

PLOT SIZE FOR EVALUATION OF AGRONOMIC AND SENSORIAL CHARACTERISTICS OF ARABICA COFFEE

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- **ABSTRACT:** Coffee cultivation is of great socioeconomic importance for the Espírito Santo State, generating, in addition to direct and indirect jobs, financial resources. According to the first survey of the 2019 crop of CONAB, it is expected a production between 12.5 to 14.7 million of benefited bags. Research on coffee cultivation has contributed to the development of new technologies, but the size of plots for experiments with coffee is variable and based mostly on the researcher's experience. Thus, the objective of this work was to determine the optimal sizes of experimental plots to evaluate the pre-harvest, production and sensory characteristics of arabica coffee. The modeling applied in this study allows concluding that according to the data tested, it is possible to recommend the optimum size of experimental plots for arabica coffee, for these edaphoclimatic conditions and variety. The conclusions are as follows: it is recommended to use seven or more arabica coffee plants to evaluate the pre-harvest and harvest characteristics (plant height, plant diameter, vigor, and wet mass), and use, at least, seven plants of arabica coffee to evaluate sensory characteristics (fragrance, flavor, aftertaste, acidity, body, uniformity, balance, clean cup, sweetness, overall, and total score).
- **KEYWORDS:** *Coffea arabica*; bootstrap; experimental accuracy; experimental planning.

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1 Introduction

Coffee farming is of great socioeconomic importance for Brazil, generating, in addition to direct and indirect jobs, resources, which according to the first survey of the 2019 CONAB season. The country is expected to harvest between 50.48 and 54.48 million of sacks of coffee benefited, and the production of arabica coffee estimated between 36.12 and 38.18 million bags and conilon coffee between 14.36 and 16.33 million bags benefited (CONAB, 2019).

In the Espírito Santo, coffee production is the main agribusiness activity, with CONAB forecasting between 12.5 million and 14.7 million bags benefited, with approximately 28% of the state's production of arabica coffee (CONAB, 2019).

The research on coffee cultivation has contributed to the development of new technologies, providing farmers with more productive varieties, resistant to biotic factors and tolerant to abiotic factors, post-harvest methods to obtain higher coffees, among others, seeking to solve problems faced by farmers.

The plots size for coffee experiments is variable and based mostly on the researcher's experience. Vilela *et al.* (2017) used 6 plants in the useful plot to evaluate plant height, diameter of the neck, number of plagiotropic branches, growth of the first plagiotropic branch, chlorophyll index and leaf nutrient content, in an experiment that evaluated four new coffee cultivars to its initial growth under different doses of nitrogen (N), phosphorus (P) and potassium (K). Paiva *et al.* (2010) evaluated the agronomic behavior of progenies of low size using 4 plants per plot. Freitas *et al.* (2007) used 8 useful plants per plot in a work that studied the association between quantitative characters related to the vegetative growth in cultivars of low size arabica coffee. Veiga *et al.* (2018) used 10 plants per plot to evaluate the agronomic performance and adaptability of new cultivars and progenies of *Coffea arabica* resistant to coffee rust.

Other authors also used different size plots in arabica coffee experiments. Bonomo *et al.* (2008) used 10 useful plants to evaluate the effect of irrigation on yield and income of coffee cultivars Catuaí IAC 44, Acaia Cerrado MG 1474, Rubi MG 1192, Topázio MG 1190, Oeiras MG 6851 and Katipó. Silva *et al.* (2013) evaluated the operational performance of mechanized and selective coffee harvesting as a function of fruit detachment force. They used 5 useful plants of progenies resulting from the cross between Catuaí Vermelho IAC 141 with Timor Hybrid, as Catuaí Amarelo IAC 86 with Timor Hybrid.

In the experimental design, the researchers must define the plot size aiming to increase the accuracy of the information obtained, beyond to optimize the cost / benefit relationship of the experiments, generating appropriate technologies with lower experimental costs. The determination of the plot size becomes important in any scientific experiment, because if the plot size is smaller than necessary, less precise estimates will be obtained. On the other hand, if plots are used in excessive sizes, time and resources will be expended more than necessary. In this way, the characterization of optimal plot size is an important tool to subsidize information that helps in future experiments.

In the tests used to determine plot size, the increase of the experimental unit decreases the error to a certain point and from which there are no gains with precision. In the literature are found several methodologies that are used to determine the optimal plots size to leave the empirical method aside. Paranaíba *et al.* (2009), in a work proposing methods to

estimate the optimal plots size, used the methods of the linear model of plateau response, and the maximum curvature of the coefficient of variation model. Viana *et al.* (2002) used the methods of maximum curvature, modified maximum curvature and comparison of variances to estimate plot size in cassava experiments. Leonardo *et al.* (2014) determined the optimal size of the experimental plot of the 'Vitória' pineapple through the linear model of plateau response and maximum curvature. These methods use uniformity trial, where only one variety is planted, receiving the same cultivation practices.

According to Le Clerg (1967), through the visual inspection method of maximum curvature, the coefficients of variation $CV_{(X)}$ are calculated for each plot size X (equation 1) where $V_{(X)}$ is the variance of the plots with X plants and \bar{X} the mean. The set of points obtained from the pairs $[X, CV_{(X)}]$ are joined forming a curve, where the point of maximum curvature is determined by visual inspection, considering the optimal plot size the abscissa value of the point.

$$CV_{(X)} = \frac{\sqrt{V_{(X)}}}{\bar{X}} * 100 (\%) \quad (1)$$

The method of maximum curvature is simple and easy to use, however, the fact of determining the optimum plot size visually, constitutes a source of error because there is no criterion to identify the maximum point of curvature on the curve (Paranaíba *et al.*, 2009).

The method of visual inspection of the maximum curvature has been improved and the maximum size of the plot X_{OP} being determined algebraically. Cargnelutti Filho *et al.* (2011) used this method to estimate the optimal plots size of corn simple, double, and triple, at where established a function type $CV_{(X)} = \frac{A}{X^B}$, for explaining a relationship between the coefficient of variation ($CV_{(X)}$) and size of the experimental plot (X), so that the size of the experimental plot was determined algebraically.

Several studies have used the modified maximum curvature method to determine the plot sizes. Viana *et al.* (2002) estimated plot sizes in cassava experiments. Smiderle *et al.* (2014) selected genotypes in the bean crop. Silva *et al.* (2012) used this method to determine plot size for radish experiments. Cipriano *et al.* (2014) verified the evaluation of masses, and volumes after drying adult coffee of cultivar Topázio MG1190. They concluded that eight plants are necessary in the useful part.

Leonardo *et al.* (2014) used the linear method of plateau response to determine the plot size of Vitória' pineapple. This is the method determines the optimal plot size the linear model turns into a plateau, in relation to the abscissa. Cargnelutti Filho *et al.* (2011) also used this method to estimate the plots size of maize hybrids and Pereira *et al.* (2018) to determine the minimum number of Q-Graders and R-Graders for a sensory evaluation of arabica and conilon coffees, respectively.

Aiming for greater consistency of the regression methods in obtaining the optimal experimental plot size, this article used the bootstrap method (MAMMEN and SANDI, 2012), which consists of a statistical resampling technique, which established a new framework for statistical analysis based on the simulation.

Research on plot size for arabica coffee is essential to increase the efficiency and to optimize the cost / benefit ratio of the experiments. Based on this demand, the objective of

this work was to determine the optimal sizes of experimental plots to evaluate the pre-harvest, production and sensorial characteristics of arabica coffee cultivar Catucaí 785.

2 Materials and methods

The work was carried out in the municipality of Brejetuba, Espírito Santo State. The experimental area is located at 850 m altitude, with slope of 40%. A uniformity trial was performed with 100 plants consisting of arabica coffee, and cultivar Catucaí 785, at six years of age, forming a grid $i \times j$, with $i = 10$ rows e $j = 10$ columns (Figure 1). The plants were conducted at 2×1 m spacing, and cultivated under the same agronomic practices.

a_{11}	a_{12}	a_{13}	...	a_{1j}
a_{21}	a_{22}	a_{23}	...	a_{2j}
a_{31}	a_{32}	a_{33}	...	a_{3j}
\vdots	\vdots	\vdots	\ddots	\vdots
a_{i1}	a_{i2}	a_{i3}	...	a_{ij}

Figure 1 - Grid $i \times j$ with $i = 10$ rows and $j = 10$ columns of plants.

Weed management was carried out by through of brushing with costal manual trimmer in the months of October, January and March. The management of soil fertilization and correction was performed according to the results of soil analysis, with liming done in June and fertilization in three plots from October to March. Phytosanitary control was carried out in October in a preventive way as characteristic of the region.

Before the harvest, agronomic characteristics such as plant height, plant diameter and vigor were evaluated. The plant height was determined using a topographic ruler placed parallel to the coffee stem, measuring from the soil surface to the apical bud of the orthotropic branch. The plant diameter was determined with the topographic ruler placed transversely to the orthotropic branch in relation to the coffee line, measuring the greatest distance between the first pair of leaves present in the opposite plagiotropic branches. Already vigor was evaluated by assigning grades on a scale of 1 to 10, depending on the vegetative development of the plants, with the grade 1 being given to plants with little vigor and 10 to those with optimal vegetative development.

At harvest, all fruits were manually harvested from tarpaulins when they reached 80% of maturity, being the transport and the wet mass measurement performed immediately after harvest.

The wet processing was used, where the green coffee, the buoy and the cherry were separated, being this peeled. Drying was carried out in suspended terrarium with plastic cover, and the coffee was spread in layers of 7 Lm^{-2} until the dry half, after this, the layers were thickened to 14 L m^{-2} . The stirring was performed manually at 1 hour intervals. The cherries coffee of the 100 plants were withdrawn from the suspended yard when they presented 12% b.u. and subsequently, after two months, all the samples were submitted to sensory analysis.

2.1 Preparation of samples for sensory analysis of coffee

Coffee samples were prepared at the Center for Sensory and Physical Analysis of Brejetuba, ES. The sensorial evaluation process was performed following the SCAA methodology. The coffee toasters were conducted using the Agtron-SCAA disc set as reference, the roasting point of these samples was standardized on the # 60 disc, and was performed for 8 to 10 minutes. The towers were executed 24 hours in advance, being that the grinding was performed at the time of the evaluation.

2.2 Method of evaluation of samples by Q-Graders

After the roasting process, coffee quality was evaluated through the Protocol for Sensory Analysis of Coffee Methodology Specialty Coffee Association of America - SCAA (SCAA, 2019), which is expressed through of a centesimal numerical scale. The tasting form provides an opportunity to evaluate eleven important attributes for coffee: Fragrance / Aroma, Uniformity, Absence of Defects (Clean Cup), Sweetness, Flavor, Acidity, Body, Aftertaste, Balance, Overall and Total Score, this being the sum of the other attributes, totaling 100 points. Coffees with total scores above 80 points are considered specials, resulting from the perception of Q-graders of a balanced set formed by the evaluated attributes.

The results of this sensory evaluation are established from a scale of 16 units representing quality levels with intervals of 0.25 between numerical values between "6" and "10". For coffees considered good 6.00 to ≤ 7.00 , very good from 7.00 to ≤ 8.00 , excellent, 8.00 to ≤ 9.00 and exceptional from 9.00 to 10.00 points.

2.3 Statistical analysis

To group the different plot sizes and their respective coefficients of variation, we used the bootstrap method with repositioning, where 1000 sample simulations were performed with plots with 1, 2, 4, 5, 10, 20, 25 and 50 plants. In other words, for sample simulations with plots with 1 plant, 1000 data were randomly removed with replacement for each characteristic to determine the respective coefficient of variation. When plots with 2 plants were used, data from 2 plants were randomly taken 1000 times with replacement to determine the coefficient of variation of each characteristic, and hence for plots with 4, 5, 10, 25 and 50 (Leonardo *et al.*, 2014).

The groupings of the pairs $[X, CV_{(X)}]$ were used to estimate the parameters of the linear plateau response model. For this method, the optimal plot size occurs when the linear model becomes a plateau (Equation 2):

$$Y_i = \begin{cases} \beta_0 + \beta_1 X_i + \varepsilon_i & \text{se } X_i \leq X_0 \\ P + \varepsilon_i & \text{se } X_i > X_0 \end{cases} \quad (2)$$

where Y_i is the response variable, β_0 is the linear coefficient of the linear model of the segment before the plateau, β_1 is the angular coefficient of this same segment, ε_i is the error

associated with the i th observation, and P is the plateau, and X_0 is the point of connecting from both segments. P and X_0 are parameters to be estimated.

The regression models were tested by the F test and the angular coefficients by the t test. The software R was used to perform the bootstrap simulations (R CORE TEAM, 2019) and the SAEG program to obtain the statistics of the methods for obtaining the optimal plot size (RIBEIRO JÚNIOR and MELO, 2008).

3 Results and discussion

The Figure 2 shows the results of coefficient of variation of the agronomic characteristics, plant height, plant diameter, vigor and wet mass, as a function of the number of plants, obtained from the 1000 sample simulations by the bootstrap method, with 1, 2, 4, 5, 10, 20, 25 and 50 plants. The optimal plots sizes - X_{op} for the characteristics, were obtained using the linear regression method of plateau response, with optimal sizes of 6.50; 6.74; 6,24 and 6,64 plants, respectively, for the characteristics of plant height, plant diameter, vigor and wet mass, that is, approximately 7 arabica coffee plants per useful experimental plot.

For the characteristics fragrance, flavor, aftertaste, acidity, body and uniformity (Figure 3), the optimal sizes of experimental plots were, respectively, 6.35; 6.17; 6.53; 6.77; 6.66 and 6.36 plants, that is, approximately 7 plants per useful experimental plot.

Finally, the Figure 4 shows that the optimal experimental plot size, for balance, clean cup, sweetness, overall and total score, was, respectively, 6.31; 6.68; 6.98; 6.51 and 6.35 plants per useful experimental plot, that is, approximately 7 plants.

All regression models and angular coefficients of Figures 2, 3 and 4 were significant, respectively, by the F and t tests.

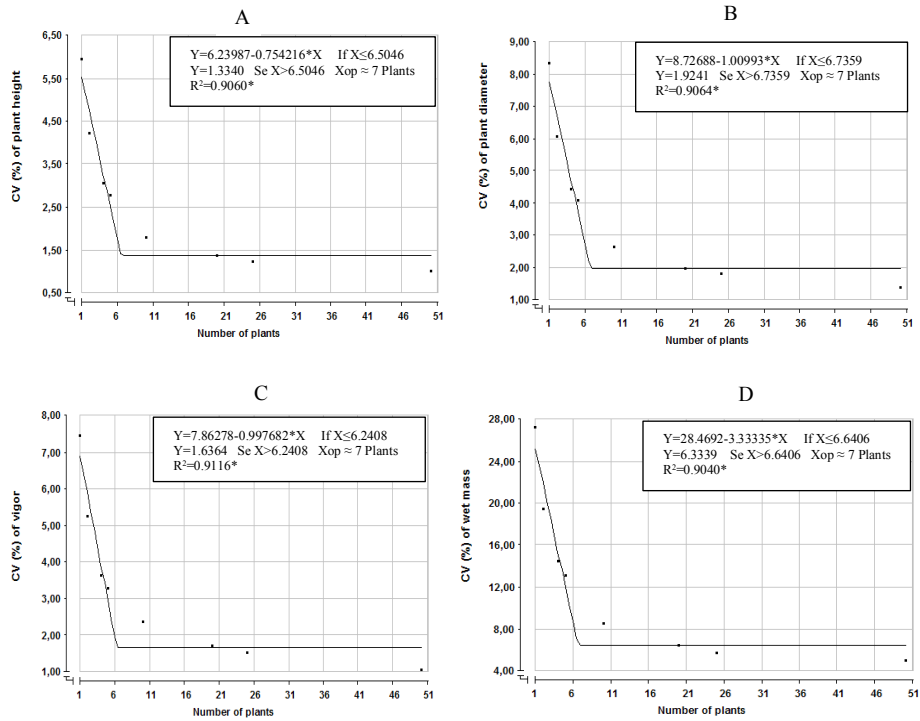


Figure 2 - Relationship between coefficient of variation and plot size by linear model of plateau response and estimated regression equation, optimal plot size and coefficient of determination for plant height (A), plant diameter (B), vigor (C) and wet mass (D). X_{op} = optimal plot size. * = significant at 5%, by the tests F and t.

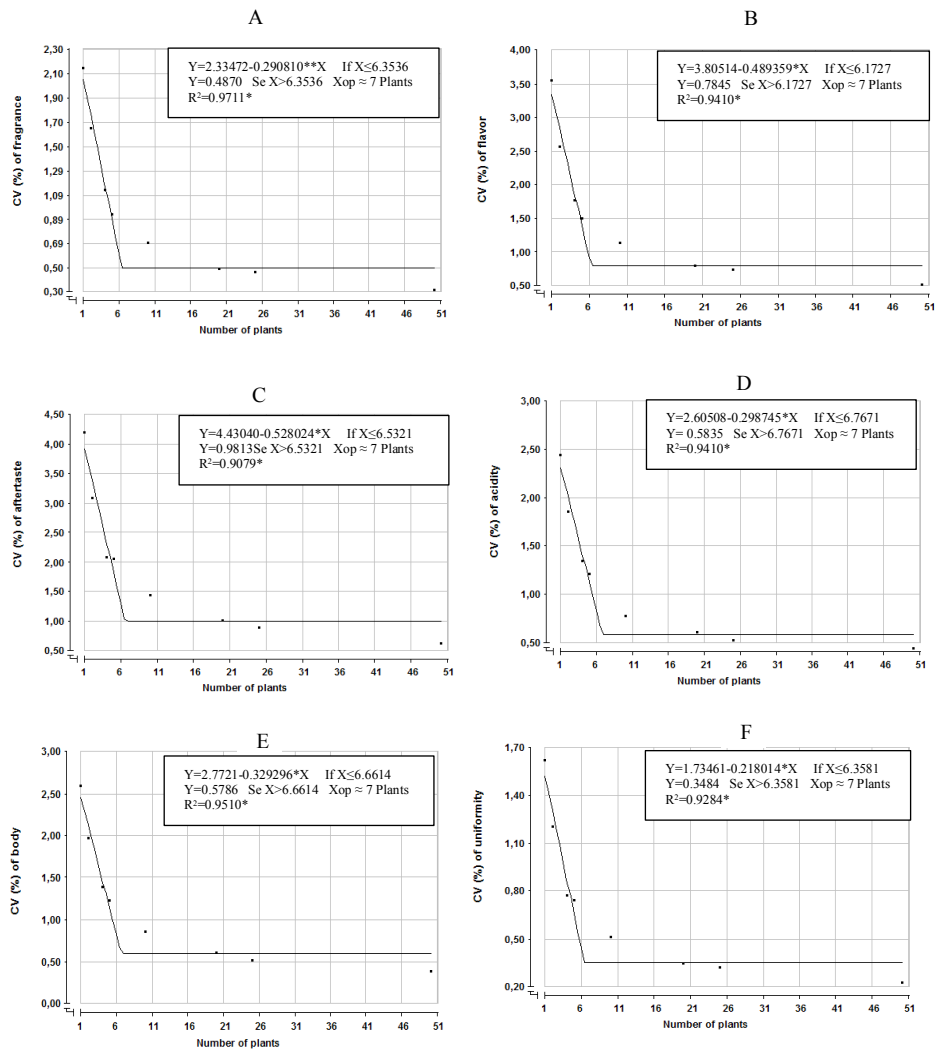


Figure 3 - Relationship between the coefficient of variation and plot size by the linear regression method of plateau response and estimated regression equation, optimal plot size and coefficient of determination for Fragrance / Aroma (A), Flavor (B), Aftertaste (C), Acidity (D), Body (E) and Uniformity (F). X_{op} = optimal plot size. * and ** = significant, respectively, at 5 and 1%, by the tests F and t.

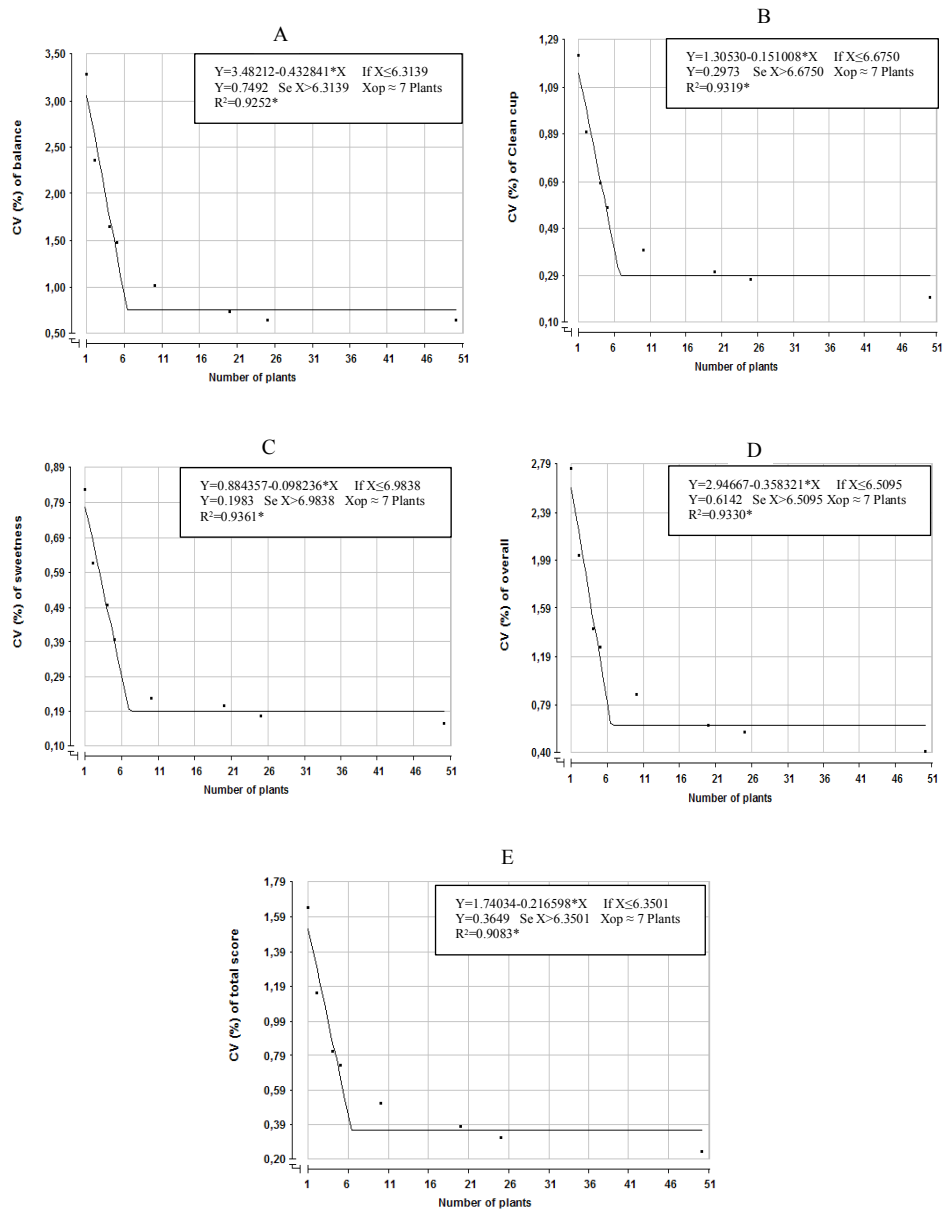


Figure 4 - Relationship between coefficient of variation and plot size by linear regression method of plateau response and estimated regression equation, optimal plot size and coefficient of determination for Balance (A), Clean Cup (B), Sweetness (C), Overall (D) and Total Score (E) characteristics. X_{op} = optimal plot size. * = significant at 5%, by the tests F and t.

These results were lower than those used in arabica coffee experiments. Bonomo *et al.* (2008) used 10 useful plants to evaluate the average yield of coffee cultivars Catuaí IAC 44, Acaiaí Cerrado MG 1474, Rubi MG 1192 and Topázio MG 1190, Oeiras MG 6851, under irrigation. Veiga *et al.* (2018) also used 10 plants per plot to evaluate the agronomic performance and adaptability of new cultivars and progenies of *Coffea arabica* resistant to coffee rust. Freitas *et al.* (2007) used 8 plants per plot in a work that studied the association between quantitative characters related to the vegetative growth in cultivars of low arabica coffee size. Cipriano *et al.* (2014) verified in the evaluation of the characteristics masses and volumes after drying adult coffee of the cultivar Topázio MG1190, using the maximum curvature method, that are necessary 8 plants in the useful plot.

On the other hand, the results obtained in this work were superior to those obtained by many researchers. Silva *et al.* (2013) who used 5 plants of arabica coffee progenies per plot to evaluate the operational performance of mechanized and selective coffee harvesting as a function of fruit detachment strength. Vilela *et al.* (2017) used 6 plants in the useful plot to evaluate plant height, diameter of the lap of the plant, number of plagiotropic branches, growth of the first plagiotropic branch, chlorophyll index and leaf nutrient contents, in an experiment that evaluated new cultivars of arabica coffee in function of NPK. Paiva *et al.* (2010) evaluated the agronomic behavior of low size progenies, using 4 plants per useful plot.

The results obtained suggest that experiments conducted with more than 7 arabica coffee plants per experimental plot will not increase the experimental accuracy, but will spend time, and human and financial resources beyond what is necessary.

Conclusions

It is recommended to use seven or more arabic coffee plants in experimental plot to evaluate preharvest, harvest characteristics and sensory characteristics.

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- **RESUMO:** *O cultivo do café é de grande importância socioeconômica para o Espírito Santo, gerando, além de empregos diretos e indiretos, recursos financeiros. O primeiro levantamento da safra 2019 da CONAB indica que a produção esperada é de 12,5 a 14,7 milhões de sacas beneficiadas. A pesquisa sobre o cultivo de café contribuiu para o desenvolvimento de novas tecnologias, mas o tamanho das parcelas para experimentos com café é variável e baseia-se, principalmente, na experiência do pesquisador. Assim, o objetivo deste trabalho foi determinar os tamanhos ótimos de parcelas experimentais para avaliar as características sensoriais e de pré-colheita e produção do café arábica. A modelagem aplicada neste estudo permite concluir que,*

de acordo com os dados testados, é possível recomendar o tamanho ótimo de parcelas experimentais para o café arábica para diversas condições e variedades edafoclimáticas. As conclusões são as seguintes: recomenda-se o uso de sete ou mais plantas de café arábica para avaliar as características de pré-colheita e colheita (altura da planta, diâmetro da planta, vigor e massa úmida) e usar, pelo menos, sete plantas de café arábica para avaliar características sensoriais (fragrância, sabor, sabor residual, acidez, corpo, uniformidade, equilíbrio, xícara limpa, doçura, pontuação geral e total).

- PALAVRAS-CHAVE: Café arábica; bootstrap; precisão experimental; planejamento experimental.

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