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New model of clonal garden for the production of robusta coffee plantlets

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Abstract – The objective of this work was to evaluate the production of cuttings of *Coffea canephora* genotypes, in a new system for training mother plants called “vertical clonal garden”. The proposed new system consists of training coffee plants with only one shoot and without bending the main shoot, so that the secondary orthotropic shoots, from which the clonal cuttings will be taken, are formed across the length of the stem in the vertical direction. The capacity for the production of cuttings of ten hybrid genotypes of coffee plants was evaluated over ten production cycles. The 'BRS 2314', 'BRS 3213', and 'BRS 3210' genotypes showed cutting production per cut of 425,000 cuttings per hectare, considered above the obtained average. The 'BRS 3193', 'BRS 2336', 'BRS 3220', and 'BRS 3137' genotypes were the least productive. Coffee plants trained in the “vertical clonal garden” system can produce about 425,000 cuttings per hectare per harvest period or about 1.275 million cuttings per hectare per year, over three harvest periods, with a greater ease in crop management and treatments.

Index terms: *Coffea canephora*, conilon, cutting, vegetative propagation.

Novo modelo de jardim clonal para a produção de mudas de café robusta

Resumo – O objetivo deste trabalho foi avaliar a produção de estacas de genótipos de *Coffea canephora*, em um novo sistema de condução de plantas matrizes denominado “jardim clonal vertical”. O novo sistema proposto consiste da condução dos cafeeiros com apenas uma haste e sem o vergamento da haste principal, de tal forma que as hastes ortotrópicas secundárias, de onde serão retiradas as estacas clonais, sejam emitidas em toda a extensão do caule, no sentido vertical. A capacidade de produção de estacas de dez genótipos híbridos de cafeeiros foi avaliada durante dez ciclos de produção. Os genótipos 'BRS 2314', 'BRS 3213' e 'BRS 3210' apresentaram produção de estacas por corte de 425,000 estacas por hectare, considerada acima da média obtida. Já os genótipos 'BRS 3193', 'BRS 2336', 'BRS 3220' e 'BRS 3137' foram os menos produtivos. Cafeeiros conduzidos em sistema de “jardim clonal vertical” podem produzir cerca de 425,000 estacas por hectare por corte ou cerca de 1,275 milhão de estacas por hectare por ano, em três cortes, com maior facilidade de manejo e tratos culturais da lavoura.

Termos para indexação: *Coffea canephora*, conilon, estaquia, propagação vegetativa.

Introduction

Coffee plants of the *Coffea canephora* Pierre ex A. Froehner species are multiplied in a sexual or asexual manner. However, due to the benefits and ease of multiplication, the asexual propagation, especially by cutting methods, is most used commercially. The technique uses segments of secondary orthotropic shoots as vegetative propagules (Verdin Filho et al., 2014a). These segments, with a length of approximately 7.0 cm (Dias et al., 2012), are commonly called clonal cuttings. The cutting should contain a node with a pair of leaves, reduced to 1/3 of its length, and a pair of vegetative buds at the axils of the plagiotropic branches, which are reduced to two centimeters at the time of the cutting preparation (Giuriatto Júnior et al., 2020).

In the commercial production of plantlets, cuttings are taken from coffee plants that are grown in a field formally known as a “mother plant field”, popularly known as a “clonal garden” (Fonseca et al., 2019; Kolln et al., 2022). These clonal gardens are developed for the exclusive purpose of producing cuttings and, for that reason, plant management includes the elimination of plagiotropic branches (Bazoni et al., 2020) which are responsible for fruit production. Because of this differentiated management practice, coffee plants can be set up at a greater density than commonly used in commercial fields for coffee fruit / bean production, in which plant spacing ranges from 2.0 m to 3.0 m between the plant rows, and from 1.0 m to 1.5 m between the plants in the row (Verdin Filho et al., 2014b). At these spacing, the plant density ranges from 2,222 to 5,000 plants per hectare. However, for the clonal garden system, the coffee plants can be grown at spacing that result in densities from 10,000 up to more than 30,000 plants per hectare, as is the case of the high-density clonal garden. It uses the 0.4 m spacing between plants, 0.6 m between the two rows in a double row, and 1.0 m between the doubled rows (Fonseca et al., 2019). Regardless of the spacing used, the bending of the main orthotropic shoots is a very common technique to induce sprouting and to produce clonal cuttings.

The bending of the orthotropic shoots of the coffee plants induces the growth of secondary orthotropic shoots (Espindula et al., 2020). However, under the conditions of the clonal garden, the bent shoots often impede the management of weeds, pests, and diseases, since the shoots are bent in the direction of the between-row area. In addition, when the main shoots are bent when still young, it is difficult to collect the shoots that are very near the soil surface.

In the present study, the coffee plants were trained with only one shoot, which was not bent, thus facilitating the plant management, plant crop treatments, and collection of vegetative material.

The objective of this work was to evaluate the production of cuttings of *C. canephora* genotypes, in a new system for training mother plants called “vertical clonal garden”.

Materials and Methods

The experiment was carried out in the experimental field of Embrapa Rondônia, in the municipality of Ouro Preto do Oeste, in the state of Rondônia, Brazil (10°43q'55"S, 62°15'25"W, at 245 m altitude), from November 2016 to December 2020. The area, with a flat topography and soil type Argissolo Vermelho-Amarelo, according to Brazilian Soil Classification System (Santos et al., 2018) was in fallow for a period of three years.

Data regarding monthly compiled temperature and relative humidity (maximum, mean, and minimum), as well as accumulated rainfall, were obtained from an automatic weather station set up in the experimental field (Figure 1).

In May 2016 (before planting) and in May 2017, 2018, 2019, and 2020, soil samples were collected at 0–20 cm soil depths to perform analyses of chemical properties (Table 1). Soil tillage was plowing in two passes with a disk. The furrows had 50 cm depth and 50 cm width at the upper part. Soil amendment and fertilization consisted of 50 g of dolomitic limestone, 50 g of triple superphosphate, and 20 g of the complex fertilizer MIB (1.8% B, 0.8% Cu, 3.0% Fe, 2.0% Mn, 0.1% Mo) and 3.0 dm^3 organic compost per plant.

Nitrogen and potassium were supplied every 30 days, throughout the entire cycle, by applying urea and potassium chloride. The N rates were 560 kg ha^{-1} (2016/2017), 570 kg ha^{-1} (2018), and 645 kg ha^{-1} (2019 and 2020); K rates were 340 kg ha^{-1} (2016/2017), 120 kg ha^{-1} (2018), and 240 kg ha^{-1} (2019 and 2020). Phosphorus was supplied using single superphosphate or triple superphosphate, always at the beginning of each cycle, in January, May, and September of each year, at the

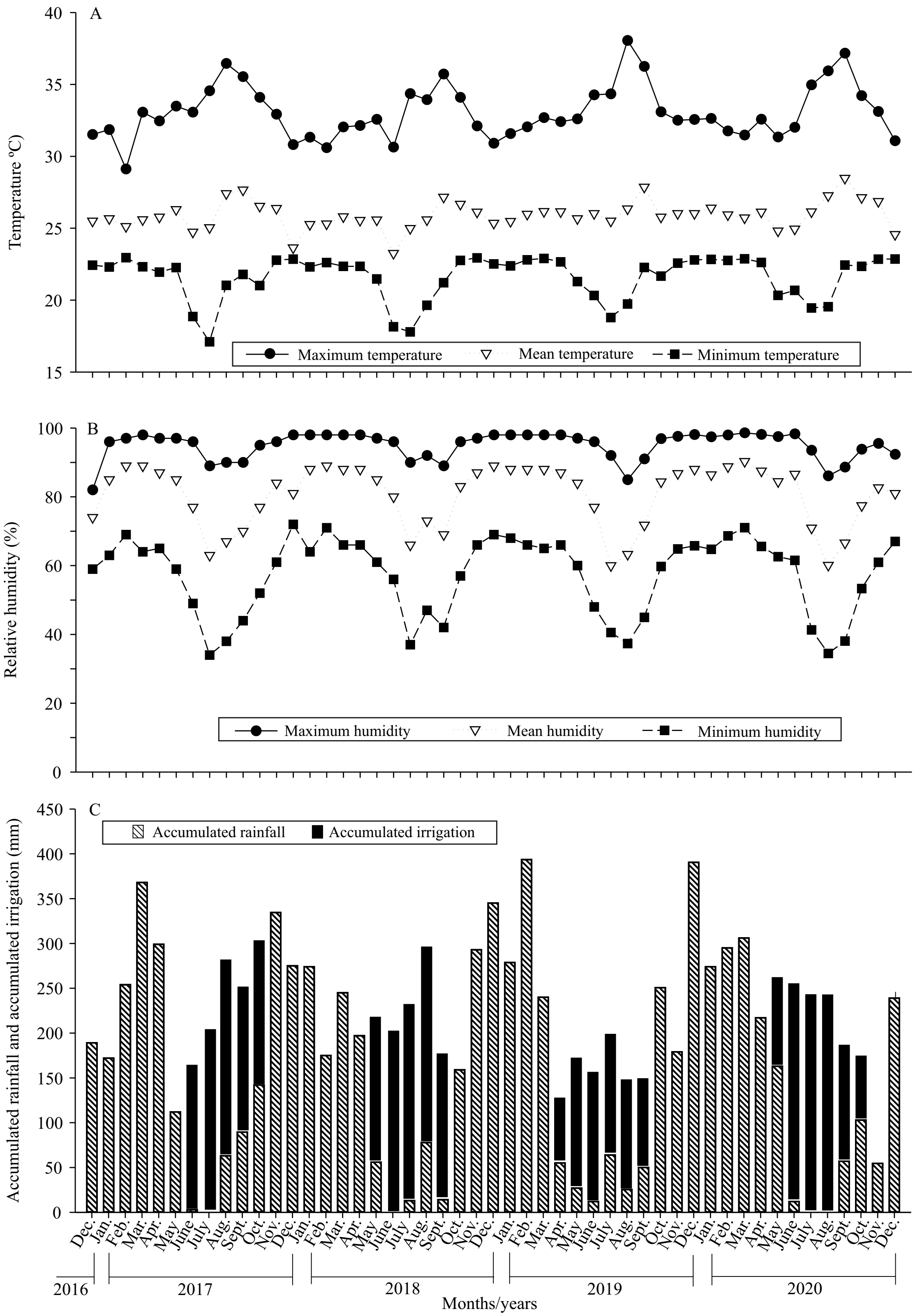

Figure 1. Experimental area conditions from December 2016 to December 2020, in the municipality of Ouro Preto do Oeste, in the state of Rondônia, Brazil: A, temperature; B, relative humidity; and C, rainfall and irrigation. Data obtained by an automatic weather station set up in the experimental field.

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following rates: 255 kg ha^{-1} (2016/2017); 165 kg ha^{-1} (2018); 81 kg ha^{-1} (2019); and 108 kg ha^{-1} (2020).

Calcium and sulfur were supplied by agricultural gypsum (calcium sulfate) and single superphosphate at the following rates: 1,000 kg ha^{-1} (2016/2017); 300 kg ha^{-1} (2018); and 500 kg ha^{-1} (2020). Calcium was also supplied by limestone, applied once a year at the following rates: 500 kg ha^{-1} (2016/2017); 1,000 kg ha^{-1} (2018 and 2019); and 2,000 kg ha^{-1} (2020). Magnesium was supplied by both limestone and applications in the form of magnesium sulfate at the following rates: 150 kg ha^{-1} (2016/2017); 260 kg ha^{-1} (2018); and 300 kg ha^{-1} (2019 and 2020).

Borax was supplied at 60 kg ha^{-1} (2016/2017 and 2018) and 90 kg ha^{-1} (2019 and 2020). Zinc sulfate was supplied at 80 kg ha^{-1} (2016/2017), 60 kg ha^{-1} (2018), and 90 kg ha^{-1} (2019 and 2020). Copper sulfate was supplied at 60 kg ha^{-1} (2016/2017), 70 kg ha^{-1} (2018), and 90 kg ha^{-1} (2019 and 2020). Just as the phosphorus supplementation, the fertilizers magnesium sulfate, borax, zinc sulfate, and copper sulfate were always supplied at the beginning of each cycle.

Organic compost – produced from cow manure, coffee plant residue, and elephant grass (*Pennisetum purpureum* Schumach.) – was applied every year, except for 2019, using the rates of 15,000 kg ha^{-1} (2016/2017) and 10,000 kg ha^{-1} (2018 and 2020).

Ten hybrid genotypes (conilon × robusta) of *C. canephora* coffee plants under the domain of Embrapa were used: 'BRS 1216', 'BRS 2299', 'BRS 2314', 'BRS 2336', 'BRS 2357', 'BRS 3137', 'BRS 3193', 'BRS 3210', 'BRS 3213', and 'BRS 3220' (Teixeira et al., 2020).

Clonal plantlets of 120 days of age were used to form the vertical clonal garden, in which mother plants are trained without bending and the full extension of the stem is used following the vertical direction. The plantlets were transplanted in December 2016 at a spacing of 2.0×0.5 m. Forage sorghum was planted between the coffee rows for the purpose of soil cover. The plants were trained with only one orthotropic shoot, and 70% of the plagiotropic branches were removed from the lower part of the stem at eight months after transplanting. That moment was considered the beginning of the first production cycle of the cuttings, and the first collection of cuttings was performed at 120 days after preparation of the plants, that is, when the clonal garden was 12 months of age, in December 2017.

After the first harvest period (December 2017), the plants were grown in 120-day cycles: December to April, April to August, and August to December, that is, three harvest periods per year (Figure 2). Thus, each new cutting production cycle began at the time of cutting harvest from the previous cycle and ended with the cutting harvest 120 days after that previous harvest (Figure 3). For the management of the plagiotropic branches, two pairs of these branch types were pruned every 60 days, always at the beginning and in the middle of each production cycle of cuttings.

In June 2019, when the plants were 30 months of age, it was necessary to prune the main shoot at the height of 1.70 m to reduce the total length of the stem. This procedure was performed in the middle of the cycle when the coffee plants were putting forth new secondary orthotropic branches. At the end of the cycle, a shoot was selected at the tip of the stem to recompose the canopy of the plant. The procedure was performed every 12 months to maintain the canopy of the plant at a height accessible for removal of the orthotropic shoots.

Table 1. Chemical properties of an Argissolo Vermelho-Amarelo (Santos et al., 2018) corresponding to the area of the robusta coffee (*Coffea canephora*) "vertical clonal garden" grown in the municipality of Ouro Preto do Oeste, in the state of Rondônia, Brazil(1).

Year	pH	P	K	Ca	Mg	H+Al	Al	CEC	m	V	OM
	water	(mg dm^{-3})	(cmol$_c$ dm^{-3})						(%)		(g kg^{-1})
May 2016	5.7	14.0	0.18	2.46	0.58	5.6	0.0	8.83	0.0	36	11.3
May 2017	5.0	33.5	0.26	1.78	0.67	6.80	0.44	9.53	15	28	12.2
May 2018	4.4	53.1	0.35	1.11	0.76	8.01	0.88	10.24	31	21	13.2
May 2019	4.8	40.0	0.32	1.08	0.63	6.70	0.61	8.76	23	23	12.8
May 2020	4.6	12.3	0.14	3.80	0.70	5.80	0.40	10.43	8.0	44	9.0

(1)pH in water 1:2.5; OM, organic matter by wet digestion; P and K determined by the Mehlich-I method; and exchangeable Ca, Mg, and Al extracted with 1.0 mol KCl; m and V, aluminum and base saturation, respectively.

During the dry season, from May to September of each year, supplemental irrigation was used in which a water depth of 6.0 mm was applied per day through a conventional fixed sprinkler system. Irrigation was applied every 48 hours, always at 6:00 p.m. Weeds were managed by a motorized backpack brush cutter whenever necessary. There was no need for control of pests and diseases, except for coffee red mite *Oligonychus ilicis* (Mc Gregor, 1919) (Acari: Tetranichidae), which was controlled using an acaricide with the active ingredient abamectin.

Cuttings were collected in ten periods. The number of viable cuttings produced per plant was counted for each harvest period, and the production of cuttings per hectare was estimated. A completely randomized design was used, with 25 replicates. Each replicate was represented by a plant; therefore, 25 plants were evaluated for each genotype.

To interpret the production of cuttings over time, the mean response of the ten genotypes was considered through regression analysis. The mean production of each genotype (mean of ten harvest periods) was considered for comparison of the production capacity of cuttings among the genotypes. Analysis of variance and the Scott-Knott test, both at 5% probability, were used to analyze the data.

Results and Discussion

The production of cuttings over ten harvest periods exhibited a nonlinear response in an increasing exponential manner to a maximum value, with a rapid increase of the first harvest periods and a tendency toward the stabilization from the fourth harvest period (Figure 4). The rapid increase of cutting productions followed by stabilization is expected, since up to 24 months, the orthotropic shoot had not yet reached its final length. In a similar way, the stabilization of production is explained by the apical pruning performed at 30 months, restricting plant growth to 1.70 m.

In coffee fruit production fields, plants first produce between 24 (Partelli et al., 2020) and 30 months (Bergo et al., 2020; Espindula et al., 2020), depending on the planting season and the flowering period, which generally occurs in July and August, under the conditions of the Western Amazon (Souza et al., 2017). As the product collected in the clonal garden is the cutting, and as the vegetative growth in crops under sprinkler irrigation in the Amazon is less affected by climate conditions (Dubberstein et al., 2017; Bazoni et al., 2020), the full production in the clonal garden can be considered as achieved from 24 to 28 months of age (Figure 4).

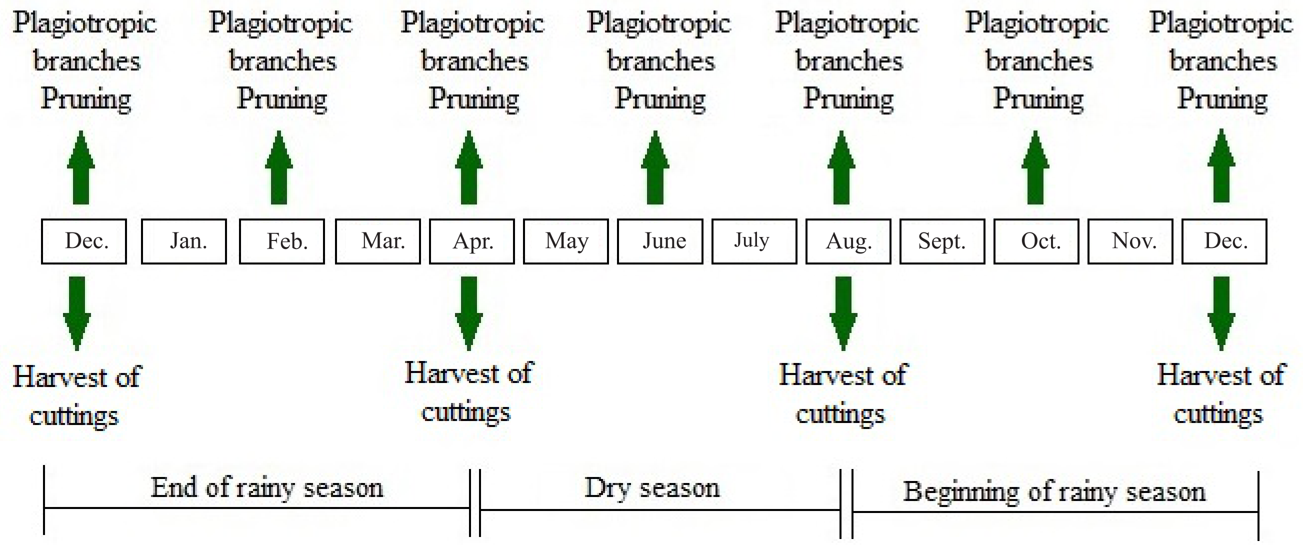

Figure 2. Annual timeline of the removal of secondary shoots for the production of cuttings (harvest of cuttings) and pruning of the plagiotropic branches in the “vertical clonal garden” of robusta coffee (*Coffea canephora*), in the municipality of Ouro Preto do Oeste, in the state of Rondônia, Brazil.

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To maintain the stimulus for the production of new shoots is to perform an annual pruning of the orthotropic shoots of coffee plants. Pruning inhibits the apical dominance of the plant and drastically reduces its auxin levels. This occurs because that hormone is predominantly synthesized in the apical meristem of shoot tips in coffee plants. Auxin functions as a mediator of the apical dominance and maintains the dormancy of the lateral buds (Taiz et al., 2017). It is understood that the lower is the synthesis of auxin in coffee plants, the greater will be the production of new shoots.

The genotypes alternated in the order of cutting production among the harvest periods over time, especially genotypes that had a cutting production near the mean value. Alternation in ordering indicates that a genotype may produce more cuttings in one harvest period and fewer cuttings in the following one, alternating its position in relation to the other genotypes.

Different production levels of cuttings from one harvest period to another, for the same genotype, may be related to the demand for resources, which in the high-production cycle can exhaust the plant and reduce its capacity for production in the next cycle of cutting production.

The stabilization of cutting production indicates that under the conditions of the Amazon region, the vegetative growth of plants is maintained with supplemental irrigation, although at lower rates during the dry period. In a commercial field for coffee fruit production in the forested region (*zona da mata*) of Rondônia, the growth of orthotropic shoots of about 0.5 mm per day was observed in June and July (Dubberstein et al., 2017). In a conventional clonal garden (2.5 × 1.5 m), coffee plants of 'BRS Ouro Preto', a conilon variety also grown in the experimental field of Embrapa, in Ouro Preto do Oeste, showed the following production (cuttings per hectare): 328,000, in January; 354,000, in May; and 498,000, in June (Bazoni et al., 2020). In this study, no difference for production was observed between harvest of January and May (beginning and end of the greatest rainfall period); however, in both periods, the production of cuttings was lower than in the dry period.

Figure 3. “Vertical clonal garden” system of robusta coffee (*Coffea canephora*) plants at 18 months of age: A, before the removal of secondary orthotropic shoots and excess plagiotropic branches (end of cycle); and B, after the harvest and cleaning of the plants (beginning of the next cycle) in April, 2018, in the municipality of Ouro Preto do Oeste, in the state of Rondônia, Brazil. Photos by Marcelo Curitiba Espindula

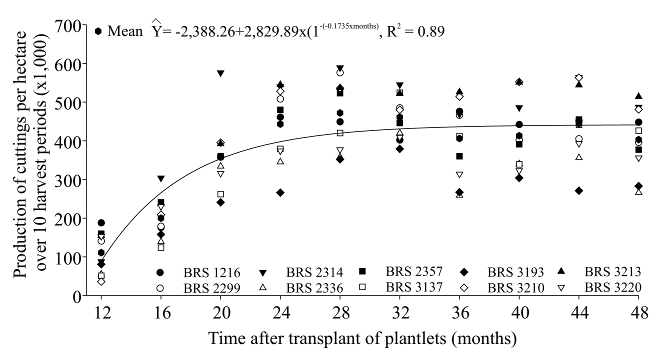

Figure 4. Production of cloning cuttings per harvest period (in thousands) from ten robusta coffee (*Coffea canephora*) genotypes in the “vertical clonal garden” system over ten harvest periods in 2021, the municipality of Ouro Preto do Oeste, in the state of Rondônia, Brazil.

In July, August, and September, the minimum relative humidity can be near 30%, and daily mean values are near 60%. The low rainfall of the period results in the increase of the maximum and mean temperatures and in the reduction of relative humidity (Figure 1). In the present study, the irrigation carried out by a fixed sprinkler system supplied the water needs and may also have led to a change of the microclimate in the area. The vegetative growth observed during the dry months occurred mainly because of the supplemental irrigation that attenuated the effect of water restriction in that period.

The absence of fruit on the plants may also be a factor for the stability of cutting production throughout the year. Since fruit is the main drain, its presence on the mother plant creates competition between the vegetative and reproductive structures. For that reason, the removal of plagiotropic branches (Figure 2) is an important practice for the management of clonal gardens, especially in the flowering period, to avoid fruit formation.

In the mean response of ten harvests, the genotypes 'BRS 2314', 'BRS 3210', and 'BRS 3213' produced the largest number of cuttings (per hectare) – 532,000, 506,000, and 516,000 per harvest period, respectively (Figure 5). If three harvest periods per year are considered, a production greater than 1.5 million cuttings per hectare is estimated for each of these three

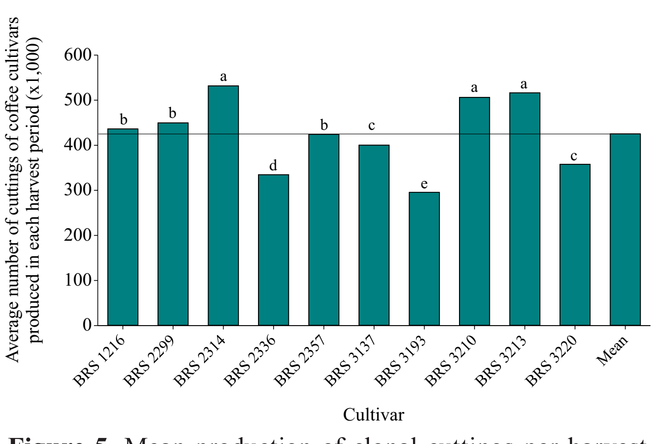

Figure 5. Mean production of clonal cuttings per harvest period (in thousands) of ten robusta coffee (*Coffea canephora*) genotypes in a "vertical clonal garden" system in 2021, in the municipality of Ouro Preto do Oeste, in the state of Rondônia, Brazil. Means followed by equal letters do not differ by the Scott-Knott test, at 5% probability.

genotypes annually. In contrast, genotypes were also observed to produce smaller number of cuttings. The genotype 'BRS 3193' produced 295,000 cuttings per harvest period, which resulted in 885,000 cuttings per hectare per year. In addition, the genotypes 'BRS 2336', 'BRS 3220', and 'BRS 3137' also exhibited productions with lower values than the overall mean. In the mean of the ten genotypes, the production per harvest period was 425,000 ha^{-1}, and the annual production was 1.275 million cuttings per hectare.

As to the observed differences for the cutting productions among the studied genotypes, we may point out that the capacity for putting forth secondary orthotropic shoots varies according to the genotype, according to the findings by Dalcomo et al. (2017) and Bazoni et al. (2020). For that reason, the knowledge of the production capacity of each genotype is important for the assistance with the clonal garden scaling, in agricultural ventures for the production of coffee plantlets. In the specific case of the genotypes 'BRS 3193', 'BRS 3220', 'BRS 2336', and 'BRS 3137', there will be the need for a larger number of plants, so that the number of cuttings will be equivalent to that of the other genotypes. Thus, if there is interest in producing plantlets of all genotypes in a balanced manner, the clonal garden can be scaled with more plants of these genotypes and fewer plants of 'BRS 2314', 'BRS 3210', and 'BRS 3213'.

Furthermore, it is important to emphasize that the spacing used was 2 × 0.5 m, which allowed of 10,000 plants per hectare. However, from visual observations, it can be deduced that a smaller spacing, especially between the plant rows, can be used to obtain a greater density of plants per area, which can result in a greater production of cuttings per hectare. In particular, the genotype 'BRS 2357' shows reduced size and short plagiotropic branches, and it is considered a genotype of less growth (Espindula et al., 2019). For 'BRS 2357', as well as for the genotypes of the conilon variety, which show smaller size than the evaluated hybrids in this study, the spacing between plants and between plant rows can be even smaller, as in the case of high-density clonal gardens, which result in densities of more than 30,000 plants per hectare (Fonseca et al., 2019), when genotypes of the conilon group are grown in the Espírito Santo state, Brazil.

Conclusions

1. Under the edaphic and climatic conditions of the Amazon, stability in the production of cuttings is achieved after 28 months of coffee (*Coffea canephora*) plant age, which allows of three harvest periods of cuttings per year.

2. Coffee plants trained in the "vertical clonal garden" system can produce on average about 425,000 cuttings per harvest period, or about 1.275 million cuttings per hectare per year over three harvest periods, with greater ease of crop management and crop treatments.

3. Of the ten coffee hybrids, which show different capacities for the production of cuttings, 'BRS 2314', 'BRS 3213', and 'BRS 3210' present an above-average yield potential, whereas 'BRS 3193', 'BRS 2336', 'BRS 3220' and 'BRS 3137' produce the lowest number of cuttings.

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References

BAZONI, P.A.; ESPINDULA, M.C.; ARAÚJO, L.F.B. de; VASCONCELOS, J.M.; CAMPANHARO, M. Production of cuttings and nutrient export by *Coffea canefora* in different periods in the Southwestern Amazon. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v.24, p.162-169, 2020. DOI: https://doi.org/10.1590/1807-1929/agriambi.v24n3p162-169.

BERGO, C.L.; MIQUELONI, D.P.; LUNZ, A.M.P.; ASSIS, G.M.L. de. Estimation of genetic parameters and selection of *Coffea canephora* progenies evaluated in Brazilian Western Amazon. **Coffee Science**, v.15, e151663, 2020. DOI: https://doi.org/10.25186/.v15i.1663.

DALCOMO, J.M.; VIEIRA, H.D.; FERREIRA, A.; PARTELLI, F.L. Growth comparison of 22 genotypes of conilon coffee after regular pruning cycle. **African Journal of Agricultural Research**, v.12, p.63-70, 2017. DOI: https://doi.org/10.5897/AJAR2016.11261.

DIAS, J.R.M.; SILVA, E.D. da; GONÇALVES, G.S.; SILVA, J.F. da; SOUZA, E.F.M. de; FERREIRA, E.; STACHIW, R. Enraizamento de estacas de cafeeiro imersas em extrato aquoso de tiririca. **Coffee Science**, v.7, p.259-266, 2012.

DUBBERSTEIN, D.; PARTELLI, F.L.; DIAS, J.R.M.; ESPINDULA, M.C. Influência da adubação no crescimento vegetativo de cafeeiros na Amazônia Sul Ocidental. **Coffee Science**, v.12, p.50-59, 2017. DOI: https://doi.org/10.25186/cs.v12i2.1228.

ESPINDULA, M.C.; ARAÚJO, L.F.B. de; SCHMIDT, R.; DIAS, J.R.M.; ROCHA, R.B. Early induction of orthotropic shoots in *Coffea canephora*. **Revista Ceres**, v.67, p.281-287, 2020. DOI: https://doi.org/10.1590/0034-737X202067040005.

ESPINDULA, M.C.; TEIXEIRA, A.L.; ROCHA, R.B.; RAMALHO, A.R.; VIEIRA JUNIOR, J.R.; ALVES, E.A.; DIOCLECIANO, J.M.; LUNZ, A.M.P.; SOUZA, F. de F.; COSTA, J.N.M.; FERNANDES, C. de F. **Novas cultivares de cafeeiros *Coffea canephora* para a Amazônia Ocidental brasileira**: principais características. Porto Velho: Embrapa Rondônia, 2019. 36p. (Embrapa Rondônia. Comunicado técnico, 413).

FONSECA, A.F.A. da; VERDIN FILHO, A.C.; VOLPI, P.S.; MAURI, A.L.; FERRÃO, M.A.G.; FERRÃO, R.G.; ARANTES, S.D.; POSSE, S.C.P. Clonal gardens, seed production and conilon coffee seedling. In: FERRÃO, R.G.; FONSECA, A.F.A. da; FERRÃO, M.A.G.; DE MUNER, L.H. (Ed.). **Conilon Coffee**. 3rd ed. Vitória: Incaper, 2019. p.289-325.

GIURIATTO JÚNIOR, J.J.T.; ESPINDULA, M.C.; ARAÚJO, L.F.B. de; VASCONCELOS, J.M.; CAMPANHARO, M. Growth and physiological quality in clonal seedlings of robusta coffee. **Revista Ciência Agronômica**, v.51, p.e20196920, 2020.

KOLLN, A.M.; ESPINDULA, M.C.; ARAÚJO, L.F.B. de; CAMPANHARO, M.; ROCHA; R.B.; LOURENÇO, J.L.R. Influence of nitrogen fertilization in mother plants on the growth and quality of clonal seedlings of *Coffea canephora* 'Robusta' plants. **Ciência Rural**, v.52, e20201008, 2022. DOI: https://doi.org/10.1590/0103-8478cr20201008.

PARTELLI, F.L.; GILES, J.A.D.; OLIOSI, G.; COVRE, A.M.; FERREIRA, A.; RODRIGUES, V.M. Tributun: a coffee cultivar developed in partnership with farmers. **Crop Breeding and Applied Biotechnology**, v.20, e30002025, 2020. DOI: https://doi.org/10.1590/1984-70332020v20n2c21.

SANTOS, H.G. dos; JACOMINE, P.K.T.; ANJOS, L.H.C. dos; OLIVEIRA, V.Á. de; LUMBRERAS, J.F.; COELHO, M.R.; ALMEIDA, J.A. de; ARAÚJO FILHO, J.C. de; OLIVEIRA, J.B. de; CUNHA. **Sistema brasileiro de classificação de solos**. 5.ed. rev. e ampl. Brasília: Embrapa, 2018. 356p.

SOUZA, C.A. de; ROCHA, R.B.; ALVES, E.A.; ESPINDULA, M.C.; RAMALHO, A.R.; TEIXEIRA, A.L.; FERRÃO, M.A.G. Componentes genéticos do desenvolvimento e maturação de frutos de *Coffea canephora* Pierre ex A.Froehner. **Coffee Science**, v.12, p.355-364, 2017.

TAIZ, L.; ZEIGER, E.; MOLLER, I.M.; MURPHY, A. **Fisiologia e desenvolvimento vegetal**. 6.ed. Porto Alegre: Artmed, 2017. 858p.

TEIXEIRA, A.L.; ROCHA, R.B.; ESPINDULA, M.C.; RAMALHO, A.R.; VIEIRA JÚNIOR, J.R.; ALVES, E.A.; LUNZ, A.M.P.; SOUZA, F. de F.; COSTA, J.N.M.; FERNANDES, C. de F. Amazonian robustas – new *Coffea canephora* coffee cultivars for the Western Brazilian Amazon. **Crop Breeding and Applied Biotechnology**, v.20, e323420318, 2020. DOI: https://doi.org/10.1590/1984-70332020v20n3c53.

VERDIN FILHO, A.C.; MAURI, A.L.; VOLPI, P.S.; FONSECA, A.F.A. da; FERRÃO, R.G.; FERRÃO, M.A.G.; RODRIGUES, W.N.; ANDRADE JÚNIOR, S. de; COLODETTI, T.V. Growth and quality of clonal plantlets of conilon coffee (*Coffea canephora* Pierre ex A. Froehner) influenced by types of cuttings. **American Journal of Plant Sciences**, v.5, p.2148-2153, 2014a. DOI: https://doi.org/10.4236/ajps.2014.514227.

VERDIN FILHO, A.C.; TOMAZ, M.A.; FERRÃO, R.G.; FERRÃO, M.A.G.; FONSECA, A.F.A. da; RODRIGUES, W.N. Conilon coffee yield using the programmed pruning cycle and different cultivation densities. **Coffee Science**, v.9, p.489-494, 2014b.