CULTURE OF THE OKRA (*Abelmoschus esculentus*) SUBMITTED TO DIFFERENT IRRIGATION LEVELS

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ABSTRACT: The objective of the present study was to evaluate the production of okra under different levels of irrigation, in the Northeast region of Brazil, Sergipe state. The experiment had five irrigation levels (25, 50, 75, 100 and 125% of crop evapotranspiration-ETc) and a control plot that did not receive irrigation. The experimental design was in randomized blocks, with four replications. Irrigations were applied via 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 following characteristics were evaluated: average fruit diameter, average fruit length, yield per plant and productivity. The application of different levels of irrigation influenced in a significant way the variables analyzed in this experiment.

KEYWORDS: Water economy; horticulture; drip irrigation

CULTURA DO QUIABO (*Abelmoschus esculentus*) SUBMETIDO 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, 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

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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. Foram avaliadas as seguintes características: diâmetro médio do fruto, comprimento médio do fruto, produção por planta e produtividade. A aplicação de diferentes níveis de irrigação influenciou de forma significativa as variáveis analisadas neste experimento.

PALAVRAS-CHAVE: Economia da água; horticultura; irrigação por gotejamento

INTRODUCTION

The okra (Abelmoschus esculentus L.) is a popular vegetable of high nutritional value, with great acceptance in the market, belongs to the family Malvácea, and is cultivated mainly in tropical regions, has fast cycle and resistance to some pests. Small producers are mainly responsible for a large part of the production of this vegetable (Paes et al., 2012; Galati, 2010).

In Brazil, the culture found favorable conditions for its development, especially in states that have high temperatures for most of the year. Due to the growing consumer preference, there has been an expressive expansion of okra throughout Brazil, especially in the states of Rio de Janeiro, São Paulo e Sergipe (Cavalcante et al., 2010).

In recent years, competition for water resources has become increasingly serious, requiring the continuous improvement of irrigation practices in the production of vegetables such as okra.

The inefficient use of irrigation water causes significant problems in irrigated areas, mainly due to non-uniform distribution of water to crops, causing man-induced salinization, desertification and degradation of water quality (Levidow et al., 2014).

For irrigation management to be performed efficiently, water slides based on crop coefficients are used, consistent with the actual water requirements demanded by the growing conditions (Gomes et al., 2010).

The okra has a high consumption of water, even presenting significant tolerance to drought (Ghannad et al., 2014). The plant forms a deeply penetrating root with complementary dense and superficial roots that reach all directions in the 0.45 m soil (Adekiya et al., 2017)

The objective of this work was to evaluate the productive characteristics in the okra culture through the application of different irrigation slides as a function of crop evapotranspiration.

MATERIAL AND METHODS

This work was carried out at the Campus Rural Experimental Station of the Agronomic Engineering Department, Federal University of Sergipe - UFS, located in the central portion of the physiographic region of Sergipe State Coast, 15 km from Aracaju, at the geographic coordinates of 10º 55 ' 27 "south latitude and 37 ° 12 '01" west longitude, with an altitude of 46 meters. The local climate according to Köppen's classification is As type, ie rainy tropical with dry summer and rainfall around 1200 mm annually, with rainfall concentrated in the months of April to September.

The local soil is a Dystrophic Red Yellow Argisol, with textural B horizon, with the following chemical characteristics in the 0-0,20 m: pH (H_2O) 5,9; 10,7 mg dm^{-3} de P (Mehlich 1); 29 mg dm^{-3} de K; 1,41 cmolc dm^{-3} de Ca; 1,12 cmolc dm^{-3} de Mg; 0,0 cmolc dm^{-3} de Al; 7,10 mg dm^{-3} de 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 edges. The treatments consisted of the application of six irrigation slides (0, 25, 50, 75, 100 and 125% of crop evapotranspiration).

The seeding was done manually, on 03/15/2017, and three seeds were distributed per pit. The pits were opened manually with the aid of a hoe. Fertilization was carried out according to the indication for okra culture in the state of Sergipe and based on soil analysis results. The weeds were controlled throughout the experiment by manual weeding.

Irrigation management was performed based on crop and reference evapotranspiration, and irrigation times were calculated in a spreadsheet using Kc values at the different stages of the crop presented by Farias et al., (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 - on the daily scale, the Penman-Monteith model adapted by Allen et al. (1989), given by Equation 1:

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

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); U_2 - wind speed measured at 2 meters height (m s^{-1}); es - vapor saturation pressure (kPa); ea - steam partial pressure (kPa); (es - ea) - vapor saturation deficit (kPa).

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

$$ETc = ETo * Kc \qquad (2)$$

Where: Kc – crop coefficient; ETc - crop evapotranspiration (mm); ETo – reference evapotranspiration.

The irrigation level (Li) applied in each treatment was determined by Equation 3:

$$Li = \left(\frac{ETc}{Ef}\right) - P \qquad (3)$$

Where: ETc = crop evapotranspiration (mm); Li = Level applied to each plot(mm); P = Precipitation in the period (mm); $Ef =$ Efficiency of the Irrigation System.

For irrigation, a gravity irrigation system was used, provided by a 1000 L water tank, the drip hoses operating with compensating drippers, with a flow rate of approximately 2 $L.h^{-1}$, one dripper per plant.

The adopted irrigation shift was fixed, that is, the irrigation was performed every day, varying the blade applied as a function of the evapotranspiration of the crop, except periods that had precipitations. The control of the irrigation time and the applied blade was performed manually, through individual records for each treatment.

The first harvest was carried out at 52 days after planting, and the others harvest was at a three day interval, with six crops being harvested along the crop cycle. Thus, the variables: mean fruit diameter, average fruit length, yield per plant and yield were analyzed at each harvest.

The diameter of the fruits of the okra was evaluated considering the average of a representative sample of fruits per plant and were measured with the aid of a digital pachymeter.

The average yield per plant was obtained by collecting the fruits per plant and later weighing, using average values according to the number of harvests. The values were converted in kg.

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

The average length of the fruits was obtained by measuring, using a ruler graduated in centimeters, all fruits harvested in each experimental plot.

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

The mathematical model that best fit the fruit length data was linear, with a significant effect ($p < 0.01$) and a determination coefficient of 0.936. Analyzing the fruit length variation as a function of the irrigation blades (Figure 2A), it is noted that as the irrigation blade increases, the fruits tend to increase their length. The data showed that, when using an irrigation blade up to 125% of ETc, the fruits are suitable for commercialization, according to the commercial classification of CEAGESP (2001).

The level yielding the largest fruit length (13.2 cm) was 132.2 mm (equivalent to 125% of the ETc). This fact can be explained by the increase in soil moisture, leaving the necessary nutrients available to the plants, allowing the plants to grow vegetatively better (El-sahookie et al., 2009). Increasing the vegetative growth rate of plants also increases the amount of hormones produced, causing fruit length to increase (Hussein et al., 2011).

Sezen et al (2011), testing irrigation levels in the sweet pepper crop, realized that the highest lengths of drip irrigated chili fruits are obtained in treatments that receive the highest water levels. Already Costa (2014), working with irrigation levels in the okra culture, found that water levels applied above 95.9% of the Evaporation of the Class A Tank (ECA), causes a decrease in fruit length. This fact that contests with the present work.

Regarding the diameter of the fruit (Figure 2B), the mathematical model that best fit the data was also the linear one, with a significant effect ($p < 0.05$) and a determination coefficient of 0.9778. It is observed that the highest value obtained was of 17.77 mm with the irrigation level of 132.2 mm (125% of ETc) and the lowest value of 12.5 mm was obtained with the irrigation level equivalent to 0, 0 mm (0% of ETc). Bertino (2014) attributes lower values of fruit diameters, the lower availability of water for the crop. Ferreira (2014), evaluating the productive characteristics of the okra submitted to irrigation levels and salinity of the irrigation water, observed that the vegetative characteristics of the okra were highlighted by the irrigation depth of 125% of ETc with the saline concentration of 3,5 $dS.m^{-1}$.

For the variable production per plant and productivity (Figure 2C, Figure 2D), there were linear increases due to the increase of the applied levels, with significant effect ($p <0.01$) and determination coefficients of 0.9284. The level that provided the highest value of the evaluated characteristics (0.6325 kg $plant^{-1}$; 21085 $t.ha^{-1}$) was 132.2 mm (125% of ETc) and the lowest (0.0775 kg. $Plant^{-1}$; 2582 t ha^{-1}), a of 0 mm, equivalent to 0% of ETc. Anant et al. (2009), working with irrigation intervals for the okra culture, noticed that there are differences among treatments applied, and this is due to the behavior of the stomata that are affected by the irrigation intervals, especially in the upper layer of sheets. This fact can be what happened in the present work on the 0% slide of ETc, where a water stress was generated in the plants, causing a lower photosynthetic rate and consequent lower fruit production per plant.

The lower production occurred in the treatments submitted to the applications of smaller irrigation slides, is explained by the condition of water deficiency of the plants, in this condition, the plants use the mechanism of closure of the stomata, so that water loss is restricted, In order to reduce the accumulation of assimilated photos, the yield of fruits in this crop (Taiz & Zeiger., 2009). This fact was also confirmed by Silva et al. (2013), who noticed a decrease in tomato production when irrigated with slides lower than the requirement of the crop, and explain this event to the water deficit, which directly influenced the photosynthetic processes of the plant and, consequently, the production.

CONCLUSIONS

1. All the analyzed variables presented a statistical difference in relation to the irrigation levels, and the irrigation level of 132.2 mm (125% of ETc) provided a maximum productivity of 21.085 $t.ha^{-1}$

BIBLIOGRAPHY

ALLEN, R.G.; PEREIRA, L.S.; RAES, D.; SMITH, M. Crop evapotranspiration: guidelines for computing crop water requirements. Rome: FAO, 1998. 301p. (FAO Irrigation and Drainage, Paper 56).

Adekiya, A. O., T. M. Agbede, C. M. Aboyeji, and O. Dunsin. 2017. “Response of Okra (Abelmoschus Esculentus (L.) Moench) and Soil Properties to Different Mulch Materials in Different Cropping Seasons.” Scientia Horticulturae 217: 209–16.

ANANT. B, SINGH K.P, ASHUTOSH. R, AJAY M.R . Physiological and yield Response of okra (Abelmoschus esculentus L.) to irrigation scheduling and organic mulching. Indian J. Agric. Sci. 79(1):813-815. 2009.

BERTINO, A. M. P. Produção do quiabeiro sob cultivo irrigado, proteção do solo e fertilização organomineral. Catolé do Rocha – PB, 2014. 21p. Trabalho de Conclusão de Curso (Licenciado em Ciências Agrárias). Uepb - Centro de Ciências Humanas e Agrárias.

CAVALCANTE, L. F. et al. Teores foliares de macronutrientes em quiabeiro cultivado sob diferentes fontes e níveis de matéria orgânica. 2010, Seminário de Ciências agrárias, Londrina, PR. Anais. v. 31, n. 1, p. 19-28, jan.-mar., 2010.

CEAGESP - Centro de Qualidade em Horticultura. Classificação do quiabo (Abelmoschus esculentus Moench). 2p. 2001.

COSTA, R.A. Cultura do quiabo submetida a lâminas de irrigação por gotejamento em função da evaporação em Tanque Classe A. Botucatu- SP, 2014. 53p. Tese (Doutorado em Irrigação e Drenagem). Unesp – Faculdade de Ciências Agronômicas – FCA.

EL-SAHOOKIE M.M, ALFALAHI A.O, ALMEHEMIDI A.F . Crop and soil management and breeding for drought tolerance. Iraq. J. Agric. Sci. 40(2):1-28. 2009.

FARIAS, D. B. S.; LUCAS, A. A. T. ; NASCIMENTO, L. F. A. ; SÁ FILHO, J. C. F. ; LIMA, I. S. . Construction, installation and calibration of water table lisymeter for conditions of state sergipe. In: CRHIAM-INOVAGRI International Meeting 'Leading Technologies for Water Management, 2016, Concepción. Proceedings - CRHIAM-INOVAGRI International Meeting, 2016. p. 811-817.

GALATI, V. C. Crescimento e acúmulo de nutrientes em quiabeiro ‘Santa Cruz 47’. Dissertação. Jaboticabal, 2010. Dissertação (Mestrado em Agronomia Produção Vegetal) UNESP.

HUSSEIN H.A, METWALLY A.K, FARGHULY K.A, BAHA M.A. Effect of Irrigation Interval (water stree) on Vegetative growth and Yield in two Geno types of okra. Austr. J. Basic Appl. Sci. 5(12):3024-3032. 2011.

PAES, H. M. F.; ESTEVES, B. dos S.; SOUSA, E. F, de. Determinação da demanda hídrica do quiabeiro em Campos dos Goytacazes, RJ. Revista Ciência Agronômica, Fortaleza, v. 43, n. 2, p. 256-261, 2012.

SILVA, J. M.; FERREIRA, R. S.; MELO, A. S.; SUASSUNA, J. F.; DUTRA, A. F.; GOMES, J. P. Cultivo do tomateiro em ambiente protegido sob diferentes taxas de reposição da evapotranspiração. Revista Brasileira de Engenharia Agrícola e Ambiental, v. 17, p. 40–46, 2013.

SILVA, F. de A. S.; AZEVEDO, C. A. V. Versão do programa computacional Assistat para o sistema operacional Windows. Revista Brasileira de Produtos Agroindustriais, Campina Grande, v. 4, p. 71-78, 2002.

TAIZ, L.; ZEIGER, E. Fisiologia vegetal. 4. ed. Porto Alegre: Artmed, 2009. 819 p.

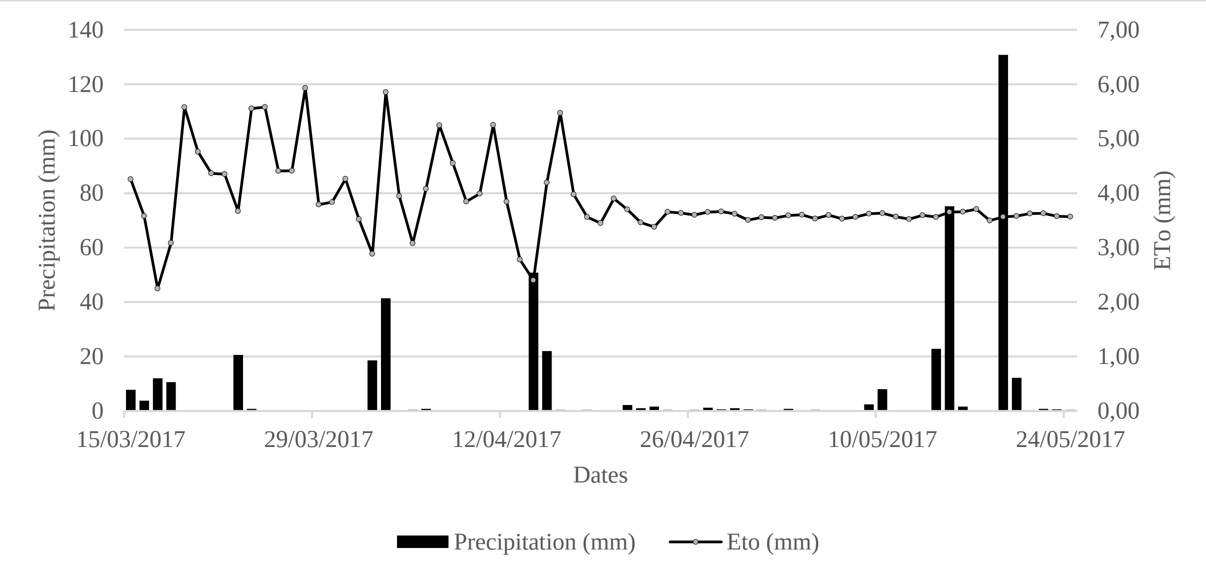

Figure 1. Daily precipitation and estimation of reference evapotranspiration (ETo), in mm, during the experimental period. São Cristóvão, SE, 2017.

Table 1. Total water levels applied in each treatment during the experiment

Treatments (%ETc)	Levels	Levels + precipitation
	(mm)	
0	0,0	456,8
25	21,6	478,4
50	49,3	506,1
75	76,9	533,7
100	104,6	561,4
125	132,2	589,0

Table 2. The variance analysis for fruit length (CF), fruit diameter (DF), average yield per plant (PMP) and yield (PDTV) as a function of irrigation levels in okra culture in São Cristóvão, SE, 2017.

		QUADRADOS MÉDIOS			
FV	GL	CF	DF	PMP	PDTV
Levels	3	13,53**	0,111*	0,208**	231,361**
Block	5	0,752	0,001	0,00242	2,6871
Error	15	1,050	0,00514	0,00164	1,82403
Average	-	11,22	1,52	0,31125	10,375
Cv (%)	-	5,42	12,76	13,02	13,02

** Significant at 1% probability, by F test (p <0.01); * Significant at 5% probability, by the F test (p <0.05)

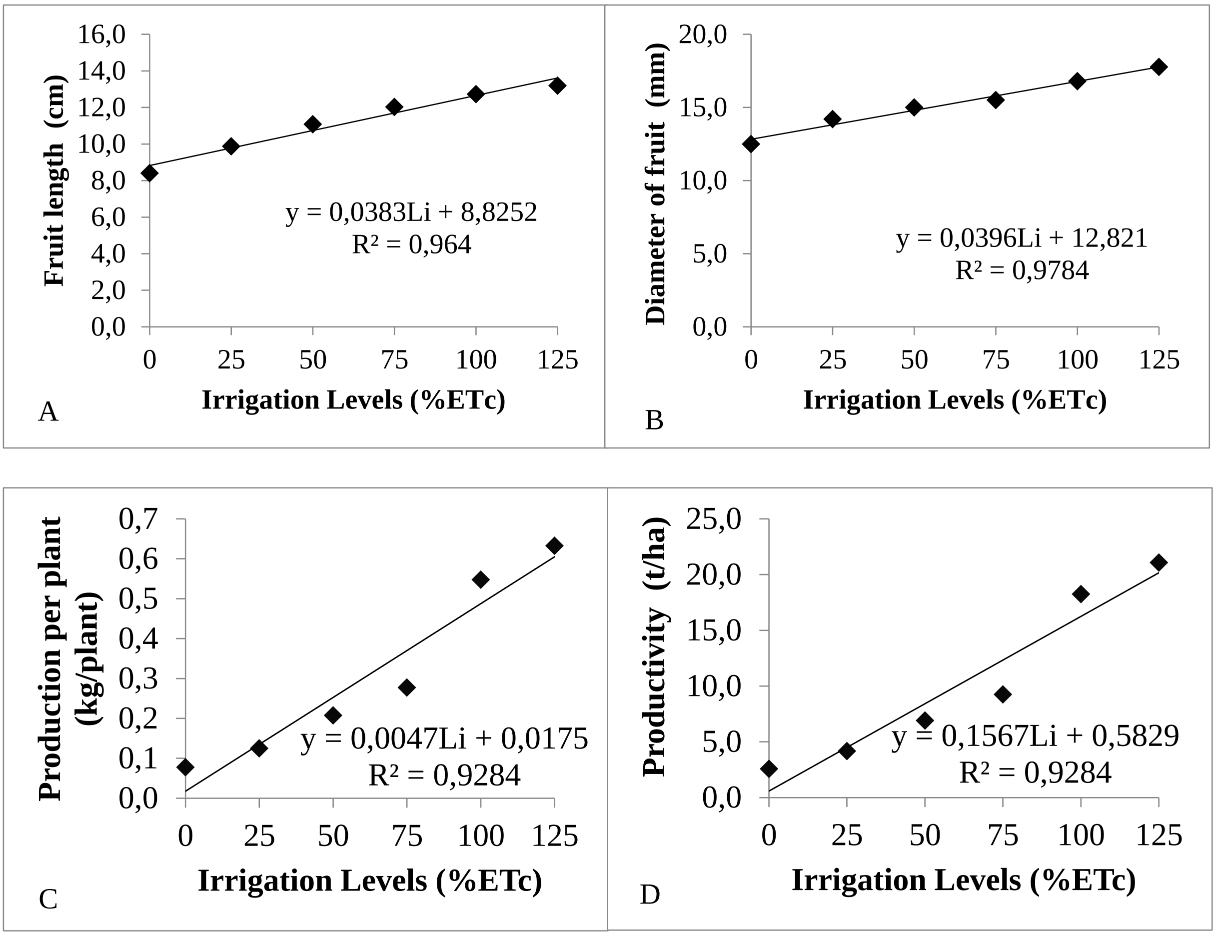

Figure 2. Fruit length (A); Diameter of fruit (B); Production per plant (C) and Productivity (D), as a function of the irrigation levels in okra culture in São Cristóvão, SE, 2017.