INFLUENCE OF WATER AVAILABILITY ON BIOMETRICAL CHARACTERISTICS OF CONILON CLONAL COFFEE

Matheus Gaspar Schwan[1], Gabriel Brioschi Andreão[2], Maria Eduarda Carolo Freitas[3], Pedro Henrique Steill de Oliveira[4], Maria Luiza Zeferino Pereira[5], Edvaldo Fialho dos Reis[6]

ABSTRACT: Brazil is the largest producer and exporter of coffee and the state of Espírito Santo is the largest producer of Conilon coffee in the country. However, due to rainfall irregularities and climate change, the low water availability acts as the main limiting factor for the development of the culture. Based on this, the present study aimed to evaluate the biometric characteristics of the clonal conilon coffee, cultivated under different levels of water availability as a function of reference evapotranspiration. The experiment was carried out in a 3 x 4 split-plot scheme, with the factor "water availability" in the plots in 3 levels (30%, 50% and 80% of ETo) and the factor “avaliations” in the subplots, in 4 levels (0, 30, 60 and 90 days after the start of treatments), in a completely randomized design with 4 replications. Water availability had an effect on the biometric variables analyzed, and it was observed that irrigated plants at the level of 30% of ETo obtained the lowest values in the analysis of the biometric variables under study.

KEYWORDS: *Coffea Canephora*, Growth, Management

INFLUÊNCIA DA DISPONIBILIDADE HÍDRICA SOB CARACTERÍSTICAS BIOMÉTRICAS DO CAFEEIRO CONILON CLONAL

RESUMO: O Brasil é o maior produtor e exportador de cafés, sendo o estado do Espírito Santo o maior produtor de café conilon do país. Entretanto devido a irregularidades pluviométricas e

[1] Universidade Federal do Espírito Santo, Centro de Ciências Agrárias e Engenharias, Departamento de Engenharia Rural, Alto Universitário, s/n, caixa postal 16, Guararema, 29500-000, Alegre - ES, schwan.matheus@gmail.com
[2] Universidade Federal do Espírito Santo, Centro de Ciências Agrárias e Engenharias, Departamento de Engenharia Rural, Alto Universitário, s/n, caixa postal 16, Guararema, 29500-000, Alegre - ES, gbandreao@gmail.com
[3] Universidade Federal do Espírito Santo, Centro de Ciências Agrárias e Engenharias, Departamento de Engenharia Rural, Alto Universitário, s/n, caixa postal 16, Guararema, 29500-000, Alegre - ES, meduardacarolo@hotmail.com
[4] Universidade Federal do Espírito Santo, Centro de Ciências Agrárias e Engenharias, Departamento de Engenharia Rural, Alto Universitário, s/n, caixa postal 16, Guararema, 29500-000, Alegre - ES, pedrosteill@gmail.com
[5] Universidade Federal do Espírito Santo, Centro de Ciências Agrárias e Engenharias, Departamento de Engenharia Rural, Alto Universitário, s/n, caixa postal 16, Guararema, 29500-000, Alegre - ES, malu_zeferino@hotmail.com
[6] Universidade Federal do Espírito Santo, Centro de Ciências Agrárias e Engenharias, Departamento de Engenharia Rural, Alto Universitário, s/n, caixa postal 16, Guararema, 29500-000, Alegre – ES, efialhodosreis@gmail.com

mudanças climáticas, a baixa disponibilidade hídrica atua como o principal fator limitante para o desenvolvimento da cultura. Com base nisso, o presente trabalho teve por objetivo avaliar as características biométricas do cafeeiro conilon clonal, cultivado sob diferentes níveis de disponibilidade hídrica em função da evapotranspiração de referência. O experimento foi conduzido em um esquema de parcelas subdivididas 3 x 4, sendo nas parcelas o fator "disponibilidade hídrica" em 3 níveis (30%, 50% e 80% da ETo) e nas subparcelas o fator "avaliações" em 4 níveis (0, 30, 60 e 90 dias após o início dos tratamentos), em um delineamento inteiramente casualizado com 4 repetições. A disponibilidade hídrica exerceu efeito sobre as variáveis biométricas analisadas, sendo observado que plantas irrigadas do nível de 30% da ETo, obtiveram os menores valores na análise das variáveis biométricas em estudo.
PALAVRAS-CHAVE: *Coffea Canephora*, Crescimento, Manejo

INTRODUCTION

Brazil is the world's largest producer and exporter of coffee, making the practice of coffee growing an important economic activity at national and international level (ICO, 2020). In the state of Espírito Santo, the largest area destined for the cultivation of conilon coffee in the country is located, being the largest producer of conilon in Brazil, producing about 67% of the country's total volume (CONAB, 2021). However, due to rainfall irregularities and climate change, a prolonged water crisis in the State of Espírito Santo resulted, causing stress on the plants that in some cases were received or uprooted (CONAB, 2017).

One of the ways adopted by producers to circumvent the effects of the water deficit is through the practice of irrigation. The practice of irrigation can provide an increase in productivity and can even double production, and also improve the quality of the final product, provided that, along with irrigation, production technologies that are recommended for the crop are incorporated (FERRÃO et al., 2012).

Entretanto, no Brasil, a grande maioria dos usuários da agricultura irrigada não adota qualquer estratégia de manejo de irrigação (BONOMO et al., 2014), atrelado a isso, os baixos índices de eficiência de sistemas de irrigação, ocasionam uma problemática relacionada ao desperdício de água (BRITO et al., 2012). Diante da escassez de água em regiões do país, é importante que se leve em consideração a eficiência na qual as plantas irão utilizar esse recurso (VICENTE et al., 2015).

For an adequate supply of water to occur, it is necessary to know the amount of water that is being lost through transpiration and evaporation. One of the ways to obtain the percentage of water lost is by estimating evapotranspiration. The Evapotranspiration can be expressed as the equivalent amount of water evaporated per unit of time, usually expressed as a sheet of water per unit of time.

Given the above, this study aimed to evaluate the initial growth through biometric analyzes of the clonal conilon coffee tree, subjected to different levels of water availability in the soil as a function of reference evapotranspiration.

MATERIAL AND METHODS

The experiment was conducted in a greenhouse at the Center for Agricultural Sciences and Engineering of the Federal University of Espírito Santo (at latitude 20º42'52" South, longitude 41º27'24" west and altitude of 136.82 m), located in the municipality of Alegre -ES, from March to July 2021. The climate of the region is characterized as of the Aw type, with a dry season in winter. The average annual precipitation is around 1200 mm and the average annual temperature is around 23°C.

To conduct the experiment, polyethylene pots with a capacity of 12L were used, filled with a Red-Yellow Latosol, collected in the 0-0.30 m layer in areas close to where coffee plantations are located. After being collected, the soil was subjected to crumbling and passed through a 4 mm sieve and sent to the laboratory for chemical and physical analysis. Corrective and nutritional fertilizations were carried out following the recommendations of Prezotti et al. (2007) following the methodology proposed by Novais et al. (1991).

After all soil preparation practices were carried out, the transplanting of clonal conilon coffee seedlings of the Diamond “INCAPER ES8112”, Jequitibá “INCAPER ES8122” and Centenary “INCAPER ES8132” varieties was carried out. The plants were kept under ideal conditions of growth and development for a period of 20 days to guarantee their establishment in the pots. After this period, the first evaluation was carried out, determined the treatments, and the experiment started.

The experiment was set up in a completely randomized design in a 3 x 4 split-plot scheme, with the water availability factor "WA" in 3 levels in the plots (80%, 50% and 30%) and the "DA" “days after induction of water deficit” factor in the subplots on 4 levels (0, 30, 60 and 90) with 4 repetitions. A randomization between the experimental units was performed weekly, in order to homogenize the treatments.

To carry out irrigation, climate management was adopted, using the method of Penman-Monteith FAO 56, according to the equation below (Equation 1) (ALLEN et al., 1998), adopting a fixed irrigation shift of 3 days.

$$ETo = \frac{0{,}4808\ (Rn\text{-}G) + \gamma \left(\frac{900\ U_2}{Tmed+273}\right)(e_s - e_a)}{\Delta + \gamma\ (1+0{,}34\ U_2)} \quad (1)$$

In which: ETo, estimate of the Penman-Monteith-Standard FAO evapotranspiration, (mm); Δ, declination of the water vapor saturation curve, (kPa °C^{-1}); Rn, radiation balance, (MJ m^{-2} d^{-1}); G, soil heat flux density (MJ m^{-2} d^{-1}); γ, psychometric factor (MJ kg^{-1}); U2, wind speed (daily average) at 2 m above the ground surface, (m/s); es, steam saturation pressure, (kPa); ea, actual steam pressure (kPa); and, Tmed, mean temperature, (°C).

The climatic variables for the calculation of evapotranspiration were obtained in an automatic meteorological station belonging to the National Institute of Meteorology (INMET), located in the municipality of Alegre, Espírito Santo. Each experimental unit had the water replacement performed manually with the aid of a graduated beaker and the amount of water needed will be determined according to Bernardo et al. (2019). The irrigation depth was calculated according to the following equation (Equation 2):

$$L = ETo_{AC} \times f \times V \quad (2)$$

Em que: In which: L = irrigation depth (mm); ETo_{AC} = sum of reference evapotranspiration obtained accumulated over a period of 3 days; wd = water deficit (0.8; 0.5 and 0.3); V = volume of soil in the pot (0.012 m³);

In the Figure 1, the monthly average data of maximum, average and minimum air temperatures (°C) (A), relative humidity (%) and global radiation (MJ m^{-2} day^{-1}) for the conduction period are presented. of the experiment (B).

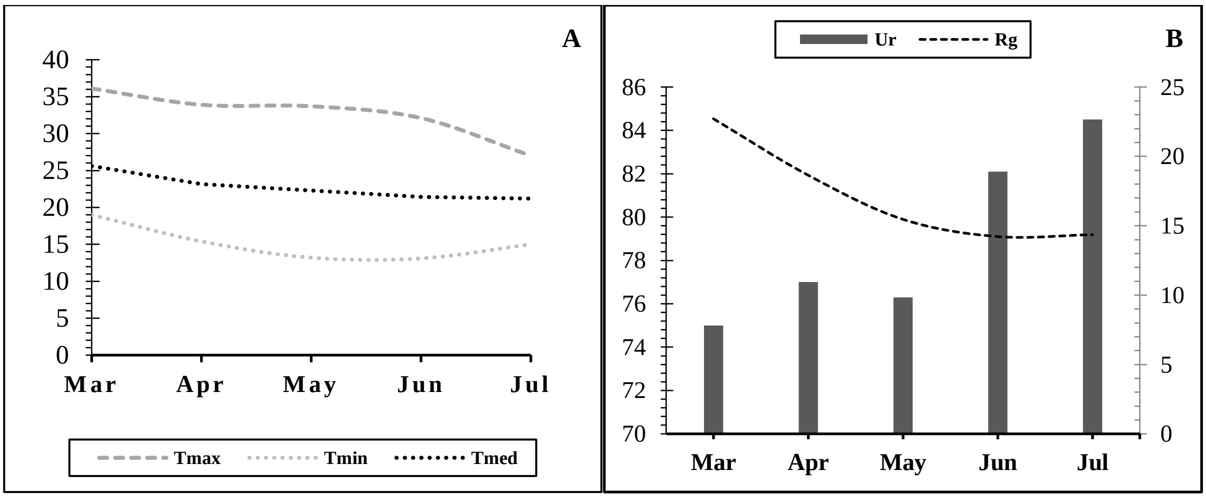

Figure 1. Values of Maximum (Tmax), Minimum (Tmin) and Average (Tmed) of Air (ºC) (A) and Relative Air Humidity (%) and Global Radiation (MJ m^{-2} day^{-1}) (B) during the period of the experiment.

Na Figura 2, são apresentados os dados de ETo mensal em milímetros (mm) determinada pelo método de Penman-Monteith FAO 56.

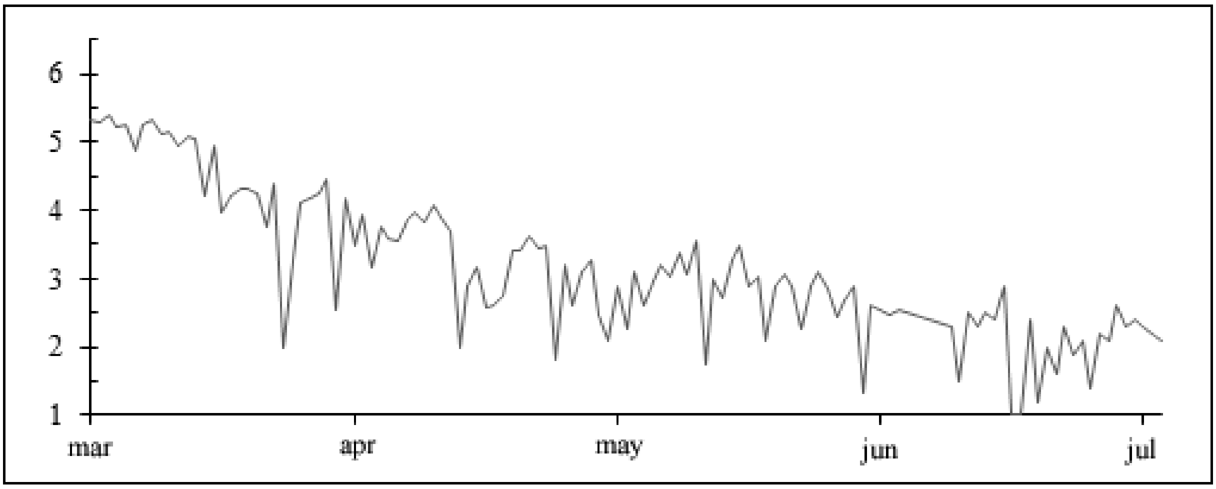

Figure 2. Monthly Reference Evapotranspiration values obtained during the experimental period.

Every thirty days after the induction of the water deficit, the biometric analysis of the plants was performed, and the variables considered in this evaluation: plant height (HEI) which comprises the length of the main stem from ground level to the apical bud, diameter of the stem (DS) at ground level, leaf area (LA) and number of leaves (NL), considering a visible leaf when at least 1 cm long. To obtain the height, a ruler was used, measuring the length of the main stem from ground level to the apical bud, the number of leaves was counted, considering as visible leaf that greater than 1cm, the diameter of the stem was measured with the aid of a digital caliper, the leaf area was obtained according to the methodology proposed by Barros et al. (1973). The growth analysis of the plants under study will be carried out as proposed by Benincasa (2004).

The data collected in the experiment were entered into an electronic spreadsheet and submitted to analysis of variance ($p \leq 0.05$) and when the F test is significant, the means will be compared by Tukey's test ($p \leq 0.05$), using the R software (R CORE TEAM, 2021).

RESULTS AND DISCUSSION

From the results obtained in the analysis of variance, it was found that there was a significant effect between the interaction of water availability and days of, in the analyzed biometric variables, and a split analysis should be carried out. The tables below show the results of the mean comparisons test for the variables under study.

The variables at the DA_0 level did not show any statistical difference between them, as they correspond to the first assessment carried out before the application of treatments, being used for the level of comparison between the means.

Table 1. Height (cm) of plants as a function of water availability for each evaluation period.

WA	DA_0	DA_{30}	DA_{60}	DA_{90}
80%	15.79aA	22.98aB	28.91aC	31.88aD
50%	15.79aA	20.35bB	23.39bC	25.76bD
30%	15.79aA	17.93cB	19.23cC	21.33cD

Means followed by the same lowercase letter in the columns and uppercase in the rows, do not differ statistically by the Tukey test, at 5% probability.

Table 2. Number of Leafs depending on water availability for each evaluation period.

WA	DA_0	DA_{30}	DA_{60}	DA_{90}
80%	8.33aA	12.94aB	19.48aC	26.02aD
50%	8.33aA	10.91bB	15.07bC	20.02bD
30%	8.33aA	9.76cB	11.91cC	12.85cD

Means followed by the same lowercase letter in the columns and uppercase in the rows, do not differ statistically by the Tukey test, at 5% probability.

Table 3. Stem Diameter (mm) as a function of water availability for each evaluation period.

WA	DA_0	DA_{30}	DA_{60}	DA_{90}
80%	3.7aA	4.68aB	5.68aC	6.82aD
50%	3.7aA	4.28bB	4.77bC	5.32bD
30%	3.7aA	3.80cA	4.0cB	4.31cB

Means followed by the same lowercase letter in the columns and uppercase in the rows, do not differ statistically by the Tukey test, at 5% probability.

Table 4. Leaf area (cm^2) as a function of water availability for each evaluation period.

WA	DA_0	DA_{30}	DA_{60}	DA_{90}
80%	46.1aA	55.92aB	64.05aC	69.46aD
50%	46.1aA	49.96bB	54.25bC	61.95bD
30%	46.1aA	46.62aA	49.97cB	52.04cC

Means followed by the same lowercase letter in the columns and uppercase in the rows, do not differ statistically by the Tukey test, at 5% probability.

Analyzing the height variable (Table 1), it’s possible observe that among all water availability levels and days of assessment, the lowest values were obtained in plants irrigated with 30% of the evapotranspiration, and the highest values were obtained in plants irrigated with 80 % and 50% of evapotranspiration respectively. Plants irrigated with 30% of evapotranspiration showed a reduction of 28.15, 50.28 and 49.46% in height values when compared to plants irrigated with 80% of evapotranspiration at the respective evaluation periods.

These results are in line with those obtained by Peloso et al. (2017), observing the limitations of the growth of the Arabica coffee tree subjected to different levels of water deficit, observing that the lower the water availability, the lower the height values of the coffee tree. Araújo et al. (2011), studying the initial development of two varieties of Conilon coffee, also observed that prolonged exposure of plants to water deficit significantly reduces plant height.

The number of leafs of the clonal coffee tree was also significantly affected by the reduction, with the lowest values obtained in plants at the 30% level of water availability. It is possible to observe that there was a reduction of 32.58, 63.56 and 102.56% in the number of leaves of plants at the 30% level of water availability, when compared to plants at the 80% level of water availability. Showing the sensitivity of the variable to water deficit.

According to Tardieu (2005), one of the first plant responses to water deficit is the reduction of leaf area, this reduction consequently results in a smaller number of leaves, due to leaf abscission processes, production of smaller leaves or reduction of leaf area. issue of new sheets. Also according to some authors such as Rena & Maestri (1985), similarly to what is observed in Arabica coffee, it is believed that the production of leaves in conilon coffee is closely associated with the growth of stems, especially of the plagiotropic branches, as the Leaf primordia result directly from apical bud activity. These results corroborate those of Oliveira et al. (2012) who observed that the number of leaves of the Conilon coffee tree reduces as water availability decreases.

The stem diameter was affected by low water availability, and it is possible to observe that although there was a difference between the water availability levels, there was no statistical difference between plants at the 30% water availability level when compared to the averages at levels DA_0 and DA_{30} , however, in the assessment performed at AV_{60} and AV_{90} days, there was a difference when compared to the first avaliation, however, it did not occur when compared to each other.

There was a reduction of 23.15, 42% and 58.23% in the respective evaluation periods. Authors such as Machado (2004) state that the relationship between stem diameter and water availability is due to the reduction in exchange activity that results in a reduction in vascularization, forming fewer vessel elements in plants under low water availability, this reduction in activity in together with less mitotic activity in the cells of the cortex results in a reduction in the total diameter of the stem. Thus, the lower water availability results in lower cell activity, which consequently results in lower values for the stem diameter. Results similar to those sought in this study, corroborating those proposed by Machado (2004), were observed by Busato et al. (2007) and Rodrigues et al. (2016), both authors observed that simultaneously with the reduction of the water fraction, the growth of the stem diameter.

Analyzing the variable leaf area, it is possible to observe that the low water availability also had a negative effect on its development. It is possible to observe that in the levels of DA_0 and DA_{30}, there was no statistical difference, however, in the other levels (DA_{60} and DA_{90}), a statistical difference was observed. Plants irrigated with 30% of water availability showed a reduction of 19.94, 28.17 and 33.47% when compared to irrigated plants with 80% of water availability. According to authors such as Taiz & Zeiger (2013), the most prominent response of plants to water deficit is the decrease in leaf area production, stomata closing, and accelerating senescence and leaf abscission.

De modo geral, o crescimento e desenvolvimento das plantas dependem de processos como: divisão, desenvolvimento e expansão celular. Esses processos são sensíveis ao déficit hídrico, principalmente na fase de alongamento celular, pois após esta fase, a célula se encontra preparada para expandir, desde que haja pressão hidrostática no interior da célula ou de turgor (TAIZ & ZEIGER, 2013).

In all biometric variables analyzed, it was possible to observe that water deficit had a negative effect on them, showing always-lower values when compared to plants irrigated with 80% and 50% of evapotranspiration.

A possible explanation for the negative effect of the water deficit on cultivated plants is the triggering of the synthesis of abscisic acid (ABA) in the root, causing it to be transported to different parts of the plant (LARCHER, 2004; CERQUEIRA, 2011).

ABA is known as the stress hormone promoting changes in plants when the water supply decreases (AASAMAA & SÕBER, 2011). Thus, it can play roles in growth and development and regulate adaptive responses under conditions of low water availability, such as regulating the opening and closing of stomata, leaf abscission and root growth (INÁCIO et al., 2011; SOUZA et al., 2013).

However, it is possible to observe that when analyzing the values obtained in each evaluation, the plants still present, even if irrigated with 50% and 30% of water availability, they present growth values greater than when compared to the first evaluation (AV0). This is due to the ability of plants to recover after a period, often under conditions of abiotic stress, this is due to their high resilience, which is extremely important to ensure acclimatization, sustainable development and production of the coffee tree due to future scenarios of possible climate change (RODRIGUES et al., 2015; MARTINS et al., 2016).

CONCLUSIONS

Water availability had an effect on the biometric variables analyzed, and it was observed that plants irrigated with 30% of ETo had the lowest growth values, when compared to plants irrigated with 50% and 80%, respectively.

ACKNOWLEDGMENTS

To the FAPES – Fundação de Amparo à Pesquisa do Estado do Espírito Santo, for the scientific initiation grant to the first author.

REFERENCES

AASAMAA, K.; SÕBER, A. Stomatal sensitivities to changes in leaf water potential, air humidity, CO2 concentration and light intensity, and the effect of abscisic acid on the sensitivities in six temperate deciduous tree species. **Environmental and Experimental Botany**, v. 71, n. 1, p. 72-78, 2011.

ALLEN, R. G.; PEREIRA, L. S.; RAES, D.; SMITH, M. **Guidelines for computing crop water requirements**. Irrigation and Drainage Paper, 56. Rome: FAO, 1998. 310p.

ARAÚJO, G. L.; DOS REIS, E. F.; MORAES, W. B.; GARCIA, G. de O.; NAZÁRIO, A. A. Influência do déficit hídrico no desenvolvimento inicial de duas cultivares de café Conilon. **Irriga**, v. 16, n. 2, p. 115–124, 2011.

BARROS, R. S.; MAESTRI, M.; VIEIRA, M.; BRAGAFILHO, L. J. Determinação de área de folhas do café (*Coffea arábica* L. cv. 'Bourbon Amarelo'). **Revista Ceres**, v. 20, n. 107, p. 44-52, 1973.

BENINCASA, M. M. P. **Análise de crescimento de plantas (noções básicas)**. Jaboticabal: Funep. 2ed., 2003. 41p.

BERNARDO, S.; MANTOVANI, E. C.; SILVA, D. D.; SOARES, A. A. **Manual de Irrigação**. 9ª ed., Viçosa: Editora UFV, 2019. 545p.

BONOMO, D. Z.; BONOMO, R.; PEZZOPANE, J. R. M.; SOUZA, J. M. de. Alternativas de manejo de água de irrigação em cultivos de conilon. **Coffee Science**, v. 9, n. 4, p. 537–545, 2014.

BRITO, R. R.; GOMES, E. R.; LUDWIG, R. Uso da água na irrigação. **Fórum Ambiental**, v. 8, n. 2, p. 373–383, 2012.

BUSATO, C.; REIS E. F. dos; MARTINS C. C.; PEZZOPANE, J. E. M. Lâminas de irrigação aplicadas ao café conilon na fase inicial de desenvolvimento. **Revista Ceres**, Viçosa, v. 54, n. 314, p. 351-357, 2007.

CERQUEIRA, R. C. **Influência do frio e do défice hídrico nas características fisiológicas e bioquímicas em videiras (*vitisvinifera* L.) cv. Thompson seedless**. Tese (Doutorado em Agronomia/Horticultura), Faculdade de Ciências Agronômicas, Universidade Estadual Paulista, Botucatu, 2011. 122p.

CONAB, C. N. A. Acompanhamento da safra brasileira de café safra 2017. **Primeiro levantamento janeiro 2017**. v. 4, n. 1, p. 98, 2017.

FERRÃO, R. G.; FONSECA, A. F. A.; FERRÃO, M. A. G.; VERDOM FILHO, A. C. V.; VOLPI, P. S.; MUNER, L. H. de; LANI, J. A.; PREZOTTI, L. C.; VENTURA, J. A.; MARTINS, D. S.; MAURI, A. L.; MARQUES, E. M. G.; ZUCATELI, F. **Café Conilon Técnicas De Produção Com Variedades Melhoradas**. 4. ed. Vitória: Incaper, 2012.

ICO - INTERNATIONAL COFFEE ORGANIZATION. **Total production by all exporting countries**. Disponível em: <http://www.ico.org/prices/po-production.pdf.>.

INÁCIO, M. C.; SILVA, E. S.; SOUZA, M. E.; ONO, E. O.; RODRIGUES, J. D. Mensageiros secundários relacionados à ação dos hormônios vegetais. **Revista Brasileira de Agrociência**, v. 17, n. 4, p. 438-446, 2011.

LARCHER, W. **Ecofisiologia vegetal**. São Carlos: RiMa, 2004. 531 p.

MACHADO, A. V.; **Efeitos do estresse hídrico em plantas jovens de *Hedyosmum brasiliense mart. (chloranthaceae)***. Dissertação (Mestrado) - Universidade federal de Santa Catarina. Florianópolis, 2004.

MARTINS, M. Q.; RODRIGUES, W. P.; FORTUNATO, A. S.; LEITÃO, A. E.; RODRIGUES, A. P.; PAIS, I. P.; MARTINS, L. D.; SILVA, M. J.; REBOREDO, F. H.; PARTELLI, F. L.; CAMPOSTRINI, E.; TOMAZ, M. A.; SCOTTI-CAMPOS, P.; RIBEIRO-BARROS, A. I.; LIDON, F. J.; DAMATTA, F. M.; RAMALHO, J. C. Protective Response Mechanisms to Heat Stress in Interaction with High [CO2] Conditions in *Coffea* spp. **Frontiers in Plant Science**, v. 7, p. 1-18, 2016.

NOVAIS, R. F.; NEVES, J. C. L.; BARROS, N. F. Ensaio em ambiente controlado. In: OLIVEIRA, A. J.; GARRIDO, W. E.; ARAÚJO, J. D.; LOURENÇO, S. (Coord.). **Métodos de pesquisa em fertilidade do solo**. Brasília : Embrapa-SEA, p. 189-253, 1991.

OLIVEIRA, A. C. R.; PIZETTA, S. C.; REIS, E. F. dos. Análise do desenvolvimento inicial do cafeeiro Conilon cultivar robusta tropical submetido a déficit hídrico. **Enciclopédia Biosfera, Centro Científico Conhecer**, v. 8, n. 15, p. 90-100, 2012.

PELOSO, A. F.; TATAGIBA, S. D.; AMARAL, J. F. T. Limitações do crescimento vegetativo em cafeeiro arábica promovido pelo déficit hídrico. **Revista Engenharia Na Agricultura - Reveng**, v. 25, n. 2, p. 139-147, 2017.

PREZOTTI, L. C.; GOMES, J. A.; DADALTO, G. G.; OLIVEIRA, J. A. **Manual de Recomendação de Calagem e Adubação para o Estado do Espírito Santo**. 5ed. Vitória: SEEA, 2007. 305p.

R Core Team. **R: A language and environment for statistical computing**. R Foundation for Statistical Computing, Vienna, Austria. 2021.

RENA, A. B.; MAESTRI, M. Fisiologia do cafeeiro. **Informe Agropecuário**, v. 11, p. 26-40, 1985.

RODRIGUES, W. P.; MARTINS, M. Q.; FORTUNATO, A. S.; RODRIGUES, A. P.; SEMEDO, J.N.; SIMÕES-COSTA, M. C.; PAIS, I. P.; LEITÃO, A. E.; COLWELL, F.; GOULAO, L.; MÁGUAS, C.; MAIA, R.; PARTELLI, F. L.; CAMPOSTRINI, E.; SCOTTI-CAMPOS, P.; RIBEIRO-BARROS, A. I.; LIDON, F. C.; DAMATTA, F. M.; RAMALHO, J. C. Long-term elevated air [CO2] strengthens photosynthetic functioning and mitigates the impact of supra-optimal temperatures in tropical *Coffea arabica* and *C. canefora* species. **Global Change Biology**, v. 22, n. 1, p. 415-431, 2015.

SOUZA, T. C. de.; MAGALHAES, P. C.; CASTRO, E. M. de.; ALBUQUERQUE, P. E. P. de.; MARABESI, M. A. The influence of ABA on water relation, photosynthesis parameters, and chlorophyll fluorescence under drought conditions in two maize hybrids with contrasting drought resistance. **Acta Physiol Plant**. v. 35, p. 515–527, 2013.

TAIZ, L.; ZEIGER, E. **Fisiologia vegetal**. 5ed. Porto Alegre: Artmed, 2013. 848p.

TARDIEU, F. Plant tolerance to water deficit: physical limits and possibilities for progress. Comptes **Rendus Geoscience**, v. 337, n. 1-2, p. 57-67, 2005.

VICENTE, M. R.; MANTOVANI, E. C.; FERNANDES, A. L. T.; DELAZARI, F. T.; FIGUEREDO, E. M. Efeito de diferentes lâminas de irrigação nas variáveis de desenvolvimento e produçao do cafeeiro irrigado por pivô central. **Irriga**, v. 20, n. 3, p. 528-543, 2015.