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FENOLOGIA DO COQUEIRO IRRIGADO EM FUNÇÃO DE DIFERENTES TAXAS EVAPOTRANSPIRATIVAS

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1 RESUMO

O coqueiro (*Cocus nucifera* L.), popularmente conhecido como 'coqueiro anão verde', é uma monocotiledônea da família Arecaceae que possui grande importância econômica. A fertirrigação, técnica na qual os fertilizantes são aplicados via água de irrigação, o que favorece uma maior absorção dos nutrientes, conjuntamente com a irrigação, são técnicas eficientes para o pleno desenvolvimento das culturas. O objetivo do estudo foi avaliar a fenologia do *Cocus nucifera* L sobre diferentes taxas da evapotranspiração (ET_0). O experimento foi realizado na Fazenda Reunidas Sococo na cidade de Santa Izabel do Pará, PA. Foi adotado o delineamento em blocos casualizados em esquema fatorial 3 x 9 (três taxas de ET_0, calculadas pelo método de Penman-Monteith, com nove períodos de análise) e três blocos. A irrigação foi realizada por microaspersão com turno de rega fixo. Foram selecionadas três plantas da parcela útil, nas quais foram avaliadas as seguintes características: comprimento do estipe, circunferência do coleto e número de folhas vivas e de folhas mortas. As características fenológicas avaliadas foram diretamente influenciadas pelas taxas evaporativas e condições climáticas, se destacando positivamente o tratamento com reposição de 100% da ET_0, confirmando que em situações de estresse, o coqueiro não apresenta um desenvolvimento vegetativo adequado.

Palavras-chave: condições climáticas, fertirrigação, irrigação.

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2 ABSTRACT

The coconut palm (*Cocus nucifera* L.), popularly known as the 'green dwarf coconut', is a monocot of the Arecaceae family with great economic importance. Fertigation, a technique in which fertilizers are applied via irrigation water, which favors a greater absorption of nutrients, with irrigation, an efficient technique for the full development of crops. This study aimed to evaluate the phenology of *Cocus nucifera* L under different evapotranspiration (ET_0) rates. The experiment was conducted at Reunidas Sococo Farm in the city of Santa Izabel do Pará, PA. The randomized block design was adopted in a 3 x 9 factorial scheme (three ET_0 rates, calculated by the Penman-Monteith method, with nine periods of analysis) and three blocks. The irrigation was performed by micro-sprinkler with a fixed irrigation scheduling. Three plants were selected from the useful plot, in which the following characteristics were evaluated: stipe length, collar circumference, and number of live and dead leaves. The phenological characteristics evaluated were directly influenced by evapotranspiration rates and climatic conditions, with the treatment with the replacement of 100% of the ET_0 standing out positively, confirming that in stress situations, coconut does not present an adequate vegetative development coconut.

Keywords: climatic conditions, fertigation, irrigation.

3 INTRODUCTION

The coconut tree (*Cocus nucifera* L.) is highly important in the economic context since, from cultivation to consumption, there is a significant generation of jobs and high profitability in its production. Because of this, interest in this crop has increased in recent years in several Brazilian states (CUENCA *et al*., 2018).

In 2019, more than 1.5 million tons of fruits were produced from 186,000 hectares of coconut trees in Brazil (IBGE, 2020). Among the main producing states, the state of Bahia stands out as the largest producer, with 22% production, followed by the states of Ceará (16.2%) and Pará (12.2%) (IBGE, 2019). Notably, the state of Pará has demonstrated expanding coconut production, with an increase in the planted area in recent years; however, there has been a low application of technologies and innovations in the production process (FRÓES JUNIOR *et al.*, 2019).

Cocus *nucifera L.* is a monocotyledon of the Arecaceae family that is highly adaptable to soils with low natural fertility, as is the case for Neossolos Quartzarenic, which makes this class of soil dependent on continuous inputs of organic material throughout its use for agricultural production (LEITE *et al*., 2017). This crop also adapts well to sandy soils, especially those found in coastal regions (MEDEIROS *et al*., 2019).

The ecophysiology of the coconut tree is a relevant factor for crop development, as temperature, atmospheric humidity, rainfall, solar radiation, and wind affect its productivity (PASSOS *et al*., 2018). This crop produces an inflorescence every 20 to 30 days throughout the year. Therefore, a prolonged dry period with low relative humidity and temperature fluctuations can reduce the number of inflorescences and, consequently, the number of fruits per bunch, which compromises its productivity (MIRANDA *et al.*, 2007).

Phenology is based on the relationship between visible facts of plant organisms and the occurrence of external events, such as climate change and changes in environmental conditions. Thus, through phenological results, which are measurable biological characteristics, it is possible to highlight which climatic and environmental conditions favor or limit the development of a crop (CASTRO *et al*., 2009; WOOD *et al*., 1991).

The state of Pará has a high annual rainfall index; however, there is an uneven distribution of rainfall throughout the months, which justifies the use of irrigation to meet the water demand of crops during periods of water deficit, as the absence of this technology can generate significant productivity losses (ALVARES *et al*., 2014). A lack of water for a crop, that is, water deficit, can cause reduced growth, premature leaf drop, delayed reproduction, and a reduction in the number of female flowers, among other adverse effects (MIRANDA *et al*., 2007).

High evapotranspiration ($_{ET0}$) rates and poor rainfall distributions are the main causes of a negative water balance, which is a limiting factor for crop development. Therefore, irrigation is necessary (CAVALCANTE *et al*., 2010). Importantly, replacing crop evapotranspiration with irrigation, a technique in which plants receive water to meet their water needs, is a strategy adopted by rural producers in areas with or without water limitations (SILVA, 2020).

Given the above findings and the lack of research associating evapotranspiration with coconut production in North Brazil, the present study aimed to evaluate the effects of irrigation at different evapotranspiration rates on coconut phenology.

4 METHODOLOGY

Sococo Farm in the municipality of Santa Izabel do Pará, PA. The region has an AFi climate (humid tropical climate), with an average temperature of 26°C according to the classification proposed by Köppen and Geiger (1928). The soil in the region is classified as Neossolo Quartz sand according to the classification of the Brazilian Agricultural Research Corporation - Embrapa (2018). The experimental area is composed of coconut trees of the variety popularly known as the green dwarf, four years old, which are arranged at a spacing of 7.5 m (equilateral triangle) and are irrigated by a microsprinkler.

A randomized block design (RBD) with a 3 × 9 factorial scheme was used, with the following factors: irrigation based on three evapotranspiration rates (S/Irr - without irrigation; irrigation to replace 50% of ET_0 and irrigation to replace 100% of ET_0) and nine evaluation periods from September 2020--May 2021, with three blocks. Fertilization was applied weekly through fertigation via an injection pump via the following fertilizers: urea, monoammonium phosphate (MAP), magnesium sulfate and potassium chloride, following the fertilization recommendations of Lins and Viégas (2008).

Prior to the implementation of the experiment in 2014, soil correction and preparation were carried out through the application of limestone and the completion of one plowing operation and two harrowing operations, respectively. At the beginning of planting, a biweekly management regimen was implemented with alternating fungicides to control leaf spots on the plants, followed by annual crop treatments such as chemical crowning, hand weeding, leaf cutting, and hilling.

The irrigation depths were applied in fixed watering shifts every two days. After the data collected by an automatic meteorological station installed at Fazenda Reunidas Sococo, the ET_0 of the previous day was recorded according to Equation 1, which expresses the Penman–Monteith method (FAO 56) (ALLEN *et al*., 1998), which determines the depth required for partial or total replacement of the crop's evapotranspiration rate.

$$ETo = \frac{0,408\Delta(Rn-G)+\left(\frac{900U_2}{T+237}\right)(e_a-e_s)}{\Delta+\gamma(1+0,34U_2)} \quad (01)$$

where:

ET_0 - reference evapotranspiration, (mm.d $^{-1}$); Δ - gradient of the vapor pressure vs. temperature curve, kPa. °C $^{-1}$; Rn - net available solar radiation, MJ m $^{-2}$. d $^{-1}$; G - soil heat flux, MJ m $^{-2}$ d $^{-1}$; γ - psychrometric constant, kPa °C $^{-1}$; U_2 - wind speed at 2 m s $^{-1}$; es - saturation pressure of atmospheric water vapor, kPa; ea - current pressure of atmospheric water vapor, kPa; and Ta - mean daily air temperature, °C.

The irrigation liquid depth (LL) was estimated as a function of the ET_0 fraction via Equation 2.

$$LL = ETo * F \quad (02)$$

where:

LL - liquid depth (mm day $^{-1}$); ET_0 - reference evapotranspiration of the experimental area (mm day $^{-1}$); and F - fraction of ET_0 (0.5 for the 50% treatment or 1 for the 100% treatment).

The gross blade (LB) was calculated via Equation 3.

$$LB = \frac{LL}{Ea*CUD} \quad (03)$$

where:

LB - gross water depth (mm dia $^{-1}$); LL - net water depth (mm dia $^{-1}$); Ea - application efficiency (dimensionless) and CUD - water distribution uniformity coefficient (dimensionless).

The irrigation time (IT) was calculated via Equation (4).

$$T = \frac{LB.A}{e*qa} \quad (04)$$

where:

T - irrigation system operating time (h); LB - gross depth (mm day $^{-1}$); A - occupied area (m²); e - number of emitters per plant; and qa - average emitter flow (m³/h).

The application efficiency (Ea) and water distribution uniformity coefficient (CUD) were determined at the beginning of the system installation, following the methodology proposed by Calgaro and Braga (2008).

Every 30 days, three plants from the useful portion of each treatment were selected to carry out phenological observations.

The values of rainfall (PP), reference evapotranspiration (ET_0) and average, minimum and maximum air temperatures (°C) were obtained from the meteorological station located in the experimental plot.

The following parameters were evaluated: stem circumference (SC), expressed in cm, measured at a point 5 cm from the ground with the aid of a tape measure; stem length (SL), expressed in cm, measured with the aid of a tape measure from the length of the stem from the ground surface to the insertion point of the oldest leaf; number of live leaves (NLL), which expresses the count of all leaves that presented 80% of their green coloration; and the number of dead leaves (NLD), which expresses the count of all leaves that presented 100% brown coloration or when all leaflets were dry.

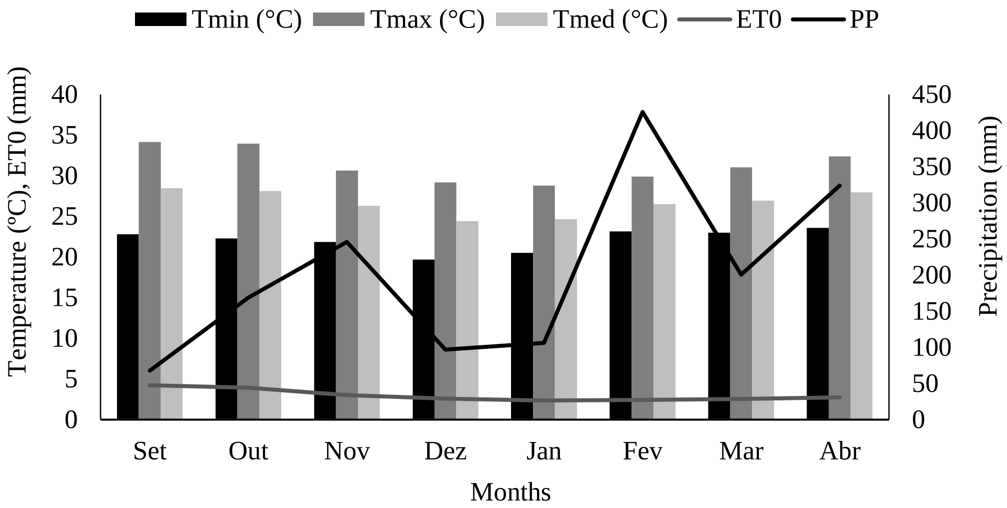
The data obtained were subjected to analysis of variance, and the means were compared via the Student–Newman–Keuls (SNK) test with $p < 0.05$ via R software (R Core Team, 2016).

5 RESULTS AND DISCUSSION

Meteorological conditions were evaluated daily from September 2020 to

May 2021 (Figure 1). The highest rainfall values were observed in February and April 2021, with values of 425.80 and 324.00 mm, respectively, whereas the lowest indices were observed in September and December 2020, with values of 67.80 and 96.80 mm, respectively. Reference evapotranspiration stood out with the highest indices in September 2020, with a value of 4.23 mm, whereas January 2021 had the lowest value, with a value of 2.35 mm. Temperature is a factor that directly influences the behavior of vegetables. For this variable, higher average values were found in the months of September and October 2020, both at 28.49°C, whereas the months of December 2020 and January 2021 presented the lowest average values, both at 24.42°C; that is, this was a colder period than the other months analyzed.

Figure 1. Rainfall (PP) values; reference evapotranspiration (ET $_0$); average, minimum and maximum temperatures (°C) during the experiment at Fazenda Reunidas Sococo, Santa Izabel do Pará, PA, from September 2020 to April 2021.



Temperature (°C), reference evapotranspiration ($_{ET0}$) and rainfall (mm) were assessed from September 2020 to April 2021.
Source: Authors (2022).

High evapotranspiration rates and poor rainfall distributions are the main factors responsible for the negative water balance in a given region, limiting the commercial exploitation of crops sensitive to water stress (CAVALCANTE *et al*., 2010). In this context, water replacement based on evapotranspiration is widely used in areas without irrigation limitations, which allows the water needs of crops to be met and the maximum yield to be achieved (SILVA, 2020).

The results obtained in this study corroborate those of Hoffmann *et al*. (2018) and Raza *et al*. (2019), who also reported that northeastern Pará experienced an increase in air temperature between August and November.

Cometti *et al*. (2018) reported that high temperatures can cause leaf edge burning or induce Ca deficiency, resulting in greater restrictions on water absorption by plant roots.

Rainfall is the main input of water into the soil, and its storage can vary according to local environmental conditions, such as solar radiation, wind speed, air temperature and relative humidity, which, in addition to influencing the evaporation process, also interferes with the dynamics of gas exchange, especially stomatal conductance and plant transpiration (TAIZ; ZEIGER, 2017).

As previously stated, environmental conditions are important factors for coconut tree development. ET_0-based irrigation is a strategy that aims to alter the environmental conditions in the planting area. ~~Reducing temperature and relative humidity~~ is an important alternative for supplementing soil water intake and creating a favorable environment (AMARAL; SILVA, 2009). Thus, according to Figure 1, the effects of irrigation based on ET_0 influenced the observed environmental variables, having distinct effects on each variable, with such effects being cumulative to those caused by seasonal climate variations (September 2020--May 2021 include the spring, summer and autumn seasons).

The variable number of live leaves was significantly influenced by the interaction between the factors ET_0 and the evaluation period (month) (Table 1), whereas the number of dead leaves was influenced separately by the factors ET_0 and the evaluation period. The variables stipe circumference at 5 cm and stipe length were significantly influenced only by ET_0.

Table 1. Summary of the analysis of variance for the variables: number of live leaves (NFV), number of dead leaves (NFM), stem circumference at 5 cm (CC) and stem length (CE), measured in nine periods (months) between September 2020 and May 2021**.**

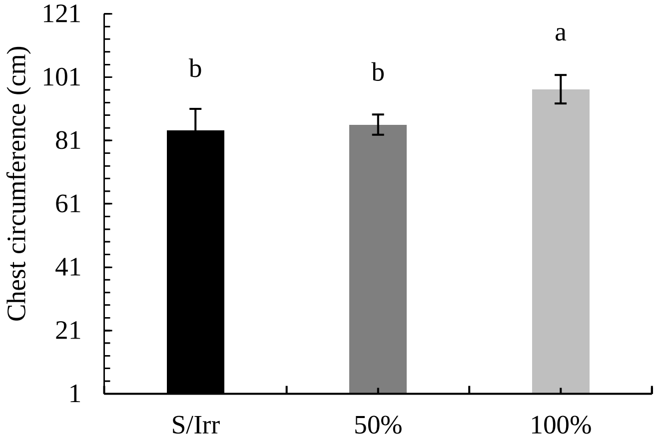
Source of variations	GL	NFV	NFM	CE	CC
ET_0	2	206.25**	16.07**	8.31**	30.73**
Periods	8	18.41**	2.69*	2.51*	1.54NS
ET_0 * Periods	16	1.97**	0.79NS	3.27**	1.73NS
Block	2	4.89*	0.48NS	17.94*	9.66*
CV (%)		3.92	17,19	5.86	5.07

GL: degrees of freedom; ET_0: evapotranspiration; CV: coefficient of variation; *significant according to the F test (p value < 5%); **significant according to the F test (p value < 1%)

Source: Authors (2022).

The circumference of the coconut tree (Figure 2) was influenced by irrigation, with the treatment with 100% ET0 replacement standing out as the treatment with the best average value in relation to the other treatments. Furthermore, this variable may be related to the fact that during the experiment, periods of low humidity (September 2020) and low rainfall (September and December 2020) occurred. Therefore, there was a greater loss of water through evapotranspiration, generating an environment capable of causing water stress to the plant, thus influencing its development. (AMARAL; SILVA, 2008). This finding can be verified by the results of this study for the circumference of the coconut tree.

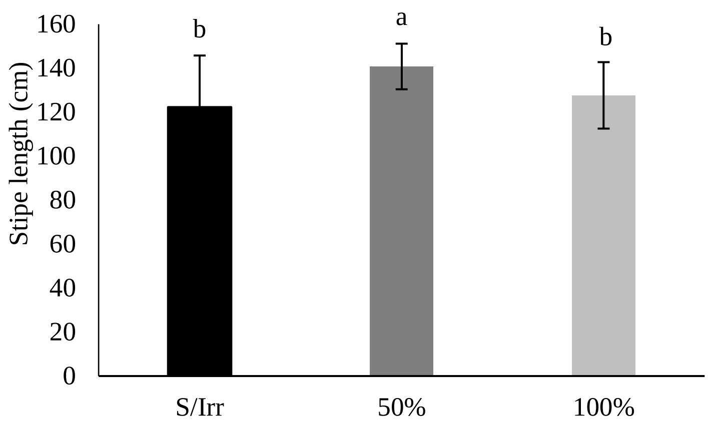
Figure 2. Collar circumference at 5 cm (CC), expressed in centimeters, was evaluated in the coconut tree *Cocus nucifera* L. during the experiment at Fazenda Reunidas Sococo, located in Santa Izabel do Pará, PA, from September 2020 to May 2021.



Means followed by the same lowercase letter do not differ from each other according to the Student–Newman–Keuls test ($p < 0.05$). S/Irr: Treatment without irrigation; 50%: Irrigated treatment with a replacement depth corresponding to 50% evapotranspiration; 100%: Irrigated treatment with a replacement depth corresponding to 100% evapotranspiration.
Source: Authors (2022).

The length of the stipe is an important variable related to harvesting, since shorter plants facilitate this process (BENASSI; SANTANA; FANTON, 2014). Figure 3 shows the average results for stem length, which was greater when the coconut tree *Cocus nucifera* L. was subjected to treatment with an irrigation depth corresponding to 50% of ET_0. However, despite presenting greater stem length than the other treatments did, the percentage increase was low, being 15% in relation to the treatment without irrigation and 10% in relation to the irrigated treatment with replacement of 100% of ET_0. Passos *et al* . (2007) stated that there is a need to understand well the relationships between climatic factors and their influences on the vegetative and reproductive parts of the coconut tree to make better interpretations regarding the implications resulting from probable stresses.

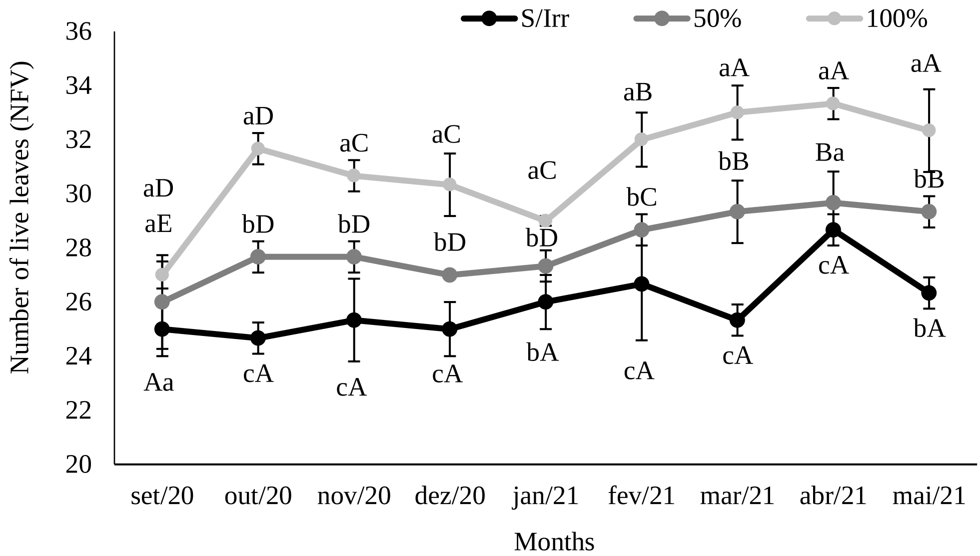
Figure 3. Stipe length (ST), expressed in centimeters, **was** evaluated in the coconut tree *Cocus nucifera* L. during the experiment at Fazenda Reunidas Sococo, which is located in Santa Izabel do Pará, PA, from September 2020 to May 2021.



Means followed by the same lowercase letter do not differ from each other according to the Student–Newman–Keuls test ($p < 0.05$). S/Irr: Treatment without irrigation; 50%: Irrigated treatment with a replacement depth corresponding to 50% evapotranspiration; 100%: Irrigated treatment with a replacement depth corresponding to 100% evapotranspiration.
Source: Authors (2022).

Figure 4 shows that the greatest number of live leaves occurred in the irrigated treatment with 100% $_{ET0}$. This result is associated with the constant meeting of the crop's water demand during the research, agreeing with Castro *et al.* (2009), who explained that a high average number of leaves is related to good vegetative conditions of the plant and that, from this phenological factor, it is possible to distinguish which conditions favor the crop. Importantly, irrigation is an activity that stimulates plant development. In this context, the water replacement was carried out in this study from September to December 2020, when the lowest rainfall amount occurred, possibly contributed to the greater number of live leaves on the coconut plants *Cocus nucifera* L. in the irrigated treatment with 100% $ET0_{replacement}$, characterizing irrigation as a benefit for better crop development, since, in parallel with the high number of leaves, there is an increase in the photosynthetic rate and evapotranspiration (BENASSI; SANTANA; FANTON, 2014).

Figure 4. Number of live leaves (NFVs) evaluated in the coconut tree *Cocus nucifera* L. during the experiment at Fazenda Reunidas Sococo, located in Santa Izabel do Pará, PA, from September 2020 to May 2021.

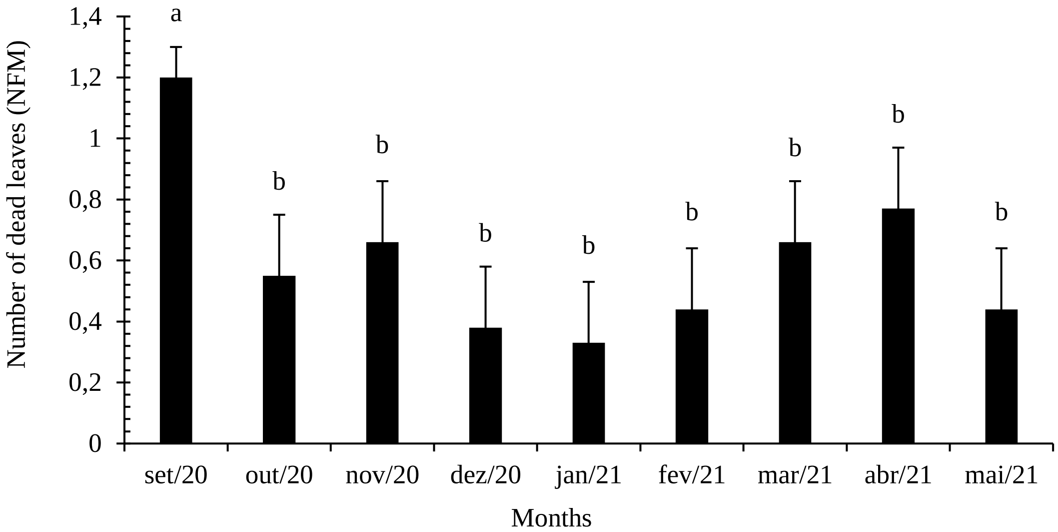


Uppercase letters (periods) and lowercase letters (evapotranspiration rates); means followed by the same lowercase letter do not differ from each other according to the Student–Newman–Keuls test ($p < 0.05$); means followed by the same uppercase letter do not differ from each other according to the Student–Newman–Keuls test ($p < 0.05$); S/Irr: Treatment without irrigation; 50%: Treatment irrigated with replacement depth corresponding to 50% evapotranspiration; 100%: Treatment irrigated with replacement depth corresponding to 100% evapotranspiration. **Source:** Authors (2022).

The number of dead leaves was not influenced by the irrigation factor; only the effect of the evaluation period was observed. Therefore, the irrigation levels applied may not have been sufficient to fully minimize the effects of water stress on this crop during the evaluated period. The highest average number of dead leaves was observed in September (Figure 5), a response resulting from adverse weather conditions such as low rainfall and high air temperatures that caused periods of water deficit in the crop, impacting its production and physiology (JAZAYERI *et al*., 2015; VIANA *et al*., 2019).

Leaf senescence during water stress is a plant strategy that aims to reduce leaf area, thus preventing water loss through stomata through transpiration. Furthermore, this leaf senescence process mobilizes reserves to maintain plant metabolism under stress (CUQUEL, 2000). In this case, it should be noted that water is important for meeting the evapotranspirometric demand of coconut trees (MIRANDA *et al*., 2007). In this study, increasing water supplementation via irrigation decreased the number of dead leaves compared with that in the treatment without irrigation (Table 1), where the irrigated treatment with 100% $ET0_{had}$ the lowest average number of dead leaves, 70% less than that in the nonirrigated treatment.

Figure 5. Number of dead leaves (NFM) of the coconut tree *Cocus nucifera* L. evaluated during the experiment at Fazenda Reunidas Sococo, located in Santa Izabel do Pará, PA, from September 2020 to May 2021.



Means followed by the same lowercase letter do not differ from each other according to the Student–Newman–Keuls test ($p < 0.05$).
Source: Authors (2022).

Considering that all the plants in all the treatments were fed the same fertilizer formulation, it is clear that abiotic ~~factors~~ directly influenced the occurrence of dead leaves. Furthermore, given that nutritional requirements are met, other factors can influence the vegetative characteristics of coconut palm, such as plant age and climatic conditions, which can lead to greater leaf fall and fruit abortion (CÂMARA *et al.*, 2019). Notably, among the fertilizers commonly used to fertilize coconut palm *(Cocus nucifera* L.), potassium plays a significant role in the vegetative development of the aerial part of this crop (SILVA *et al.*, 2017).

6 CONCLUSION

Vegetative phenological traits are directly influenced by the amount of water provided via irrigation. The treatment that stood out was the one irrigated with 100% ET replacement, which presented higher mean values for the variables number of live leaves and stem circumference.

Considering that all the phenological variables evaluated were negatively affected by ~~the~~ lack of irrigation (treatment without irrigation), notably, under water stress, the coconut palm *(Cocus nucifera* L.) does not exhibit adequate vegetative development. Furthermore, coconut palm, like most fruit trees, requires specific irrigation management during periods of low rainfall to ensure that the crop reaches a level of development close to that considered ideal.

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