

EFFICIENCY IN WATER USE AND YIELD OF OKRA (*Abelmoschus esculentus*) IN RESPONSE TO DIFFERENT LEVELS OF IRRIGATION

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ABSTRACT

The objective of this work was to determine the irrigation levels that result in the maximum productivity and efficient use of water for the cultivation of okra. The experiment had five irrigation levels (25, 50, 75, 100 and 125% of crop evapotranspiration-ET_c) and a control plot that did not receive irrigation. The experimental design was in randomized blocks, with four replications. Irrigations were applied through a drip system and for irrigation management, the FAO Penman-Monteith standard method was used to estimate the reference evapotranspiration, and crop evapotranspiration was obtained through a constant water table lysimeter installed in the area experimental. The productivity was obtained considering the production of the useful area of each plot with subsequent conversion to kg.ha⁻¹. The efficiency of water use was determined by dividing the amount produced in kg of fruits per millimeter of water applied in okra culture. The application of different irrigation levels influenced in a significant way the variables analyzed in this experiment.

Keywords: Water economy; irrigation management; horticulture

EFICIÊNCIA NO USO DA ÁGUA E PRODUÇÃO DE QUIABO (*Abelmoschus esculentus*) EM RESPOSTA A DIFERENTES NÍVEIS DE IRRIGAÇÃO

RESUMO

O objetivo do presente estudo foi avaliar a produção de quiabo em diferentes níveis de irrigação, na região Nordeste do estado de Sergipe. O experimento teve cinco níveis de irrigação (25, 50,

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75, 100 e 125% da evapotranspiração-ETc) e uma parcela de controle que não recebeu irrigação. O delineamento experimental foi em blocos casualizados, com quatro repetições. As irrigações foram aplicadas através de um sistema de gotejamento, e para o manejo da irrigação, o método padrão da FAO Penman-Monteith foi utilizado na estimativa da evapotranspiração de referência e a evapotranspiração da cultura foi obtida através de um lisímetro de lençol freático constante instalado na área experimental. A produtividade foi obtida considerando a produção da área útil de cada parcela com subsequente conversão em kg. ha⁻¹. A eficiência de uso da água foi determinada pela divisão da quantidade produzida em kg de frutos por milímetro de água aplicada em cultura de quiabo. A aplicação de diferentes níveis de irrigação influenciou de forma significativa as variáveis analisadas neste experimento.

Keywords: Economia da água; manejo da irrigação; horticultura

INTRODUCTION

The okra (*Abelmoschus esculentus* L.) is a popular vegetable with high nutritional value, great acceptance in the market and belongs to the Malvaceae family. It is cultivated mainly in tropical regions and it has fast cycle and resistance to some pests. The small producers are the main responsible for much of the production of this vegetable. As a result of the increasing consumer preference, there has been a significant expansion of the okra in Brazil, especially in the states of Rio de Janeiro, São Paulo and Sergipe (CAVALCANTE et al., 2010; PAES et al., 2012).

Nowadays, the sector that consumes the most water in Brazil is agriculture, and due to the scarcity of this resource, it is necessary to manage irrigation rationally and take care to the implementation of irrigation systems, so they can work more efficiently, reducing waste in irrigated agriculture (Vieira, 2012). Through the efficient irrigation use, irrigated crops do not suffer water stress, improving their productive characteristics (Inman-Bamber and Smith, 2005). The efficiency in the use of water is given by the quotient between the productivity of a crop and the amount of water applied throughout its cycle (Pereira et al., 2002).

To manage efficiently the irrigation farmers should carried out techniques that apply water to crops based on crop coefficients that correspond to the actual water requirements demanded by the growing conditions (Gomes et al., 2010).

The purpose of this work was to evaluate the efficiency in water use and productivity of okra culture by applying different water depths as a function of crop evapotranspiration.

MATERIALS AND METHODS

This work was carried out at the Experimental Station of the Agronomic Engineering Department, Federal University of Sergipe - UFS, located in the central portion of the physiographic region of Sergipe State, 15 km from Aracaju, at the geographic coordinates of 10° 55' 27" south latitude and 37° 12' 0" west longitude, with an altitude of 46 meters. The local climate according to Köppen's classification is As type, which is tropical rainy with dry summer and 1200 mm annually of rainfall, concentrated in the months of April to September.

The local soil is Red Yellow Argisol Distrophic, with textural B horizon, according to Embrapa (2013), with the following chemical characteristics in the 0-0.20 m layer: pH (H₂O) 5.9; 10.7 mg dm⁻³ of P (Mehlich 1); 29 mg dm⁻³ K; 1.41 cmolc dm⁻³ Ca; 1.12 cmol dm⁻³ Mg; 0.0 cmolc dm⁻³ Al; 7.10 mg dm⁻³ Na (Mehlich 1).

The experimental design was in randomized blocks, with six treatments and four replications; the experimental unit consisted of a seven meter long plant line containing twenty three plants spaced 1.0 x 0.3 m and only twenty-one plants were evaluated due to the elimination of the border. The treatments consisted of the application of six

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irrigation water depths (0, 25, 50, 75, 100 and 125% of crop evapotranspiration).

The sowing was done manually, on fifteenth day of March of 2017, and three seeds were distributed per hole. The hole were opened manually with the aid of a hoe. The fertilization was carried out according to the indication for okra culture in the state of Sergipe and based on results of soil analysis. The weeds were controlled throughout the experiment by manual weeding.

The irrigation management was carried out based on crop and reference evapotranspiration, follow by irrigation time

calculated in a spreadsheet using Kc values at the different stages of the okra crop presented by Farias (2016) for the region of São Cristóvão, SE. The meteorological data for the determination of the reference evapotranspiration were obtained through Meteorological Stations of the National Institute of Meteorology (INMET), located in Aracaju - SE.

For the estimation of reference evapotranspiration - ETo in the daily scale, the Penman-Monteith model adapted by Allen et al. (1989), given by Equation 1, was used.

$$ET_o = \frac{0,4082\Delta(R_n - G) + \gamma^* \frac{900}{T + 273} u_2(e_s - e_a)}{\Delta + \gamma^*(1 + 0,34 u_2)} \quad (1)$$

where: ETo - reference evapotranspiration (mm d⁻¹); Δ - slope of the saturation vapor pressure curve (kPa ° C⁻¹); γ* - psychrometric constant = 0.063 kPa ° C⁻¹; R_n - surface radiation balance (MJ m⁻² d⁻¹); G - heat flow in soil (MJ m⁻² d⁻¹); T - average air temperature (° C); U₂ - wind speed measured at 2 meters height (m s⁻¹); e_s - vapor saturation pressure (kPa); and e_a - steam partial pressure (kPa); (And s - and a) - vapor saturation deficit (kPa).

For the calculation of crop evapotranspiration, Equation 2 was used:

$$ET_c = ET_o * K_c \quad (2)$$

where: K_c - crop coefficient; ET_c - crop evapotranspiration (mm); ET_o - reference evapotranspiration.

The water depth (Wd) applied in each treatment was determined by Equation 3:

$$Wd = \left(\frac{ET_c}{Ef} \right) - P \quad (3)$$

where: ET_c = crop evapotranspiration (mm); Wd = water depth applied in each plot (mm); P = Precipitation in the period (mm); Ef = Irrigation system efficiency.

For the irrigation, a gravity irrigation system was used, supplied by a water tank of 1000 L, the irrigation hose working with self-compensating drippers, with a flow rate of approximately 2 L.h⁻¹, and each plant had one dripper.

The irrigation schedule was fixed, that is, the irrigation was performed every day, varying the water depth applied as a function of the crop

evapotranspiration, except periods that had precipitations. The control of the irrigation time and the applied water depth was performed manually, through individual records for each treatment.

The first harvest occurred at 52 days after sowing, the followings harvested crops were each three day interval, with a total of six harvested along the crop cycle. Thus, the variables: Yield (Y) and Water use efficiency (WUE), were analyzed in each harvest.

The productivity was obtained considering the production of the useful area of each plot with subsequent conversion to kg ha⁻¹.

The results were submitted to the analysis of variance, with effects ranging, according to their significance, the means compared by the F and Tukey tests at the 5% probability level, using the ASSISTAT statistical program (Silva & Azevedo, 2002). The choice of the regression model was made based on the model of greater degree significant by the test F.

RESULTS AND DISCUSSION

During the experiment the average temperature was 28° C and the average relative humidity was 66.5%. The accumulated precipitation was 456.8 mm, so that even the smallest water depth could present positive

results.

The precipitation values observed during the cultivation period in the field can be seen in Figure 1, and the highest precipitation was observed on nineteenth day May of 2017, with a value of 130.8 mm.

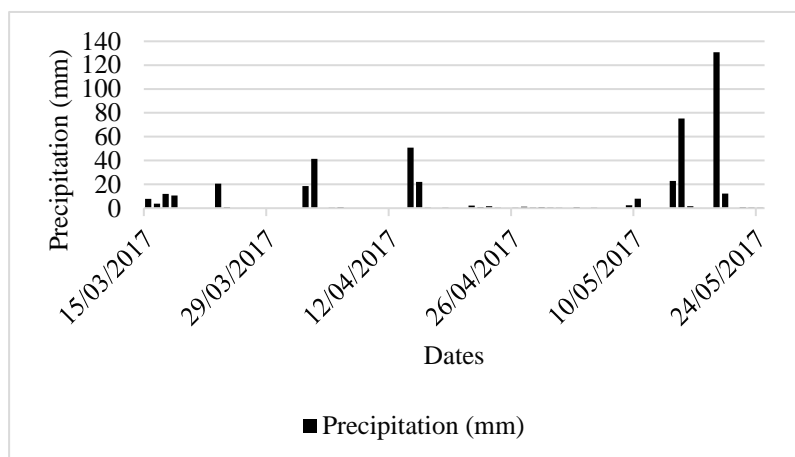


Figure 1. Daily precipitation in mm, during the experimental period. São Cristóvão, SE, 2017.

From the analysis of variance, it was observed that the Water use efficiency (WUE) and Yield (Y) were significantly

influenced by the different irrigation depths, by the F test ($p < 0.01$), as can be seen in Table 1.

Table 1. Summary of the variance analysis for the Yield (Y) and Water Use Efficiency (WUE) as a function of the irrigation depths in okra culture in São Cristóvão, SE, 2017.

SV	GL	Average Squares	
		WUE	Y
Levels	3	623.80 **	231.361 **
Blocks	5	9.26	2.6871
Error	15	6.6	1.82403
Mean	-	18.95	10.375
Cv (%)	-	13.58	13.02

The water depth that provided the highest yield value (0.6325 kg plant⁻¹; 21.09 t ha⁻¹) was 132.2 mm (125% ETc) and the lowest (0.0775

kg plant⁻¹; 2.58 t ha⁻¹) a of 0 mm, equivalent to 0% of ETc, as we can seen in Table 2, as well as, the differences among the treatments.

Table 2. Mean of Yield (Y) and Water Use Efficiency (WUE) as a function of the irrigation depths in okra culture in São Cristóvão, SE, 2017.

Treatments	Yield (t.ha ⁻¹)	WUE (Kg.ha ⁻¹ .mm ⁻¹)
0% ETc	2,583 d	5,65 d
25% ETc	4,168 cd	8,71 cd
50% ETc	6,918 bc	13,67 bc

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75% ETc	9,248 b	17,33 b
100% ETc	18,25 a	32,51 a
125% ETc	21,09 a	35,80 a
CV (%)	13,02	13,58

Mean followed by the same letter in a row not differ statically among then by the test Scott-Knott to 5%.

For this variable, linear increases were observed as a function of the increase of the applied water depth (Figure 2). The lower productivity can be associated with the water stress caused in plants, because the plants when

they suffer water déficit this stress tend to close their stomata and thus reduce the photosynthetic rate, causing them not to produce efficiently well, causing a reduction in the productive characteristics of the fruits.

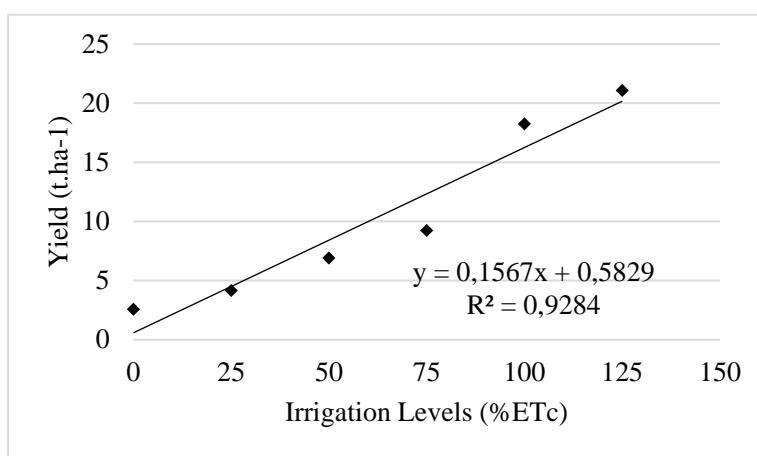


Figure 2. Yield, as a function of the irrigation levels in okra culture in São Cristóvão, SE, 2017.

Andrade Júnior et al. (2002), working with cowpea cv. Gurguéia under different irrigation depths, verified that the increase of the irrigation depth from a great point caused a decrease of the production. While in the present work, the water depth above 100% of ETc was the one that obtained the highest productivity, in contrast to the experiment previously mentioned.

The water depth that provided the highest Water Use Efficiency (WUE) ($35.80 \text{ kg.ha}^{-1}.\text{mm}^{-1}$) was 132.2 mm (125% of ETc) and the lowest ($5.65 \text{ kg.ha}^{-1}.\text{mm}^{-1}$) a of 0 mm, equivalent to 0% of ETc. For this variable,

linear increases were observed as a function of the increase of the applied water depth (Figure 3). The greater WUE, is associated with greater productivity and the greater availability of water for the plants, allowing the plants to extract better the soil solution, thus to take advantage of the nutrients, besides being able to carry out the photosynthesis without impediments. Dagdelen et al. (2009) observed that there was an increase in the WUE when the 25% of the water depth was applied, reaching 1.46 kg m^{-3} , while in irrigation with 100% ETc the WUE was 0.81 kg m^{-3} .

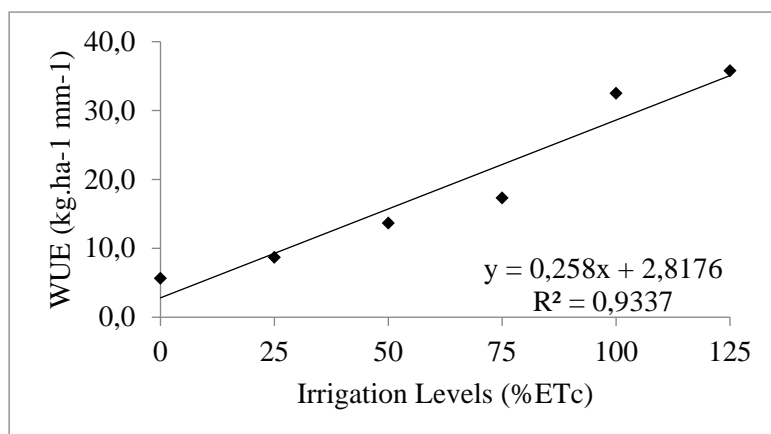


Figure 3. Water Use Efficiency (WUE), as a function of the irrigation levels in okra culture in São Cristóvão, SE, 2017.

Singh et al. (2010), working with water deficit in cotton in semi-arid region, they found a significant effect in relation to the WUE for the different irrigation depths studied, where the 100% ETc irrigation water depth obtained a value of 0.54 kg.m⁻³, and the 50% ETc water depth obtained a value of 0.64 kg.m⁻³.

CONCLUSION

The results showed that the Water use efficiency (WUE) and Yield (Y) were influenced by the different irrigation depths. The water depth that farmers can use for okra crop is 100% of ETc that provide a yield no different from 125% of ETc.

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