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TAMANHO DE GRÃOS DO CAFEEIRO CONILON IRRIGADO E NÃO IRRIGADO DURANTE QUATRO SAFRAS[1]

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1 RESUMO

A pesquisa foi desenvolvida com o objetivo de verificar o tamanho dos grãos do cafeeiro conilon irrigado e não irrigado, durante quatro safras, por meio da classificação física por peneiras. O experimento foi instalado em novembro de 2013 no Instituto Federal do Espírito Santo, Campus Alegre, em esquema de parcela subdividida 3 x 4, sendo nas parcelas o fator manejo de irrigação em três níveis (irrigado com reposição de 100% da evapotranspiração da cultura (ETc), irrigado com 50% da ETc e sem irrigação) e nas subparcelas o fator safra em quatro níveis (2013, 2014, 2015 e 2016), em um delineamento em blocos casualizados, com três repetições. Foi avaliado o percentual de grãos retidos em peneira 13 e superiores, grãos moca e grãos retidos no fundo do conjunto de peneiras. A irrigação influenciou positivamente no tamanho dos grãos. Plantas irrigadas com 100% da ETc obtiveram 72,5% de grãos retidos em peneiras 13 e superiores, já plantas sem irrigação obtiveram 33,1%. Nas safras de 2013 e 2014, foi observado maiores valores de grãos retidos em peneiras 13 e superiores e menores valores de fundo, 76,1% e 7,5%, respectivamente.

Palavras-chave: *Coffea canephora*, cafeicultura sustentável, déficit hídrico, manejo de irrigação.

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SIZE OF CONILON COFFEE BEANS IRRIGATED AND NON-IRRIGATED DURING FOUR HARVESTS

2 ABSTRACT

The research was conducted with the objective of verifying the grain size of irrigated and non-irrigated conilon coffee during four harvests, through the physical classification by sieves. The

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experiment was installed in the year of 2013 in the Instituto Federal do Espírito Santo (Federal Institute of Espírito Santo), in a subdivided-plots scheme 3 x 4, being the plots the factor irrigation management in three levels (irrigated with replacement of 100% of the crop evapotranspiration (ETc), irrigated with 50% of the ETc, and non-irrigated), and in the subplots, the harvest factor in 4 levels (2013, 2014, 2015, and 2016), in a randomized block design, with three replications. The percentage of grains retained in sieve 13 and above, mocha grains, and grains retained at the fund of the sieve set were evaluated. Irrigation had a positive influence on grain size. Plants irrigated with 100% of the ETc obtained 72.5% of grains retained in sieves 13 and higher, while plants without irrigation obtained 33.1%. In the 2013 and 2014 harvests, higher values of grains retained in sieves 13 and higher and lower bottom values, 76.1% and 7.5%, respectively, were observed.

Keywords: Coffea canephora, sustainable coffee growing, water deficit, irrigation management.

3 INTRODUCTION

Coffee stands out as a product of global importance and has grown in more than 80 countries (INTERNATIONAL COFFEE ORGANIZATION, 2020). Brazil produced approximately 63.30 million 60-kg bags in the 2020 harvest; of this total, conilon coffee production represented approximately 22.6%, at 14.31 million bags. Conilon production in Brazil comes mostly from the state of Espírito Santo. In addition to being the second-largest coffee producer in the country, with 22.0% production, the state also stands out as responsible for 64.2% of all Brazilian conilon coffee (COMPANHIA NACIONAL DE ABASTECIMENTO, 2021).

Coffee beans are sorted into sieves on the basis of bean size and shape, with round sieves used to measure and separate flat coffees and elongated sieves used to separate mocha beans. Although flat beans are sorted between sieves No. 8 and 22, coffee for international trade is only accepted between sieves No. 13 and 20, with importers tending to prefer coffees with sieves above No. 16 (LAVIOLA *et al*., 2006). This occurs because a medium/high sieve is associated with good coffee quality (FERREIRA *et al*., 2013).

Therefore, it is necessary to study the influence of irrigation on coffee bean size, as drought is the main problem affecting the productivity, yield, quality, and sustainability of conilon coffee production in the state of Espírito Santo (FERRÃO *et al*., 2018). Furthermore, more than 60% of the state's areas with agroclimatic zoning for conilon coffee have water restrictions for cultivation, requiring irrigation (TAQUES; DADALTO, 2017). Even recently improved and highly productive cultivars have been created with genotypes that generally still have high water demands and are vulnerable to droughts (FERRÃO *et al*., 2017). Thus, the role of irrigated agriculture becomes fundamental to minimize the impact of irregular weather conditions on crops, since even in traditional coffee-growing areas, irrigation is justified by the fact that these areas often suffer from prolonged droughts during critical periods of water demand by the coffee plant (VICENTE *et al*., 2015; DARDENGO *et al*., 2018).

Coffee productivity is the most important variable to quantify when working with irrigation-related research (VICENTE *et al*., 2015). However, according to Rezende *et al*. (2006), fruit size is also influenced by a plant's water conditions. Adequate soil moisture leads to greater fruit expansion, resulting in larger and betterlooking fruits. Therefore, the objective of this study was to determine the bean size of irrigated and nonirrigated conilon coffee plants over four harvests via physical sieves.

4 MATERIALS AND METHODS

The experiment was conducted at the Federal Institute of Education, Science and Technology of Espírito Santo - Alegre Campus, Fazenda Caixa D'Água, Rive district, located at latitude 20°25'53" S and longitude 41°27'25" W, with an average altitude of 137 m and an average annual precipitation of 1250 mm. According to the Köeppen classification, the climate of the region is of the "Aw" type with a dry season in winter, where the average annual temperature is 23.1 °C (KOPPEN, 1948). In an area of approximately 0.42 ha cultivated with *Coffea canephora* Pierre, the variety 'Conilon Vitória Incaper 8142', consisting of thirteen clones, was cultivated.

The seedlings were planted in November 2010, using a 3 × 1 spacing 1,1 m. The plants were subsequently trained with four stems, with thinning performed when necessary. Cultural and phytosanitary treatments were carried out according to the needs of the crop, following current recommendations for conilon coffee (FERRÃO *et al*., 2017).

The soil at this site is classified as Red Yellow Latosol, with a sandy clay texture. Table 1 shows the physical and water characteristics of the soil at depths of 0–20 and 20–40 cm. The water and physical data were obtained according to the recommendations of the Brazilian Agricultural Research Corporation (Embrapa), adapted by Dardengo, Reis and Passos (2009).

Table 1. Physical and water-physical data of the soil at depths of 0–20 and 20–40 cm.

	Depth (cm)	
Parameters	**0 - 20**	**20 - 40**
Total Sand (%)	52	47
Silt (%)	5	6
Clay (%)	43	47
Soil Density (g cm^{-3})	1.57	1.55
Soil water content at field capacity (%)	26.91	26.63
Soil water content at wilting point (%)	2:30 pm	16.11

The application of correctives and chemical fertilizers was carried out on the basis of the chemical analysis of the soil, according to the Liming and Fertilization Recommendation Manual for the State of Espírito Santo: 5th approximation (PREZOTTI *et al*., 2007).

To characterize the climate, daily measurements of maximum and minimum temperatures were taken via a climatological station near the experiment. Rainfall was measured via a rain gauge installed at the experimental site.

The experiment was set up in a 3 × 4 split-plot scheme, with the irrigation management factor at three levels in the plots (irrigated with 100% replacement of crop evapotranspiration (ETc) , irrigated with 50% ETc and without irrigation) and the harvest factor at four levels (2013, 2014, 2015 and 2016) in the subplots in a randomized block design, with three replications. The experimental plots consisted of five plants.

For irrigation, climate-based management was adopted. The reference evapotranspiration (ETo) was estimated via the Hargreaves and Samani (1985) method (Equation (1)).

$$ETo = 0,0023 \left(\frac{Ra}{2,45}\right) (Tmax - Tmin)^{0,5} (Tmed + 17,8) \quad (1)$$

where:

ETo: reference evapotranspiration (mm d^{-1}); T med: average temperature (°C); Tmed: 0.5 (T_{max} + T_{min}); T max: maximum temperature (°C); Tmin: minimum temperature (°C); and R_a: solar radiation at the top of the atmosphere ($MJ.m^{-2}.d^{-1}$).

The crop evapotranspiration values were calculated via the daily evapotranspiration results (Equation 2). For this purpose, crop coefficient (Kc) values between 0.8 and 1.0 (from planting to 18 months) and 1.1 from 18 months onward were used.

$$ETc = ETo \times Kc \quad (2)$$

where:
ETc: crop evapotranspiration, mm d^{-1};
ETo: reference evapotranspiration, mm d^{-1};
and Kc: culture coefficient, dimensionless.

The irrigation system was a conventional sprinkler, consisting of three lateral lines, each with four sector sprinklers spaced 18 × 18 m, with a service pressure of 30 mca, with 5.6 × 3.2 mm nozzles and a flow rate of 2.66 $m^3 h^{-1}$, with a Christiansen uniformity coefficient (CUC) of 81.0%.

Harvesting was carried out visually, with at least 80% of the fruit ripe, given that within the variety, there are early-, intermediate-, and late-ripening clones. Coffee tree ripening periods vary among different management systems. The harvesting was performed manually via a sieve.

After each plant in the experimental plot was harvested, the fruits were weighed, and a 2.0 kg sample was taken, which was subjected to drying on a suspended patio until the average grain moisture content was 12.0%, which was measured via a GEHAGA G 600 grain moisture tester, version 7.3. The samples were then processed.

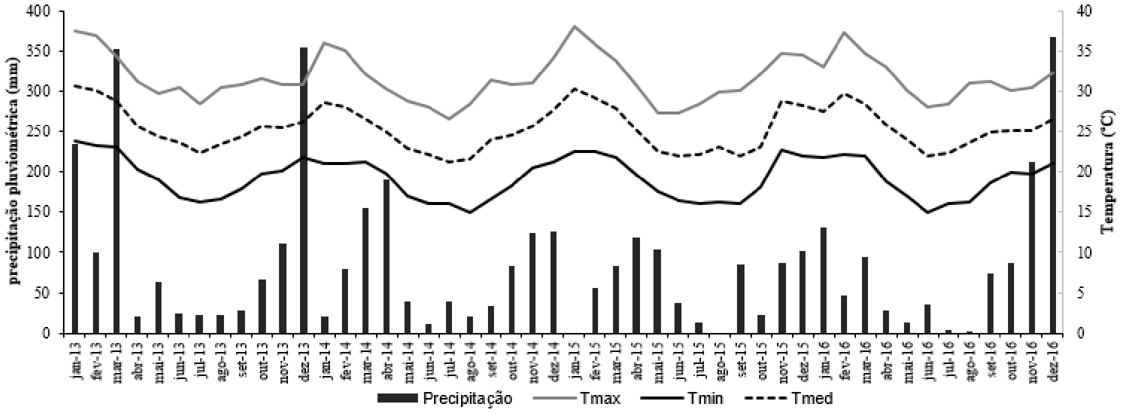
The sieve classification was carried out on 300 g of processed coffee sample according to the dimensions of the sieves, numbered 10, 11 and 12 for mocha beans; 13, 15 and 17 for flat beans; and < 10 for the bottom. The percentages of beans retained in sieves 13 and above and mocha beans and beans retained at the bottom of the set of sieves were determined , following Normative Instruction No. 8, of June 11, 2003 (BRASIL, 2003).

The data were subjected to analysis of variance, and when significant, the means were compared via the Scott–Knott test to compare the harvest factor. For the irrigation management factor, the Tukey test was applied, both at 5% probability.

5 RESULTS AND DISCUSSION

Figure 1 presents data on the average maximum, minimum and average air temperatures and the total monthly rainfall at the experimental site from January 2013 to December 2016.

Figure 1. Monthly averages of maximum, minimum and average air temperatures and total monthly rainfall from January 2013 to December 2016 in Rive, Alegre, ES.



The total precipitation in 2013, 2014, 2015 and 2016 was 1397.2, 923.7, 709, and 1098.1 mm, respectively. The highest average maximum temperatures were 37.4, 36.0, 38.0 and 37.2 °C for the years 2013, 2014, 2015 and 2016, respectively; these values were observed in the month of January, with the exception of the year 2016, in which the month with the highest maximum temperature value was February. The drought from 2014--2016 was considered the most intense drought in the last fifty years in the state of Espírito Santo, with approximately 50% less rainfall, with poorly distributed rainfall combined with temperatures averaging 3 °C higher. This combination of factors resulted in a reduction of approximately 50% in Espírito Santo production and caused major economic and social problems in 80% of the state's municipalities, reducing coffee production (FERRÃO *et al*., 2018; GALEANO *et al*., 2016).

The analysis of variance for the variables sieve 13 and higher, foundation and mocha are presented in Table 2. There was a significant effect for the interaction (irrigation) × harvest (year) at the 5% probability level for the variables studied, and the analysis should be carried out in an unfolded manner.

Table 2. Analysis of variance for sieve 13 and higher, foundation and mocha of the conilon coffee tree.

Source of Variation	GL	Mean square		
		13 ≥	**Foundation**	**Girl**
Block	2	3,2695	1,27980	1.6191
Management	2	5713.3150*	7289,905*	105,1908*
Error (A)	4	3,2176	2,2985	0.7467
Harvest	3	359.2794*	604.7251*	52.4202*
Management x harvest	6	41.5877*	191.8645*	86.9362*
Residue	18	2,3347	1,1078	1,8043
CV (%)	-	2.64	3.83	9.15

*F significant at the 5% probability level; ^{ns} not significant.

Table 3 shows the percentage of grains retained on sieves 13 and above according to the irrigation management for each conilon coffee harvest (2013, 2014, 2015 and 2016) and according to the conilon coffee harvests for each management (irrigated with 100% ETc, irrigated with 50% ETc and without irrigation).

Table 3. Percentages of grains retained on sieves 13 and higher (%) for each irrigation management (irrigated with 100% ETc, irrigated with 50% ETc and without irrigation) in the four harvests (2013, 2014, 2015 and 2016) of conilon coffee.

	Harvests			
Management	**2013**	**2014**	**2015**	**2016**
Irrigated	76.7 Aa	75.6 Aa	64.3 Ab	73.4 Aa
50% ETc	72.8 Ba	72.1 Ba	60.3 Bc	67.7 Bb
Nonirrigated	40.7 Ca	40.5 Ca	26.7 Cb	24.4 Bc

Means followed by the same letters do not differ from each other according to the Tukey test in the column and the Scott–Knott test in the row at the 5% probability level.

observed between the management systems for all harvest years, with higher percentages of grains retained on sieves 13 and higher percentages found in the irrigated management system with 100% ETc and lower percentages in the management system without irrigation. The averages for these management systems, considering all years, were 72.5% and 33.1%, respectively. Fruits that expand with adequate soil moisture have larger locules, producing high-sieve grains (DAMATTA *et al*., 2007). In this context, the influence of irrigation is notable, constituting an important tool for reducing productivity losses, increasing yield, and improving the physical quality of the final product (CORRÊA *et al*., 2016).

The medium/high sieve is associated with good coffee quality, which is normally traded at a relatively high market value (FERREIRA *et al*., 2013). Furthermore, Laviola *et al.* (2006) highlighted the importance of sieves for identifying varieties with greater production potential.

Some authors, such as Dardengo *et al*. (2018), irrigated crops have a greater percentage of grains retained on sieve sizes of 13 and above than do rainfed crops, demonstrating greater grain size in irrigated coffee. In their work, the authors reported values of grains retained on sieve sizes of 13 and above for irrigated Robusta Tropical coffee, ranging from 65.0 to 93.0% for different harvests, whereas for rainfed plants, the values were between 40.0 and 88.0%. Sakai *et al*. (2013) concluded that irrigation increased the grain size of the Catuaí coffee cultivar. The authors also highlighted that the adoption of irrigation is very important for adding value and ensuring export quality standards.

A comparison of the harvest factors within each irrigation management system revealed that, for the irrigated management system, the 2015 harvest had the lowest sieve 13 and highest values. There were no significant differences between the other years, with an average of 75.2%. In the irrigated management system with 50% ETc, the 2015 harvest also had the lowest sieve 13 and highest values. The 2013 and 2014 harvests had higher sieve values, at 72.8 and 72.1%, respectively. In the nonirrigated management system, the best performance of the variety was observed in the 2013 and 2014 harvests. In the 2016 harvest, grains from plants under the nonirrigated management system had a lower sieve 13 and higher percentages.

For Rena and Maestri (2000), coffee bean size is determined in the period between the 10th and 17th weeks after flowering, when the fruit expands rapidly, with water being responsible for this increase in volume. Thus, the low percentages of beans retained in sieves 13 and above for dryland coffee in this study are justified, as the period of expansion and grain formation coincided with a typical dry spell in January/February, as observed in Figure 1.

Table 4 shows the percentage of soil according to the irrigation management for each conilon coffee harvest (2013, 2014, 2015, and 2016) and according to the conilon coffee harvests for each management (irrigated with 100% ETc, irrigated with 50% ETc, and without irrigation). Statistical differences were noted across all management practices at all harvests, with the percentage of soil being lower in the management practices irrigated with 100% ETc and higher in the management practices without irrigation.

Table 4. Percentage of foundation (%) in irrigation management (irrigated with 100% ETc, irrigated with 50% ETc and without irrigation) and in the four harvests (2013, 2014, 2015 and 2016) of conilon coffee.

	Harvests			
Management	**2013**	**2014**	**2015**	**2016**
Irrigated	7.9 Aa	7.2 Aa	14.2 Ac	10.4 Ab
50% ETc	12.9 Ba	12.2 Ba	23.4 Bc	18.1 Bb
Nonirrigated	38.1 Ca	43.8 Cb	68.8 Cc	71.7 Cd

Means followed by the same letters do not differ from each other according to the Tukey test in the column and the Scott–Knott test in the row at the 5% probability level.

This difference between plants irrigated with 100% ETc, those irrigated with 50% ETc, and those without irrigation is because more grains settle at the bottom of the sieve set for grains produced by plants without irrigation. This is due to low water availability, especially during the grain-filling period, when water is essential for increasing grain volume. This leads to the formation of poorly shaped and smaller grains, which are not retained in the sieves and instead pass directly to the bottom. In addition to resulting in lower yields, smaller grains reach a certain roasting point faster than others do, potentially becoming carbonized until the remaining larger grains reach the ideal roasting point, imparting unpleasant flavors and aromas to the beverage and compromising product quality.

A comparison of the harvest factor within each irrigation management system revealed that for the irrigated management system with 100% ETc, there were no significant differences between the 2013 and 2014 harvests, with an average foundation of 7.5%, while the highest value was observed in the 2015 harvest. The same result was observed in plants irrigated with 50% ETc, where the average number of grains retained in the foundation of the 2013 and 2014 harvests was 12.5%, with no significant difference. The highest foundation value was observed at the 2015 harvest. For plants grown under management without irrigation, there were significant differences across all years, with a lower foundation value observed at the 2013 harvest and higher values at the 2016 harvest.

According to Galeano *et al*. (2016), the water crisis that hit the state of Espírito Santo between 2014 and 2016, in which precipitation was 50% lower than the historical average and caused irregular rainfall distribution, coupled with high sunlight on crops, even irrigated ones, influenced the timing and number of flowers, flower abortion, fruit growth and set at fruit fall, and grain filling, resulting in lower yields, smaller grains, lower production, and a lower quality final product. This influence is evident in the results obtained for comparisons between the harvest factors, since the 2015 and 2016 harvests presented the highest percentages of founding (Table 4), concomitant with the period of greatest water crisis and high temperatures occurring in the state of Espírito Santo (Figure 1).

Table 5 shows the percentage of mocha beans according to the irrigation management for each conilon coffee harvest (2013, 2014, 2015 and 2016) and according to the conilon coffee harvests for each management (irrigated with 100% ETc, irrigated with 50% ETc and without irrigation).

Table 5. Percentages of mocha beans (%) under different irrigation management practices (irrigated with 100% ETc, irrigated with 50% ETc and without irrigation) and during the four harvests (2013, 2014, 2015 and 2016) of conilon coffee.

	Harvests			
Management	**2013**	**2014**	**2015**	**2016**
Irrigated	15.3 Aa	17.2 Aa	21.3 Cb	15.8 Ba
50% ETc	14.2 Aa	15.5 Aa	16.2 Ba	14.0 Ba
Nonirrigated	21.0 Bc	15.6 Ab	4.9 Aa	4.5 Aa

*Means followed by the same letters do not differ from each other according to the Tukey test in the column and the Scott–Knott test in the row at the 5% probability level.

Mocha beans can be said to have a rounded shape, originating from the development of a single seed, resulting from a genetic abnormality or from environmental or physiological factors, such as prolonged drought and a lack of nutrients (VACARELLI; MEDINA; FAZUOLI 2003). In each year, there was a different behavior in each management system for mocha beans. However, higher percentages were observed in the 2015 harvest for the irrigated management with 100% ETc; however, this value is within the average percentage found for mocha beans of the Vitória conilon coffee variety, which is 21.4% (FONSECA *et al*., 2004).

The lower value of mocha-type grains, observed under management without irrigation, stands out, especially at the 2015 and 2016 harvests. This is due to the smaller size of the grains produced under this management method, with the vast majority going to the bottom of the sieve set, as shown in Table 4.

It is important to evaluate these bean types within the coffee genetic material, since mocha beans, compared with flat beans, produce lower yields. Furthermore, the mixture of flat beans and mocha beans negatively impacts beverage quality, as during coffee roasting, larger beans roast slowly, whereas smaller beans roast quickly and burn, reducing beverage quality (SILVEIRA *et al*., 2015). Therefore, producers should pay attention to the selection of genetic material to be planted, with the goal of reducing the number of mocha beans in the crop to achieve higher yields.

6 CONCLUSION

Irrigation had a positive effect on grain size. In the plants irrigated with 100% ETc, 72.5% of the grains were retained on sieves of size 13 or greater, whereas 33.1% of the plants without irrigation were retained.

In general, as the percentage of background increases, the percentage of mocha-type grains decreases, depending on the climatic conditions.

In the 2013 and 2014 harvests, higher values of grains retained on sieve 13 and higher and lower values at the bottom were observed (76.1% and 7.5%, respectively).

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