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Water consumption and water use efficiency of 'Biquinho' pepper in hydroponic cultivation with brackish water

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ABSTRACT: The knowledge of water consumption and the efficiency of water use by crops is extremely important in the elaboration of agronomic and hydraulic projects of hydroponic systems. Thus, the present study determined the water consumption and water use efficiency of 'Biquinho' pepper cultivated in the hydroponic system using seven levels of electrical conductivity of the nutrient solution (ECsol) of 2.70, 3.64, 4.58, 5.28, 6.09, 6.90, and 7.77 dS m^{-1} and six replicates in randomized blocks. The hydroponic system used was the Nutrient Film Technique (NFT). The water consumption per plant was determined at an interval of ten days in the crop cycle (120 days after transplanting). The maximum mean daily water consumption was equal to 5.88 L $plant^{-1}$ during the period 111-120 DAT, for ECsol of 4.58 dS m^{-1}. The maximum water consumption for the crop cycle (120 DAT) was 275.66 L per plant for an estimated ECsol = 4.11 dS m^{-1}. The highest water use efficiency (WUE), based on the total production of fruit fresh mass (ripe and unripe fruits) of 'Biquinho' pepper was 10.84 kg m^{-3} up to an estimated ECsol of 5.18 dS m^{-1}, with an exponential reduction thereafter. The salinity of the nutrient solution, biomass production, and evapotranspiration are factors that influence the most water consumption of 'Biquinho' pepper.
Key words: *Capsicum chinense* Jacq, salinity, soilless culture.

Consumo hídrico e eficiência do uso da água da pimenta 'Biquinho' em cultivo hidropônico com água salobra

RESUMO: O conhecimento do consumo hídrico e eficiência do uso da água pelas culturas são extremamente importantes para o dimensionamento de sistemas agronômicos e projeto hidráulico dos sistemas hidropônicos. Neste contexto, o presente estudo determinou o consumo de água e a eficiência do uso da água da pimenta 'Biquinho' cultivada no sistema hidropônico utilizando sete níveis de condutividade elétrica da solução nutritiva (CEsol) de 2,70, 3,64, 4,58, 5,28, 6,09, 6,90 e 7,77 dS m^{-1} e seis repetições em blocos casualizados. O sistema hidropônico utilizado foi a técnica do fluxo laminar de nutrientes. O consumo hídrico por planta foi determinado em um intervalo de dez dias no ciclo da cultura (120 dias após o transplantio). O consumo hídrico médio diário máximo foi igual a 5,88 L $planta^{-1}$ no período de 111-120 DAT, para a CEsol de 4,58 dS m^{-1}. O consumo máximo de água para o ciclo da cultura (120 DAT) foi de 275,66 L por planta para uma estimada CEsol = 4,11 dS m^{-1}. A maior eficiência do uso da água (EUA) observada foi de 10,84 kg m^{-3} (frutos maduros e não maduros) até ao CEsol estimada de 5,18 dS m^{-1}, com posterior redução exponencial. A salinidade da solução nutritiva, a produção de biomassa e a evapotranspiração são fatores que mais influenciam o consumo de água da pimenta 'Biquinho'.
Palavras-chave: *Capsicum chinense* Jacq, salinidade, cultivo sem solo.

INTRODUCTION

Responsibility for more sustainable and rational agriculture should not be seen as additional pressure on production costs but as an economic criterion for agricultural production and preservation of the system. Some studies recently conducted worldwide have investigated efforts to evaluate the effects of salinity under hydroponic conditions, with emphasis on aspects of production and water consumption (ATZORI et al., 2019; CAPARROTTA et al., 2019; MODESTO et al., 2019; LIMA et al., 2018; SILVA et al., 2020). This evidence the direction of research to update the expectations of commercial production with the use of brackish water, based on the premise that, when the production systems evolve, the responses of plants to salinity tend to be positively altered.

In line with the main approaches to environmental impacts, production, and profitability, according to CAVALCANTE et al. (2019), hydroponic cultivation has been suggested as a technique that aims

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to solve various environmental impacts and economic issues, especially in regions where freshwater is scarce for agricultural production. Among the several advantages of the Nutrient Film Technique (NFT) hydroponic system, its sustainability stands out, which results from the increased efficiency of water use, as it is possible to recycle water and nutrients not used by plants or provide at the end adequate disposal of reject of the nutrient solution (SOARES et al., 2009; PUTRA & YULIANDO, 2015). SAMBO et al. (2019), for example, compiled scientific results demonstrating the higher water use efficiency in soilless cultivation for various crops when compared with soil-based cultivation. Similar results were also observed in other studies (LEAL et al., 2020; VERDOLIVA et al., 2021). In addition, BIONE et al. (2014) draw attention to the need to study new crops in hydroponic systems, to increase the options in this type of cultivation, which today, in Brazil, is mainly used for the cultivation of leafy species. In this context, VAN OS et al. (2019) highlighted that the crops to be grown in hydroponic systems should have high profitability potential compatible with the investment essential for the success of the enterprise. 'Biquinho' pepper (*Capsicum chinense* Jacq.) has great demand in the market and has been increasingly valued in the consumer market (HEINRICH et al., 2015), which justifies the evaluation of its cultivation in a hydroponic system. However, this crop is susceptible to several abiotic stresses, including salinity (SÁ et al., 2019).

In traditional soil-based cultivation systems, the salts contained in the brackish waters reduce the total water potential, hampering the water absorption by the roots, decreasing water consumption, and causing problems in metabolism with direct reduction of production (ZANETTI et al., 2019). Some of these effects of water salinity are attenuated in the hydroponic cultivation system (due to the absence of matric potential) when compared to traditional cultivation in soil and may even increase biomass production and water use efficiency, as observed by LEAL et al. (2020) in the cultivation of spinach (*Spinacia oleracea*) with the increase of salinity of the nutrient solution.

The exact knowledge of nutritional requirements for *C. chinense* is still incipient; therefore, normally it has been performed similar to species from the same family Solanaceae such as bell pepper (OLIVEIRA et al., 2014; COSTA et al., 2020) or based on the proportion of nutrients in the aerial parts of the plant or on the contents in dry matter (FURLANI et al., 1999b). In leaves, adequate levels of macronutrients are between 30 to 60 g kg^{-1} of N, 3 to 7 g of P, and 40 to 60 g kg^{-1} of K (TRANI, 2014). For *Capsicum annuum*, under hydroponic conditions, FURTADO et al. (2017) and SANTOS et al. (2018) used the nutrient solution formulated by FURLANI et al. (1999a) and BENOIT (1987), respectively, both with good results.

Water consumption and water use efficiency are also affected by salinity in different crops under hydroponic conditions. Studying these variables is essential for the elaboration of agronomic and hydraulic projects of the hydroponics systems. In addition, especially under conditions of water scarcity, alternatives such as hydroponics cultivation become strategic, which improve water use efficiency, including in cases of marginal quality water such as brackish water. In this context, it is proposed to evaluate the water consumption and water use efficiency of 'Biquinho' pepper cultivated in the hydroponic system using brackish waters in the preparation of the nutrient solution.

MATERIALS AND METHODS

The study was conducted in a single-arch greenhouse, located in the municipality of Cruz das Almas, Bahia, Brazil (12º 40'19" South latitude, 39º 06' 23" West longitude, and mean altitude of 220 m). The greenhouse installed in the East-West direction, is 7 m wide and 33 m long, with a ceiling height of 4 m being protected on the sides by a black net (50% shade) and on the top by 150-micron anti-UV plastic film.

The experiment started 43 days after sowing (DAS). At 20 days after transplanting (DAT), a 50% shade net was installed at 3.5 m height to reduce radiation and avoid thermal stress in plants. The experiment was completed at 163 DAS, i.e., 120 DAT. In this period, the minimum, maximum, and mean values of temperature, relative humidity of the air, and evapotranspiration were, respectively: 17.20, 35.70, and 23.88 °C (Figure 1A); 66.46, 93.29, and 78.79% (Figure 1A), and 1.31, 5.97, and 4.05 mm day^{-1} (Figure 1B), according to data retrieved from the weather station in the network of the National Institute of Meteorology (INMET, 2017), located at Embrapa Cassava and Tropical Fruits, about 2.3 km away from the experimental site.

The experimental design was randomized blocks, with seven levels of electrical conductivity of the nutrient solution (ECsol), with six replicates. The water was salinized by dissolving NaCl in municipal supply water (ECw = 0.34 dS m^{-1}). The ECw levels used were: 0.34, 1.5, 2.5, 3.5, 4.5, 5.5, and 6.5 dS m^{-1},

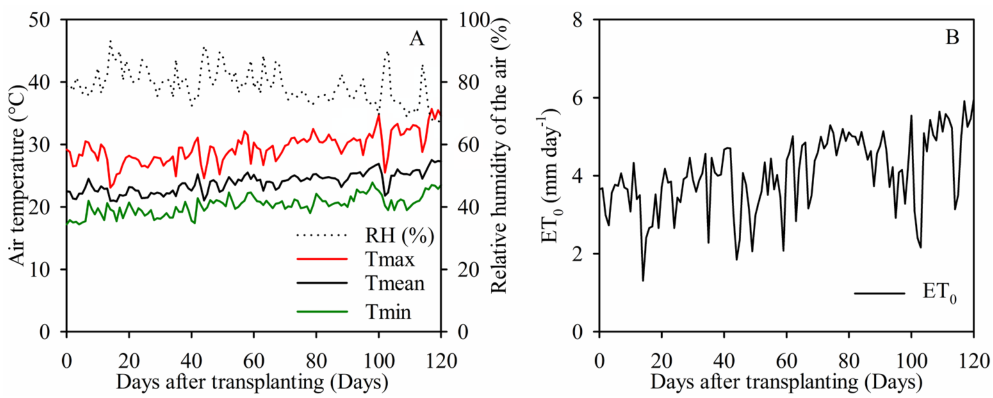

Figure 1 - Minimum (Tmin), maximum (Tmax), mean temperature (Tmean), and mean relative humidity - RH (A) and mean reference evapotranspiration – ET_0 (B) during the 120 days after transplanting (Source: INMET, 2017).

corresponding to the weighted means (during the experimental period) of the electrical conductivity of the nutrient solution (ECsol) of 2.70, 3.64, 4.58, 5.28, 6.09, 6.90, and 7.77 dS m^{-1}, respectively. The treatments were distributed longitudinally in the greenhouse and occupied 42 experimental plots. Each unit was composed of five plants arranged in a PVC channel (0.075 m in diameter and 6.0 m in length). Each cultivation channel was independent, concerning its hydraulic system, nutrient solution reservoir, and supply water tank.

The hydroponic system used was the Nutrient Film Technique (NFT), in which the nutrient solution circulated for 15 minutes and remained at rest for 15 minutes. The studied crop was pepper (*Capsicum chinense* Jacq.) of the varietal group 'Biquinho', without pungency. The seeds were acquired from the Horticeres Seed Company and sown in previously washed cubical cells of phenolic foam (0.02 x 0.02 x 0.02 m).

Water consumed by the crop was replenished daily, at fixed hours, as described by SANTOS et al. (2018). A float valve ('drinking water' type) was installed in the reservoir (capacity 60 L) of the nutrient solution (NS) and connected to another cylindrical reservoir (capacity 25 L) kept at a higher elevation. In this system, as there was water consumption in the plot, water was replenished by gravity from the cylindrical reservoir to the NS reservoir, controlled by the float valve located at a height in the reservoir to maintain a constant volume (50 L) in the reservoir. The measurement of water consumption was made daily through a graduated millimeter scale installed along with a microtube in the cylindrical reservoir.

The nutrient solution adapted was the one recommended by SONNEVELD & STRAVER (1994) with the following composition: NH_4^+-N, NO_3^--N, P, K, Ca, Mg, S, B, Cu, Fe, Mn, Mo, and Zn with concentrations of: 18.2, 188.3, 40.3, 244.1, 144.3, 31.6, 41.7, 0.39, 0.05, 2.00, 0.40, 0.05, and 0.06 mg L^{-1}, respectively.

For all treatments, solution consumed by plants was replenished with municipal supply water (ECw= 0.34 dS m^{-1}). Due to the absorption of nutrient ions by the plant, the NS of all plots was completely changed at 28, 61, and 90 DAT, aiming to keep the ECsol and elemental concentration similar to the original composition. The spacing used was 0.83 m between plants and 0.70 m between rows, according to the recommendations of ANDRADE JÚNIOR et al. (2018). The plants were grown without any pruning and, from 18 DAT, were trained using a polyethylene string tied to the wire positioned at a 2.00 m height above the crowns.

Water consumption was evaluated by daily readings, at the pre-fixed hour, of the water level in the cylindrical tank connected to the NS reservoir in each plot. In this way, daily water consumption was obtained through equation. (1).

$$WC = \frac{(Lf - Li)\times\pi\times D^2}{4\times n\times \Delta T}\times 10^3 \quad (1)$$

Where: WC - water consumption, L per plant per day; Lf - final reading of the water level in the supply tank, m; Li - initial reading of the water level in the supply tank, m; D - internal diameter of the supply tank, m; ΔT - time interval between readings, days, and n - number of plants grown in the hydroponic channel during the observed time interval (ΔT).

The number of plants in each cultivation channel for each reading was observed, including after performing periodic destructive harvests (at 30, 60, and 90 DAT). To minimize the effects of reading errors (human factor, float valve malfunction, presence of air bubbles in the water level display, variation in the daily crop evapotranspiration due to climatic factors, etc.), the daily values were accumulated for ten-day periods and were used to calculate mean daily water consumption. The accumulated water consumption along the cycle (1 to 120 DAT) was also estimated by summation.

At 30, 60, 90, and 120 DAT, the shoot dry mass (SHDM) was determined, which was composed of the dry mass of leaves and stem. For SHDM determination, one plant was collected from each plot. These plants were placed in a paper bag and taken to a forced-air ventilation oven at 65 °C. When they reached a constant mass, their shoot dry mass was obtained on a precision scale (0.001 g).

Water use efficiency (WUE) was calculated as the ratio between production (fresh fruit mass) and accumulated water consumption until the end of harvest (Equation 2). WUE measurements were based on data of total accumulated production (ripe and unripe fruits), reported earlier by BIONE et al. (2021), with yield (up to 120 DAT) of 2.869, 2.731, 3.160, 2.667, 1.069, 0.551, and 0.151 kg plant^{-1} for ECsol of 2.70, 3.64, 4.58, 5.28, 6.09, 6.90, and 7.77 dS m^{-1}, respectively.

$$WUE = \frac{Yp}{WC_{accum}} \quad (2)$$

Where: WUE - water use efficiency of 'Biquinho' pepper production, kg m^{-3}; Yp - fruit fresh mass (ripe + unripe fruits), kg per plant and WC_{accum} - accumulated water consumption until 120 DAT, m^3 per plant.

The statistical program SAS University Edition (SAS, 2017) was used to analyze data. When significant by the F test of the analysis of variance, the effect of the factor ECsol was evaluated by regression analysis, selecting the models based on the significance of their terms, the coefficient of determination, and the agronomic significance of the behavior. The maximum or minimum points were obtained by the first derivative of the equations. The models of MAAS & HOFFMAN (1977) and plateau followed by exponential decay were also used. The Solver Microsoft Excel tool was used to analyze the parameters, aiming to minimize the sum of squares deviations. The Pearson correlation coefficient matrix between the variables analyzed was constructed using the six repetitions of each salinity level, totaling 42 observations, with the aid of the Sigma Plot 14.5 program.

RESULTS

The differentiation of daily water consumption (WC) began on the last day of the first ten-day period (1-10 DAT), but without significant effect on the daily mean within this period, estimated at 0.083 L plant^{-1} (Figure 2A). After this period, there was a reduction in the water consumed by 'Biquinho' peppers with the increase in ECsol. The reduction was linear in the second (11-20 DAT) and fourth (31-40 DAT) ten-day periods, corresponding to a 7.64 and 9.76% per unit increase of ECsol, respectively (Figure 2B and 2D). In the evaluation of 21-30 DAT, the data were adjusted to a quadratic model, whose maximum estimated value of ECsol was 2.80 dS m^{-1}, promoting WC of 0.366 L plant^{-1} (Figure 2C).

For the periods 41-50 and 51-60 DAT, the relative linear reductions in WC were more stable: 10.28 and 10.15% per unit increase in ECsol (Figure 2E and 2F). Thus, when comparing plants under the control treatment (ECsol=2.7 dS m^{-1}) and at the highest level of nutrient solution salinity (ECsol=7.77 dS m^{-1}) in the interval between 11 to 60 DAT, there were reductions per ten-day period in WC of 48.88, 55.38, 67.19, 72.14, and 70.88%, respectively.

In the ten-day periods of 61-70 and 71-80 DAT, the WC showed a plateau trend followed by linear decay response, with salinity thresholds of 4.45 and 4.50 dS m^{-1} and mean daily consumptions up to these salinity levels of 2.33 and 3.78 L plant^{-1}, respectively (Figure 2G and 2H). Subsequently, in the ten-day periods 81-90 (Figure 2I), 91-100 (Figure 2J), 101-110 (Figure 2K), and 111-120 (Figure 2L) DAT, water consumption adjusted to a quadratic function. Thus, the maximum values were no longer linked to the control treatment (ECsol=2.7 dS m^{-1}) and its statistical equivalents, but to the ECsol of 4.04, 4.61, 4.93, and 4.70 dS m^{-1}, respectively for the ten-day periods mentioned above. In addition, it was also observed that progressively these quadratic equations began to explain less variation of water consumption as a function of ECsol since the coefficients of determination (R^2) reduced from 91% (81-90 DAT) to 62% (111-120 DAT) (Figure 2I and 2L).

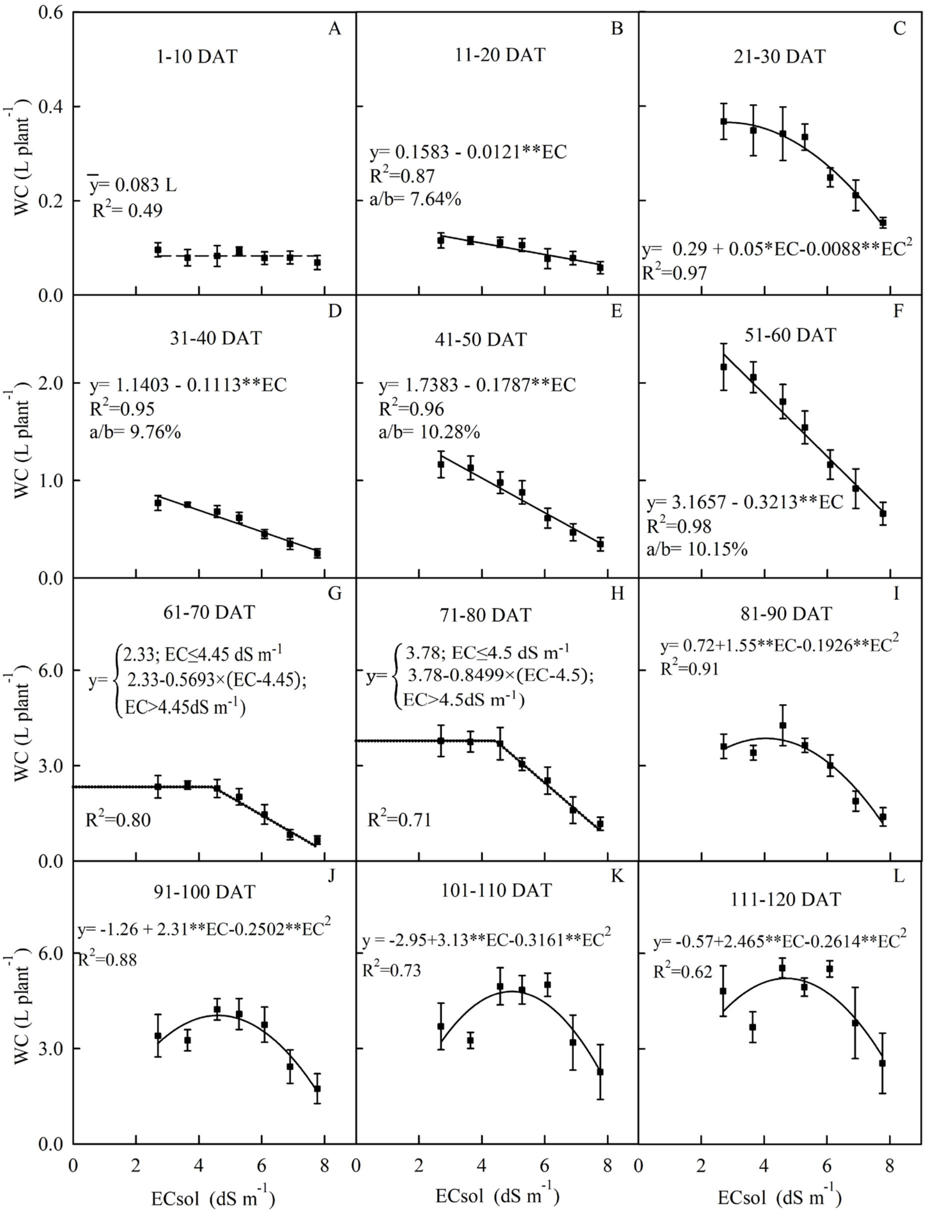

Figure 2 - Mean estimated daily water consumption (WC) per plant based on the 10-day interval of ‘Biquinho’ pepper grown in the hydroponic system as a function of electrical conductivity of the nutrient solution (ECsol), from 1 to 120 days after transplanting (DAT).

Pearson’s correlation coefficient (r) showed a positive linear association between all variables analyzed: WC each 10-day interval, SHDM at 30, 60, 90, and 120 DAT and WUE (Figure 3). In general, it is observed that the correlation is stronger between the WC of close intervals. SHDM evaluations at 30 (r=0.83), 60 (r=0.80), 90 (r=0.86), and 120 (r=0.79) DAT are associated with WC 21-30, 51-60, 81-90, and 111-120 DAT, respectively. There was also a strong correlation coefficient in the evaluations 10 DAT before and after these periods. For the WUE and the variables SHDM and WC, a low correlation

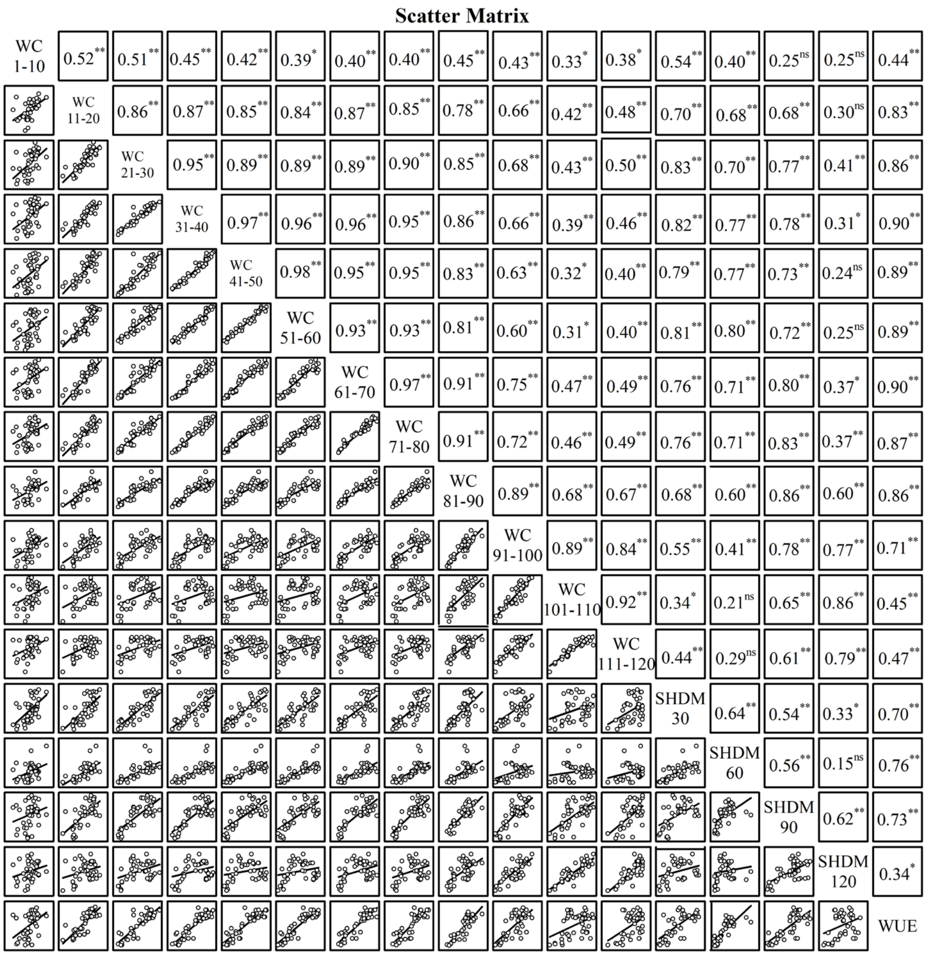

Figure 3 - Pearson's correlation coefficient matrix between mean estimated daily water consumption per plant on the 10-day interval (WC), shoot dry mass (SHDM) at 30, 60, 90, and 120 days after treatment and water use efficiency (WUE) of 'Biquinho' pepper grown in the hydroponic systems as a function of electrical conductivity of the nutrient solution (ECsol).

coefficient was observed with the evaluations WC 110-111 DAT (r=0.45) WC111-120 DAT (0.47) and SHDM120 DAT (0.34).

In figure 4A, it is observed that plants subjected to the lowest levels of ECsol (2.70 and 3.64 dS m^{-1}) had a reduction in water consumption from 81 to 100 DAT with stabilization in this interval but with a new increase thereafter up to 120 DAT. For plants subjected to the highest levels of ECsol, water demand increased progressively, reflecting their recovery in terms of SHDM but remained lowest throughout the entire period.

Although, the linear effect of ECsol occurred in most of the ten-day periods of water consumption evaluations up to 60 DAT, the greater magnitude of water consumption coincided with intervals in which the quadratic model adjusted satisfactorily. As a result, the accumulated water consumption throughout the period (1 to 120 DAT) was described by the second-order polynomial model (Figure 4B), with a maximum value (275.66 L $plant^{-1}$) estimated for an ECsol of 4.11 dS m^{-1}. The total water consumption in the study ranged from 106.79 to 275.66 L $plant^{-1}$, for ECsol between 2.70 to 7.77 dS m^{-1}.

The quadratic equation presented in figure 4B permits to estimate different salinity levels of the nutrient solution for the same accumulated water consumption. Thus, the ECsol levels of 2.70 and 5.53

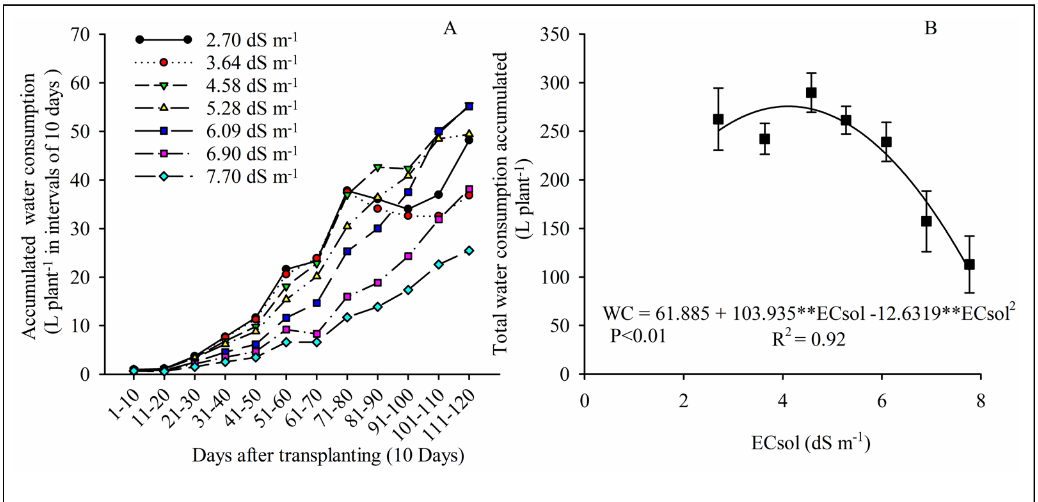

Figure 4 - Accumulated water consumption per plant (estimated on the ten days interval) of 'Biquinho' pepper under different treatments of the electrical conductivity of the nutrient solution (ECsol) (A) and total water consumption accumulated during the crop cycle (1-120 days after the transplanting - DAT) (B) as a function of the electrical conductivity of the nutrient solution (ECsol).

dS m^{-1} have approximately the same accumulated water consumption (250 L $plant^{-1}$) at 120 DAT, i.e., plants under the ECsol of 5.53 dS m^{-1} had accumulated water consumption compatible with that of plants in the control treatment.

When analyzing the highest values of water consumption per plant for each ECsol, per ten-day period, the maximum values of daily water consumption observed are presented in table 1. These results confirmed that, during the first ten-day periods (up to 71-80 DAT), the highest absolute values were related to the control treatment but later, the treatments with intermediate ECsol (4.58 and 5.28 dS m^{-1}) started to consume more water. The maximum mean daily WC was equal to 5.88 L $plant^{-1}$ for the treatment ECsol of 4.58 dS m^{-1} during the period 111-120 DAT coinciding with the highest value of ETo 5.05 mm (Table 1).

Considering the total production of 'Biquinho' pepper (ripe plus unripe fruits), the water use efficiency (WUE) was estimated at 10.84 kg m^{-3} up to a threshold ECsol of 5.18 dS m^{-1}. There was an exponential decrease in the WUE with the increase in water salinity above the threshold with a WUE of 0.93 kg m^{-3} $plant^{-1}$ at ECsol of 7.77 dS m^{-1} (Figure 5).

DISCUSSION

Salinity is one of the abiotic stresses that most affects plant development, even in the hydroponic systems when brackish water is used to prepare the nutrient solution, as observed in the present study for 'Biquinho' pepper and also for other crops, such as spinach (*Spinacia oleracea* L.) (LEAL et al., 2020), okra (*Abelmoschus esculentus* L.) (MODESTO et al., 2019), tomato (*Lycopersicon esculentum* Mill 'Unicorn') (ISLAM et al., 2018). However, under salt stress, the hydroponic system generally promotes higher yield compared to soil (conventional cultivation) due to the readily available

Table 1 - Mean evapotranspiration (ET_0) and mean maximum daily water consumption (WCmax) of 'Biquinho' pepper per plant estimated at an interval of ten days and respective electrical conductivity of the nutrient solution (ECsol).

DAT	ETo* (mm day^{-1})	WCmax (L $plant^{-1}$ day^{-1})	ECsol (dS m^{-1})
1-10	3.50	0.123	2.7
11-20	3.02	0.137	2.7
21-30	3.75	0.433	2.7
31-40	3.96	0.847	2.7
41-50	3.26	1.299	2.7
51-60	3.68	2.312	2.7
61-70	4.19	2.860	2.7
71-80	4.95	4.514	2.7
81-90	4.68	5.339	4.58
91-100	4.20	4.985	5.28
101-110	4.35	5.715	5.28
111-120	5.05	5.885	4.58

*Data obtained at the INMET Meteorological Station.

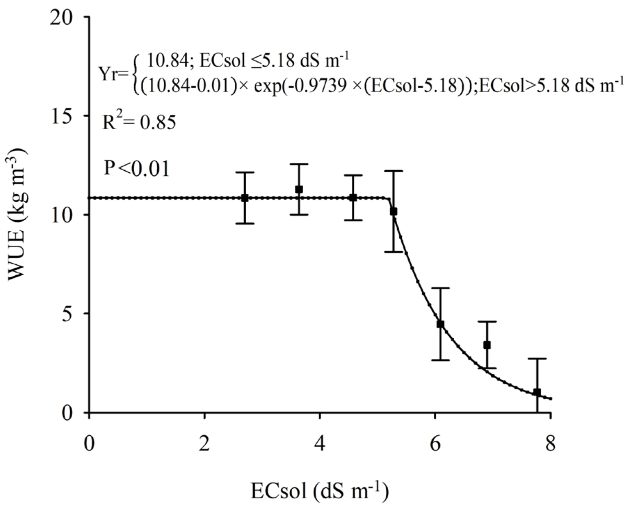

Figure 5 - Water use efficiency (WUE) of the 'Biquinho' pepper as a function of the electrical conductivity of the nutrient solution (ECsol), based on the production of ripe + unripe fruits.

water and nutrients that provide plants with better conditions for root development (LEAL et al., 2020).

Overall, the increase in salinity reduced the water consumption of 'Biquinho' pepper in the evaluations every ten days (Figure 2). In addition, it was observed that WC is directly related to SHDM during plant development (Figure 3). At 30 DAT (r= 0.83) the coefficient of correlation was high between WC and SHDM, but the maximum was reached at 90 DAT (r=0.86). At 30 DAT the plant was still in the acclimatization phase to the hydroponic system, probably with preference to the development of the root system of the plant. At 60 and 90 DAT the plant was in the full vegetative growth, which is reinforced by the decrease in the coefficient of correlation after 90 DAT, i.e., the beginning of the reproductive phase period, as shown by BIONE et al. (2021) with the production peak at 120 DAT with which the coefficient of correlation is lowest. At this stage, the plant was in the maximum production stage under the treatments with higher electrical conductivity of the solution (ECsol), it infers that the water and nutrients absorbed are directed towards fruit production rather than vegetative growth, justified by the low WUE correlation coefficient with WC101-110 DAT (r=0.45), WC111-120 DAT (0.47), and SHDM120 DAT (0.34).

A similar behavior of water consumption reduction (Figure 2) was observed by SANTOS et al. (2018) for a species of the same genus as the 'Biquinho' pepper, *C. annuum* cultivated for 67 DAT. In the cited study, the water consumption decreased by 9.81% per unit increase in the salinity of water used to prepare the nutrient solution, in the NFT hydroponic system thus, total water consumption decreased from 33.66 to 10.54 L plant^{-1}, with ECsol ranging from 2.11 to 8.54 dS m^{-1}. In the present study, the accumulated WC corresponding to this volume occurred between 51 and 60 DAT, reducing from 46.78 to 10.05 L plant^{-1} from ECsol of 2.70 to 7.77 dS m^{-1} (Figure 4A).

The reduction in the water consumption of 'Biquinho' pepper due to an increase in salinity is compatible with the difficulty of glycophyte plants to absorb water under saline conditions. Because the reduction in the osmotic potential of the nutrient solution, resulting from the increase in the concentration of NaCl, reduces the absorption capacity of the roots due to the inability of the plant to perform the osmotic adjustment necessary for the absorption of water, in addition to the fact that ions such as Na^+ and Cl^- cause direct toxic effects in plant metabolism preventing an adequate ionic homeostasis within plant tissues (SOARES et al., 2015; ZANETTI et al., 2019).

Knowledge of the water requirements of 'Biquinho' pepper in hydroponic cultivation under a protected environment is important for the farmers and projectors of hydroponic systems; as such information is not often available in the specialized literature. It is assumed that a system capable of meeting the maximum critical demand will attend to other situations. Thus, the maximum water consumption per plant is one of the most important data.

The maximum daily water consumption of ‘Biquinho’ pepper plants was 5.9 L plant^{-1} during the period 111-120 DAT, under ECsol of 4.58 dS m^{-1} (Table 1). This is equivalent, for example, to the water consumption of a lettuce plant in its entire post-transplanting stage, from 21 to 35 DAT, which ranges from 2.07 to 6.5 L, according to PAULUS et al. (2012) and SOARES et al. (2015). That way, daily water consumption of ‘Biquinho’ pepper plants under a hydroponic system, with ECsol of 4.58 dS m^{-1} varies from 2.8 to 0.9 times that of a lettuce plant throughout its cycle. This comparison with lettuce is justified because it is the most exploited crop in NFT hydroponic cultivation in Brazil. Caution should be taken when using this maximum value recorded in the present study because, in general, there was a trend of continued increase in daily water consumption, even at 120 DAT (Figure 4A, Table 1) indicating that ‘Biquinho’ pepper plants may not yet have reached their full potential in terms of water absorption capacity in the hydroponic production system employed. In addition, local environmental conditions (radiation, wind speed, air humidity, and temperature) can influence plant evapotranspiration, demanding greater consumption of water or not, as was observed in higher ETo, temperature (Figure 1A and 1B) and higher values of water consumption (Table 1).

Contrary to what might be expected, the highest values of water consumption were not found under the control treatment (ECw=2.7 dS m^{-1}). This may be due to an interaction between the precocity of production in these treatments and the acclimatization of the pepper plant to salinity after an initial period of strong osmotic restriction. Thus, in periods of greater atmospheric demand (Figure 1A e 1B), which coincides with the last twenty days of the present study, the plants of the low salinity treatments (ECw 2.7 and 3.64 dS m^{-1}) were more directed to fruit production, while the plants in the more saline treatments were in the resumption of vegetative growth, which may explain their higher water consumption.

Nutrient solution electrical conductivity of 5.18 dS m^{-1} in the hydroponic cultivation of ‘Biquinho’ pepper promoted an estimated WUE of 10.83 kg m^{-3} (Figure 5). This is a result that is difficult to compare with other studies as the genotype used and the weather conditions vary from place to place, but it is important to compare our results with the WUE values indicated in the specialized literature. For *C. annuum* peppers the values ranged from 17.85 to 20.24 g L^{-1}, for the cultivar ‘Battle’, produced under greenhouse conditions in China, using a cotton-based substrate (hydroponic) (AHMED et al., 2014). However, the WUE reported in the present study is higher than that observed by LÓPEZ-LÓPEZ et al. (2015), for a cultivar of *C. chinense* ‘Habanero’ in Mexico under drip irrigation, in a clayey soil, with a WUE of 6.51 kg m^{-3}; and when these authors used plastic mulch under the same conditions, the efficiency increased to 8.68 kg m^{-3}. This last-mentioned value is more comparable with the one obtained in the hydroponic condition of the present study, since under both conditions, most of the water consumption is due to transpiration, to the detriment of evaporation, which tends to zero. In this context, it can be inferred that the WUE observed in the present study, up to ECsol of 5.18 dS m^{-1} (10.83 kg m^{-3}), exceeds that obtained by LÓPEZ-LÓPEZ et al. (2015). When comparing the data mentioned above with those of *C. chinense* peppers, the WUE of the present study can be considered higher or within the expected magnitude.

In terms of water conservation, the ‘brackish water’ input can provide the advantage of increasing the WUE when the crop does not loose production so drastically and/or when water consumption is low but without much impact on production. This has been verified up to a certain limit of water salinity for bell pepper (SANTOS et al., 2018), basil (BIONE et al., 2014), and coriander (SILVA et al., 2018). For ‘Biquinho’ pepper, WUE remained constant until ECsol of 5.18 dS m^{-1}. Thus, the use of brackish water in a hydroponic system represents, by itself, a way of reducing the pressure on freshwater (low salinity), besides representing the possibility of use in many situations when it is the only available source of water.

CONCLUSION

The maximum estimated water consumption throughout the 120 days after transplanting was 275.66 L plant^{-1} for a nutrient solution salinity of 4.11 dS m^{-1}. The highest daily water consumption was 5.88 L per plant (based on the ten-day interval) during the period 111-120 days after transplanting, with nutrient solution salinity of 4.58 dS m^{-1}. The mean daily water consumption in the interval of 10 days before or after has a high correlation with corresponding shoot dry mass. The salinity of the nutrient solution, biomass production and evapotranspiration are factors that influence the water consumption of 'Biquinho' pepper in a hydroponic system. The water use efficiency of 'Biquinho' pepper cultivated in the NFT hydroponics was 10.84 kg m^{-3} up to nutrient solution salinity of 5.18 dS m^{-1}.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare that they have no competing financial interests or personal relationships that could have influenced the study reported in this paper.

AUTHORS' CONTRIBUTIONS

All authors contributed equally to the conception and writing of the manuscript. All authors critically reviewed the manuscript and approved the final draft.

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