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# POTENCIAL HÍDRICO FOLIAR E DESENVOLVIMENTO VEGETATIVO DO CAFEEIRO CONILON SOB DIFERENTES LÂMINAS DE IRRIGAÇÃO NA REGIÃO E CAMPOS DOS GOYTACAZES - RJ

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## 1 RESUMO

Na atividade cafeeira, o Brasil se destaca como maior produtor mundial, porém verifica-se que a sua produtividade é afetada de forma negativa pela seca, o que torna a produção dependente de complementação hídrica. Este trabalho tem como objetivo determinar estresse hídrico e o desenvolvimento do café Conilon em diferentes lâminas de irrigação. O delineamento experimental foi constituído de blocos casualizados, com três repetições, distribuídos em cinco tratamentos, sendo estes as lâminas de água de 0, 25, 50, 100 e 125% da $ET_0$. Cada parcela foi constituída de seis plantas, sendo as duas primeiras plantas de cada bloco consideradas bordadura. O potencial hídrico foliar foi determinado pela medição da pressão de turgescência da folha, utilizando a bomba de Scholander, em uma planta por bloco e por tratamento. A altura da planta, secção transversal do caule e diâmetro da copa foram avaliados em três plantas por bloco, utilizando régua e paquímetro graduados. Os valores para o potencial hídrico foliar realizado na antemanhã variaram ente –0,15 a -1,18 MPa e, ao meio dia, de -1,17 a -2,3 MPa. As lâminas de irrigação equivalentes a 100 e 125% da $ET_0$ apresentaram maiores valores ao longo do desenvolvimento da cultura até o momento da avaliação.

**Palavras-Chave:** cafeeiro, bomba de Scholander, status hídrico, parâmetros biométricos.

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**POTENTIAL LEAF WATER AND VEGETATIVE DEVELOPMENT OF COFFEE CONILON UNDER DIFFERENT IRRIGATION DEPTHS IN THE REGION OF CAMPOS DOS GOYTACAZES - RJ**

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## 2 ABSTRACT

In terms of coffee production, Brazil stands out as the world's largest producer, but its productivity is negatively affected by drought, which makes production dependent on water supplementation. This work aimed to determine the water stress and development of Conilon coffee at different irrigation depths. The experimental design consisted of randomized blocks with three replications, which were distributed into five treatments, with irrigation depths of 0, 25, 50, 100 and 125% of ET0. Each plot was composed of six plants, with the first two plants of each block considered the border. The leaf water potential was determined by measuring leaf turgor pressure via a Scholander pump in a single plant per block and by treatment. The plant height, stem cross-section and crown diameter were evaluated for three plants per block via a graduated ruler and pachymeter. The values for leaf water potential measured in the morning ranged from -0.15 to -1.18 MPa, and those measured at noon ranged from -1.17 to -2.3 MPa. The irrigation depths equivalent to 100 and 125% of the ET0 presented higher values throughout the development of the culture until the moment of the evaluation.

**Keywords:** coffee, Scholander pump, water status, biometric parameters.

## 3 INTRODUCTION

The national coffee production in 2016 was 51.37 million 60-kg bags, 18.8% higher than the 2015 production of 43.24 million 60-kg bags. Among the total coffee produced in the country (Arabica and Conilon), Conilon coffee accounted for 15.6% of the total production in 2016, equivalent to 7.98 million bags. Despite the considerable increase in the coffee harvest in 2016, specifically in the production of Conilon coffee, there was a 28.6% reduction compared with the previous cycle. This decrease in production is characterized by a 4% reduction in the total area cultivated with Conilon and, mainly, by the drought and poor distribution of rainfall that occurred in the last two consecutive years in the flowering, formation and grain filling stages in the state of Espírito Santo, the largest Brazilian producer of Conilon coffee (CAFÉ, 2016).

Given this scenario, the influence of environmental factors on coffee production becomes evident. According to DaMatta et al. (2010), water deficit is the main environmental factor affecting agricultural production in Brazil. Short periods of water deficit can be sufficient to reduce coffee production (SILVA et al., 2013), suggesting the need for techniques capable of mitigating these production problems.

Plant water potential has been used as a strong indicator of water status in coffee cultivation. The water potential of a leaf indicates its energy status, whose gradients explain water fluxes in the soil–plant–atmosphere system; thus, a sharp reduction in leaf water potential can affect plant carbon assimilation (BERGONCI et al., 2000).

Within this context, the present work aims to determine water stress and the development of Conilon coffee at different irrigation depths, thus contributing to the identification of water stress and assisting in irrigation management, reducing costs and rationalizing the use of water, which is an increasingly valuable resource.

## 4 MATERIALS AND METHODS

### 4.1. Experimental conditions and plant material

The experiment was installed in an area belonging to the evapotranspirometric station of the State University of Northern Fluminense "Darcy Ribeiro" (UENF), located on the premises of the State Center for Research in Agroenergy and Waste Use (CEPEAA), of the Experimental Station of the Agricultural Research Corporation of the State of Rio de Janeiro (PESAGRO-RIO), in Campos dos Goytacazes, RJ, with a geographic location of 21°44'45.7" south latitude, 41°18'24.1" west longitude and 11 m altitude.

In the Köppen climate classification, the climate of the North Fluminense region (RJ) is classified as Aw, that is, a humid tropical climate, with a rainy summer, dry winter, and coldest month above 18°C. The average annual temperature is approximately 24°C, with a very small thermal amplitude. The average annual rainfall is approximately 1,023 mm (MENDONÇA et al., 2007). The soil of the experimental area has a flat topography and was classified as Neossolo. Fluvic Tb dystrophic, according to the Brazilian soil classification system (SiBCS) of Embrapa (1999). The physical characteristics of the soil are presented in Table 1.

**Table 1.** Physical characteristics of the soil in the experimental area.

| Depth (m) | Granulometry ($g \cdot kg^{-1}$) | | | Water content (%) | | Soil density |
|---|---|---|---|---|---|---|
| | Sand | Clay | Silt | [1]CC | [2]PMP | ($g \cdot cm^{-3}$) |
| 0.0 – 0.10 | 764 | 161 | 75 | 21 | 14 | 1.60 |
| 0.1 – 0.2 | 731 | 223 | 46 | 22 | 15 | 1.77 |
| 0.2 – 0.3 | 672 | 276 | 52 | 25 | 19 | 1.79 |
| 0.3 – 0.4 | 579 | 579 | 64 | 28 | 22 | 1.65 |

[1]Field capacity; [2]Permanent wilting point. Source: Adapted from Gottardo (2016).

Different irrigation depths were evaluated for Conilon coffee (*Coffea canephora*). The genotype used for the evaluation was one of the clones of the Vitória variety: the early cycle clone 02. The seedlings were produced in a nursery specialized in seedling production (*Coffea canephora*). The seedlings were purchased at approximately 15 cm in height and underwent a 30-day acclimatization period. Transplanting was carried out in May 2014 in 30 cm deep furrows with a spacing of 2.5 m × 1.5 m. At the time of evaluation, the plants were two years old after transplanting.

Water was applied with NETAFIM® drippers at flow rates of 2.5, 4.0, and 8.0 $L \cdot h^{-1}$. Emitters with different flow rates were used to facilitate management during irrigation; thus, the entire experiment was irrigated immediately. The irrigation depth was controlled by the emitter flow rate. To replace the depth at 25% of $ET_0$, an emitter with a flow rate of 2.5 $L \cdot h^{-1}$ was used; for a depth at 50% of $ET_0$, two emitters with a flow rate of 2.5 $L \cdot h^{-1}$ were used; for a depth at 100% of $ET_0$, two emitters with a flow rate of 4.0 $L \cdot h^{-1}$ were used; and for a depth of 125% of $ET_0$, two emitters with flow rates of 2.5 and 8.0 $L \cdot h^{-1}$ were used. The irrigation depths were determined as a function of the reference evapotranspiration ($ET_0$). Using meteorological data collected from a station located near the planting area, the reference evapotranspiration was calculated via the Penman–Monteith method (ALLEN et al., 1998), according to Equation (1).

$$ET_0 = \frac{0{,}408 \,.\, \Delta \,.\, (R_n - G) + \gamma \,.\, \frac{900}{T+273} \,.\, U_2 \,.\, (e_s - e_a)}{\Delta + \gamma \,.\, (1 + 0{,}34 \,.\, U_2)} \quad (1)$$

Where $ET_0$ is the reference evapotranspiration (mm $day^{-1}$); Δ is the slope of the vapor pressure curve (kPa°$C^{-1}$); $R_n$ is the total daily net radiation (MJ $m^{-2}$ $day^{-1}$); G is the ground heat flux (MJ $m^{-2}$ $day^{-1}$); Y is the psychrometric constant (kPa °$C^{-1}$); T is the mean air temperature (°C); $U_2$ is the mean wind speed measured at 2 m height ($ms^{-1}$); $e_s$ is the saturation water vapor pressure (kPa); and $e_a$ is the current water vapor pressure.

The experimental design consisted of randomized blocks with three replicates distributed into five treatments: water depths equivalent to 0, 25, 50, 100, and 125% of $ET_0$. Each plot consisted of six plants, with the first two plants in each plot being considered the border. The last plot in each treatment consisted of two plants as the border, one at the beginning and one at the end.

For data analysis, the SAEG Statistical Analysis System software, version 9.1, was used, and the means of the data obtained were compared via the Tukey test at a 5% probability of error level.

## 4.2. Evaluated variables

In this experiment, plant water status assessments were performed via a Scholander pump throughout the winter season. Crop development parameters, including plant height, stem diameter, and canopy diameter, were also assessed. The experimental period began on July 1, 2016, and lasted 140 days after the start of the growing season (DAP). Leaf water potential was assessed on five different occasions: at 16, 44, 90, 86, and 107 DAP. The assessment was performed one day after irrigation. At 90 and 107 DAP, the assessments were performed three days after irrigation. At 44 and 86 DAP, the assessments were performed six days after irrigation. Development parameters were assessed once a month for five months and were measured at 28, 56, 84, 112, and 140 DAP.

The leaf water potential (Ψwf) was obtained via a portable Scholander pressure chamber, model SEC-3115, P40G4V, from Soilmoisture. Measurements were taken before sunrise and at noon. This evaluation was performed on one vigorous plant per plot in each treatment, with a leaf reading being taken. The leaves used for measurement were fully expanded, mature, and located in the middle third of the plants. The potential of each leaf was assessed immediately after the leaf was detached from the plant.

To measure crop development parameters, three plants were used per plot in the applied treatments, resulting in a total of 45 plants being evaluated. Plant height was measured via a graduated ruler, starting from the base of the stem and extending to the crown apex, with the last node used as a reference. The stem cross-sections were measured between the first and second internodes via a graduated caliper. The crown diameter was measured via a graduated ruler in the north–south and east–west directions, and the average of these two measurements (in cm) was calculated.

## 4.3. Meteorological Data

During the experimental period, the average daily temperature remained in conditions favorable for good crop development, oscillating around the ideal range of 22–26°C. The monthly rainfall data collected during the evaluation period are shown in Table 2.

**Table 2.** Monthly precipitation values in Campos dos Goytacazes (RJ) during the experimental period, June–October 2016.

| | June | July | August | September | October |
|---|---|---|---|---|---|
| Precipitation (mm) | 42.9 | 4.3 | 29.7 | 33 | 79 |

Soil water storage during the experimental period was established according to the daily water balance (Equation 2), with ETr calculated via Equation 3 (ALLEN et al., 1998).

$$\Theta_i = \Theta_{i-1} + I_i + P_i - ETr_i \quad (2)$$

where:
$\Theta_i$ – Water depth in the soil on day i, mm;
$\Theta_{i-1}$ – Water depth in the soil on the previous day (i-1), mm;
$I_i$ – Irrigation applied on day i, mm;
$P_i$ – Precipitation occurring on day i, mm;
$ETr_i$ – Actual crop evapotranspiration on day i, mm.

With the following boundary conditions:
If $\Theta_i < 0$, then $\Theta_i = 0$
If $\Theta_i >$ CTA, then $\Theta_i =$ CTA

$$ETr_i = ETo_i \, . \, Kc_i \, . \, Ks_i \quad (3)$$

where: being
$ETo_i$ – Reference evapotranspiration occurring on day i, mm;
$Kc_i$ – Crop coefficient on day i, dimensionless;
$Ks_i$ – Soil moisture coefficient on day i, dimensionless;

$$(Ks_i = \frac{\ln(LAA_i + 1)}{\ln(CTA_i + 1)}) \quad (4)$$

$LAA_i$ – Current soil water depth on day i, mm;
$CTA_i$ – Total soil water capacity on day i, mm.

Table 3 shows the water availability in the soil on the days when the LWP was evaluated for each irrigation depth applied.

**Table 3.** Values of soil water availability (mm) for the days on which plant water status assessments were made in each applied layer in the Campos dos Goytacazes-RJ region (July to October 2016).

| Treatment | Water availability (mm) | | | | |
|---|---|---|---|---|---|
| | 16 DAP | 44 DAP | 79 DAP | 96 DAP | 107 DAP |
| 0% | 15.2 | 27.2 | 24.5 | 28 | 29.3 |
| 25% | 11.1 | 23 | 22.7 | 25.8 | 27.7 |
| 50% | 6.16 | 16.32 | 18.57 | 21 | 22 |
| 100% | 2.15 | 12.9 | 14.8 | 14 | 11,13 |
| 125% | 2.15 | 12.9 | 13.6 | 13.2 | 11,13 |

## 5 RESULTS AND DISCUSSION

### 5.1. Leaf water potential

The average variations in the leaf water potential before the morning ($\Psi_{AM}$) and the leaf water potential at noon ($\Psi_{MD}$) of Conilon coffee under different irrigation depths are shown in Figures 1 and 2, respectively.

**Figure 1.** Average variation in the premorning leaf water potential ($\Psi_{AM}$) measured in Conilon coffee plants (clone 2) at different irrigation depths in Campos dos Goytacazes-RJ (June to October 2016).

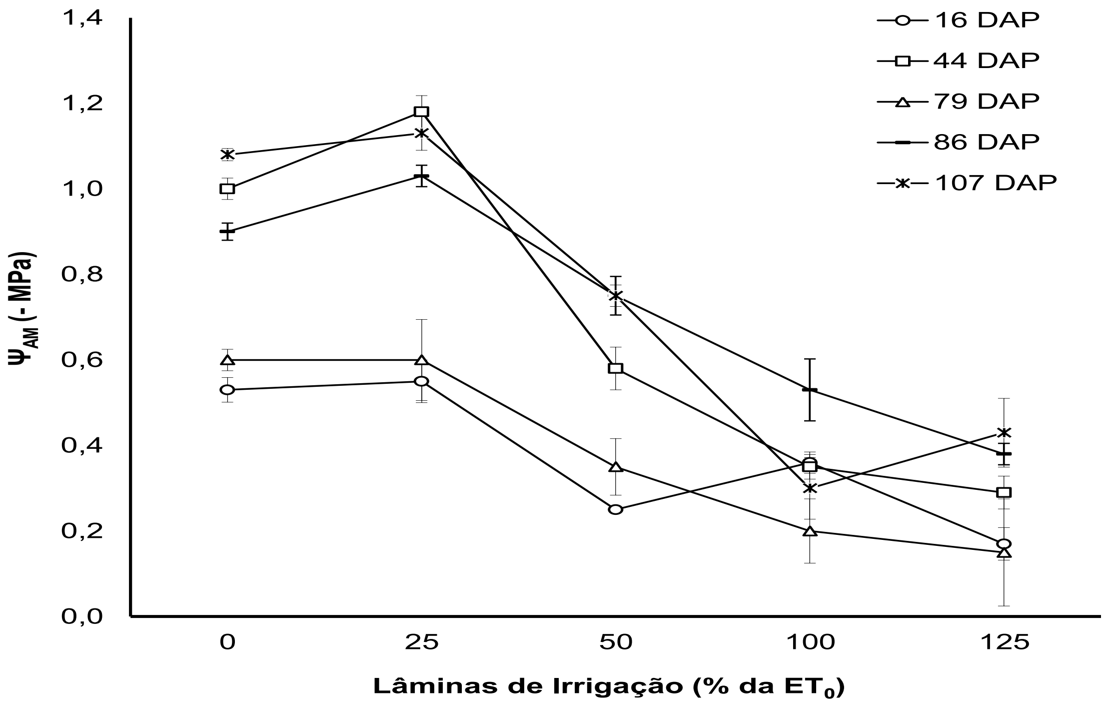
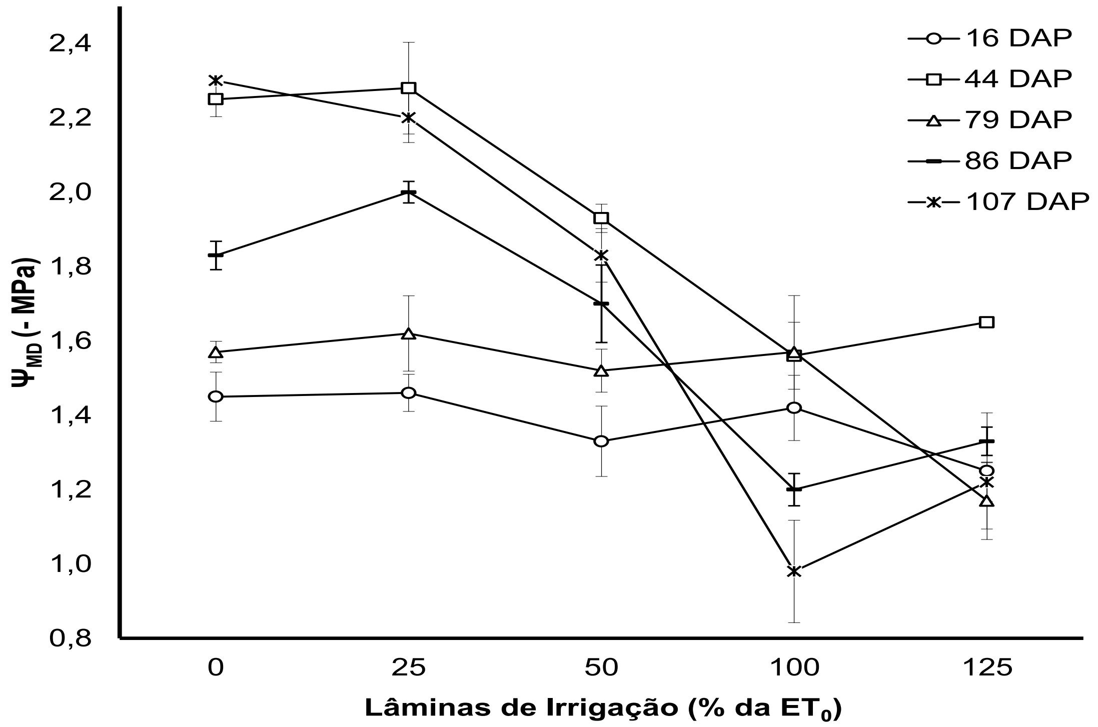


**Figure 2.** Average variation in the leaf water potential at noon ($\Psi_{MD}$) measured in Conilon coffee and clone 02 under different irrigation depths at Campos dos Goytacazes-RJ (June to October 2016).




The $\Psi_{AM}$ values of the plants (Figure 1) ranged from –0.17 to –0.55 MPa at 16 DAP. The $\Psi_{AM}$ values of the evaluations carried out 3 days after irrigation (79 and 107 DAP) ranged from –0.15 to –1.13 MPa. For the plants evaluated six days after irrigation, the values obtained ranged from –0.29 to –1.18 MPa. The 0% and 25% irrigation treatments did not significantly differ from each other (Tukey test, $r \leq 0.05$) and were always significantly lower than the other treatments on all days evaluated. Figure 1 shows that the leaf water potential ($\Psi_{AM}$) values for 107° DAP, despite being obtained three days after irrigation, are closer to the values obtained six days after irrigation at the depths with the lowest soil water replenishment (0%, 25%, and 50% $ET_0$ replenishment). This behavior may have occurred because of the low accumulated precipitation during the month, which may have contributed to the reduction in leaf water potential in these treatments.

For day 16 DAP, the $\Psi_{MD}$ value (Figure 2) varied between -1.25 and -1.46 MPa. The $\Psi_{MD}$ values of the evaluations carried out three days after irrigation ranged from -1.17 to -2.3 MPa and from -1.2 to -2.28 MPa for the evaluations carried out six days after irrigation. For the 16th and 79th DAPs, there was no significant difference between the applied treatments. For the evaluation carried out at 107 DAP, the depths with the lowest water replacement values, 0, 25 and 50% of $ET_0$, presented values closer to those evaluated six days after irrigation at the same depths. The depths of 100 and 125% of $ET_0$ presented values close to those observed at the other depths and at the other evaluations carried out one and three days after irrigation, which was justified by the possible response to the greater availability of water in the soil via irrigation (Table 3).

The values of $\Psi_{AM}$ (Figure 1) and $\Psi_{MD}$ (Figure 2) reflected the treatments applied. The depths with the greatest soil water replenishment had the highest water potentials, which decreased as the applied depths were reduced.

Leaf water potential can vary depending on the plant species, time of year and time of day, with the lowest values found in dry seasons and in measurements taken close to noon, i.e., periods in which leaf transpiration is more intense (TOBIN; LOPEZ; KURSAR, 1999).

When measured in the morning, water potential can indicate water availability in the soil, since there is a tendency for balance between the water conditions of the plant and the soil in situations where the water deficit is not severe (SILVA et al., 2003).

The lowest $\Psi_{AM}$ values throughout the experimental period were -0.9 MPa, -1.0 MPa, and -1.08 for the 0% depth and -1.18 MPa, -1.03 MPa and -1.13 MPa for the 25% depth at the longest period of soil water deficit, which was due mainly to the low volume and poor distribution of rainfall prior to these dates. According to Camargo and Camargo (2001), despite the lower $\Psi_{AM}$, the coffee crop is not negatively affected by water stress when it coincides with the time of flower bud induction and maturation, which helps promote more uniform flowering.

Assessments conducted during the predawn hours revealed higher water potentials (Figure 1), as observed in the 100 and 125% $ET_0$ slides, reflecting the good recovery capacity of the plant's water status after reaching a lower value. According to Silva et al. (2008), when there is no water restriction, plant tissues are maximally hydrated shortly before dawn, whereas measurements taken throughout the day suffer the effects of transpiration, consuming more nitrogen and being more susceptible to climate variations, such as incident radiation, temperature, and air saturation pressure deficit.

Golberg et al. (1988) reported that coffee leaf photosynthesis was little affected when the leaf water potential reached values up to -1.5 MPa under field conditions. For the $\Psi_{AM}$ (Figure 1), none of the treatments presented leaf water potential values greater than -1.18 MPa, which suggests that the plants at this time were not negatively affected by the applied stress. The evaluations carried out for the $\Psi_{MD}$ (Figure 2) revealed that at 44° DAP, the $\Psi$ MD ranged from -1.56 MPa to -2.28 MPa across all the applied water depths. For 79° DAP, the $\Psi_{MD}$ values were greater than -1.5 MPa for water depths of 0, 25, 50, and 100% $ET_0$.

Silva et al. (2008), working with Catuaí coffee in irrigated and nonirrigated treatments, reported premorning leaf water potential values similar to the values shown in Figure 1, according to the treatments applied.

### 5.2. Development parameters

Drought is considered the main environmental stress capable of affecting the development and production of coffee plantations in Brazil and worldwide (DAMATTA and RAMALHO, 2006). Covre et al. (2016), studying Conilon coffee in the state of Bahia, reported that irrigation is important for the good development of the crop and the consequent increase in productivity. Similar results were also reported for Arabica coffee (FERREIRA et al., 2013; SAKAI et al., 2015).

Therefore, maintaining soil moisture at satisfactory levels for crops will benefit their development and production. The results of the development parameters collected during the five months of evaluation of the Conilon coffee plant are presented in Tables 4, 5, and 6.

**Table 4.** Height (mean ± SD) of Conilon coffee plants as a function of irrigation depth (% of $ET_0$) in days after the first evaluation (DAP), Campos dos Goytacazes-RJ (June to October 2016)

| (% $ET_0$) | | | | | B1 | B2 | $R^2$ |
|---|---|---|---|---|---|---|---|
| **0** | **25** | **50** | **100** | **125** | | | |
| (28 DAP) Eq. $\hat{Y}$= -0.00084X²+0.196X+86.24 | | | | | | | |
| 86.4Bb | 92.6Bb | 89.2Cb | 102.5Ca | 95.1Ca | -1.59 ns | -0.86 ns | 0.61* |
| (56 DAP) Eq. $\hat{Y}$= -0.0011X²+0.242X+86.83 | | | | | | | |
| 86.6ABc | 94.4Bb | 92.2BCb | 103.6 BCa | 98.0Ca | 1.79 * | -1.07 ns | 0.77* |
| (84 DAP) Eq. $\hat{Y}$= -0.00079X²+0.218X+88.46 | | | | | | | |
| 88.4ABc | 95.3Bb | 93.6BCb | 106.1 BCa | 101.5 BCa | 1.79 * | 0.84 ns | 0.82* |
| (112 DAP) Eq. $\hat{Y}$= -0.00088X²+0.25X+89.69 | | | | | | | |
| 90.1ABb | 96.4Bb | 97.3ABb | 110.4ABa | 106.2ABa | 2.32 * | -1.04 ns | 0.89* |
| (140 DAP) Eq. $\hat{Y}$= 0.0017X²+0.35X+94.94 | | | | | | | |
| 94.2Ac | 105.5Ab | 104.6Ab | 115.1Aa | 110.8Aa | 2.76 * | -1.79* | 0.89* |

[1] Means followed by the same uppercase letters in the column (%$ET_0$) and lowercase letters in the row (DAP) do not differ from each other according to the Tukey test (P≤0.05; DMS = 3.25); ns – nonsignificant effect and * significant effect of the terms of B1 and B2 to the regression model, according to the t test (P≤0.05) and * significant effect for the coefficient of determination, according to the F test (P≤0.05).

**Table 5.** Stem cross-sections (means ± SDss) of Conilon coffee plants as a function of irrigation depth (% of $ET_0$) in the soil in days after the first evaluation (DAP), Campos dos Goytacazes-RJ (June to October 2016).

| (% $ET_0$) | | | | | B1 | B2 | $R^2$ |
|---|---|---|---|---|---|---|---|
| **0** | **25** | **50** | **100** | **125** | | | |
| (28 DAP) Eq. $\hat{Y}$= 0.00045X²+0.0016X+7.24 | | | | | | | |
| 7.1Ac | 7.4Ac | 9.0Ab | 11.1Ab | 14.8Ba | 0.05 ns | 1.81* | 0.97* |
| (56 DAP) Eq. $\hat{Y}$= 0.00056X²-0.0083X+8.13 | | | | | | | |
| 8.0Ac | 8.2Ac | 9.4Ab | 12.4Ab | 16.0ABa | -0.28 ns | 2.47 * | 0.99* |
| (84 DAP) Eq. $\hat{Y}$= 0.00050X²+0.0046X+8.94 | | | | | | | |
| 8.8Ac | 9.4Ac | 10.7Ac | 14.1Ab | 17.5ABa | 0.13 ns | 1.57* | 0.99* |
| (112 DAP) Eq. $\hat{Y}$= 0.0007X²-0.017X+9.30 | | | | | | | |
| 9.1Ac | 9.4Ac | 10.3Ac | 14.1Ab | 18.3Aa | -0.52 ns | 2.75* | 0.99* |
| (140 DAP) Eq. $\hat{Y}$= 0.00081X²-0.031X+9.66 | | | | | | | |
| 9.4Ac | 9.6Ac | 10.1Ac | 14.3Ab | 18.7Aa | -0.85 ns | 2.95* | 0.99* |

[1] Means followed by the same uppercase letters in the column (%$ET_0$) and lowercase letters in the row (DAP) do not differ from each other according to the Tukey test (P≤0.05; DMS = 3.25); ns – nonsignificant effect and * significant effect of the terms of B1 and B2 to the regression model, according to the t test (P≤0.05) and * significant effect for the coefficient of determination, according to the F test (P≤0.05).

**Table 6.** Crown diameter (DC, mean ± SD) of Conilon coffee plants as a function of irrigation depth (% of $ET_0$) in the soil, in days after the first evaluation (DAP), Campos dos Goytacazes-RJ (June to October 2016).

| (% $ET_0$) | | | | | B1 | B2 | $R^2$ |
|---|---|---|---|---|---|---|---|
| **0** | **25** | **50** | **100** | **125** | | | |
| (28 DAP) Eq. $\hat{Y}= -0.0022X^2-0.11X+103.56$ | | | | | | | |
| 101.3Ab | 105.8Ab | 103.2Ab | 110.8Aa | 125.8Aa | -0.56 $^{ns}$ | 1.46* | 0.91* |
| (56 DAP) Eq. $\hat{Y}= 0.0016X^2-0.0043X+104.69$ | | | | | | | |
| 105.5Ab | 104.1Ab | 108.7Ab | 122.2Aa | 129.4Aa | -0.02 $^{ns}$ | 1.27 $^{ns}$ | 0.99* |
| (84 DAP) Eq. $\hat{Y}= 0.0018X^2-0.036X+105.48$ | | | | | | | |
| 104.6Ab | 107.6Ab | 107.3Ab | 119.8Aa | 130.2Aa | -0.22 $^{ns}$ | 1.27 $^{ns}$ | 0.98* |
| (112 DAP) Eq. $\hat{Y}= 0.0019X^2-0.048X+110.15$ | | | | | | | |
| 109.5Ab | 112.5Ab | 109.9Ab | 125.8Aa | 133.2Aa | -0.28 $^{ns}$ | 1.48 $^{ns}$ | 0.96* |
| (140 DAP) Eq. $\hat{Y}= 0.00089X+0.035X+116.58$ | | | | | | | |
| 115.7Ab | 119.7Aa | 119.7Aa | 128.5Aa | 135.3Aa | 0.24 $^{ns}$ | 0.82 $^{ns}$ | 0.98* |

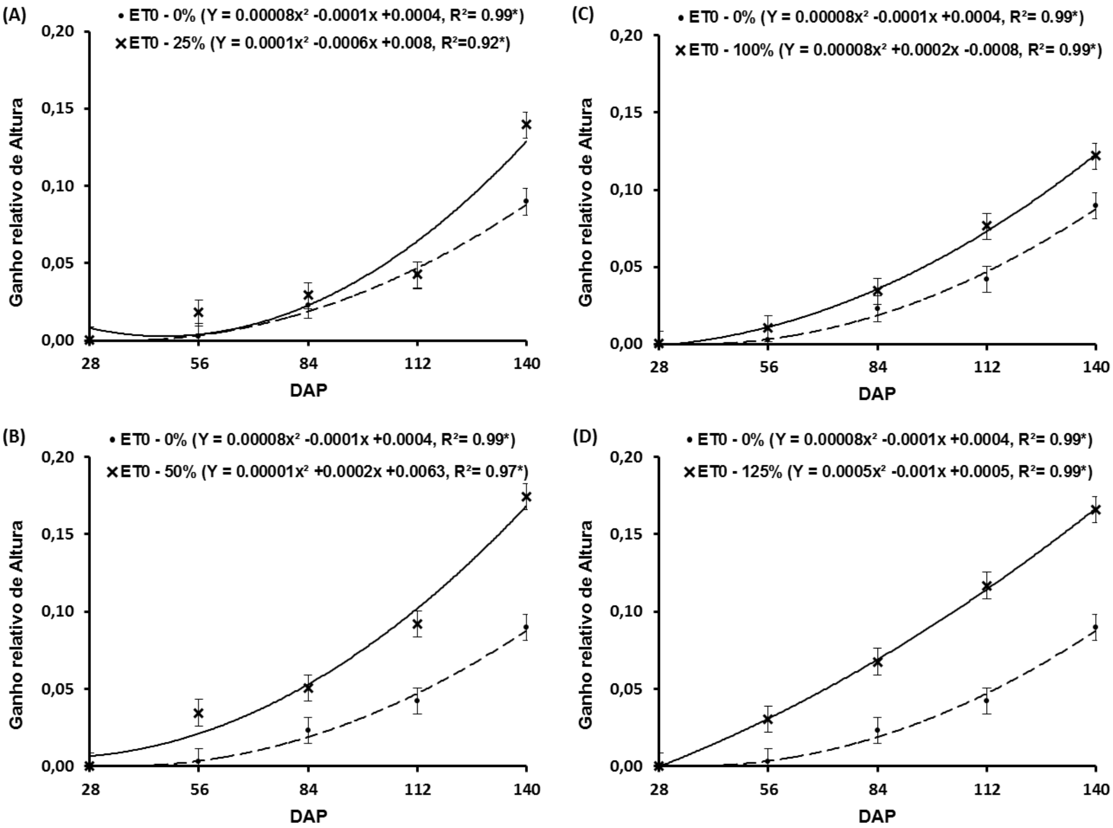
[1] Means followed by the same uppercase letters in the column (%$ET_0$) and lowercase letters in the row (DAP) do not differ from each other according to the Tukey test (P≤0.05; DMS = 3.25); ns – nonsignificant effect and * significant effect of the terms of B1 and B2 to the regression model, according to the t test (P≤0.05) and * significant effect for the coefficient of determination, according to the F test (P≤0.05).

Over the five months of evaluation, the 100% and 125% irrigation depths with an ET of $_0$ were always significantly greater than the other depths. At the beginning of the experimental period, the 100% and 125% irrigation depths of $ET_0$ were 102.56 cm and 95 cm high, whereas at 140 days, the recorded heights were 115.11 cm and 110.89 cm, respectively.

The 0% replacement blade presented the worst statistical result, ranging from 86.44 cm (beginning of the experimental period) to 94.22 cm (140 DAP). The 25 and 50% replacement blades of ET0 did not differ significantly from each other, with values of 92.67 cm and 89.22 cm (beginning of the experimental period) and 105.56 cm and 104.57 cm (140 DAP), respectively (Table 4).

It was also observed that the 50% and 125% replacement water depths of ET0 presented the highest relative growth rates, with increases of 17.2% and 16.6% cm, respectively. The 125% ET at the 0% irrigation depth presented the most uniform development. Despite the highlight in height gain at the 50% and 125% water depths, when observing the development from the first evaluation, there was no significant difference between the evaluated water depths (Figure 3). The 0% replacement water depth of $ET_0$ presented the lowest numerical value of relative development during the evaluated period (Figure 3).

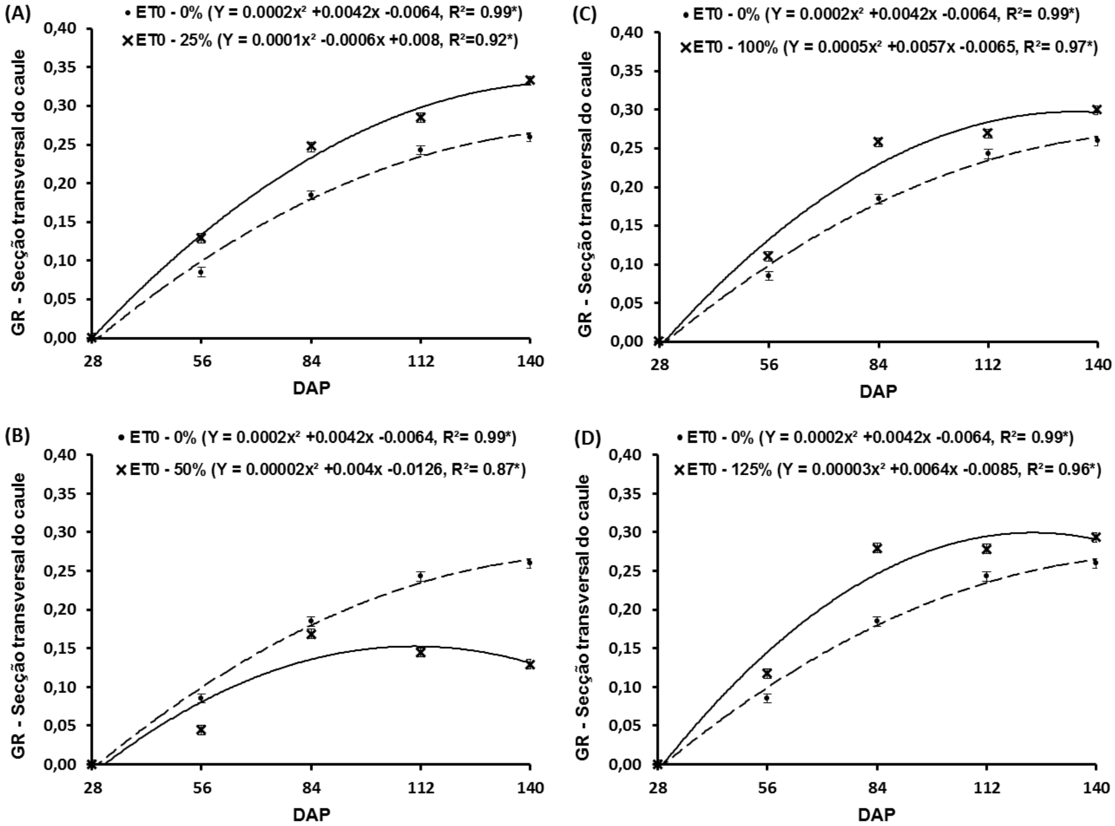
**Figure 3.** Relative height gain of Conilon coffee plants, comparisons between water depth levels and the treatment without irrigation over the days after the first evaluation (DAP), Campos dos Goytacazes-RJ (June to October 2016): (A) ET $_0$ 25%, (B) ET $_0$ 50%, (C) ET $_0$ 100%, (D) ET $_0$ 125%.




Despite the more uniform development of plants in the better-irrigated treatments (100 and 125% ET0 replacement), at lower replacement depths (0, 25, and 50% ET $_{0\ \mathrm{replacement}}$), there was a peak in height gain in the last month of evaluation (Figure 3). This accentuated development in the last evaluation may be related to the high rainfall recorded in October (Table 2), indicating that after being subjected to deficient water conditions for development, Conilon coffee plants exhibited good recovery capacity as the soil moisture level increased.

Rodrigues et al. (2015) reported that coffee plant height is compromised by water deficit and tends to reduce height development gains as the period of water restriction increases, demonstrating the sensitivity of crops to lower soil moisture levels. These results corroborate the data obtained in this study and highlight the importance of water for cell growth and expansion.

**Figure 4.** Relative gain of the stem cross-sections of Conilon coffee plants, comparisons between water depth levels and the treatment without irrigation over the days after the first evaluation (DAP), Campos dos Goytacazes-RJ (June to October 2016): (A) $ET_0$ 25%, (B) $ET_0$ 50%, (C) $ET_0$ 100%, (D) $ET_0$ 125%.




For stem diameter, plants with 125% replacement blades presented the largest stem cross-sections, followed by plants with 100% replacement blades. The plants with 0% and 25% replacement blades presented the smallest stem cross-sectional values, reaching maximum values of 9.48 cm² and 9.68 cm², respectively (Table 5). These two treatments did not differ significantly over the evaluated period. Although plants with 125% replacement had the highest statistical value, this treatment, followed by the 50% replacement treatment, presented the smallest gain in stem cross-sections within the evaluated period (Figure 4). The 50% replacement blade differed statistically, presenting a smaller cross-sectional gain in the last evaluation. This fact may be related to the greater investment of plants in height gain (Figure 3).

Araújo et al. (2011) reported that plants of the Conilon RT and V5 coffee cultivars under different periods of water stress application presented a reduction in stem diameter in relation to that of plants that did not undergo periods of stress, on the order of 34.05% and 44.13%, for RT and V5, respectively, at 180 days of initial development.

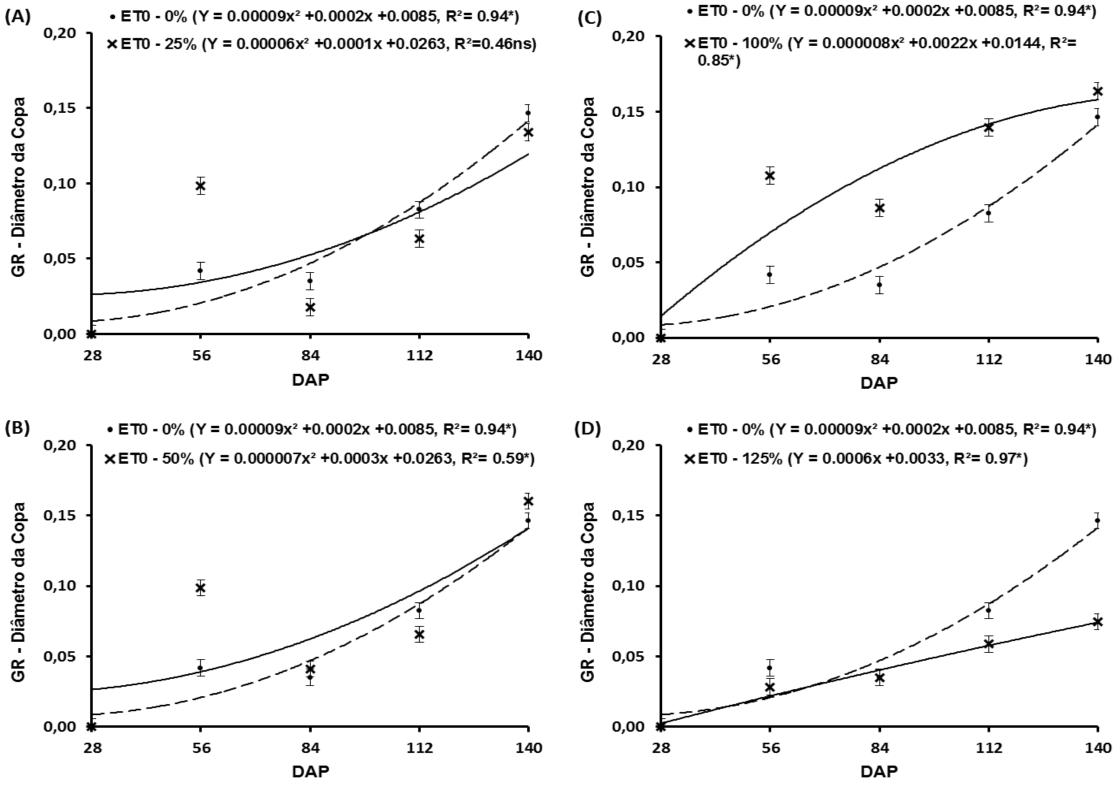
Alves et al. (2000), working with Arabica coffee, concluded that irrigation had significant effects on stem and canopy diameter. These authors also concluded that irrigation promoted better crop growth, ensuring greater plant vigor.

When working with Conilon coffee plants, Zonta et al. (2009) reported that lower seedling development and, consequently, a smaller stem diameter were associated with longer irrigation shifts, indicating that longer periods of water restriction can negatively influence Conilon coffee.

With respect to the results for canopy diameter, the 100% and 125% ETo treatments presented statistically the highest values, which did not differ from each other, followed by the 25% and 50% ETo replacement treatments, which also did not differ from each other at the 5% level according to the F test (Table 6). Although the treatments presented significant differences throughout the evaluations, for the last evaluation, there was no statistically significant difference between the depths of 25% to 125% ETo, a fact that, compared with Figure 5, the depths of lower replacement (0%, 25% and 50% of ET $_0$) may be related to greater precipitation in this last month (Table 2), as well as what occurred with the relative height gain, as shown in Figure 3, reinforcing the idea of the good recovery capacity of plants' development when well hydrated after a period of lower water availability.

This last month (Table 2), as occurred with the relative height gain shown in Figure 3, reinforces the idea of the good recovery capacity of plant development when well hydrated after a period of lower water availability.

**Figure 5.** Relative gain in canopy diameter of Conilon coffee plants, comparisons between water depth levels and the treatment without irrigation over the days after the first evaluation (DAP), Campos dos Goytacazes-RJ (June to October 2016): (A) $ET_0$ 25%, (B) $ET_0$ 50%, (C) $ET_0$ 100%, (D) $ET_0$ 125%.




The results for the canopy diameter (Figure 5) demonstrated that the treatments with the greatest replacement depths (100% and 125% replacement of $ET_0$) presented relatively high values, thus highlighting the benefits of irrigation in the development of the coffee tree, which directly reflects its productivity.

In the present study, Lambert (2009) reported that Arabica coffee plants of the

Rubi variety, lineage MG-1192, presented a larger canopy diameter under different irrigation levels than nonirrigated plants did.

Water deficit causes a reduction in the photosynthetic rate, as affected plants tend to close their stomata to reduce water loss through transpiration. With reduced stomatal opening, in addition to reducing water loss, plants tend to decrease CO2 assimilation , resulting in a reduction in the production of photoassimilates. Thus, a long period of water deficit can negatively affect plant production (TAIZ; ZEIGER, 2013).

Studying different coffee varieties grown at different spacings, Martinez et al. (2008) reported that the variables plant height, canopy diameter, and stem diameter correlated well with crop yield, highlighting the importance of these parameters in determining coffee productivity. Comparing these data and drawing an analogy with the results obtained in this study, it is clear how important it is to minimize water deficits in plantations to maximize crop development and generate productivity gains.

## 6 CONCLUSION

The $\Psi_{wf}$ corresponded to the treatments applied. The depths with greater water replacement presented lower $\Psi_{wf}$ values premorning and midday than did the $\Psi_{wf}$ values in the treatments with less water replacement, which were negatively affected. The premorning $\Psi_{wf}$ values were lower than those observed at midday among the treatments applied.

It can be concluded that the vegetative development of the coffee plant was responsive to the applied water depth when analyzed throughout the development of the crop. The 100% replacement water depth of $ET_0$ resulted in better crop development until the end of the evaluated period, justifying the use of this water depth in the irrigation management of Conilon coffee plants.

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