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LISIMÉTRIA DE DRENAGEM PARA DETERMINAÇÃO DO COEFICIENTE DE CULTIVO DA CULTURA DA PITAYA BASEADO NA EVAPOTRANSPIRAÇÃO DE REFERÊNCIA E EVAPOTRANSPIRAÇÃO DA CULTURA

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1 RESUMO

A determinação da quantidade de água usada na agricultura é fundamental para um manejo eficiente da irrigação. Existem diferentes métodos para determinar a necessidade hídrica de uma cultura, sendo feito de forma direta ou indireta. O objetivo desse trabalho foi determinar a ETc da Pitaya (Hylocereus ssp) com o uso de lisímetros de drenagem, calcular a ETo através dos modelos matemáticos de Penman-Monteith (horária e diária), Hargreaves e Samani, Jensen-Haise, Makking, Blaney-Criddle e Priestley-Taylor e determinar o Kc para a cultura. O experimento foi conduzido em área experimental no campus de Ciências Agrárias e da Biodiversidade (CCAB) da Universidade Federal do Cariri (UFCA), Crato – Ceará e os dados para o cálculo da ETo foram obtidos através da estação meteorológica, localizada no próprio campus. Para a obtenção do Kc da cultura foi utilizada a razão entre a ETc e ETo. Os lisímetros de drenagem permitiram estimar a ETc da cultura para o período de estudo. O método de ETo de soma horário superestimou o método padrão diário e método alternativo que mais se aproximou ao método padrão foi o de Blaney-Criddle. O valor de Kc médio pelo método padrão da FAO diário foi de 0,66.

Palavras-chave: *Hylocereus ssp,* kc, eto, precipitação.

CARNEIRO, A. A. C.; MEIRELES, A. C. M.; OLIVEIRA, C.W.; PATRICIO, E. A.; LIMA, L. S.; MENEZES, S. M.

DRAINAGE LYSIMETRY FOR DETERMINING THE CROP COEFFICIENT OF PITAYA CROP BASED ON REFERENCE EVAPOTRANSPIRATION AND CROP EVAPOTRANSPIRATION

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2 ABSTRACT

Determining the amount of water used in agriculture is fundamental for efficient irrigation management. There are different methods for determining a crop's water needs, either directly or indirectly. The objective of this work was to determine the ETc of Pitaya (Hylocereus spp.) using drainage lysimeters; calculate the ETo using the mathematical models of Penman–Monteith (hourly and daily), Hargreaves and Samani, Jensen–Haise, Makking, Blaney–Criddle, and Priestley–Taylor; and determine the Kc for the crop. The experiment was conducted in an experimental area on the Agricultural and Biodiversity Sciences Campus (CCAB) of the Federal University of Cariri (UFCA), Crato–Ceará, and the data for calculating ETo were obtained from the meteorological station located on the campus itself. The Kc of the crop was calculated using the ratio between ETc and ETo. Drainage lysimeters allowed for the estimation of crop ETc for the study period. The hourly summation ETo method overestimated the standard daily method, and the alternative method that most closely approximated the standard method was Blaney-Criddle. The average Kc value obtained using the standard daily FAO method was 0.66.

Keywords: *Hylocereus ssp*, kc, eto, precipitation.

3 INTRODUCTION

Determining the amount of water used in agriculture is fundamental for efficient irrigation management, especially in arid and semiarid regions of the planet. Understanding the relationship between climatic conditions and evapotranspiration is key to quantifying water demand in a production system (Matos *et al.*, 2025). There are different methods for determining a crop's water needs, which can be performed directly using equipment such as lysimeters or indirectly through mathematical models.

The Penman–Monteith method (Allen *et al.*, 1998) is the standard mathematical model for calculating reference evapotranspiration (ETo); however, it presents a series of complex and extensive variables that need to be used for the calculation, which limits its use in certain regions. On the other hand, owing to their direct measurement, lysimeters have been used to determine crop evapotranspiration (ETc) and the crop coefficient (Kc) in conjunction with alternative mathematical models for determining ETo, facilitating irrigation management. Regions with more limited water availability throughout the year need to adopt strategies that allow for agricultural practices, as well as improve irrigation techniques and determine water consumption, along with the use of crops better adapted to these conditions (Corte *et al.*, 2020).

Pitaya (*Hylocereus)* emerges. *(ssp.*), a fruit-bearing plant from the cactus family that has been increasingly cultivated in arid and semiarid regions under irrigation conditions (Santos; Santos; Amaral, 2024). It is a plant native to the Americas that tolerates long periods of drought and develops well in poorer soils, being more sensitive to low temperatures and large amounts of accumulated water (Souza *et al.*, 2025). In response to its place of origin, it is a cactus that develops in regions with a hot tropical climate with average temperatures of 21°C to 29°C and average rainfall of 650 to 1,500 mm/year (Santos; Santos; Amaral, 2024).

Given the facts presented above and considering the economic importance of this crop in semiarid regions, this study aims to determine the ETc of Pitaya (*Hylocereus).*

ssp) using drainage lysimeters, calculate the ETo of the region through mathematical models of Penman–Monteith (hourly and daily), Hargreaves and Samani, Jensen–Haise, Makking, Blaney–Criddle and Priestley–Taylor and determine the Kc of the crop during the different phases of development and growth.

4. MATERIALS AND METHODS

The experiments were conducted in an experimental area on the Agricultural and Biodiversity Sciences (CCAB) campus of the Federal University of Cariri (UFCA), Crato - Ceará. The region is located in the subbasin of the Salgado River hydrographic basin in the Cariri region of Ceará and has a Köppen classification of tropical climate—Aw. The climatic characteristics of the study area are humid, with well-defined rainy and dry seasons, with annual temperatures varying between 24°C and 27°C.

Three drainage lysimeters were constructed from plastic containers measuring 0.40 m × 0.40 m and 0.69 m deep. A polyvinyl chloride (PVC) pipe was placed to act as a drain at the bottom of each container; this part was covered with sand, gravel, and a screen. Channels were made for the passage of the pipe that carried the drained volume to the collection containers. The three lysimeters were filled with soil removed from the area in the same order in which it was removed during excavation. Two pitaya sprouts were transplanted into each lysimeter. The collection containers were installed inside a trench measuring 2 m × 1 m. Daily collections were carried out, with respect to a 24-hour interval between collections, to record the amount drained by each lysimeter. The ETc calculation was based on the water balance recorded through the collections and calculated using equation (1).

$$ETc = P + I - D \quad (1)$$

where ETc = crop evapotranspiration; P = precipitation (mm); I = applied water depth (mm); and D = water drained in the lysimeter (mm).

The data for calculating ETo were obtained from the HOBO RX3000 automatic weather station, which is installed on campus at the following geographic coordinates: 7°14' S and 39°22' W, at an altitude of 425 m above sea level. The meteorological variables used were air temperature (average, minimum, and maximum, in °C), solar radiation (MJ m^{-2} day^{-1}), wind speed (m s^{-1}), precipitation (mm), and relative humidity (average, minimum, and maximum, in %). The equations used (Table 1) for calculating ETo were Penman–Monteith, hourly and daily (Allen *et al*., 1998); Hargreaves and Samani (Pereira *et al*., 1997); Jensen–Haise (1963); Makking (1957); Blaney–Criddle (1977); and Priestley–Taylor (1972).

Table 1. Methods for estimating reference evapotranspiration (ETo) and their respective equations.

Methods	ETo estimation equations	Input Variables
Penman–Monteith horary , Allen *et al*. (1998)	$ETo = \frac{0,408\,\Delta(R_n - G) + \gamma(\frac{37}{T_h + 273} u_2\,(e^{\circ}(T_h - e_a)}{\Delta + \gamma(1 + 0,34u_2)}$	Tmed , Rg , UR, V
Penman–Monteith diary , Allen *et al*. (1998)	$ETo = \frac{0,408\Delta(Rn - G) + \gamma + \frac{900}{(T+273)} U_2 (ea - es)}{\Delta + \gamma + (1 + 0,34U_2)}$	Tmed , Rg , UR, V
Hargreaves and Samani , Pereira *et al*. (1997)	$ETo = A\,R_a(Tmed + 0,17)(T\,max - T\,min)^c$	Tmax , Tmed Tmin
Priestley and Taylor, (1972)	$ETo = \mathrm{A}\left(\frac{\Delta}{\Delta + \gamma}\right)\left(\frac{Rn - G}{\lambda}\right)$	Tmed , Rg
Jensen- Haise , (1963)	$ETo = Rs\ (\mathrm{A\ x}\ Tmed + B)$	Tmed , Rg
Blaney-Criddle , (1977)	$ETo = a + bp(0.457xTmed + 8.13)$	Tmed
Makking (1957)	$ETo = 0.61 * W * RT - 0.12$	Rg

To obtain the crop coefficient (Kc), the ratio between ETc and ETo was used according to equation (2).

$$Kc = \frac{ETo}{ETc} \quad (2)$$

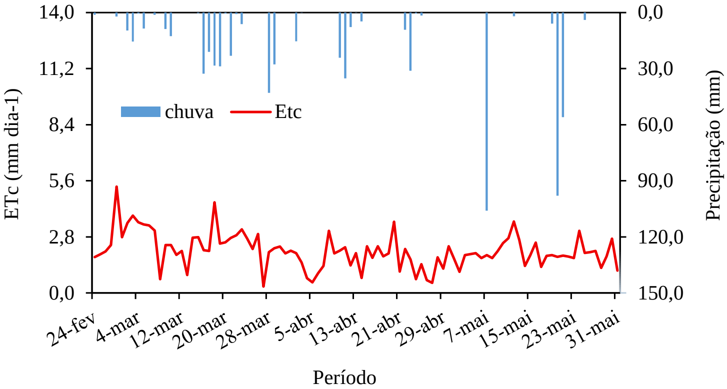
where KC = crop coefficient; ETo= reference evapotranspiration (mm day^{-1});

And ETc=crop evapotranspiration (mm day^{-1}).

4 RESULTS AND DISCUSSION

The variation in the ETc of the crop during the analyzed period is shown in Figure 1, where the highest consumption was 5.30 mm after 4 days of transplanting, and the lowest consumption was 0.32 mm after 32 days of transplanting; the lower value was justified by the period of rainfall, which reduced the water consumption of the plants. The total accumulated ETc during the observation months was 204.3 mm. The accumulated precipitation was 675.8 mm, with a peak on 07/05/2025.

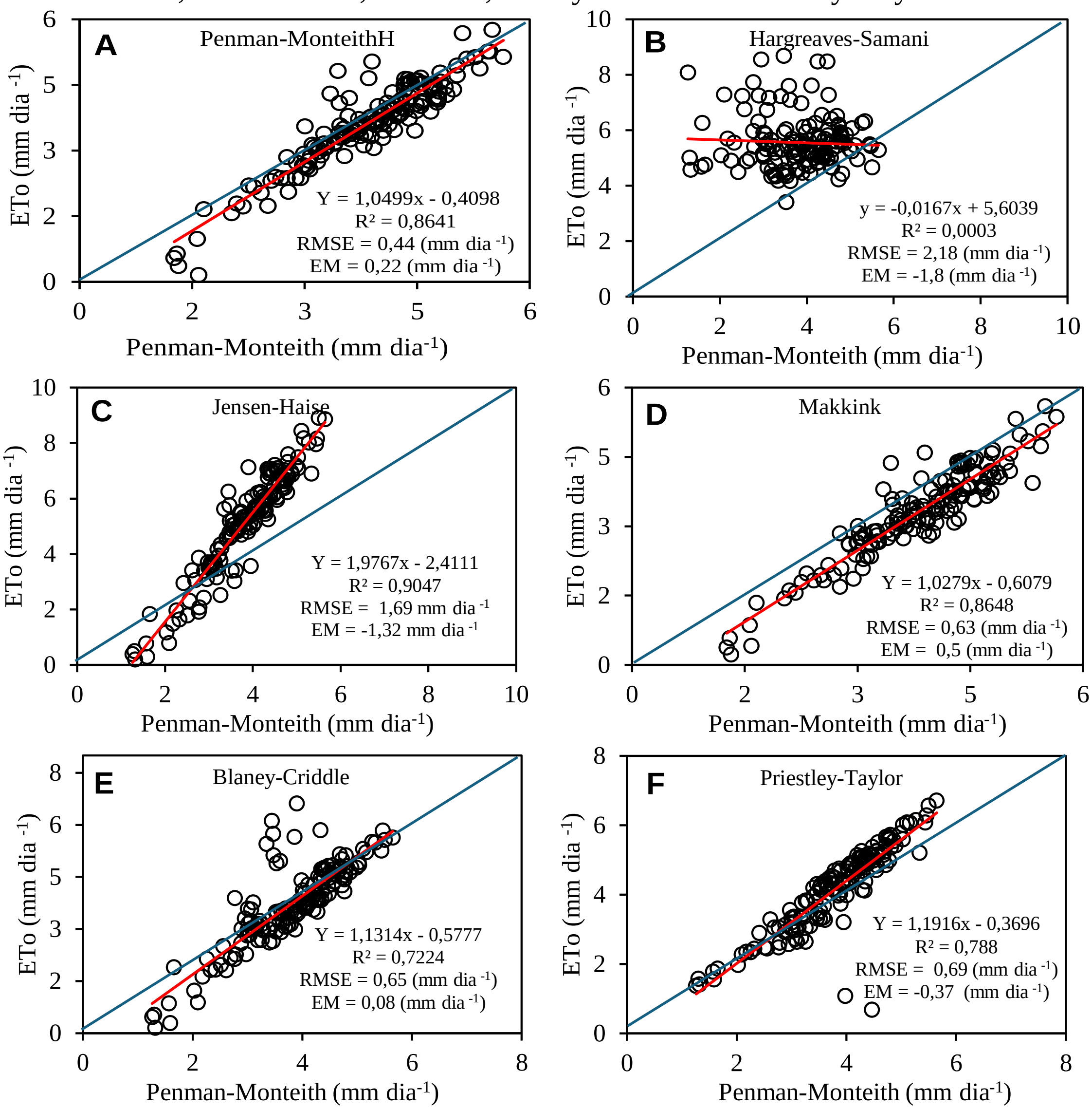
Figure 1. Evapotranspiration of the pitaya crop (ETc) and rainfall distribution during the evaluated period.



Source: Authors (2025)

The linear regression analysis for the FAO standard method with daily summation compared with that with hourly summation is shown in Figure 2A, where it was observed that the methods had a good correlation (R^2 of 0.86) despite a tendency to overestimate lower ETo values. The Hargreaves–Samani method, represented by Figure 2B, deviated most from the standard method, with a low correlation with the daily summation method (R^2 of 0.003) and high associated error values (RMSE of 2.18 and EM of -1.8). According to Farias *et al*. (2020) and Sales *et al. (2018), the* Hargreaves–Samani model does not consider the evaporative power of the air; therefore, the model tends to overestimate ETo values. On the other hand, the alternative method that most closely approximated the standard was the Blaney–Criddle method (Figure 2E), which demonstrated a good correlation coefficient (R^2 of 0.72) and low associated error values (RMSE of 0.65 and EM of 0.08). The Penman–Monteith H and Makkink models also presented good correlation coefficients (R^2 of 0.86 for both) and low associated errors; however, they tended to overestimate the ETo values. Despite presenting good correlation coefficients (R^2 values of 0.90 and 0.78, respectively), the Jensen–Haise and Priestley–Taylor models tended to underestimate the ETo values.

Figure 2. Scatter plots of reference ETo values calculated by Penman–Montheith with daily values compared with the sum of hourly values and with the methods of Hargreaves - Samani, Jensen–Haise, Makkink, Blaney–Criddle and Pristley–Taylor.



Source: Authors (2025)

Table 2 shows the average Kc values for pitaya obtained using different ETo methods. Hargreaves-Samani was the method that most underestimated the average Kc values; Makkink was the one that most overestimated the average Kc values; and Priestley-Taylor was the method that most closely approximated the average Kc values calculated by the standard daily summation method. The same behavior was observed by Menezes *et al*. (2024), where the Jensen–Haise and Priestley–Taylor methods were closest to the FAO standard daily method but tended to overestimate the Priestley–Taylor method. Unlike the aforementioned author, the Makkink method tended to overestimate the Kc value.

Table 2. Kc values for pitaya cultivation in the Penman–Montheith models with daily values and the sum of hourly values, Hargreaves–Samani (HS), Blaney–Criddle (BC), Pristley–Taylor (PT), Makkink (MK) and Jensen–Haise (JH).

KC	Kc (P- M $_{Daily}$)	Kc (P- M $_{Schedule}$)	Kc (HS)	Kc (BC)	Kc (PT)	Kc (MK)	Kc (JH)
Average	0.66	0.97	0.39	0.90	0.66	0.91	0.79

Source: Authors (2025)

5 CONCLUSIONS

Drainage lysimeters allowed for the estimation of crop ETc for the study period, totaling 204.3 mm. The hourly summed ETo method overestimated the standard daily method, and the alternative method that most closely approximated the standard method was the Blaney–Criddle method. The average Kc value obtained using the standard daily FAO method was 0.66.

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