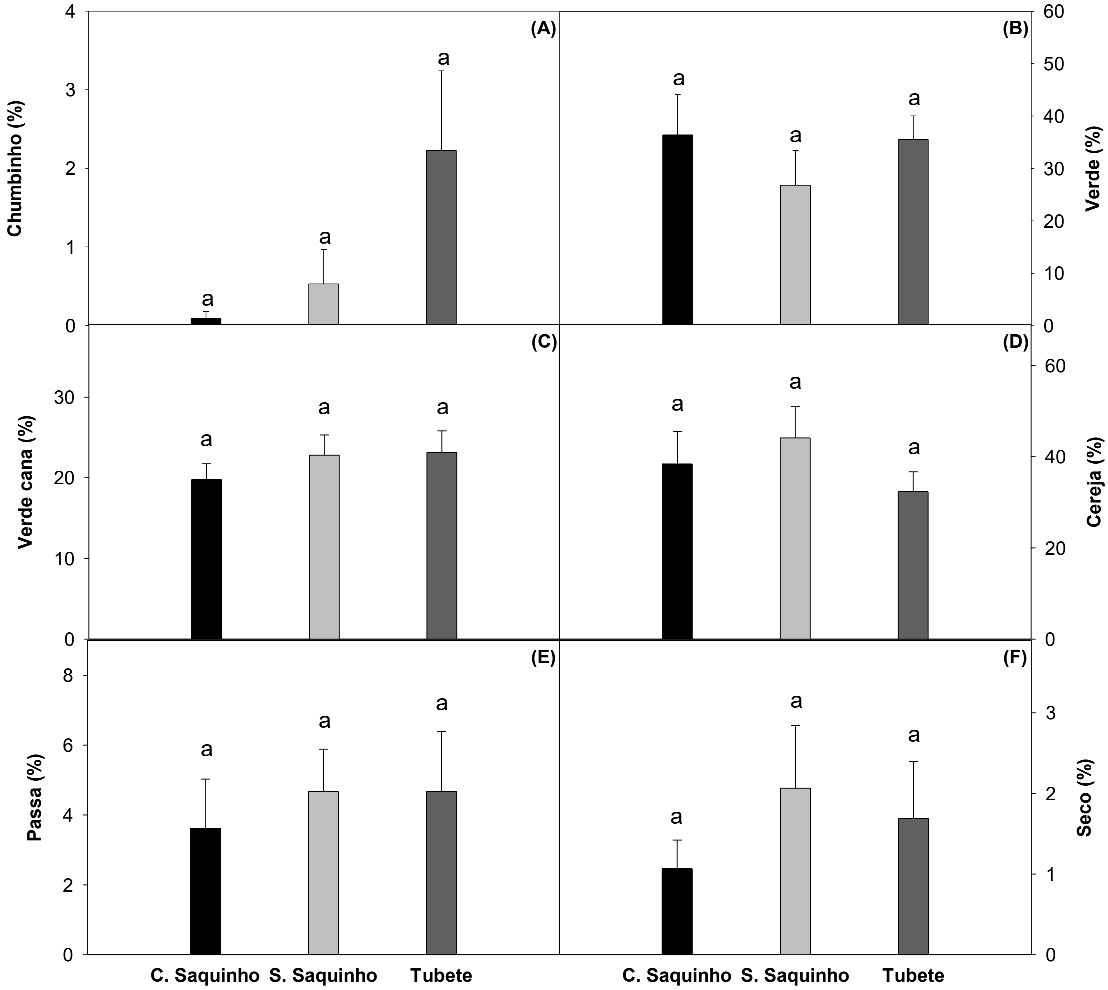

Figure 2. Average percentage of coffee fruits in the green, cane green, cherry, raisin, and dry stages according to treatments. Not significant according to the F test (p>0.05). C. Bag: with bag; S. Bag: no bag

Several factors affect the physical and chemical characteristics of coffee, including climatic and environmental conditions, genetics, coffee tree nutrition, coffee plantation management, and harvest season (SILVEIRA et al. 2018). Coffee tree management can be managed in a way that maximizes productivity and achieves high quality standards (RODRIGUES et al. 2019).

MENDONÇA et al. (2021) and SOUZA et al. (2023) report that water deficit is one of the main factors influencing fruit size and shape by reducing the translocation of water and nutrients and consequently slowing fruit development.

This study shows that planting seedlings in tubes and bags, regardless of whether the plastic was removed or not, did not interfere with root development to the extent of altering water and nutrient absorption, as the cultivar presented the same fruit size and shape pattern in all treatments adopted.

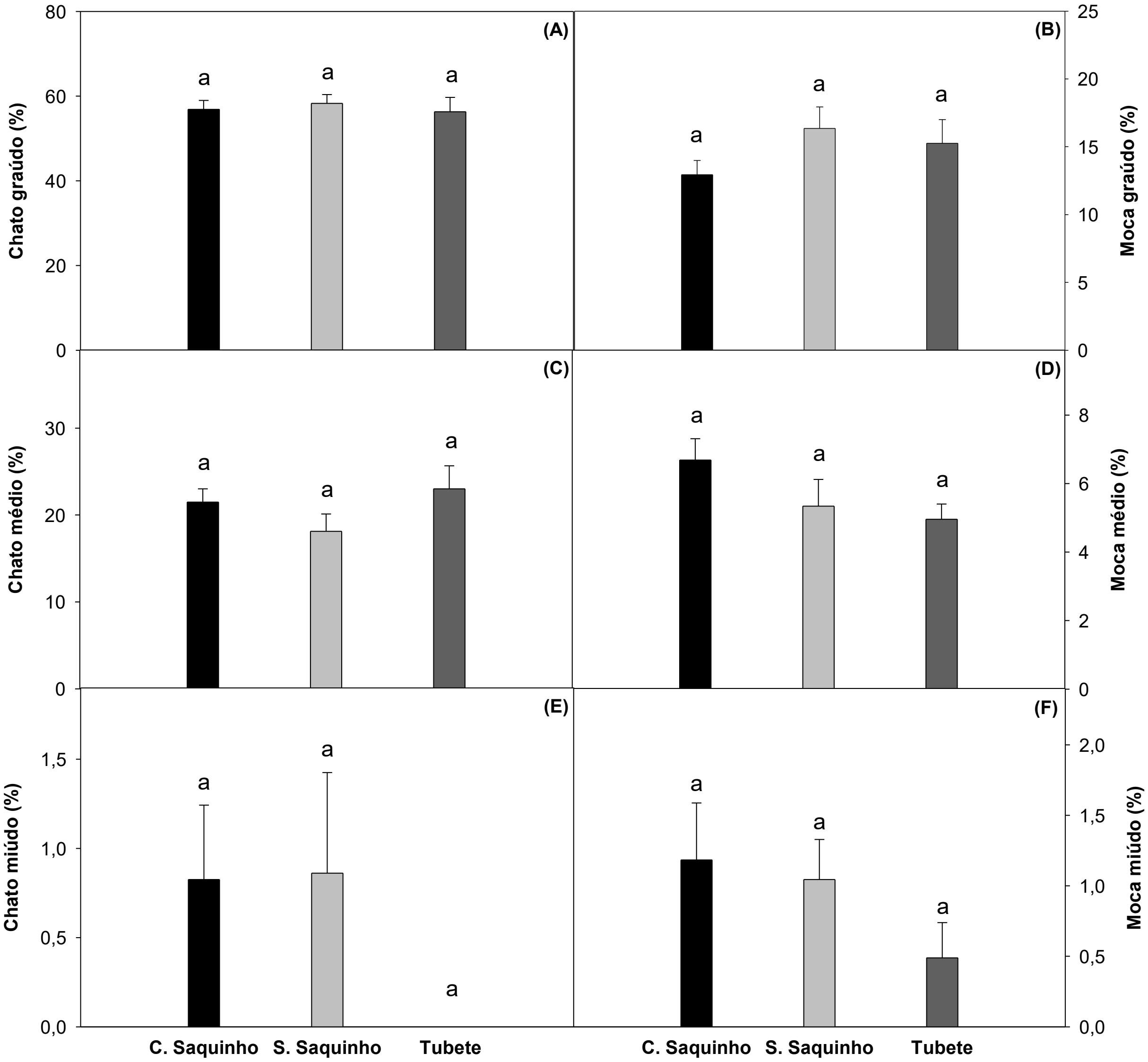

Figure 3. Average percentage of beans retained in circular and oblong sieves of IPR100 coffee cultivars depending on the use of seedlings in bags and tubes. Not significant according to the F test (p>0.05). C. Bag: with bag; S. Bag: no bag

The same pattern is observed for processed coffee yield per hectare, with no significant difference between planting seedlings in bags, regardless of whether the plastic and tube are removed or not (Figure 4). The average crop yield was 37.7 bags ha^{-1}, which is above the average for the Triângulo, Alto Paranaíba, and Northwest Minas regions of 35.1 bags ha^{-1} (CONAB 2023), possibly due to the use of irrigation at the beginning of crop implementation, adequate management of pests, diseases, and weeds, and the use of genetic material that is better adapted to the growing region and resistant to the nematode species *Meloidogyne paranaensis*.

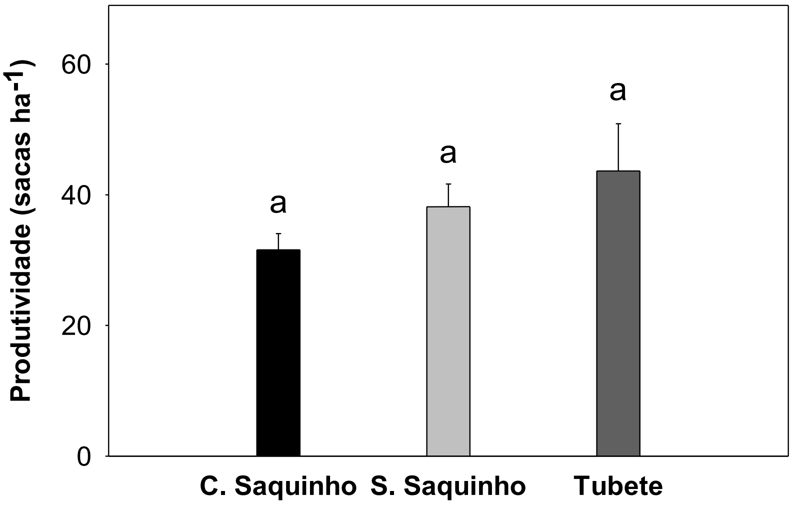

Figure 4. Productivity of the IPR100 cultivar as a function of the use of seedlings in bags and tubes. Not significant according to the F test (p>0.05). C. Bag: with bag; S. Bag: no bag

Thus, given the insignificance between treatments in terms of the vegetative characteristics and productivity of coffee trees, coffee growers' decision-making should be based on the cost analysis of seedlings and the crop implementation process, since mechanized planting facilitates the use of seedlings produced in tubes. Aspects related to land management, such as irrigation, should also be taken into account, as seedlings produced in tubes tend to be more sensitive to water stress in the early stages of cultivation, depending on the volumetric capacity of the container.

The use of tubes can be an additional element of sustainability in the coffee production chain, as it does not cause soil contamination with non-organic residues and can be reused up to eight times for the production of new seedlings.

CONCLUSION

The production of seedlings in bags or tubes was not a decisive factor in the initial implementation and development of the crop in the first harvest of the IPR 100 cultivar.

The management adopted in the cultivation of the crop since its implementation has proven decisive in exploiting the full potential of the coffee tree, regardless of the seedling production container or planting method.

Sustainability, plant material health, operational advantages, and productivity make tubes the best alternative for seedling production and crop implementation with mechanized management.

AUTHORS' CONTRIBUTIONS

Conceptualization, methodology, and formal analysis, Gleice Aparecida de Assis, Edson Simão, Hanna Eduarda Nunes Sugawara, Letícia Gonçalves do Nascimento, Marco Iony dos Santos Fernandes, Gustavo Dantas Silva, and Deyvid da Silva Gallet; software and validation, Gleice Aparecida de Assis, Letícia Gonçalves do Nascimento, and Marco Iony dos Santos Fernandes; research, Hanna Eduarda Nunes Sugawara and Gustavo Dantas Silva; resources and data curation, Gleice Aparecida de Assis, Hanna Eduarda Nunes Sugawara, and Deyvid da Silva Gallet; writing - preparation of the original draft, Gleice Aparecida de Assis, Edson Simão, Hanna Eduarda Nunes Sugawara, Letícia Gonçalves do Nascimento, Marco Iony dos Santos Fernandes, Gustavo Dantas Silva, and Deyvid da Silva Gallet; writing - revision and editing, Gleice Aparecida de Assis and Edson Simão; visualization, Gleice Aparecida de Assis and Edson Simão; supervision, Gleice Aparecida de Assis and Edson Simão; project management, Gleice Aparecida de Assis; funding acquisition, Gleice Aparecida de Assis. All authors have read and agreed to the published version of the manuscript.

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STATEMENT BY THE INSTITUTIONAL REVIEW BOARD
Not applicable to studies that do not involve humans or animals.

INFORMED CONSENT STATEMENT
Not applicable because this study did not involve humans.

DATA AVAILABILITY STATEMENT
Data can be made available upon request.

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CONFLICTS OF INTEREST
There are no conflicts of interest.

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