Determining the minimum size of experimental plot for evaluating field parameters for Arabica coffee

Determinação do tamanho mínimo da parcela experimental para avaliação de parâmetros de campo para café arábica

Determinación del tamaño mínimo de la parcela experimental para la evaluación de parámetros de campo para café arábigo

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Abstract

The coffee production chain has great socio-economic importance in Brazil, generating foreign exchange with great job-generating capacity. The Brazilian coffee production is circa 2.863 k tons and coffee research has contributed to the development of new technologies in order to increase yield. However, the size of plots used for coffee experiments has been variable and mostly based on the empirical researcher's experience. Therefore, this research was carried out aiming to determine the optimal size of experimental plots to evaluate field growing parameters of Arabica coffee. The modified maximum curvature model and the comparison of variances were the methods used. It is concluded that 2, 3, 3, and 6 plants per useful experimental plot of Arabica coffee are enough to evaluate the field growing parameters plant height, plant canopy diameter, vigor, and wet mass, respectively by the method of modified maximum curvature. Two plants per experimental plot were required when using the variance comparison method to the parameters plant height, and plant canopy diameter, and 4 plants were enough to the parameters vigor and wet mass. In general, four useful plants per experimental plot were enough using the variance comparison method and six useful plants when using the modified maximum curvature method.

Keywords: Bootstrap; Experimental accuracy; Experimental planning; Simulation.

Resumo

A cadeia produtiva do café tem grande importância socioeconômica no Brasil, gerando divisas com grande capacidade de geração de empregos. A produção brasileira de café é de cerca de 2.863 mil toneladas e a pesquisa cafeeira tem contribuído para o desenvolvimento de novas tecnologias a fim de aumentar a produtividade. No entanto, o tamanho das parcelas usadas para experimentos com café tem sido variável e baseado principalmente na experiência do pesquisador empírico. Portanto, esta pesquisa foi realizada com o objetivo de determinar o tamanho ideal de parcelas experimentais para avaliar parâmetros de cultivo de café arábica em condições de campo. O modelo de curvatura máxima modificado e a comparação de variâncias foram os métodos utilizados. Conclui-se que 2, 3, 3 e 6 plantas por parcela experimental útil de café arábica são suficientes para avaliar os parâmetros de cultivo em campo altura da planta, diâmetro da copa da planta, vigor e massa úmida, respectivamente pelo método da máxima curvatura modificada. Foram necessárias duas plantas por parcela experimental quando se utilizou o método de comparação de variância para os parâmetros altura de planta e diâmetro da copa da planta, e 4 plantas foram suficientes para os parâmetros vigor e massa úmida. Em geral, quatro plantas úteis por parcela experimental foram suficientes pelo método de comparação de variância e seis plantas úteis pelo método da máxima curvatura modificada.

Palavras-chave: Bootstrap; Planejamento experimental; Precisão experimental; Simulação.

Resumen

La cadena productiva del café tiene gran importancia socioeconómica en Brasil, generadora de divisas con gran capacidad para generar empleos. La producción brasileña de café es de alrededor de 2.863 mil toneladas y la investigación del café ha contribuido al desarrollo de nuevas tecnologías para aumentar la productividad. Sin embargo, el tamaño de las parcelas utilizadas para los experimentos con café ha sido variable y se ha basado principalmente en la experiencia del investigador empírico. Por lo tanto, esta investigación se realizó con el objetivo de determinar el tamaño ideal de parcelas experimentales para evaluar parámetros de cultivo de café arábigo en condiciones de campo. El modelo modificado de máxima curvatura y la comparación de varianzas fueron los métodos utilizados. Se concluye que 2, 3, 3 y 6 plantas por parcela experimental útil de café Arábica son suficientes para evaluar los parámetros de cultivo en campo altura de planta, diámetro de copa de planta, vigor y masa húmeda, respectivamente por el método de curvatura máxima modificada. Se necesitaron de 2 plantas por parcela experimental cuando se utilizó el método de comparación de varianza para los parámetros altura de planta y diámetro de copa de planta, y 4 plantas fueron suficientes para los parámetros vigor y masa húmeda. En general, 4 plantas útiles por parcela experimental fueron suficientes por el método de comparación de varianza y 6 plantas útiles por el método de curvatura máxima modificada.

Palabras clave: Bootstrap; Planificación experimental; Precisión experimental; Simulación.

1. Introduction

The coffee production chain has great socio-economic importance in Brazil, generating foreign exchange with great job-generating capacity. The Brazilian coffee production is circa 2.863 k tons. This number represents a 25.7% of decrease when compared to the result of the 2020’ coffee harvest. The total area of Arabica and Robusta coffee in production is currently estimated at 2.2 million hectares, 1.8% greater than the estimated in the previous harvest. Arabica coffee represents 65% of Brazilian coffee production with an estimation of 1.884 k tons that will be yielded, signaling a 24.4% of total reduction (CONAB, 2021). The areas for the implantation of Arabica and Conilon coffee crops need to be properly mapped aiming to avoid significant production losses, as well as damage to coffee growers (Ferreira et al., 2021).

Due to the great importance of coffee growing for the Brazilian agribusiness, research must be carried out aiming to develop new technologies in order to improve technologies to increase yield such as those related to coffee cultivars developing. However, in the scientific investigations a different size of experimental plots had been used, generally defined by the empirical researcher's experience, and based on the financial and human resources available to carry out the trials (Guarçoni el al., 2017, 2020a). As an example, Silva et al. (2021) used 28 plants per plot in a field trial aiming to evaluate the initial growth of seedlings of six coffee cultivars in Areia-PB, Brazil, and Fernandes et al. (2020) used 10 plants per plot in Alto Paranaíba, MG, Brazil.

The researcher must define the experimental plot size in the experimental plans before installing your trials under field conditions aiming to increase the precision of results in research trials because. If the plot size is smaller than that obtained in the research, the estimates will be less precise inducing experimental errors and imprecise conclusions. The optimal size of experimental plots may be determined using several statistical methods including the modified maximum curvature, and the variance comparison. The former was used to determine the optimal experimental plot size for pineapple 'Vitória' (Leonardo et al., 2014), to determine the sample size for forage cactus traits and common beans (Guimarães et al., 2019b, 2021), cabbage (Mateus et al., 2020), and to determine the plot size for physicochemical parameters of Arabica coffee (Guarçoni et al., 2020b). It was also used to compare three methods of estimating the optimal plot size to evaluate the fresh matter productivity of millet, slender leaf rattlebox and showy rattlebox (Cargnelutti Filho, 2021).

The method of variance comparison estimates the variances of different plot sizes and compares them using the Bartlett test. This method was used to determine the size of experimental plots for field sweet potato production (Vallejo and Mendoza, 1992). This method was also used aiming to estimate plot size in forage cactus and cassava field trials (Guimarães et al., 2019a; Viana et al., 2002). These methods use blank or uniformity tests where only one variety is planted, receiving the same cultivation practices. For a greater consistency of the regression methods in obtaining the optimal experimental plot size, Mammen and Nandi (2012) used the bootstrap method, which consists of a statistical resampling technique based on simulation.

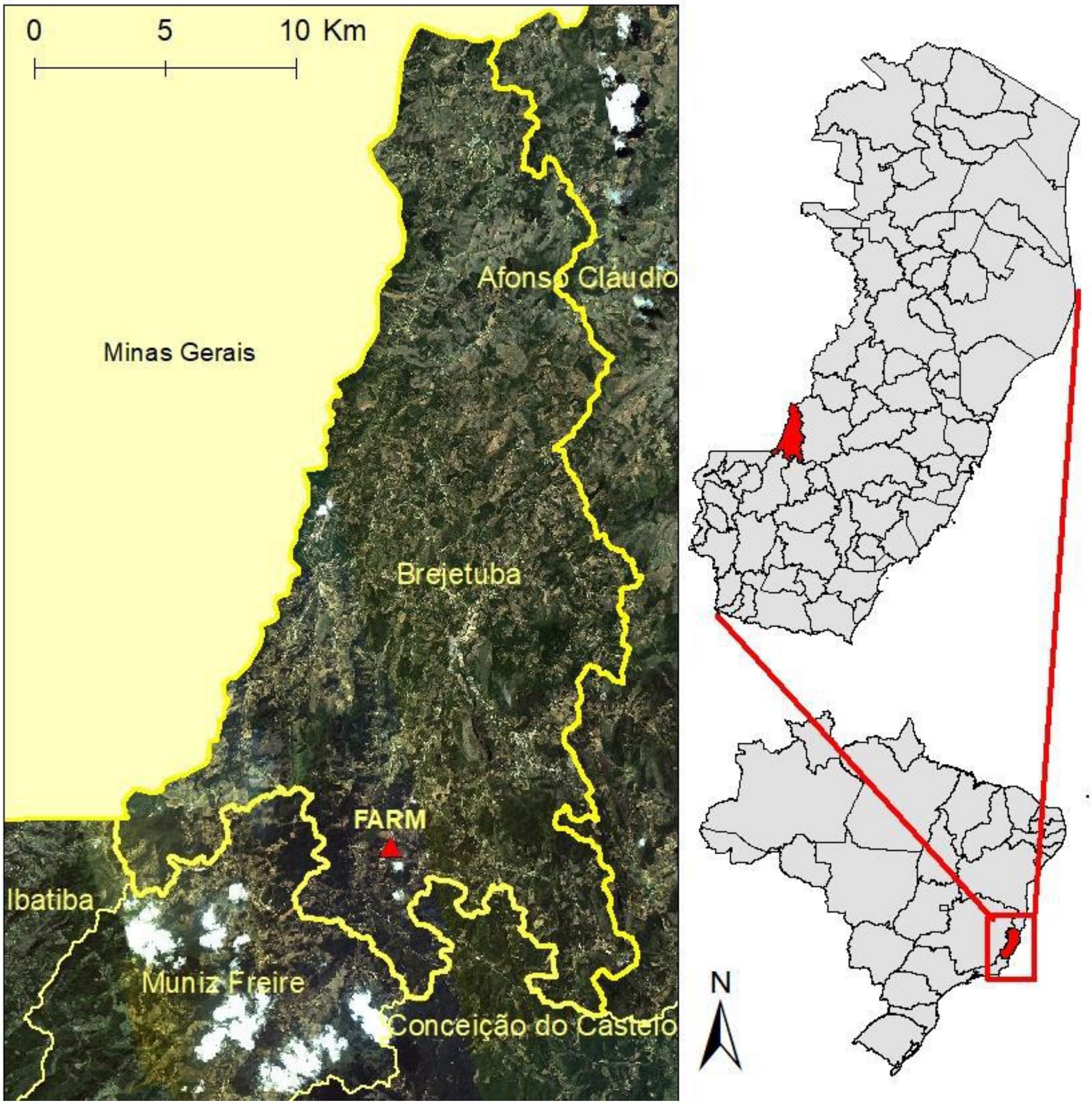
Research on optimal experimental plot size for Arabica coffee is important to increase experimental efficacy, as well as to optimize the cost/benefit ratio of the field trials. Based on this need, this research was carried out aiming to determine the optimal experimental plot size to evaluate the growing parameters of Arabica coffee under field conditions using the modified maximum curvature and variance comparison methods.

2. Methodology

2.1 Experimental trial

The uniformity trial was carried out using 100 useful plants with 10 lines of 10 Arabica coffee plants cultivar Catucaí 785/15 (CAK selection). The experimental area was located in a sloped (40%) region at 850 m altitude in the municipality of Brejetuba (20°13’08”S, 41°18’56W), State of Espírito Santo, Brazil (Figure 1). The coffee crop was six-years old and spaced 2 x 1 m. The same good agricultural practices were used in all coffee plants (Alixandre et al., 2020; Chávez et al., 2022). Weed control was performed using a manual costal mower from October to March. Liming was used in June and the fertilizer application was divided into three equal doses from October to March, according to the results of soil analysis. Chemical control of insects and diseases was carried out in the second half of October as a preventive measure.

Figure 1 – Map of farm location where the research was carried out according to altitude and geographical coordinates, municipality of Brejetuba, State of Espírito Santo, Brazil.



Source: Elaborated by Cecília U. Zandonadi (2022).

The field parameters plant height, plant canopy diameter, vigor, and wet mass 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 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. Vigor was evaluated by assigning grades on a scale of 1 to 10, depending on the vegetative development of the plants; grade 1 was given to plants with little vigor and 10 to those with optimal vegetative development (Guarçoni et al., 2020a).

2.2 Models for estimating the optimal experimental plot size

Statistical analyses were performed for the method of comparison of variances according to the criterion of hierarchical classification with the plots differing in size and number of plants, however, all of them filled the experimental area (Vallejo and

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Mendonza, 1992) (Table 1). This method consists of consecutive Bartlett tests to verify the homogeneity of the variances, excluding, in each test, the smallest portion in which the variance was statistically different. Testing continued until a group of plot sizes with statistically similar variances was obtained. Then, it was inferred that the smallest plot size of the tested group corresponded to the optimal experimental plot size (Vallejo and Mendoza, 1988).

Table 1 - Number of plants (#plants), area (area) and number of plots (#plots).

# plants	Area (m^2)	# plots
1	2	100
2	4	50
4	8	25
5	10	20
10	20	10
20	40	5
25	50	4
50	100	2

Source: Authors.

To determine the optimal size of experimental plots for the modified maximum curvature model method, the grouping of different plot sizes and their respective coefficients of variation was used by the bootstrap method with 1000 sample simulations with 1, 2, 4, 5, 10, 20, 25 and 50 plants per experimental plot (Leonardo et al., 2014). For the modified maximum curvature method (Lessman and Atkins, 1963) the process begins with the adjustment of equation 1 for the evaluated parameters:

$$CV_X = \frac{A}{X^B} \quad (equation\ 1)$$

For this method, the optimal plot size - X*op* is calculated algebraically through equation 2, where A and B are obtained by the least-squares method.

$$X_{OP} = \left[\frac{A^2B^2(2B+1)}{B+2}\right]^{\frac{1}{2+2B}} (equation\ 2)$$

2.3 Statistical analysis

Free software R was used to carry out the bootstrap process simulations and to obtain the statistics on the methods for the optimal plot size (R Core Team, 2021). The regression models of the modified maximum curvature method were tested using the F test, and the variances of the comparison of variances test were compared using the Bartlett test.

3. Results and Discussion

The variances of the plots with 1 and 2 plants differed statistically from each other for the parameters plant height and plant canopy diameter; the variances of the other sizes of plots also did not differ statistically from each other, two by two, by the Bartlett test ($p>0.05$). The optimal experimental plot size was 2 plants for these two variables or for the 4 m^2 area (Table 2) (Vallejo and Mendonza, 1992). On the other hand, for the parameters vigor and wet mass, the variances of the plots with 2 and 4 plants differed from each other, and the optimal experimental plot size for these two characteristics was 4 plants.

These data confirm the inverse relationship between plot sizes and their respective variances, as these tend to decrease with increasing plot size (Vallejo & Mendonza, 1992).

Table 2 - Estimates of plot size variances for the evaluated field parameters of Arabica coffee plants.

# plants	# plots	Evaluated field parameters of Arabica coffee plants			
		plant height	plant canopy	vigor	wet mass
1	100	0.008344758 a*	0.0020872350 a	0.24270200 a	2771096 a
2	50	0.003838408 b	0.0009317827 b	0.15002550 a	1305509 b
4	25	0.002221500 b	0.0006527162 b	0.06260417 b	403812.7 c
5	20	0.002189168 b	0.0005419790 b	0.04155263 b	251048.8 c
10	10	0.001061289 b	0.0004150382 b	0.03669444 b	225322.6 c
20	5	0.000708300 b	0.0003220250 b	0.02668750 b	113708.0 c
25	4	0.000338080 b	0.0001299870 b	0.01103333 b	69739.64 c
50	2	0.000079380 b	0.0000316013 b	0.00320000 b	64296.98 c

*Variances followed by the same letter in the column do not differ by the Bartlett test ($p<0.05$). Source: Authors.

The coefficient of variation of the parameters plant height, plant canopy diameter, vigor, and wet mass was a function of the number of plants using the modified maximum curvature model method (Figure 1). The optimal size of experimental plots for the parameters plant height, plant canopy diameter, vigor, and wet mass was respectively 1.83; 2.35; 2.20 and 5.12, respectively, with approximately 2, 3, 3, and 6 plants per useful experimental plot.

The results of the optimal plot size using the two studied methods were lower than those used in field Arabica coffee trials such as Veiga et al. (2018) and Bonomo et al. (2008). These trials used 10 plants per plot to evaluate field parameters of Arabica coffee genotypes resistant to rust and also the yield under irrigation. Our results were also inferior to those carried out by Freitas et al. (2007) and Cipriano et al. (2014). These authors used 8 plants in the useful plots in order to study quantitative parameters in small heights Arabica coffee cultivars, and also the mass and volume parameters of the coffee cultivar Topázio MG1190.

The results obtained using the methods of variance comparison and using the modified maximum curvature model were lower than those pointed out by Guarçoni et al. (2020a); these authors found the number of 7 plants per useful experimental plot in the linear plateau response model method when evaluating agronomic and sensory parameters.

The results obtained in this study using the modified maximum curvature model, e.g., six plants were also found by Guarçoni et al. (2020b) with physicochemical parameters of coffee. On the other hand, the number of four useful plants per plot was pointed out using these authors using the method of variance comparison for the same physicochemical parameters.

Plot size for field parameters pointed out in the maximum curvature model has already been found by Vilela et al. (2017) evaluating parameters of new Arabica coffee cultivars as a function of NPK fertilization when they used six plants in the useful plot. Paiva et al. (2010) evaluated the agronomic behavior of small heights progenies using four plants per useful plot, a result observed for the three characteristics in the method of comparison of variances.

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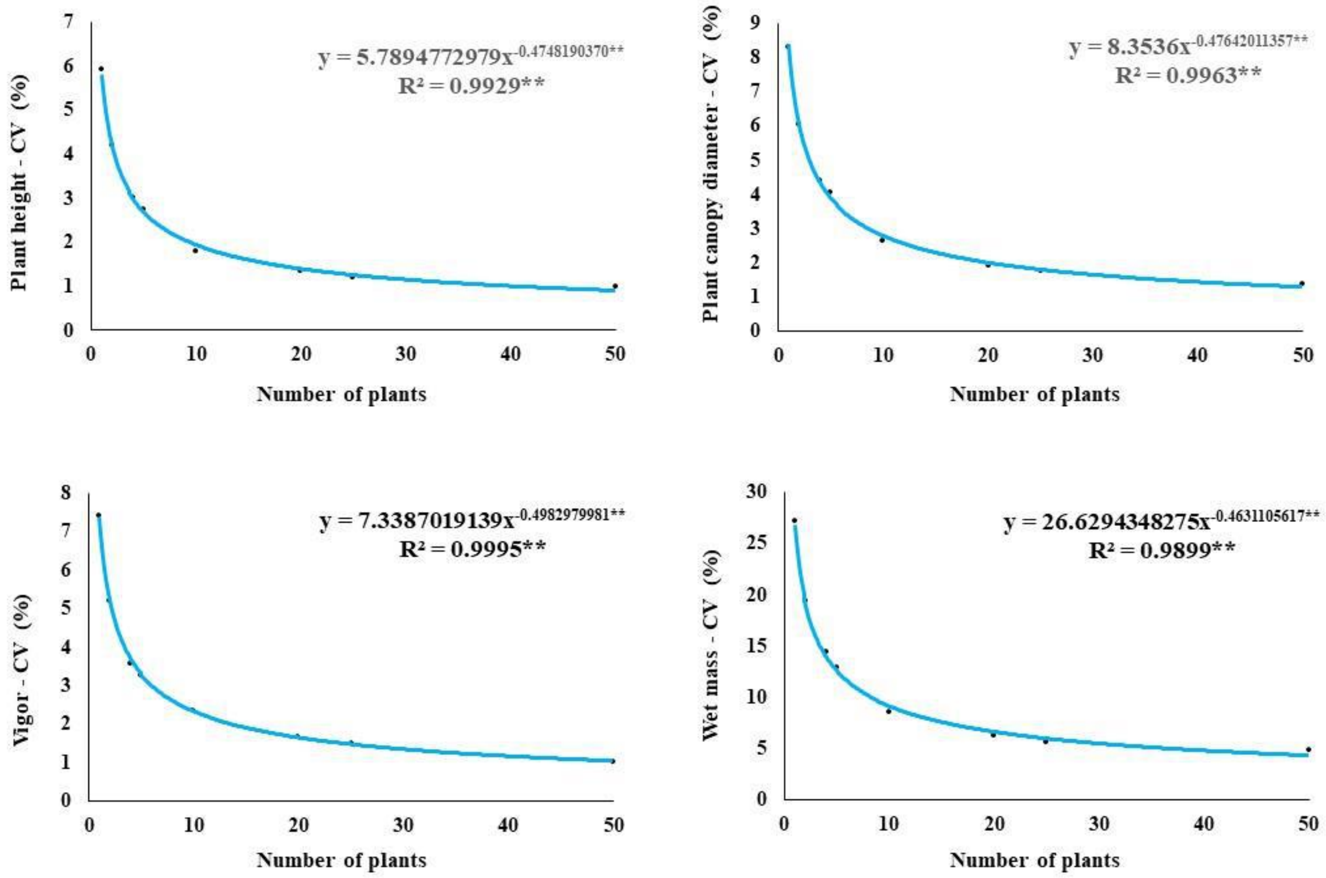
Figure 2 – Relationship between the coefficient of variation and plot size using the modified maximum curvature method for the parameters plant height (A), plant canopy diameter (B), vigor (C), and wet mass (D); * = significant at 5%; ** = significant at 1%, by the F test; ns = not significant.



Source: Authors.

4. Conclusion

The modeling used in the present study allows us to conclude that it is possible, according to the tested data, to recommend the optimal size of experimental plots for Arabica coffee.

According to the modified maximum curvature method it is needed 2, 3, 3, and 6 plants per useful experimental plot of Arabica coffee to evaluate the parameters of plant height, plant canopy diameter, vigor, and wet mass.

According to the method of variance comparison, two useful plants per experimental plot are enough for evaluating the plant height and plant canopy diameter, and four plants to evaluate the vigor and wet mass.

In general, four useful plants per experimental plot are needed for the variance comparison method and six useful plants for the modified maximum curvature method.

Other uniformity experiments with other Arabica coffee cultivars need to be carried out in order to not harm the final experimental accuracy.

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References

Bonomo, R., Oliveira, L. F. C., Silveira Neto, A. N. & Bonomo, P. (2008). Produtividade de cafeeiros arábica irrigados no cerrado goiano. *Pesquisa Agropecuária Tropical*, 38 (4), 233-240.

Cargnelutti Filho, A., Loregian, M. V, Bubans, V. E., Somavilla, F. M., Da Costa, S. L. (2021). Comparison of methods for estimating the optimum plot size for pearl millet, slender leaf rattlebox, and showy rattlebox. *Revista Caatinga*, 34 (2), p. 267-256.

Chávez, D. M. N., Jácome, M. G. O. & Florentino, L. A. (2022). Good agricultural practices in enterprises led by young people and women from family farming in Minas Gerais. *Research, Society and Development*, 11 (4), e44811427537.

Cipriano, P. E., Ferreira Junior, J. B., Almeida, S. L. S. & Campos, K. A. (2014). Tamanho útil de parcela para produtividade de cafeeiro adulto. *Revista da Estatística*, 3 (3), 734-738.

CONAB - Companhia Nacional de Abastecimento. Acompanhamento da Safra Brasileira de Café. Safra 2021. (2021). *Quarto Levantamento*. https://www.conab.gov.br/info-agro/safras/cafe/boletim-da-safra-de-cafe.

Fernandes, M. I. S., Assis, G. P., Nascimento, l. G., Cunha, B. A., Airão, A. L. C. & Gallet, D. S. (2020). Coffee cultivars productive and quality parameters in the Alto Paranaiba region, Minas Gerais, Brazil. *Research, Society and Development*, 9 (9), e147996681.

Ferreira, M. L., Andrade, A; M. & Santiago, W. E. (2021). Geoprocessing applied to the identification of areas suitable for coffee cultivation. *Research, Society and Development*, 10 (4), e17410414050.

Freitas, Z. M. T. S., Oliveira, F. J., Carvalho, S. M., Santos, V. F. & Santos, J. P. O. (2007). Avaliação de caracteres quantitativos relacionados com o crescimento vegetativo entre cultivares de café arábica de porte baixo. *Bragantia*, 66 (2), 267-275.

Galvão, R. N., Silva, S. S., Costa, V. C., Caliman, G. B., Betini, R. P., Oliveira, T. N., Côco, L. G., Andrião, N. B., Pereira, L. L., Caliman, R. B., Guarçoni, R. C. & Rodrigues, F. C. (2018). Tamanho de amostra para avaliar características físico-químicas de tomate. *Revista Científica Intelletto*, 3, 1-10.

Guarçoni, R. C., Souza, J. L., Favarato, L. F., Angeletti, M. P. & Bahiense, D. V. (2017). Determinação do tamanho ótimo de parcela experimental para experimentos com repolho utilizando simulação e métodos de estimação. *Revista Científica Intelletto*, 2 (2), 79-87.

Guarçoni, R. C., Alixandre, F. T., Sousa, D. G., Pereira, L. L., Brioschi Junior, D., Souza, L. H. B. P., Favarato, L. F. & Marcate, J. P. P. (2020a). Plot size for evaluation of agronomic and sensorial characteristics of arabica coffee. *Revista Brasileira de Biometria*, 38 (1), 57- 68.

Guarçoni, R.C., Brioschi Junior, D., Alixandre, F. T., Pereira, L. L., Sousa, D. G., Marcate, J. P. P., Favarato, L. F., Souza, L. H. B. P., Fornazier, M. J. & Filete, C. A. (2020b). Tamanho ótimo de parcela experimental para avaliar características físico-químicas de café arábica. *Revista Ifes Ciência*, 6 (3), p.03-11.

Guimarães, B. V. C., Carvalho, A. J., Aspiazú, I., Silva, L. S., Silva, R. R. P., Pimenta, A. M. L., & Moura, M. M. A. (2021). Optimal plot size for experimentation of common beans (*Phaseolus vulgaris* L.) in the northern region of Minas Gerais, Brazil: Experimental plots. Revista De La Facultad De Ciencias Agrarias UNCuyo, 53(2), 55–63. https://doi.org/10.48162/rev.39.039

Guimarães, B. V. C., Donato, S. L. R., Aspiazu, I., Azevedo, A. M. & Carvalho, A. J. (2019a). Methods for Estimating Optimum Plot Size for 'Gigante' Cactus Pear. *Journal of Agricultural Science*, 11 (14), 205-215.

Guimarães, B. V. C., Donato, S. L. R., Aspiazu, I., Azevedo, A. M. & Carvalho, A. J. (2019b). Size of plots for experiments with cactus pear cv. Gigante. *Revista Brasileira de Engenharia Agrícola e Ambiental*, 23 (5), 347-351.

Leonardo, F. A. P., Pereira, W. E., Silva, S. M., Araújo, R. C. & Mendonça, R. M. N. (2015). Tamanho ótimo da parcela experimental de abacaxizeiro 'Vitória'. *Revista Brasileira de Fruticultura*, 36 (4), 909-916.

Lessman, K.J. & Atkins, R.E. (1963). Optimum plot size and relative efficiency of lattice designs for grain sorghum yield test. *Crop Science*, 3 (1), 477-481.

Mammen, E. & Nandi, S. Bootstrap and resampling. (2012). In: Gentle, J. E., Hardle, W. K. & Mori, Y. (Ed.). *Handbook of computational statistics*, p. 499-527.

Mateus, V. F., Moreira, G. R., Jaeggi, M. E. P. C. Rocha, R. S., Silva, R. K. G., Pereira, I. M., Oliveira, T. R. A., Cruz, D. P., Moreira, T. B. R., Oliveira, W. B. S.., Rocha, J. G., Monteiro, E. C., Souza, A.; Sant'Anna, C. Q. S. S.., Gravina, G. A., Daher, R. F.; Rodrigues, R R., Parajara, M. C.; Batista, J. N., Capetini, S. A. (2020). Optimal plot size for cabbage experiments. Research, Society and Development, 9 (11), e2239119744.

Paiva, R. N., Carvalho, C; H. S., Mendes, A. N. G., Almeida, S. R., Matiello, J. B. & Ferreira, R. A. (2010). Field performance of coffee progênies (*Coffea arabica* L.) in Varginha, Minas Gerais State. *Coffee Science*, 5 (1), 49-58.

R CORE TEAM. R: *A language and environment for statistical computing, version 4.0.5.* (2021). https://www.R-project.org.

Silva, G. R., Sousa Neto, A. T., Costa, J. E., Podestá, G. S. & Souza Júnior, S. L. (2021). Initial development of cultivars of *Coffea arabica* L.in Brejo Paraibano. *Research, Society and Development*, 10 (6), e45410615906.

Vallejo, R. L. & Mendoza, H. A. (1992). Plot technique studies on sweet potato yield trials. *Journal of the American Society for Horticultural Science*, 117 (3), 508-511.

Veiga, A. D., Rocha, O. C., Guerra, A. F., Bartholo, G. F., Rodrigues, F. C., Pereira, W., Silva, T. P. & Silva, E. R. P. (2018). Agronomic performance and adaptability of Arabic coffee resistant to leaf rust in the central Brazilian savanna. *Coffee Science*, 13 (1), 41-52.

Viana, A. E. S., Sediyama, T., Cecon, P. R., Lopes, S. C. & Sediyama, M. A. N. (2002). Estimativas de tamanho de parcelas em experimento com mandioca. *Horticultura Brasileira*, 20 (1), p. 58-63.

Vilela, D. J. M., Carvalho, G. R., Botelho, C. E., Carvalho, A. M., Praxedes, M. A., Santos, M. C. & Fernandes, F. C. (2017). Crescimento inicial de cultivares de cafeeiro com diferentes doses de nitrogênio, fósforo e potássio. *Coffee Science*, 12 (4), 552-561.