EVAPOTRANSPIRATION AND CROP COEFFICIENT OF GREEN CHIVES GROWN IN A PROTECTED ENVIRONMENT

EVAPOTRANSPIRAÇÃO E COEFICIENTE DE CULTIVO DA CEBOLINHA VERDE CULTIVADA EM AMBIENTE PROTEGIDO

EVAPOTRANSPIRACIÓN Y COEFICIENTE DE CULTIVO DEL CEBOLLINO CULTIVADO EN AMBIENTE PROTEGIDO

10.56238/edimpacto2025.058-001

João Vitor Trindade de Souza[1], Maria Damiana Rodrigues Araújo[2], Maria Deyse Silva dos Santos[3], Hugo Rodrigues dos Santos[4], Julianna Catonio da Silva[5], Márcio Aurélio Lins dos Santos[6], Kivia Caroline da Costa[7], Cícero Gomes dos Santos[8]

ABSTRACT

Objective: This study aimed to evaluate the water consumption and reference evapotranspiration (ET_0) of green chives grown in a protected environment using different mathematical models.

Theoretical Framework: The present research is based on concepts of plant physiology and irrigation management, both in a protected environment.

Method: To obtain the crop coefficient (Kc), the ratio between crop evapotranspiration (ETc), determined using the SLIMCAP system, and reference evapotranspiration (ET_0), estimated by the Penman-Monteith, Hargreaves-Samani, Solar Radiation, Blaney-Criddle, and Priestley-Taylor methods, was calculated.

Results and Discussion: The accumulated ETc of the chive crop in a protected environment was 178.12 mm over a 35-day cycle, corresponding to an average daily ETc of 4.95 mm. The maximum water consumption of the chive crop was 7.56 mm per day, and the Kc values for

[1] Agronomist. Universidade Federal de Alagoas, Campus de Arapiraca. Alagoas, Brazil. E-mail: vitor.trindade0406@gmail.com
[2] Master in Agriculture and Environment. Universidade Federal de Alagoas, Campus de Arapiraca. Alagoas, Brazil. E-mail: rmariadamiana2@gmail.com
[3] Master in Agriculture and Environment. Universidade Federal de Alagoas, Campus de Arapiraca. Alagoas, Brazil. E-mail: lisboadayse383@gmail.com
[4] Master in Agriculture and Environment. Universidade Federal de Alagoas, Campus de Arapiraca. Alagoas, Brazil E-mail: hugo19116@gmail.com
[5] Dr. in Plant Production. Universidade Federal de Alagoas, Centro de Engenharias e Ciências Agrárias. Alagoas, Brazil. E-mail: julianna_cds@hotmail.com
[6] Professor of the Graduate Program in Agriculture and Environment. Universidade Federal de Alagoas, Campus de Arapiraca. Alagoas, Brazil. E-mail: mal.santo@arapiraca.ufal.br
[7] Master in Agriculture and Environment. Universidade Federal de Alagoas, Campus de Arapiraca. Alagoas, Brazil. E-mail: kiviacaroline1@hotmail.com
[8] Professor of the Graduate Program in Agriculture and Environment. Universidade Federal de Alagoas, Campus de Arapiraca. Alagoas, Brazil. E-mail: cggomes@arapiraca.ufal.br

chives under protected environment conditions are: Phase I: 0.59; Phase II: 0.80; Phase III: 1.06 (according to the FAO Penman-Monteith standard).

Research Implications: This research can help seedling producers understand how the crop coefficient and crop evapotranspiration work, thereby contributing to plant production projects in protected environments.

Originality/Value: The research is relevant as it addresses a crop that is rarely studied or mentioned in the literature, providing data applicable to sustainable management in protected environments.

Keywords: *Allium fistulosum L*. Water Consumption. Lysimetry. Vegetables. Protected Environment.

RESUMO

Objetivo: Este estudo teve como objetivo avaliar o consumo hídrico e a evapotranspiração de referência (ET0) da cebolinha verde cultivada em ambiente protegido por meio de diferentes modelos matemáticos.

Referencial Teórico: A presente pesquisa fundamenta-se em conceitos de fisiologia vegetal e manejo da irrigação ambos em ambiente protegido.

Método: Para obter-se o coeficiente de cultivo (Kc), foi calculda a razão entre a evapotranspiação da cultura (ETc), que foi determinada por meio do sistema SLIMCAP e a evapotranspiração de referência (ET0), que foi estimada pelos métodos de Penman-Monteith, Hargreaves-Samani, Radiação Solar, Blaney-Criddle e Priestley-Taylor.

Resultados e Discussão: A ETc da cultura da cebolinha em ambiente protegido acumulado foi de 178,12 mm no ciclo de 35 dia, o que equivale a Etc média diária de 4,95 mm. O consumo hídrico da cebolinha teve um valor máximo de 7,56 mm dia-1, e o Kc da cebolinha indicado para condições de ambiente protegido é: fase I: 0,59; fase II: 0,80; fase III: 1,06 (padrão FAO de Penman-Monteith).

Implicações da Pesquisa: A presente pesquisa pode auxiliar o produtor de mudas a entender como o coeficente de cultivo e a evapotrasnpiração da cultura funcionam, dessa forma contribuindo para projetos de produção vegetal em ambientes protegidos.

Originalidade/Valor: A pesquisa é relevante por abordar uma cultura pouco trabalhada e mensionada na literatura, oferecendo dados aplicáveis ao manejo sustentável em ambientes protegidos.

Palavras-chave: *Allium fistulosum L.* Consumo Hídrico. Lisimetria. Hortaliças. Ambiente Protegido.

RESUMEN

Objetivo: Este estudio tuvo como objetivo evaluar el consumo hídrico y la evapotranspiración de referencia (ET_0) del cebollino cultivado en ambiente protegido mediante diferentes modelos matemáticos.

Marco teórico: La presente investigación se fundamenta en conceptos de fisiología vegetal y manejo del riego, ambos en ambiente protegido.

Método: Para obtener el coeficiente de cultivo (Kc), se calculó la razón entre la evapotranspiración del cultivo (ETc), determinada mediante el sistema SLIMCAP, y la evapotranspiración de referencia (ET_0), estimada por los métodos de Penman-Monteith, Hargreaves-Samani, Radiación Solar, Blaney-Criddle y Priestley-Taylor.

Resultados y discusión: La evapotranspiración del cultivo (ETc) acumulada del cebollino en ambiente protegido fue de 178,12 mm en un ciclo de 35 días, lo que equivale a una ETc promedio diaria de 4,95mm. El consumo hídrico máximo del cebollino fue de 7,56 mm día^{-1}, y los valores de Kc indicados para condiciones de ambiente protegido son: fase **I**: 0,59; fase **II**: 0,80; fase III: 1,06 (según el estándar FAO de Penman-Monteith).

Implicaciones de la investigación: La presente investigación puede ayudar al productor de plantas a comprender cómo funcionan el coeficiente de cultivo y la evapotranspiración del cultivo, contribuyendo así a proyectos de producción vegetal en ambientes protegidos.

Originalidad/Valor: La investigación es relevante porque aborda un cultivo poco trabajado y mencionado en la literatura, ofreciendo datos aplicables al manejo sostenible en ambientes protegidos.

Palabras clave: *Allium fistulosum L*. Consumo Hídrico. Lisimetría. Hortalizas. Entorno Protegido.

1 INTRODUCTION

Green onion (Allium fistulosum L.) is originally from Siberia, belonging to the Alliaceae family and commonly used as a condiment to improve the flavor and nutritional quality of food (Makishima, 1993; Freddo et al., 2014). It is considered a perennial crop, and can be propagated via seeds or vegetatively, they are characterized by intense tillering, forming clumps. They produce small conical bulbs and have dark green and fistulous leaves, with a height of around 300 to 500mm (Filgueira, 2013).

To achieve a satisfactory economic return in the cultivation of leafy vegetables, it is essential to adopt the proper management of abiotic factors. Among the essential resources for plant development, water and nutrition are considered the most important, as they are crucial for the various metabolic processes of plants (Souza et al., 2021). Vegetables are strongly influenced by soil moisture conditions, as they often have a high water content in their tissues. Water stress, whether due to lack or excess of water, causes changes such as the reduction of leaf water potential, stomatal closure, decrease in photosynthetic rate, reduction of its aerial part, acceleration of senescence, abscission of leaves, among others (Ferrari et al., 2015).

Taking into account these factors, it is necessary to use certain strategies in order to mitigate this stress, thus, one of the best irrigation management strategies is related to the study done on crop water consumption curves (Silva et al., (1999). Thus, for a better application of a given irrigation depth, the water consumption by the plants has been quantified mainly through the use of climatological variables, the reference evapotranspiration and the cultivation coefficient (Kobayashi, 2007).

This crop coefficient (KC) is determined by the ratio between crop evapotranspiration (ETC) and reference evapotranspiration (ET0) (Albuquerque, 2000). CTE can be determined by direct and indirect methods, among the direct methods, it is from the lysimetry method (Mendonça et al., 2003). To estimate ET0, it is necessary to apply some empirical method or equation, which are calculated through edaphoclimatic factors (Santos, 2020).

With the search for constant production and the maximization of the use of producing areas for Agricultural production, cultivation in a protected environment has been a profitable and promising alternative for production, especially of vegetables, reducing the cycle and reducing the use of pesticides. The protected environment contributes both to the increase in crop productivity, to the improvement in product quality and also to the reduction of water consumption (Viol et al., 2017).

In this context, the objective of this study was to determine the water intake of green onion and reference evapotranspiration in a protected environment through different mathematical models in the agreste region of Alagoas.

2 THEORETICAL FRAMEWORK

2.1 GREEN ONIONS

Chives (Allium fistulosum L.), belonging to the Alliaceae family, are composed of about 300 genera and more than 3000 species, where they are distributed in a cosmopolitan way around the world, such as garlic, lily, and tulip (Maestrovirtuale, 2022). Originally from the Asian continent, chives are one of the most used ingredients to attenuate Brazilian cuisine, constituting a characteristic and specific knowledge.

The plant is considered perennial, has tubular-elongated, soft and aromatic leaves, with high condimentary value and is characterized by intense tillering forming clumps (Filgueira, 2008). Very similar to onions, except for the non-development of such juicy bulbs. The best known cultivars are "Todo Ano", "Futonegui" and "Hossonegui" (Mota, 2013). Harvesting takes place through cuts that begin between 55 and 60 days after planting or between 85 and 100 days after sowing, when the leaves reach around 0.20 to 0.40 m in height (Araújo; Peruch; Stadnik, 2012).

Similar to onions, but it does not develop the bulb well and several nutrients are found, including potassium, carbohydrates, proteins, calcium, and vitamins A and C, which offer a number of health benefits, including cancer prevention (Ecycle, 2019). Its leaves are used as a condiment in recipes for meat, poultry, fish, sauces and salads. It is a plant rich in carbohydrates, protein, lipids, potassium, sodium, phosphorus, iron and vitamin C (Faz Fácil, 2019).

2.2 IRRIGATION MANAGEMENT

The word evaporation is used to indicate the development of water, in the form of vapor, into the atmosphere. This water can come from moist soils without vegetation, oceans, lakes, rivers, and ice surfaces. Transpiration, on the other hand, is the process of water loss in the form of steam through plant tissues (Silva, 2006). Plants have the ability to lose almost all of the water that is absorbed by the roots through the stomata, and only a portion is used in their physiological processes (Allen, 1998).

Evapotranspiration is the total amount of water in the gaseous state that is lost to the atmosphere, through two processes, evaporation and transpiration, which occur simultaneously. With this, it can be said that it encompasses physical and physiological phenomena in the transfer of water vapor in terms of the earth's surface and atmosphere (Ferreira, 2021). Evapotranspiration is considered the second most relevant aspect in terms of the amount of water that is transferred, second only to precipitation (Brutsaert, 2005).

According to Castiglio (2021), there are two classifications for evapotranspiration: actual evapotranspiration (REE), which refers to the natural loss of water to the atmosphere; and potential evapotranspiration (ET0), which under optimal conditions brings a balance between evaporation and transpiration. Studying ET0 is important for hydrology and irrigation, as it is possible to estimate, through a water balance, what is left and the water deficit of a region, for better decision-making with regard to water resources.

3 METHODOLOGY

3.1CHARACTERIZATION AND PREPARATION OF THE EXPERIMENTAL AREA

The experiment was carried out in a protected environment (greenhouse), in the experimental area of the Federal University of Alagoas – Arapiraca Campus , located in the municipality of Arapiraca, Agreste region of the State of Alagoas, with the following geodetic coordinates 9° 45' 09" S, 36° 39' 40" W and with an altitude of 325 meters, during the period from December 18, 2024 to January 23, 2025.

During the crop cycle, meteorological data were collected through the agrometeorological station of UFAL, Arapiraca Campus , to obtain data on average temperature, wind speed, relative humidity and precipitation to compose the climatic situation during the experiment.

Fertilization was carried out according to the results of the chemical analysis of the soil and the recommendation manual of the Agronomic Institute of Pernambuco (IPA). Foundation fertilization was carried out with nitrogen (N), phosphorus (P) and potassium (K), using the sources ammonium sulfate [$(NH_4)_2SO_4$)] with 21% N, simple superphosphate with 18% P_2O_5 and potassium chloride with 60% K_2O.

Taking into account the protected environment, 0.47 g of ammonium sulfate (100% of the recommended fertilization), 1.65 g of simple superphosphate and 0.165 g of potassium chloride were applied to each plot at planting. And at 15 days after transplanting, 0.62 g (100% of the recommended fertilization) of ammonium sulfate was applied.

The experimental design was randomized blocks, with 4 replications, arranged in a 5x5 factorial, with 25 treatments and 100 experimental plots. The treatments were composed of 5 levels of irrigation depths, corresponding to: L1: 50, L2: 75, L3: 100, L4: 125 and L5: 150% of crop evapotranspiration (ETC) and 5 doses of ammonium sulfate AR1: 50, AR2: 75, AR3: 100, AR4: 125 and AR5: 150% of the recommended fertilization for green onion crop.

The experimental plots were composed of containers with a capacity of 4L and a diameter of 0.19 mm. In each bucket there was a plant and represented an experimental plot containing an irrigation depth. In these reservoirs, 4 holes were made in the bottom of the container, placed a screen and approximately 10 cm high of gravel nº 0 to facilitate the natural drainage of water, and finally, filled with soil (Figure 1 and Figure 2).

The chive cultivar used was Natsuyo from the Topssed line, belonging to the Agristar group. It has a good adaptation to crop variations, erect leaves of green and thin color, little brittle and with thick wall. In addition, it has good tolerance to foliar diseases and early tasseling and excellent yield, in which it is indicated to be cultivated throughout the year, with better performance in autumn/winter plantings (Agristar, 2025).

3.2 IRRIGATION SYSTEM

The irrigation depths were determined through the Lysimetric Information System for Monitoring Water Consumption by Plants (SLIMCAP), which consists of accounting for the inflows and outflows of water in the soil. The lysimeter set was composed of 5 lysimeters with the same container (0.19 mm diameter and 4L capacity) that was used in the experimental plots. The lysimeters were on the benches where the experimental plots are located.

3.3 METEOROLOGICAL VARIABLES

Environmental data such as temperature, relative humidity, wind speed, precipitation and solar radiation were obtained from the Agrometeorological Station located at the Arapiraca Campus of UFAL (Table 1). Emphasizing that relative humidity, temperature, wind speed and solar radiation are factors of paramount importance in monitoring the development of the plant, the table and graph that were produced through the data collected from the crop during the experiment period in question (Table 1 and Figures 1 and 2) are as follows.

Table 1

Average values of climatic data of temperature, relative humidity (maximum, average and minimum), wind speed and solar radiation

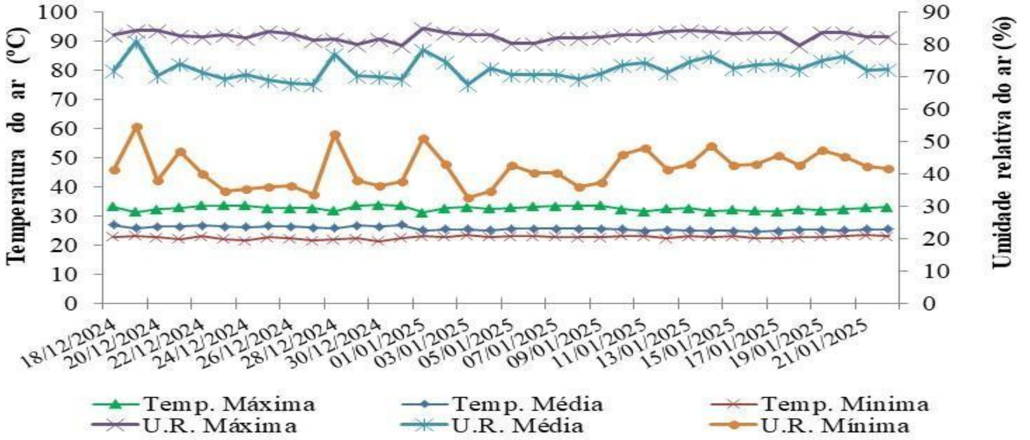
Temperature			Relative humidity			Wind Speed	Rs
Maxim	Minim	Average	Maxim	Minim	Average		
32,55	22,49	25,65	91,70	41,09	72,02	2,23	24,75

The mean values of maximum, average and minimum daily temperatures that were obtained during the cultivation and management period of the crop were respectively 32.55;

25.65 and 22.49 °C. The average values of maximum, average and minimum relative humidity were 91.70; 72.02 and 41.09%, respectively (Table 1 and Figure 1).

Figure 1

Air temperature and relative humidity (maximum, average and minimum)

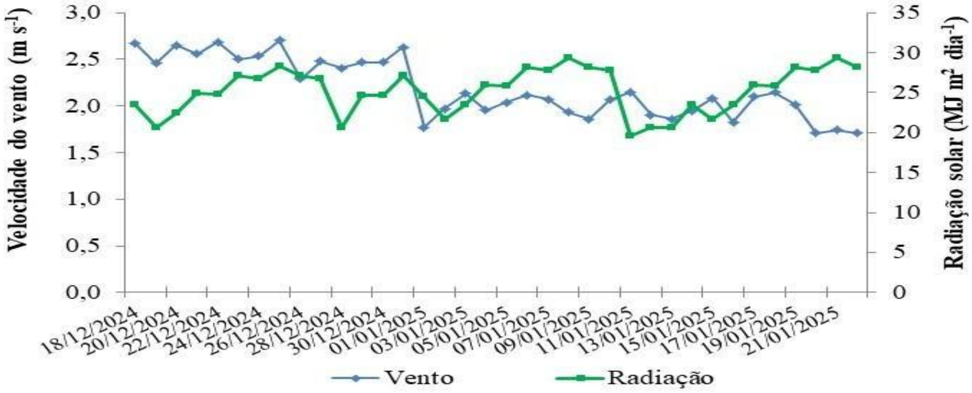


Source: The author (2025).

Table 1 shows their respective mean values: 2.23 ms-1 and 24.75 MJ m2 day-1. Figure 2 represents the values of wind speed (Vv) and solar radiation (Rs) during the entire period of cultivation of green chise.

Figure 2

Wind speed and solar radiation



Source: The author (2025).

3.4 DETERMINATION OF REFERENCE EVAPOTRANSPIRATION (ET0)

The methodology considered standard that is used to determine ET0 is the combined Penman-Monteith method, however, for the execution of this methodology it is necessary to use several climatic variables. As alternatives, it is necessary to search for estimation models considered simpler, such as the Hargreaves-Samani, Solar Radiation, Blaney-Criddle and Priestly-Taylor methods, since they are considered simpler because they do not require as many variables as the standard method. Therefore, the Penman-Monteith (FAO-Standard) (Allen et al., (1998), Hargreaves-Samani (Pereira et al., (1997)), Solar Radiation (Doorenbos; Pruitt (1977), Blaney-Criddle (Frevert et al., (1983)) and Priestley-Taylor (Sumner; Jacobs (2005), in order to make a comparison between the standard method and the others.

3.5 DETERMINATION OF CROP EVAPOTRANSPIRATION (ETC)

To determine the CTE of green onions, the SLIMCAP system (Lysimetric Information System for Monitoring Water Consumption by Plants) was used. The SLIMCAP system is a technology that seeks to monitor water consumption by plants on a daily basis, such a system is composed of a mobile application (slimcap.app), five drainage lysimeters, five water supply reservoirs and five drainage containers of surplus water (Santos et.al., 2020).

3.6 CULTIVATION COEFFICIENT (KC)

From the values of ETC and ET_0, the cultivation coefficients for each water balance during the development of the crop were determined, under the experimental conditions, by means of the relationship between the ETC (obtained by the water balance in the lysimeters of the SLIMCAP system) and the ET_0 expressed in the following equation:

$$Kc = \frac{ETc}{ET_0} \quad (1)$$

where:

KC = crop coefficient (dimensionless)

ETC = crop evapotranspiration (mm $^{day-1}$)

ET0 = reference evapotranspiration (mm $^{day-1}$)

4 RESULTS AND DISCUSSIONS

The CTE of the crop obtained at the end of its cycle an accumulated of 178.12 mm, thus presenting a daily average of 4.95 mm. TSC presented its highest and lowest value on 01/21/2025 and 12/19/2024, consisting of 7.56 mm and 2.60 mm, respectively (Table 2 and Figure 2).

Table 2

Average and accumulated values of evapotranspiration of the chive crop during its vegetative development phases up to 35 days after transplanting

Development Phases		Crop evapotranspiration (ETC)	
Phases	Days	average	Accumulated
I	10 days	3,76	37,57
II	10 days	4,51	45,08
III	10 days	5,39	26,97
I V	5 days	6,23	68,50
Total	**35 days**	**4,95**	**178,12**

The ET0 estimated by the FAO standard Penman-Monteith method obtained the respective maximum and minimum values of 6.90 mm day-1 (12/25/2024) and 5.00 mm day-1 (01/11/2025), with

Thus, presenting a total value of 219.48 mm for the crop cycle. For the ET0 values, the FAO standard method (Penman-Monteith) obtained the highest minimum value (5.00), and the Blaney-Criddle method the lowest minimum value (2.81), while the solar radiation method obtained the highest maximum value (7.54) and the Hargreaves-Samani method obtained the lowest maximum value (5.68) (Table 3 and Figure 3).

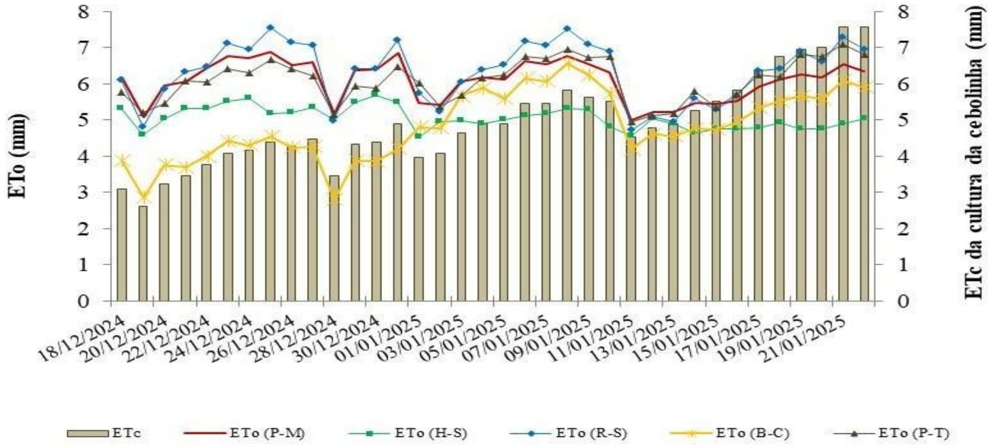
Table 3

Maximum, mean and minimum values of reference evapotranspiration (ET0) estimated by the FAO standard Penman-Monteith methods (ET0(P-M)); Hargreaves-Samani (ET0(H-S)); Solar Radiation (ET0(R-S)); Blaney-Criddle (ET0(B-C)); Priestley-Taylor (ET0(P-T)), ceve crop evapotranspiration (ETC)

Values	And so on	ET0(P-M)	ET0(H-S)	ET0(R-S)	ET0(B-C)	ET0(P-T)
		------------------------------------Mm-----------------------------------				
Maximum	7,56	6,90	5,69	7,54	6,57	7,09
Medium	4,95	6,09	5,06	6,34	4,84	6,10
Minimum	2,60	5,00	4,54	4,74	2,81	4,94
Total	**178,12**	**219,48**	**182,10**	**228,11**	**174,32**	**219,61**

Figure 3

Reference evapotranspiration estimated by the Penman-Monteith, ETo(P-M) methods; Hargreaves-Samani, ETo(H-S); Solar Radiation, ETo(R-S); Blaney-Cridlle, ETo(B-C); Priestley-Taylor, ETo(P-T), evapotranspiration of chive culture (Etc)



Source: The author (2025).

Taking into account these data presented and according to Table 3, it is possible to observe that the mean values obtained through the Solar Radiation (R-S) and Priestley-Taylor (P-T) methods were higher than the average value presented by the FAO standard (Penman-Monteith), thus, it is possible to state that the methods (R-S and P-T) can be used in the absence of the standard method (Figure 5).

It is possible to observe that there is a certain similarity between all methods together with CTE on 01/11/2025, after that day, the methods studied began to show ambiguous behavior from each other again, emphasizing the moment when CTE underestimated all methods from 01/18/2025. It was observed that the FAO standard method (P-M) estimated 6.90 mm, 6.09 mm and 5.00 mm of maximum, average and minimum, respectively. Thus, estimating a total of 219.48 mm during the entire crop cycle (Figure 5 and Table 3).

The P-T method showed a greater similarity to the FAO-standard (P-M) in relation to the other methods until 01/18/2025, later, a difference was presented between the two methods that happened on the following day until the end of the crop cycle in the experiment (01/19/2025 to 01/22/2025) with the P-T underestimating ET0 by 6.81 mm to the P-M method. It is possible to observe the behavior of the R-S method, where together with P-T it was very similar to the standard method, underestimating it several times during the period of the experiment. Throughout the crop cycle, the method that showed the most difference in relation to P-M was the B-C method, where at the end of the crop cycle, as of 01/11/2025, both it and H-S showed an overestimation of ET0 in relation to the other methods (Table 3 and Figure 3).

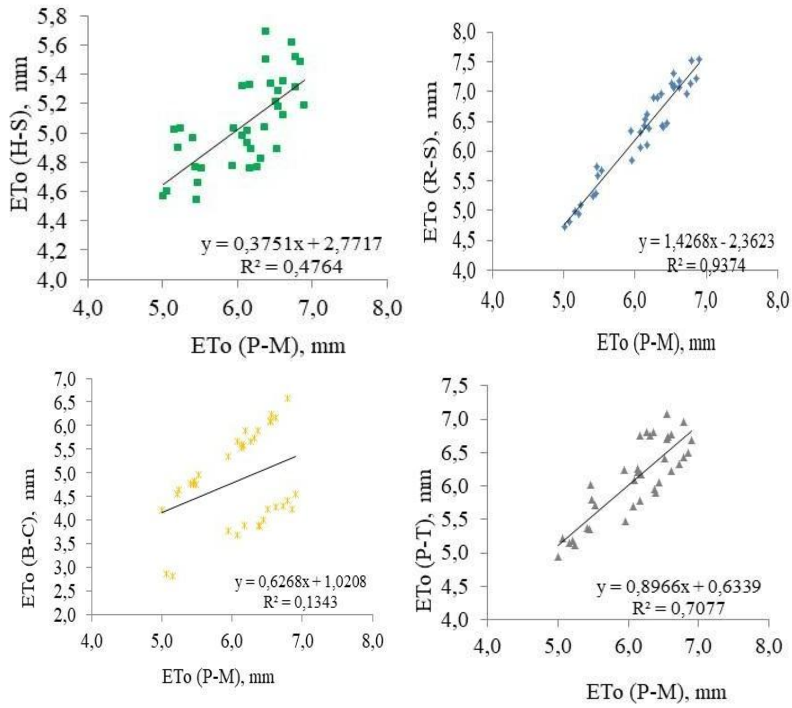
According to Lyra et al., (2012) air temperature is directly influenced by radiation; however, other factors can also influence it, such as air humidity. Air humidity is a variable that depends on temperature and acts indirectly on evapotranspiration (Almeida, 2012). ET0 estimation methods that use only air temperature as a climatic variable limit the representativeness of climatic conditions for the purpose of reference evapotranspiration estimates, because according to the humidity and wind conditions, the atmospheric water demand will be different for the same values of air temperatures (Conceição, 2003).

The more detailed analysis of the relationship between the different methods used to estimate ET0 and correlating with the FAO standard method, observed that the performance of each method through the value of the slope coefficient (Figure 6).

It is observed that the methods that present a higher performance in relation to the FAO standard method of P-M (X-axis) were the P-T, R-S (Y-axis) methods, both presented the angular coefficient closest to 1, with values of 0.8966 and 1.4268 for Priestley-Taylor and Solar Radiation, respectively. It was also observed that even within of the methods that presented a higher performance in relation to the standard method, the P-T method was the one that obtained the highest correlation with P-M, because it presented an angular coefficient closer to 1, i.e., underestimating the FAO standard method (Figure 4).

Figure 4

Correlation between the reference evapotranspiration methods (ET0) estimated by Hargreaves-Samani (H-S); Solar Radiation (R-S); Blaney-Cridlle (B-C) and Priestley-Taylor (P-T) with the standard Penman-Monteith (P-M) method



Source: The author (2025).

The comparison between the P-M method (X-axis) and the H-S method (Y-axis) showed an angular coefficient of 0.3751, which means that this method presented a low value in response to its poor performance. Similar results were found in a study on the management of irrigation in pepper in the Agreste Alagoano, in which the H-S method underestimated ET0 compared to the FAO standard method. Thus, it is not recommended as an alternative method to the standard method (Santos et al., 2020).

Silva et al., (2018) in a study on the determination of the carrot crop coefficient , also proved an underestimation of ET0 by the Hargreaves-Samani method for climatic conditions present in the agreste of Alagoas, comparing it with the FAO standard method.

It is possible to observe that the values of the standard error of estimation (EPE) was higher for both H-S and B-C, while the standard error of adjusted estimation (EPEa) was higher only for H-S, thus indicating a poor correlation between the methods of H-S and B-C and the FAO standard method (P-M). On the other hand, the Solar Radiation and P-T methods presented EPE and EPEa values lower than their agreement indexes, indicating an excellent correlation with the FAO standard (P-M). The coefficients of determination and correlation (r^2) were classified as moderate for ET0(H-S)xET0(P-M), low for ET0(B-C)xET0(P-M) and almost perfect for ET0(R-S)xET0(P-M), and very high for ET0(P-T)xET0(P-M), with concordance indices (d) and performance (c), very bad for ET0(H-S)xET0(P-M) and ET0(B-C)xET0(P-M), and great for ET0(R-S)xET0(P-M) and ET0(P-T)xET0(P-M) (Table 4).

Table 4

Standard error of the estimate (EPE) and the adjusted estimate (EPEa), slope coefficient (a), coefficient of determination (r^2), correlation coefficient (r), agreement index (d), performance index (c) between the Hargreaves-Samani methods, ET0(H-S); Solar radiation, ET0(R-S); Blaney-Criddle, ET0(B-C) and Priestley-Taylor, ET0(P-T) and the standard Penman-Monteith method ET0(P-M)

$ETo_{(P-M)}$ x ...	EPE	EPEa	*a*	*b*	*R2*	*r*	*d*	*c*
$ETo_{(H-S)}$	1,1317	1,1099	0,375	2,772	0,4764	0,6902	0,2698	0,1862
$ETo_{(R-S)}$	0,3994	0,3415	1,427	-2,362	0,9374	0,9682	0,9509	0,9207
$ETo_{(B-C)}$	1,5687	1,2892	0,627	1,021	0,1343	0,3665	0,2432	0,0892
$ETo_{(P-T)}$	0,3288	0,0582	0,897	0,634	0,7077	0,8413	0,9128	0,7679

Both Almeida et al., (2010), in Fortaleza, CE, and Cavalcante Junior et al., (2010), in Mossoró, RN, obtained "excellent" performance and excellent r^2. however, when the errors for this method were analyzed, high values of EPE and EPEa errors were found, indicating that the method does not fit the region and the study period.

Table 5 shows the behavior of the KC curve of the chive crop by the methods studied in each phenological phase of the crop. The K C values obtained had a low initial behavior in phase I, with a significant increase in phase II, stabilization in phase III and again an increase in phase IV with the exception of the KC obtained through the B-C method.

Table 5

Cultivation coefficient (phases) determined by the Penman-Monteith methods, Kc(P-M); Hargreaves-Samani, Kc(H-C); Solar Radiation, Kc(R-S); Blaney-Criddle, Kc(B-C) and Priestley-Taylor, Kc(P-T), during 30 days after transplanting (DAT) of the scallion culture

DAYS	PHASES	Kc (P-M)	Kc (H-S)	Kc (R-S)	Kc (B-C)	Kc (P-T)
10 days	10 days	0,59	0,71	0,57	0,94	0,62
20 days	10 days	0,59	0,71	0,57	0,94	0,62
30 days	10 days	0,74	0,88	0,73	0,97	0,75
35 days	5 days	0,87	1,07	0,82	0,94	0,84
Total	**35 days**	**1,06**	**1,29**	**1,02**	**1,18**	**1,02**

Comparing the KC values found with the ET 0 method variables, it is noted the similarity in the initial phases of the R-S method (phase I: 0.57; phase II: 0.57), when compared to the P-M method, FAO standard (phase I: 0.59; phase II: 0.59), and a similarity in the final phases of the P-T method (phase III: 0.75; phase IV: 0.84), when compared to the final phases of the FAO standard method (phase III: 0.74; phase IV: 0.87), in addition to an overestimation of the B-C method (phase I: 0.94; phase II: 0.94 ~ 0.97; phase III: 0.97; and an underestimation in phase IV: 0.94 in relation to the standard P-M method.

Lira et al., (2014) observed in a study carried out in Arapiraca – AL, that for the lettuce crop, the minimum KC values had an average of 0.26 in the first days after transplanting and with development it had a maximum value of 0.79. Nunes et al., (2009), for veronica lettuce, found that at the beginning of the crop's development there were lower KC values, and during its development, it obtained values higher than 1.0.

According to Oliveira et al., (2013), where they worked with the onion crop, determined that the highest water consumption of the crop occurred in the stage of greatest vegetative development of the crop, where the formation of bulbs also occurs, that is, stage III, as well as the present work, where the highest consumption of water of chives occurred in its stage of greatest vegetative development. They reported that values of up to 6.2 mm day-1 were reached, since for the entire period, the average was 4.0 mm day-1 in a total of 487.9 mm. According to the same authors, the water consumption of the crop varies not only according to its development, but also according to the local climatic conditions.

5 CONCLUSION

1. The total water consumption of the green onion crop was 178.12 mm; with a daily average of 4.95 mm day-1, and had its peak consumption of 7.56 mm day-1, minimum consumption of 2.60 mm day-1, thus reflecting the variability of water demand throughout the crop cycle;
2. The culture coefficients (KC) determined by the FAO standard method for protected environment conditions were: phase I – 0.59; phase II – 0.59; phase III – 0.74; phase IV – 0.87. These values are fundamental for the estimation of crop evapotranspiration (ETC) in different phenological phases, allowing a more efficient and sustainable water management;
3. In the absence of meteorological data that would preclude the use of the Penman-Monteith (FAO) method, it is recommended to use the KC coefficients obtained by the alternative Solar Radiation methods (0.57, 0.57, 0.73 and 0.82, for the respective phases I, I, III and IV) or the Priestley-Taylor method (phase I: 0.62; phase II: 0.62; phase III: 0.75; phase IV: 0.84), since both presented a good correlation with the results of the standard method;

4. The results obtained in this study offer practical subsidies for the efficient management of green onion irrigation in protected environment conditions, contributing both to the sustainability of agricultural production and to the decision making by producers and technicians.

REFERENCES

Albuquerque, P. E. P. (2000). Requerimento de água das culturas para fins de manejo e dimensionamento de sistemas de irrigação localizada (Embrapa Milho e Sorgo Circular Técnica, 1). Sete Lagoas: Embrapa Milho e Sorgo.

Allen, R. G., Pereira, L. S., Raes, D., & Smith, M. (1998). Crop evapotranspiration: Guidelines for computing crop water requirements (FAO Irrigation and Drainage Paper, 56). Rome: FAO.

Almeida, B. M. (2012). Evapotranspiração, coeficiente de cultura e produção do milho sob condições de salinidade residual [Master's dissertation, Universidade Federal Rural do Semi-Árido]. Mossoró, RN.

Almeida, B. M., Araújo, E. M., Cavalcante Júnior, E. G., Oliveira, J. B., Araújo, E. M., & Nogueira, B. R. C. (2010). Comparação de métodos de estimativa da ETo na escala mensal em Fortaleza-CE. Revista Brasileira de Agricultura Irrigada, 4(2), 93–98.

Araújo, I. B., Peruch, L. A., & Stadnik, M. J. (2012). Efeito do extrato de alga e da argila silicatada na severidade da alternariose e na produtividade da cebolinha comum (Allium fistulosum L.). Tropical Plant Pathology, 37(5), 363–367.

Brutsaert, W. (2005). Hydrology: An introduction. New York, NY: Cambridge University Press.

Castiglio, V. S., Campagnolo, K., & Kobiyama, M. (2021). Análise da evapotranspiração potencial no município de Cambará do Sul/RS. Revista Geonorte, 12(39), 26–43.

Conceição, M. A. F. (2003). Estimativa da evapotranspiração de referência com base na temperatura do ar para as condições do Baixo Rio Grande, SP. Revista Brasileira de Agrometeorologia, 11(2), 229–236.

Doorenbos, J., & Pruitt, W. O. (1977). Guidelines for predicting crop water requirements (FAO Irrigation and Drainage Paper, 24). Rome: FAO.

Ecycle. (n.d.). Propriedades da cebolinha e seus benefícios à saúde. Faz Fácil: Cebolinha (Allium fistulosum). Retrieved from https://www.fazfacil.com.br/jardim/cebolinha-allium-fistulosum/

Ferrari, E., Paz, A., & Silva, A. C. (2015). Déficit hídrico e altas temperaturas no metabolismo da soja em semeaduras antecipadas. Nativa, 3(1), 67–77. https://doi.org/10.31413/nativa.v3i1.1855

Filgueira, F. A. R. (2008). Novo manual de olericultura: Agrotecnologia moderna na produção e comercialização de hortaliças (3rd ed.). Viçosa, MG: UFV.

Freddo, A. R., Cechim, F. E., & Mazaro, S. M. (2014). Conservation of post-harvest leaves of green onion (Allium fistulosum L.) with the use of salicylic acid solution. Brazilian Journal of Applied Technology for Agricultural Science, 6(3), 87–94.

Frevert, D. R., Hill, R. W., & Braaten, B. C. (1983). Estimation of FAO evapotranspiration coefficients. Journal of Irrigation and Drainage Engineering, 109(2), 265–270.

Kobayashi, E. S. (2007). Consumo de água e produtividade de cafeeiros arábicas na região de Mococa, SP. Campinas: Instituto Agronômico de Campinas.

Krause, W., & Tieppo, R. C. (2013). Desempenho e orientação do crescimento do pepino japonês em ambiente protegido. Horticultura Brasileira, 31(4), 649–653.

Lyra, G. B., Silveira, E. L., Pereira, C. R., Silva, L. D. B., & Silva, G. M. (2012). Coeficiente da cultura da cana-de-açúcar no estádio inicial de desenvolvimento em Campos dos Goytacazes, RJ. Revista Irriga, 17(1), 102–113.

Makishima, N. (1993). O cultivo de hortaliças. Brasília: Embrapa-CNPH.

Mendonça, J. C., Souza, E. F., Bernardo, S., Dias, G. P., & Grippa, S. (2003). Comparação entre métodos de estimativa da evapotranspiração de referência (ETo) na região Norte Fluminense, RJ. Revista Brasileira de Engenharia Agrícola e Ambiental, 7(2), 275–279.

Mota, N. F. (2013). Efeito do Bokashi no crescimento da cebolinha, do coentro e em alguns atributos químicos e biológicos do solo [Master's dissertation, Universidade Federal do Ceará]. Fortaleza, CE.

Nunes, A. L., Bispo, N. B., Hernandez, R., & Navarini, L. (2009). Evapotranspiração e coeficiente de cultura da alface para a região Sudoeste do Paraná. Scientia Agricola, 10(5), 397–402.

Oliveira, G. M., & et al. (2013). Coeficiente de cultura e produtividade da cebola submetida a diferentes lâminas de irrigação. Revista Brasileira de Engenharia Agrícola e Ambiental, 17(9), 969–974.

Pereira, D. R., Yanagi, S. N. M., Mello, C. R., Silva, A. M., & Silva, L. A. (2009). Desempenho de métodos de estimativa da evapotranspiração de referência para a região da Serra da Mantiqueira – MG. Ciência Rural, 39(9), 2488–2493.

Santos, M. A. L., Santos, L. A., Lucas, A. A. T., Gomes Filho, R. R., & Santos, D. P. (2020). Desenvolvimento de pesquisa científica na agricultura irrigada: Sistema lisimétrico de informações para monitoramento do consumo de água pelas plantas (SLIMCAP). In Editora Atena (pp. 58–65). https://doi.org/10.22533/at.ed.8872028107

Silva, E. M., Azevedo, J. A., Guerra, A. F., Figuerêdo, S. F., Andrade, L. M., & Antonini, J. C. A. (1999). Manejo de irrigação por tensiometria para culturas de grãos na do cerrado. [Publisher not specified].

Silva, J. C., & et al. (2018). Evapotranspiração e coeficiente de cultura da cenoura irrigada no agreste alagoano. Revista Ceres, 64(4), 297–305.

Silva, M. A. V. (2006). Meteorologia e climatologia. Recife, PE: [Publisher not specified].

Souza, M. P. S., Prins, C. L., Ribeiro, L. N., Marciano, C. R., Vieira, I. J. C., & Freitas, S. P. (2021). Crescimento, fisiologia e compostos voláteis de cebolinha em resposta a diferentes níveis de restrição hídrica. Revista Cultura Agronômica, 30(1), 1–13. https://doi.org/10.32929/2446-8355.2021v30n1p1-13

Viol, M. A., Carvalho, J. A., Lima, E. M. C., Rezende, F. C., Mattos, R. W. P., & Rodrigues, J. L. M. (2017). Déficit hídrico e produção do tomate cultivado em ambiente protegido. Revista Brasileira de Agricultura Irrigada, 11(1), 1244–1253.

Xavier, R. A., & Dornellas, P. C. (2012). Caracterização ambiental do município de Arapiraca, Região Agreste de Alagoas. Revista Ambientale, 3(3), 108–121.