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Controlled water stress in uniformity of maturity and productivity of conilon coffee

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The aim of this work was to evaluate the uniformity of fruit maturity and the productivity of conilon coffee in function of different periods of water stress in the post-harvest period. The study was conducted in a field from August 2014 to July 2015 in an old coffee crop of conilon coffee, cultivar Vitória 'Incaper 8142', cultivated at a spacing of 3.0 × 1.2 m, located at the Federal Institute of Espírito Santo Campus Santa Teresa, ES, Brazil. The experimental design was in randomized blocks, with 4 treatments and 10 repetitions. Each useful plot consisted of 12 plants. The treatments consisted of the application of different levels of water deficit, being: control (continuous irrigation with humidity close to the field capacity) (T1); water deficit of 20 (T2); 40 (T3); and 60 (T4) days after harvest. Productivity was determined by harvesting and weighing the grains of each useful plot. The maturation uniformity was evaluated by random harvesting of 100 fruits in each plot. The application of the treatment with 60 days of water deficit presented greater uniformity of fruit maturation and water saving when compared to the other treatments. The treatment with estimated water deficit of 33 days after harvest showed higher average grain yield (79.2 sc ha^{-1}).

Key words: *Coffea canephora*, irrigation management, grain quality, water, productivity.

INTRODUCTION

Coffee cultivation is one of the most important economic activities in Brazil. Conab (2016), the country produced in 2015 about 43.24 million sacks of coffee benefited. The State of Espírito Santo (ES), which occupies less than 0.5% of the national territory, is the largest Brazilian coffee conilon state (*Coffeea canephora*), yielding 10.7

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Figure 1. Municipality of Santa Teresa in the state of Espírito Santo where studies were carried out.

million bags of the benefited product in the 2015 harvest (CONAB, 2016). The culture is present in 65 of the 78 municipalities of the ES, which represents more than 80% of the municipalities (Pezzopane et al., 2010).

The improvement of the quality without damaging the productivity of conilon coffee in Espírito Santo is of utmost importance for coffee growers, since the consumer market is increasingly demanding, and there is a trend towards the progressive differentiation of the market in quality (Silva and Guimarães, 2012). One challenge faced by coffee growers in relation to coffee quality is the harvesting of cherry fruits at the same maturation stage.

The quality of the coffee beverage is directly related to the fruit maturation. In regions with good rainfall distribution, the appearance of different bloomies contributes to a disuniform fruit maturation, with a direct effect on the product price (Matiello et al., 2005).

In Espírito Santo State, the practice of selective harvesting of cherry coffee beans is not common due to labor difficulties and increased cost of production of the benefited sack. It is believed that controlled water stress in irrigation may be an alternative to selective harvesting, since such practices have the potential to increase flowering uniformity and, consequently, improve the final grain quality without reducing crop productivity.

After the harvest, the coffee tree goes through a period of physiological rest, keeping its metabolism reduced. This period coincides with the cold and dry period in most of the producing regions, which favors the control of the water supply to the crop. At this stage, the crop is sensitive to climatic elements, especially hydration and/or temperature drops, leading to the growth recovery and eventually flower opening. Under normal conditions of cultivation, the crop not only resists satisfactorily, but also recovers quickly after the end of a dry period. Thus, the control of the irrigation period significantly affects the coffee maturation, since water is the stimulus to the emission of floral buds.

There are few studies comparing controlled water regime with maturation uniformity for conilon coffee, but some studies on arabic coffee (*Coffea arabica*) showed that such management can improve fruit quality. Mera et al. (2011) verified that the interruption of the irrigation for 70 and 109 days, from June, in the region of Planaltina (DF), provided higher fruit percentages for cherry coffee and higher grain yield for 70 days' interruption, and lower grain yield for interrupted irrigation for 109 days. Similar results were also found by Silva et al. (2009). Nascimento (2008) reported that year-round irrigation reduced the emission of flowers, and treatments with controlled water regime obtained superior results to those without irrigation and all year-round irrigation for most of the variables evaluated in arabica coffee.

The objective of this work was to evaluate the uniformity of fruit maturation and conilon coffee yield in function of different periods of water stress in the post-harvest period.

MATERIALS AND METHODS

The study was performed in a field, from August 2014 to July 2015, in an old crop of conilon coffee, cultivar Vitória Incaper 8142, cultivated in spacing of 3.0 × 1.2 m, located at the Federal Institute of Espírito Santo Campus Santa Teresa (Figure 1), at 130 m of altitude and coordinates 19°49'S, 40°40'W. In the classification of Köppen, the climate of the region is a Cwa type (subtropical of dry winter) with temperature and average annual precipitation of 18°C and 845.2 mm, respectively.

The soil of the experiment area was classified as eutrophic argisol and had the following characteristics in the 0 to 30 cm layer in Table 1.

The experiment was arranged in randomized blocks, with four treatments and ten repetitions. Each plot consisted of 20 plants, where only 12 were considered useful. The treatments consisted of different levels of water deficit, being: T1: Control (continuous irrigation with humidity always close to the field capacity); T2: water deficit of 20 days after harvest; T3: water deficit of 40 days after harvest; T4: water deficit of 60 days after harvest. Water stress higher than this time period in the conilon coffee may impair the development of the crop, affecting productivity at the end of the harvest.

The plants were irrigated by a drip irrigation system with 3 × 1.2

Table 1. Soil analysis of the study area.

pH (in H_2O)	6
Al exchangeable (cmolc dm^{-3})	0.0
H + Al (cmolc dm^{-3})	2.5
Ca (cmolc dm^{-3})	2.5
Mg (cmolc dm^{-3})	0.7
P Mehlich (cmolc dm^{-3})	0.8
P remaining (mg L^{-1})	28.0
K (cmolc dm^{-3})	110.0
S (cmolc dm^{-3})	9.0
Organic matter (dag kg^{-1})	2.2
Fe (mg dm^{-3})	85.0
Zn (mg dm^{-3})	9.9
Cu (mg dm^{-3})	3.2
Mn (mg dm^{-3})	218.0
B (mg dm^{-3})	0.31
Na (mg dm^{-3})	40.0
Base saturation (V) (%)	58.2
Effective Cation Exchange Capacity (CTC) (cmolc dm^{-3})	3.5
CTC at pH 7.0 (cmolc dm^{-3})	6.0
Base sum (cmolc dm^{-3})	3.5
Base saturation (%)	58.2
Ca saturation at CTC (%)	41.8
Mg saturation at CTC (%)	11.7
K saturation in CTC (%)	4.7
Clay (g kg^{-1})	300
Silt (g kg^{-1})	118
Sand (g kg^{-1})	582

m spacing, a dripper for each plant, with a flow rate of 20 L h^{-1} and an application intensity of 5.5 mm h^{-1}. The drip irrigation system consisted of buried PVC main and branch lines and lateral lines with the respective drippers, passing over the soil along the crop lines.

The determination of the irrigation uniformity for the measurement of the applied blade was carried out semi-annually using the methodology cited by Bernardo et al. (2005). The field capacity was determined by the field method and the permanent wilting point was obtained at a tension of 1,500 kPa using the Richards Extractor (Mantovani et al., 2009), representative of the layers from 0 to 0.20 m, 20 to 0.40 m deep. The soil density of the two layers was determined by the volumetric ring method, as described by Oliveira and Ramos (2008).

In order to perform irrigation management and characterize the influence of climatic elements on the floral bud behavior of coffee plants, daily temperature (°C) and precipitation (mm) data were obtained in an automatic meteorological station near the experimental area.

Irrigation management was carried out with Irrisimples® program, which determines the water demand of the crop, evaluating the daily water balance using coefficients of adjustments on the reference evapotranspiration (ETo). The program defines the irrigation depth according to the difference between water demand and effective precipitation, generating the irrigation slides. The ETo was determined using the Hargreaves model. To calculate the crop evapotranspiration, the Gesai model was used (Mantovani et al., 2009).

Weekly, soil samples were taken at depths of 0 to 20 and 20 to 40 cm for determination of soil moisture by the standard greenhouse method (Bernardo et al., 2005), to guarantee the measurement of the method. Kc (coefficient of culture) values were obtained from Mantovani et al. (2009). The coefficient, due to soil moisture and total soil water retention capacity were calculated according to Bernardo (2005). The values of Kl (coefficient due to localized irrigation) were obtained by Keller and Bliesner method (Mantovani et al., 2009).

Irrigation was performed when the sum of the evapotranspiration of the crop, subtracted from the effective precipitation, was approximately equal to the value of the actual soil water capacity (CRA), calculated by the formula: CRA = CTA (Total Soil Water Capacity) × f (Availability factor = 0.6). The duration of each irrigation event was calculated by the ratio between the total required irrigation (ITN), which considers the irrigation efficiency, and the intensity of water application of the emitters, determined with an evaluation of the irrigation system.

The fertilizations were performed according to the recommendations of Prezotti et al. (2007), and practices followed the recommendations of Ferrão et al. (2008), and these are the most common recommendations for the conillon coffee in ES State.

The productivity of the crop was determined by manually collecting through sieves all useful plants from each treatment and converting the harvested beans into ha^{-1} sacks. The uniformity of maturation was evaluated by taking 100 fruits, randomly, in each plant harvested, to determine the percentage of green, yellow, cherry and black grains.

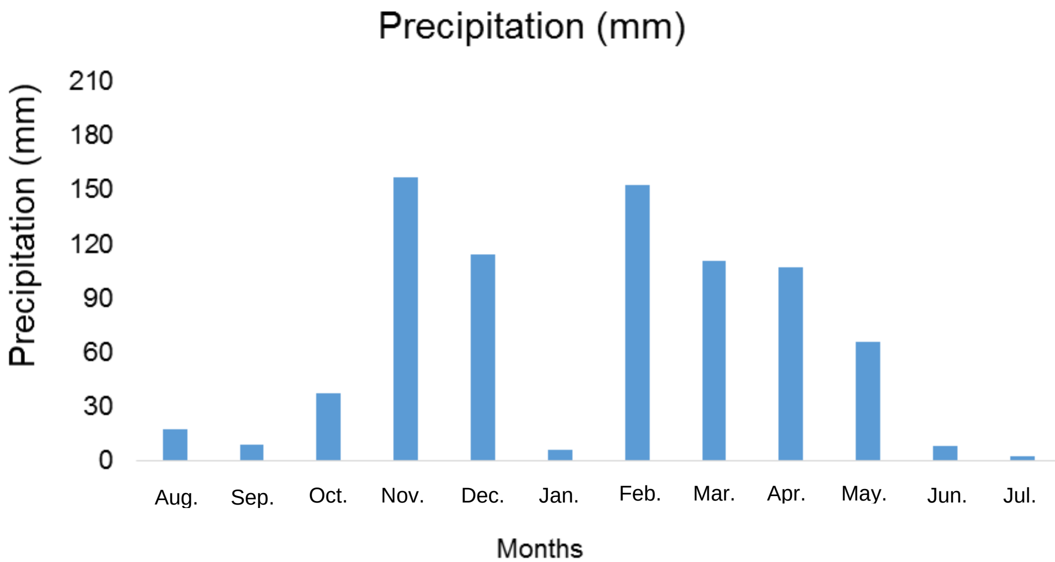

Figure 2. Monthly precipitations occurred in the period from August 2014 to July 2015.

The productivity data were submitted to variance analysis, where the quantitative character factors were compared by the analysis regression. The maturation uniformity data were submitted to the Chi-square test, quantitatively evaluating the ratio between the results of the treatments and the expected distribution for the phenomenon of maturation uniformity. The software SAEG 9.1 (UFV, 2007) was used in the analysis.

RESULTS AND DISCUSSION

In the drier months (August to October 2014 and June and July 2015), where rainfall was lower, there was a higher need of irrigation, as evapotranspiration of the crop was higher in these periods, so a larger slide of water was performed to supply the irrigation. In January, the precipitation was low, but the average temperature and the irradiance indexes were higher, there was a greater need of irrigation, as shown in Figure 2.

The soil of the experimental area has a permanent wilting point of 16.28%, soil water availability factor of 22%, and field capacity of 28%. It was sought to maintain soil moisture always between the safety factor of soil water availability and field capacity, thus ensuring that the plants did not suffer any stress, as shown in Figure 3. Due to technical problems in the irrigation system, there was a sudden drop in soil moisture in September 2014.

The abrupt drop in soil moisture did not affect crop development. In a short period of time, soil moisture has resumed to the level of safety. The uniformity of maturation and the highest proportion of mature grains at harvest were higher in the treatment that was the longest time under post-harvest water stress (T4), as shown in Figure 4.

Uninterrupted supply of water by irrigation can stimulate the opening of new flowers, which generates fruits at different stages of development and desuniform maturity at the time of harvest (Nascimento, 2008). Therefore, it will directly interfere on yield, since smaller grains demand greater volume of coffee to reach 60 kg sack of the benefited product.

Marsetti et al. (2013), evaluating the effects of water deficit, on floral bud dormancy and floral opening of conilon coffee produced under climatic conditions in the northern state of Espírito Santo, verified that the treatment that interrupted the irrigation for 63 days guarantee the uniformity of flowering, which is directly related to the maturation uniformity of grain.

Statistically, it was possible to estimate the behavior of grain maturity uniformity by chi-square analysis at 5% probability, which revealed that the application of the 60-day water deficit provided the harvest of most fruits at the cherry maturation stage (Figure 5).

Usually, the harvesting started when the percentage of mature fruits is above 80%. Green coffee fruits produce defects during fermentation and drying, giving rise to black or black-green grains, while fruits after their complete ripening (blacks/raisins) resulted in black and burned grains. These defects will negatively interfere with the type and quality of the beverage (Fonseca et al., 2007).

Proper management of irrigation in the post-harvest period is of a great importance for producers to add value to their product, since harvesting at the appropriate maturation stage is one of the factors that will influence the final quality of the beverage. Treatment 4 presented a lower proportion of dried fruits, which provides better coffee quality at the end of its processing. It is known that the final quality of green coffee is associated both to its intrinsic characteristics of coffee species and cultivar and post-harvesting processes (Saraiva et al., 2009), in order

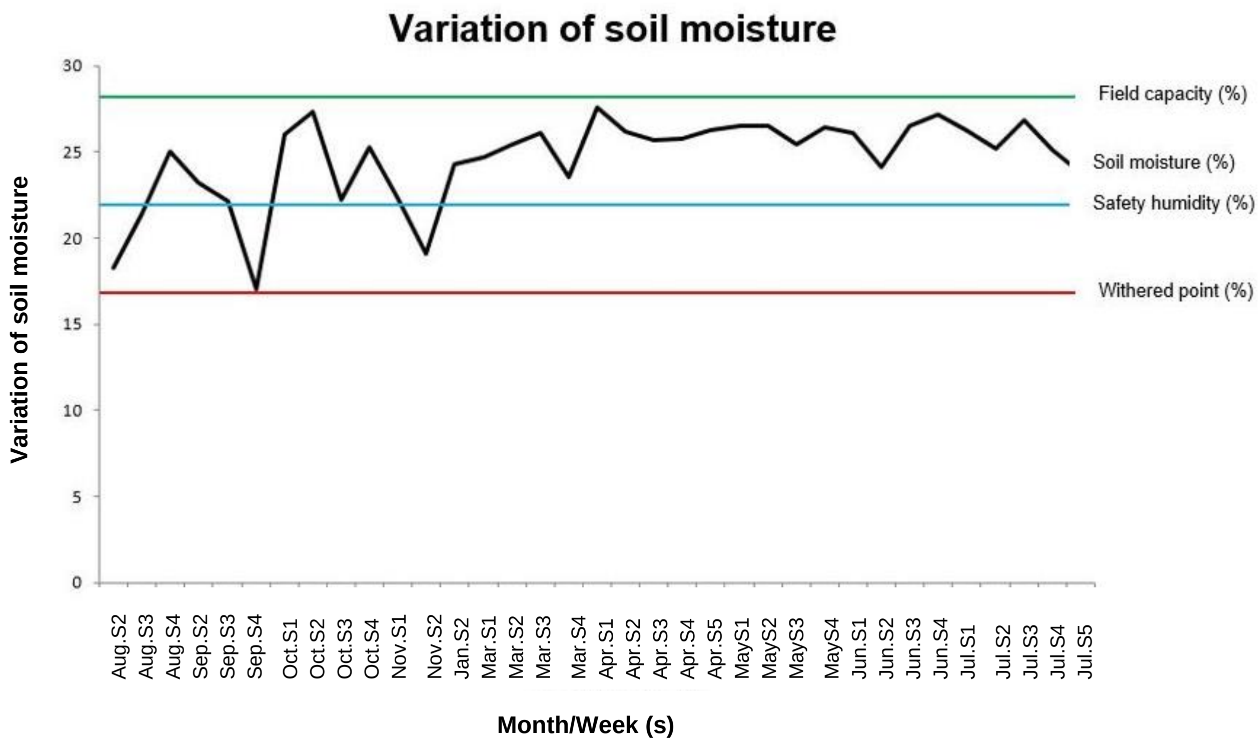

Figure 3. Variation of soil moisture throughout the experimental period.

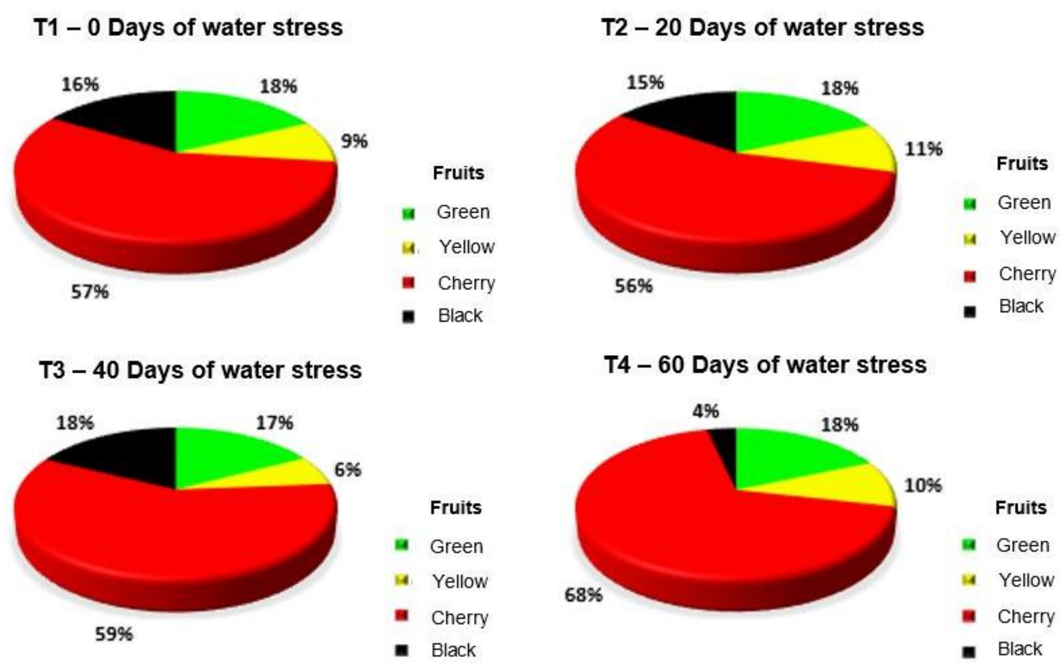

Figure 4. Percentage of maturity of the coffee beans of Conilon Vitória for the 4 treatments.

to achieve a better quality beverage, several factors are involved in the process, from the coffee genotype, the management of the crop up to the post-harvest processing of the coffee fruits.

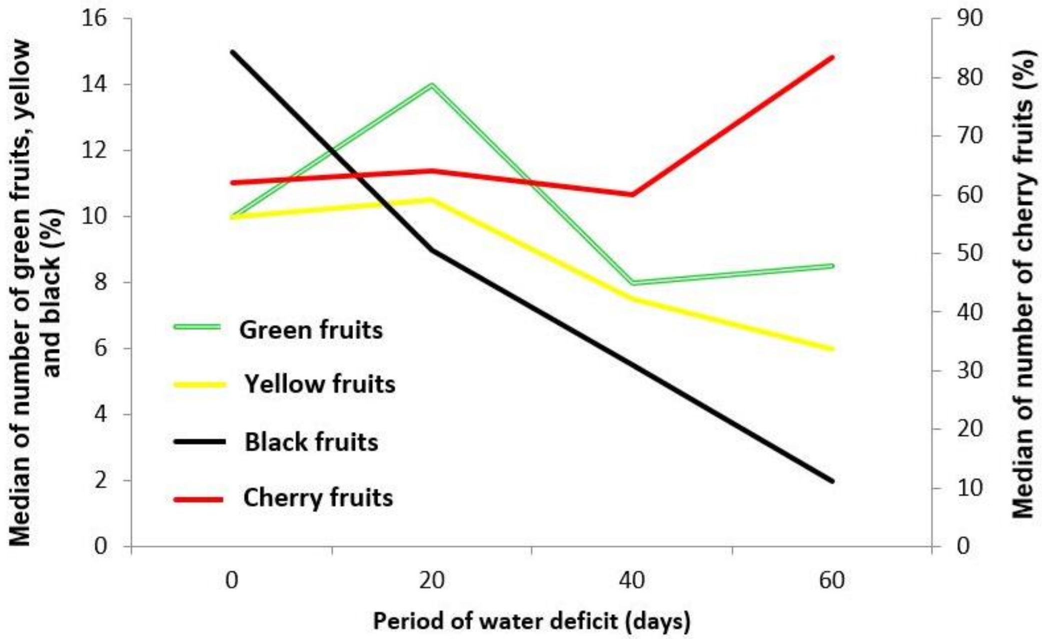

Figure 5. Uniformity of fruits maturation due to periods of water deficit.

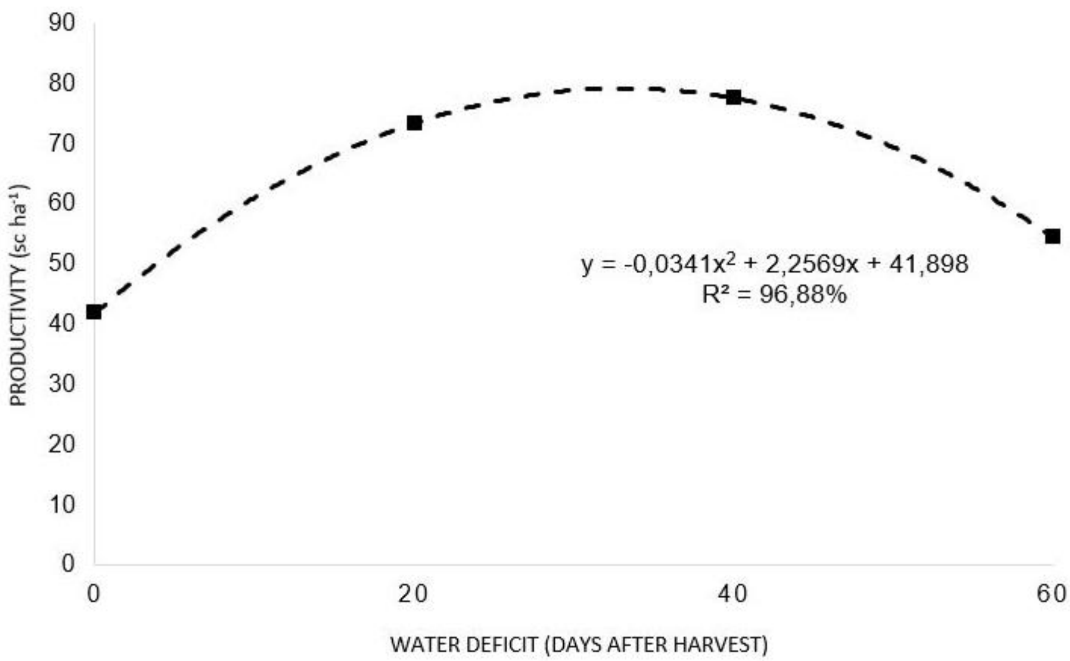

Figure 6. Productivity of coffee Conilon Vitória for the appropriate treatments.

Regarding productivity, it was verified that the control had a lower value (41 sacks ha^{-1}) when compared with the other treatments. The higher estimated productivity (79.2 sc ha^{-1}) in the quadratic regression occurred when there was a water regime of 33 days after harvest, as shown in Figure 6. The T4 treatment produced about 54 sc ha^{-1}, higher productivity than the constant irrigated treatment. In addition, this management can generate savings of water, energy and labor for the coffee farmer, making the production cost of the crop relatively smaller. Silva et al. (2003), observed a similar behavior in arabica coffee, obtaining a great difference between irrigated and non-

Table 2. Water use during the experimental period (sum of irrigation slides applied and rainfall occurred during the period).

Period	T1	T2	T3	T4
	mm			
August	40.7	22.2	17	17
September	40.8	40.8	40.8	8.5
October	78.4	78.4	78.4	78.4
November	156.8	156.8	156.8	156.8
December	121.7	121.7	121.7	121.7
January	35.4	35.4	35.4	35.4
February	157.7	157.7	157.7	157.7
March	161.9	161.9	161.9	161.9
April	146.6	146.6	146.6	146.6
May	75.71	75.71	75.71	75.71
June	20.6	20.6	20.6	20.6
July	11.6	11.6	11.6	11.6
Total	1047.91	1029.41	1024.21	991.91

irrigated coffee, with values of 66, 72, 72.2 and 72.4 sc ha^{-1} in the non-irrigated treatments, irrigated constantly, irrigated with suspension of 30 days and irrigated with suspension of 60 days, respectively. The water deficit for a longer period of time (60 days) is related to producers that aim to produce a higher quality coffee, causing a greater uniformity of maturation in the grains.

The adoption or not of a period of water deficit in the stage of development of the floral bud called "E4", to standardize the flowering of the coffee tree, is perhaps one of the major bottlenecks of irrigated coffee in Brazil. In addition to the synchronization of the flowering, irrigation affects the maturation of the fruits of the coffee tree to make it slower, when compared with the maturation of the fruits without irrigation, which is more precocious (Fernandes, 2011).

As expected, water savings were higher as the period of water stress increased. Treatment 4 presented a smaller total applied slide compared to Treatment 1 (Table 2), generating an economy of 56 mm of water per productive cycle of the crop. There are considerable values for a commercial area since there is a saving of 56 L of water per m², and consequently there was greater saving of electricity, labor, and less detrition of the irrigation system since it will be used less times.

Conclusion

The water stress of 60 days after harvesting gives a higher uniformity of maturation of the coffee conilon, obtaining up to 68% of cherry grains. The water stress of 33 days after harvest increases 37.3 sc ha^{-1} the productivity of coffee conilon, when compared with coffee irrigated throughout the year. The water stress of 60 days after the harvest contributed to save 56 L of water per m^2 during a productive cycle of the coffee conilon Vitoria 'Incaper 8142'.

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