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EFEITO DE DIFERENTES LÂMINAS DE IRRIGAÇÃO NA UNIFORMIDADE DE GRÃOS MOCA DO CAFÉ CONILON, EM CAMPOS DOS GOYTACAZES, RJ

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1 RESUMO

O café tem grande importância econômica na agricultura brasileira, sendo o Brasil o segundo maior produtor mundial, atrás apenas do Vietnã. Entretanto, para exportação, cada vez mais é requerido alta qualidade e seletividade dos grãos, para que esses tenham um processamento adequado nas indústrias. O objetivo do presente trabalho foi avaliar os efeitos da aplicação de diferentes condições de irrigação na uniformidade e classes de peneira dos grãos moca do café conilon. O experimento foi conduzido na área pertencente à Universidade Estadual do Norte Fluminense. O delineamento experimental utilizado foi em parcelas subdivididas, com quatro repetições, composto pelos fatores: sistema de irrigação (superficial e subsuperficial) e lâminas de água (0, 25, 50, 100 e 125% da evapotranspiração de referência (ETO)). A classificação por peneiras foi determinada segundo o formato do grão, sua granulometria e diferentes números de peneiras, sendo definidos como moca graúdo (MG), moca médio (MD) e moca miúdo (MM). Após realização do estudo concluiu-se que há tendência na uniformização da produção nas peneiras 10 e 11, classificadas como moca médio conforme houve ~~o~~ aumento da irrigação, de modo que as lâminas 100 e 125% da ETO apresentaram o maior percentual para essa classe de grãos.

Palavras-Chave: agrometeorologia, balanço hídrico, umidade do solo.

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2 ABSTRACT

Coffee has great economic importance in Brazilian agriculture, Brazil is the second largest producer in the world, behind only of the Vietnam. However, for export, an increasing number of high-quality and selectivity of the grains are required, so that they have adequate processing in the industries. This work evaluated the effects of the applicationof different irrigation conditions on the uniformity and sieve classes of mocha beansconilon coffee. The experiment was conducted in the area belonging to the State University North Fluminense. The experimental design used was split plots, with four replications, composed of the factors: irrigation system (superficial and subsurficial) and water depths (0, 25, 50, 100, and 125% of the evapotranspiration of reference (ETO)). The classification by sieves was determined

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according to the shape of the grain, its granulometry, and different numbers of sieves, being defined as big mocha (MG), medium mocha (MD), and small mocha (MM). After conducting the study, it was concluded that there is a trend toward a uniform production in sieves 10 and 11, classified as mocha medium as there was an increase on irrigation, in such a way that the water depths of 100 and 125% of ETO presented the highest percentage for this class of grains.

Keywords: agrometeorology, soil moisture, water balance.

3 INTRODUCTION

Coffee stands out as one of the main products of Brazilian agricultural production, with Brazil being the world's largest producer and exporter of this *commodity* (MINISTRY OF AGRICULTURE, LIVESTOCK AND SUPPLY, 2019). Considering only the Conilon species, Brazil has become the second largest producer, with 15 million bags, behind only Vietnam, which produces approximately 31 million bags of bean, according to data obtained from the Executive Summary of Coffee published by the Ministry of Agriculture, Livestock and Supply (2020). According to data provided by the National Supply Company (CONAB) (CAFÉ, 2019), in the agricultural survey for the Rio de Janeiro region, the area planted with coffee in production was 13,445 hectares, 3% greater than the 2017 harvest. Moreover, the area under development is approximately 462 hectares. Thus, the total estimated area should reach 13,907 hectares.

Coffee farming in the North Fluminense region accounts for approximately 71% of all coffee production in the state of Rio de Janeiro. Furthermore, producers in this region have become a benchmark for quality in the rest of the state. The high quality of these fruits is due to the introduction of new technologies, the acquisition of individual and collective equipment, improved production processes in the field and postharvest, and support for the opening of new consumer markets (FERREIRA, 2016; KAWASAKI, 2018).

According to studies by Pinheiro et al. (2017) and Ribeiro et al. (2018), in Brazil, as well as in other coffee-producing countries, drought is considered the main abiotic stress capable of impacting coffee plant development and production. Drought affects evapotranspiration, root moisture consumption, root system distribution, canopy size, and crop development rates. Water deficit is responsible for the decline in coffee production, as water availability is one of the main constraints on crop economic productivity.

The cultivation of Conilon coffee is an option for diversification, given that the northern region of the state has areas with favorable characteristics for planting coffee, with an altitude of less than 500 m, without pedological impediments, with an annual water deficit of less than 350 mm and an average annual temperature of 22 to 26°C (RODRIGUES et al., 2012).

The profitability of a crop is measured not only byproductivity but also byproduct quality. Quality is estimated by bean size (sieve) and cup quality, so these characteristics are strongly influenced by the uniformity of fruit ripening, which depends first on the uniformity of coffee flowering and, second, on adequate water management to avoid water stress during key stages of bean formation (VICENTE et al., 2015).

According to Rezende et al. (2006), fruit size is strongly influenced by a plant's water conditions. From 12 to 18 weeks after flowering, grains are formed, and filling begins, rapidly increasing dry weight and reducing the increase in fruit size.

The grains of Robusta or Conilon species are smaller than those of Arabica species, and the shape of their fruits varies from spherical or rounded to “canoe”. In addition, as a color characteristic, Robusta or Conilon species have less shiny skin and a brownish color, although there is great genetic variability in terms of such characteristics (FERRÃO et al., 2017).

Despite causing a reduction in final productivity due to its smaller size, according to Daviron and Ponte (2005), mocha coffee, owing to its rounded shape and because it is a single grain formed in the coffee fruit, presents more homogeneous roasting and a higher sugar content compared with flat beans, which favors the set of aromas of the final beverage, providing a flavor profile in the cup.

The mocha coffee market in Brazil is still small compared with other types of coffee; however, it is highly valued internationally, with that produced in Tanzania being the most appreciated and having the highest commercial value compared with the others (Soto et al., 2018).

Given this scenario, the objective of this work was to evaluate the effects of applying different types of irrigation systems and depths on the uniformity, size and sieve classes of conilon coffee mocha beans.

4 MATERIALS AND METHODS

4.1 Characterization of the site

The experiment was conducted in an existing crop field in the area belonging to the Evapotranspirometric Station of the Darcy Ribeiro State University of Northern Fluminense, located on the premises of the State Center for Research in Agroenergy and Waste Use (CEPEAA), of the PESAGRO-RIO Experimental Station, in Campos dos Goytacazes, RJ at geographic coordinates 21° 24' 48" South latitude and 41° 44' 48" West longitude and 11 m altitude, referred to the WGS 1984 Datum.

According to the Köppem climate classification, the region's climate is classified as Aw, meaning a humid tropical climate with rainy summers, dry winters, and an average air temperature in the coldest month above 18°C. According to the municipality's latest climatological normal, the average temperature is approximately 24°C, with a very small temperature range. The region has an average annual rainfall of 1,055.3 mm, with dry spells common in January and February (MENDONÇA, 2014).

4.2 Experimental design

The genotypes used were clones of the Vitória variety: clone 02 with an early cycle and the pollinating clones: clone 3 V (medium cycle), clone 6 V (medium cycle), clone 11 V (early cycle) and clone P2 (medium cycle). The seedlings were produced in a nursery specializing in the production of *Coffea canephora*, which is located in the state of Espírito Santo.

These seedlings were acquired in April 2014 and measured approximately 15 cm in height. The plants were acclimated for 30 days and then transplanted on May 21 of the same year. A total of 350 seedlings were transplanted into 30 cm deep furrows, 190 of which were used as pollinators.

The experimental design used was randomized blocks, with four replications, in a split-plot scheme, composed of the following factors: factor I (plots): irrigation system (surface and subsurface), and factor II (subplots): water depths (control, 25, 50, 100 and 125% of the reference evapotranspiration (ETO)), which constituted the treatments.

The spacing used was 2.5 m between rows and 1.5 m between plants in the row, totaling an area of 22.5 m^2 per subplot and a useful area of the subplot of 15 m^2. Each subplot consisted of six plants, with the two at the ends considered borders.

4.3 Irrigation system

In the surface drip irrigation system, 16 mm diameter hoses were installed on the soil surface with two emitters 30 cm from the plant stem (one on each side). In the subsurface system, the irrigation hoses were placed approximately 25 cm deep, where the emitters were installed inside perforated PET bottles. The purpose of using PET bottles was to protect the emitters from clogging and root penetration by the coffee plant, as these are the greatest obstacles to subsurface irrigation. Each plant received two emitters 30 cm from the stem (one on each side) inside the bottles at a depth of approximately 23 cm.

The irrigation depths were determined on the basis of reference evapotranspiration, which was calculated via the Penman–Monteith method (ALLEN et al., 1998) (Equation 1), with data observed from an automatic station located close to the planting area.

$$ETo = \frac{0.408\,\Delta\,(Rn - G) + \gamma\,\frac{900}{T+273}\,U2\,(Es - Ea)}{\Delta + \Upsilon\,(1 + 0.34U2)} \quad (1)$$

where ETo is the reference evapotranspiration ($mm \cdot day^{-1}$); Δ is the slope of the vapor pressure curve ($kPa \cdot °C^{-1}$); Rn is the total daily net radiation ($MJ \cdot m^{-2} \cdot day^{-1}$); G is the ground heat flux ($MJ \cdot m^{-2} \cdot day^{-1}$); γ is the psychrometric constant ($kPa \cdot °C^{-1}$); T is the mean air temperature (°C); U2 is the mean wind speed measured at 2 m height ($m \cdot s^{-1}$); es is the saturation water vapor pressure (kPa); and ea is the current water vapor pressure.

4.4 Grain classification

After being harvested and dried on an open-air patio, the ground coffee beans were separated and classified via sieves, and the beans were differentiated by type and size. The bean size data (sieve) were obtained from harvest results from five consecutive years, i.e., the 2016, 2017, 2018, 2019, and 2020 harvests in predetermined areas. The harvest occurred during the dry season, with little rainfall, between the months of May (end of the month) and August (beginning of the month).

The size of the grains (sieves) was defined according to the classification recommended by the National Rural Learning Service (2017), in which moca is defined as a sample consisting of ovoid-shaped grains, which have a central groove in the longitudinal direction.

The classification by sieves was determined according to the shape of the grain and its granulometry, using 300 g of crushed grain and different numbers of sieves, defined as large mocha (MG): sieves 12 and 13; medium mocha (MD): sieves 10 and 11; and small mocha (moquinha) (MM): sieve 9. With the sieves arranged in ascending order, the grains were ejected into them, which underwent a “back and forth” movement with a slight inclination, thus imitating the same movement performed by the classification machines.

Once the grain samples were defined, the relationships between the dependent variables (size) and the independent variables (applied water depth) were obtained via second-degree polynomial regression analysis, according to Equation 2.

$$G = a + bL + cL^2 \quad (2)$$

where G represents the average number of grains in %, L represents the number of applied blades (mm) and *a, b,* and c represent the adjustment coefficients of the regression equation.

4.5 Statistical analysis

The values obtained from the replicates were subjected to analysis of variance (ANOVA), and then quadratic polynomial regressions were constructed according to the variables. The coefficients found for the regression equations were then subjected to the t test, with subsequent correction, considering the mean square of the residual and the degrees of freedom of the ANOVA and the mean square independent of the regression. The regression confidence intervals were added at the 95% probability level.

5 RESULTS AND DISCUSSION

A summary of the analysis of variance for the sieve classes used in this experiment can be found in Table 1. Significant differences were observed for the different irrigation depths at the 5% probability level, and regression analysis of the data obtained was then performed.

Table 1. Analysis of variance table of the sieves in relation to the irrigation system.

FV	GL	Mean Square		
		MM	MD	MG
Blocks	4	16373.68*	20232.52*	20444.09*
Irrigation system	1	80.55 NS	82.10 NS	0.385 NS
Residue 1	4	13.92	43.43	48.72
Irrigation blades	4	250.96 NS	529.26*	89.90*
Blades x System	4	95.93 NS	61.35 NS	34.35 NS
Residue 2	182	180.98	175.37	30.54
Total	199			
CV (%)		(1) 14.16 (2) 52.11	(1) 11.74 (2) 23.58	(1) 38.62 (2) 30.57

Source: Authors themselves. *Significant at 5% probability; NS not significant; FV variation factor; GL degrees of freedom; MM small moca; MD medium moca; MG large moca; CV coefficient of variation.

An analysis of the data in Table 1 revealed a significant difference between the growing years, that is, a difference in the percentage of grains between one harvest and its subsequent harvest. This result can also be verified, as presented in Table 2.

Table 2. Percentage of grains retained on the sieves for each productive year.

Years	MM (%)	MD (%)	MG (%)
2016	34.992 d	45,098 b	19,909 b
2017	9.166 b	34.25 a	56,583 c
2018	27.426 c	66.004 c	6.819 a
2019	53,814 and	44.723 b	1.462 a
2020	3.692 a	90.702 d	5.605 a

Source: Authors themselves. *Means followed by different lowercase letters vertically (columns) differ significantly between percentages (Tukey's test at P <0.05); MM Small Moca; MD Medium Moca; MG Large Moca.

According to Boaventura and Cruz (1987), Arabica coffee (*Coffea arabica*) has greater grain uniformity, as well as a smaller number of grains classified as mocha, whereas Conilon coffee (*Coffea canephora)* has a greater quantity of mocha grains and presents greater variation in grain size.

Vacarelli and Medina Filho (2003), in a study comparing fruit quality between the two species *C. arabica and C. canephora*, reported that, for Conilon coffee hybrids, up to 53.6% of the beans can be classified as mocha type, with the remaining 26.2% and 20.3% classified as concha and flat type, respectively. According to the authors, this fact, in addition to being related to some external factors or environmental effects, is also intrinsic to the genetics of the species.

According to research conducted by Dardengo et al. (2018) with Conilon coffee species, younger plants, aged up to 2 years or 28 months after the start of production, are more likely to produce a greater percentage of beans below sieve 13; thus, they generally account for approximately 35% and 60% of the fruits produced in irrigated and nonirrigated crops, respectively. In this sense, the beans classified on sieves below 11 and at the bottom constitute the majority, similar to what was observed in the present study.

No significant differences were detected in the interaction effect between irrigation depth and the type of irrigation system used. The use of different types of irrigation systems aims to help producers improve management and promote water conservation (provided that the irrigation system is properly managed). The results obtained from the evaluation of the subsurface and surface drip systems are shown in Table 3.

Table 3. Percentages of classes according to irrigation system.

Class/Sieve	Irrigation system	% of grains
MOCA MM	Superficial	25.18 ^{NS}
	Subsurface	26.45 ^{NS}
MOCA MD	Superficial	56.79 ^{NS}
	Subsurface	55.51 ^{NS}
MOCA MG	Superficial	18.11 ^{NS}
	Subsurface	18.03 ^{NS}

Source: Authors themselves. NS - not significant between irrigation systems; MM - small moca; MD - medium moca; MG - large moca.

On the basis of the results obtained, no significant differences were found in the percentage of grain size in relation to the irrigation system adopted, underground or superficial, with no correlation between the irrigation method used and granulation.

Matiello et al. (2010) reported that the presence of a high number of anomalous grains indicates some deficiency in fertilization, a phenomenon related to genetic problems, with interference from climatic and nutritional factors. From the base to the middle of the productive branches, the fruits are relatively large and have a relatively high percentage of flat grains. At the tips of the branches, the grains are smaller, and there is a higher percentage of anomalous grains.

The percentage of mocha beans separated according to the sieve and the relationships among the irrigation depths are shown in Figure 1. Significant results were found mainly at the different irrigation depths for the beans on sieves 10 to 13, that is, medium and large mocha. Table 4 presents the significance coefficients for the coefficients of the equations obtained from the sample means for small, medium, and large mocha.

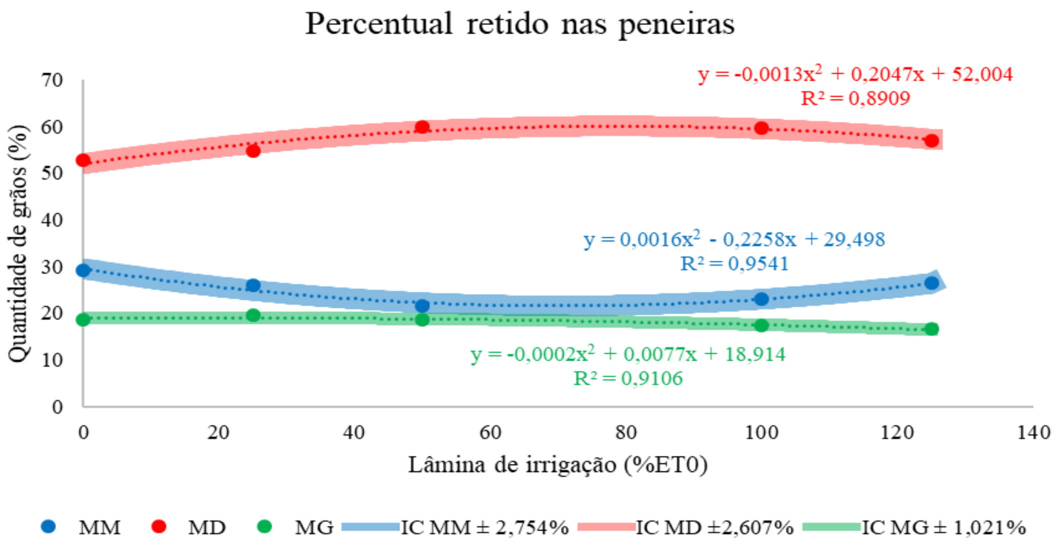
Table 4. Significance of the equation coefficients.

Coefficients	Pr > |t|		
	b0	b1	b2
Little Girl	0.0000	0.0919	0.1872
Medium Mocha	0.0000	0.0340	0.1503
Big Girl	0.0000	0.2336	0.6949

Source: Authors themselves. Significance level at a minimum of 5% probability.

Table 4 shows that b0 was highly significant for all the grain classes evaluated. For b1, only the equation obtained for medium mocha was significant at the 5% probability level. The coefficient b2 was not significant in any of the equations.

Figure 1. Behavior of the percentage of number of grains according to the irrigation depth.



Source: Authors themselves. CI = confidence interval at the 95% significance level. MM = Small moca, MD = Medium moca, MG = Large moca.

Figure 1 shows that the average percentage of grains classified as medium mocha was greater at all irrigation depths, followed by small mocha and large mocha.

Moreover, with increasing irrigation depth, the percentage of grains classified as medium mocha tended to increase up to a depth of 50% of ETo, with a decrease with increasing depth, and the opposite trend was observed for small mocha, which began to increase with increasing depth.

The greater presence of grains classified as medium mocha generates discussion and divergence among authors, as while some indicate that when in large quantities these can compromise productivity, others indicate that the more uniform the quantity of grains in this range is, the better the processing quality in the industry.

According to Matiello et al. (2010), separating processed coffee into sieves is crucial for achieving a more uniform roast, since in the "bica corrida" roasting process, the large beans are only toasted, whereas the small ones can be charred, compromising the quality of the beverage. This is especially true when carried out by large roasting companies that perform this process more frequently.

However, Bonomo et al. (2017) indicated that it is necessary to adopt only sieve 13 as a reference because, for Conilon coffee, the requirement of most food industries is that it be classified as superior to the aforementioned sieve.

In the study carried out by Silveira et al. (2015), nonirrigated coffee plants presented higher percentages of beans in the mocha category (22.23%) and lower percentages of irrigated coffee plants. According to Custódio et al. (2015), in irrigated coffee plants, there is a greater increase in beans with sieves 16 and above, which are normally located on the side of the plants exposed to northwest solar radiation, to the detriment of mocha beans (sieves below 13).

Coffees with a higher sieve, combined with other good quality characteristics, generally have a higher market value. Therefore, irrigation at depths between 75 and 137% of ETo helps increase grain uniformity within the most acceptable quality range (LAVIOLA et al., 2006).

According to Rezende et al. (2010), another important factor affecting the quantity or percentage of mocha beans is the irrigation season. Irrigation from September to November or August to October led to an increase in the percentage of mocha beans. One explanation for this phenomenon is that, physiologically, during this period, the coffee plant is primarily dormant and partially in the expansion phase, whereas the most recommended period for irrigation is between April and June, which corresponds to the maturation and budburst phases.

This difference in percentages can be explained by the fact that, by meeting water and nutritional demands, favorable conditions are established for vigorous plant development, which positively influences fruit development (filling, grain size, and size). On the other hand, irrigation favors the setting of several blooms, which could lead to uneven ripening, resulting in high percentages of green fruit at harvest (CUSTÓDIO; GOMES; LIMA, 2007).

6 CONCLUSION

There was no statistically significant difference in grain size depending on the subsurface or surface irrigation system used. Furthermore, the type of system adopted did not directly influence the grain shape or size, so the adoption of the most viable system in each situation is recommended.

Under the conditions of the present study, the production of medium and large mocha beans tended to increase up to an irrigation depth of approximately 75% of the ETO, with a reduction occurring for depths above this value, whereas for small mocha beans, the opposite behavior was observed. Notably, for all the depths evaluated, medium mocha (50 to 55% of the beans) was predominant, followed by small mocha (30 to 25%) and large mocha (20 to 25% of the beans) were predominant.

Few studies relating edaphoclimatic aspects to the physical–chemical characteristics of Conilon coffee beans were found in the bibliographic survey of this research; therefore, it is recommended that research concerning themes that seek to add value to bean quality rather than just increasing their production be conducted.

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