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EFFECT OF DIFFERENT BORON DOSES ON YIELD IRRIGATED OKRA WITH PHOTOVOLTAIC PUMPING SYSTEM

EFEITO DE DIFERENTES DOSES DE BORO NA PRODUTIVIDADE DO QUIABO COM SISTEMA DE BOMBEAMENTO FOTOVOLTAICO

EFECTO DE DIFERENTES DOSIS DE BORO EN LA PRODUCTIVIDAD DE QUIMBOMBÓ CON EL SISTEMA DE BOMBEO FOTOVOLTAICO

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ABSTRACT
Crop production is directly related to adequate nutritional management to achieve higher productivity. The goal of this work was to evaluate the yield of okra, irrigated with microirrigation, when subjected to different doses of Boron in the municipality of Iporá, Goiás, Brazil. The field experiment was conducted from April to July 2021, in a Dystrophic Litholic soil, in the experimental field of School Farm of Instituto Federal Goiano. The experimental design was in randomized blocks with six treatments of foliar sprays: 5 doses of boron (100, 200, 300, 400, 500 mL ha^{-1}) and the control, with 8 replications each. The irrigation system was powered by a pumping system using photovoltaic solar energy. To evaluate the development of the culture, fruit weight, fruit diameter, number of fruits and fruit length were measured. Boron doses had no significant effect on the yield of irrigated okra.

KEYWORDS: Renewable energy. Solar energy. Water management. Drip irrigation. Brazilian Savanna.

RESUMO
A produção agrícola está diretamente relacionada ao manejo nutricional adequado para alcançar maiores produtividades. O objetivo deste trabalho foi avaliar a produtividade do quiabo, irrigado com microirrigação, quando submetido a diferentes doses de Boro no município de Iporá, Goiás, Brasil. O experimento de campo foi conduzido de abril a julho de 2021, em solo Neossolo Litólico distrófico, no campo experimental da Fazenda Escola do Instituto Federal Goiano. O delineamento experimental foi em blocos casualizados com seis tratamentos de pulverizações foliares: 5 doses de boro (100, 200, 300, 400, 500 mL ha^{-1}) e a testemunha, com 8 repetições cada. O sistema de irrigação foi acionado por um sistema de bombeamento utilizando energia solar fotovoltaica. Para avaliar o desenvolvimento da cultura, foram medidos a massa do fruto, o diâmetro do fruto, o número de frutos e o comprimento do fruto. As doses de boro não tiveram efeito significativo sobre a produtividade do quiabo irrigado.

PALAVRAS-CHAVE: Energias renováveis. Energia solar. Manejo da água. Irrigação por gotejamento. Cerrado.

RESUMEN
La producción agrícola está directamente relacionada con un manejo nutricional adecuado para lograr una mayor productividad. El objetivo de este trabajo fue evaluar la productividad de la okra, regada con microirrigación, cuando se sometió a diferentes dosis de Boro en el municipio de Iporá, Goiás,

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Brasil. El experimento de campo se realizó de abril a julio de 2021, en suelo distrófico litólico neosol, en el campo experimental de la Fazenda Escola do Instituto Federal Goiano. El diseño experimental fue aleatorizado con seis tratamientos de pulverización foliar: 5 dosis de boro (100, 200, 300, 400, 500 mL ha-1) y el control, con 8 replicaciones cada una. El sistema de riego fue activado por un sistema de bombeo que utiliza energía solar fotovoltaica. Para evaluar el desarrollo del cultivo, se midió la masa del fruto, el diámetro del fruto, el número de frutos y la longitud del fruto. Las dosis de boro no tuvieron un efecto significativo sobre la productividad de la okra irrigada.

PALABRAS CLAVE: Energías renovables. Energía solar. Gestión del agua. Riego por goteo. Matorral.

INTRODUCTION

The culture of okra (*Abelmoschus esculentus* (L.) Moench) is one of the most traditional vegetables in the cuisine of the State of Goiás, Brazil. Okra is a popular food of high nutritional value, with great acceptance in the market, with family farmers being most responsible for its production. Due to the growing preference for consumers, there has been a significant expansion of okra culture throughout Brazil (CAVALCANTE, 2010). Despite of their importance, foliar application of boron on this economically valuable crop received little attention so far (MALIHA et al., 2022). With the growth in the crop planting rate, the need arises for fertilization that includes micronutrients, such as boron, as it plays an important role in plants, reflecting on their growth and production. It is estimated that about 108 million hectares of Brazilian Savanna soils are deficient in boron (LOPES, 1984). The physiological function of boron differs from any other nutrient, it is associated with cell division, nucleic acid synthesis, carbohydrate metabolism and sugar transport across membranes (MENGEL; KIRBY, 1987).

The intensification of irrigation is a strategic move to increase the supply of products by increasing productivity, income and employment in rural areas (LIMA; FERREIRA; CHRISTOFIDIS, 1999). The implementation of irrigation in the crops guarantees the safety of producers in relation to the stability of productions without dependence on rain, mitigating losses due to dry periods (ARCE, 2018). The drip irrigation system has a higher application efficiency because it applies water to the root area of the crop, which reduces the wet soil surface exposed to the sun and consequently to evaporation loss and water consumption (BERNARDO, 2002). Places where the water supply is lower and regions where drought periods are prolonged this system is recommended (ESTEVES et al., 2012).

Family farming has high potential to boost sustainable production systems, since family management allows for activities that require greater care in the management of resources (ALTAFIN, 2007). To perform irrigation efficiently it is necessary to have water and energy, and among the difficulties encountered by family farming, are the availability of electric energy and its cost. Thus, the use of photovoltaic energy assumes great importance for its efficiency and cost savings. The use of solar matrix energies can contribute in a multifunctional way to local rural development, generating savings and income, reducing energy consumption from conventional sources and contributing, in a concrete way, to the sustainability of productive rural activities (CUNHA, 2009). Considering all the new ways of generating electricity, the use of solar energy has gradually emerged as an important alternative, economically viable, environmentally acceptable and suitable for isolated areas where the installation costs of conventional systems are relatively high.

The goal of this work was to evaluate the yield okra, irrigated with microirrigation, when subjected to different doses of Boron in the municipality of Iporá, Goiás, Brazil

MATERIAL AND METHODS

The experiment was carried out at the School Farm of Instituto Federal Goiano, Campus Iporá. The farm's soil is classified by Embrapa as Dystrophic Litholic Soil with a predominance of quartz gravel. According to the classification adapted (CARDOSO; MARCUZZO; BARROS, 2015) the climate of the region is Aw type, tropical climate, with two well-defined seasons: dry and rainy. The dry period lasts an average of 5 months, with an average annual temperature of 24°C, and an average annual rainfall of 1,613 mm. Climatic data during the experiment were obtained through a meteorological station (model WS-18, Plugfield) installed near the experimental area.

To carry out the experiment, the production of seedlings of Okra cultivar Santa Cruz, sown in plastic cups, the substrate used had a proportion of 1:1:1, cow dung, sand and commercial substrate (Figure 1a). They were placed in a nursery for 21 days, after which they were transplanted to the field (Figure 1b). Fertilization was carried out in the planting holes following the recommendation of the Soil Fertility Commission in Goiás (1988). The plants were arranged in 4 rows with 29 plants, with a spacing of 0.5 x 0.5 m.

Figure 1. Nursery containing cups with substrates for the growth of okra seedlings (left - Figure a). Transplantation of irrigated okra seedlings (Santa Cruz cultivar), with a drip irrigation system (right - Figure b).

For Irrigation, the drip system was used, with Netafim drip tapes, with a spacing between drippers of 0.5 m. After the installation of irrigation, the uniformity test of the drippers was performed, obtaining a uniformity of 96%. Irrigation management was based on the evapotranspiration of the crop, the daily irrigation depth calculated using an Electronic Spreadsheet, containing the Cultivation coefficient, at each stage of the crop, and the reference evapotranspiration that was obtained through the meteorological station. A daily irrigation schedule was adopted. The pumping system consisted of a motor pump set (Shurflo 2088) that was powered by a 150 Wp photovoltaic panel (Risen RSM36-6-150P) facing north with an inclination equal to the local latitude (16°).

The experimental design was in randomized blocks, with six treatments, five doses of foliar sprays boron plus the control (with zero dose), being applied in the leaf area, totaling 6 treatments. The doses used were 100, 200, 300, 400 and 500 mL ha^{-1} with 8 replications. The treatments were not applied in the borders, therefore only the plants of the two central lines received the treatments. Two foliar sprays were given after the blossoming and subsequently at one week interval.

Harvesting started 56 days after emergence and was done manually every 3 days. After harvesting, the fruits were taken to the laboratory where they were evaluated: fruit weight, fruit diameter, number of fruits and fruit length. The results were submitted to analysis of variance and the Tukey test was applied at 5% probability.

RESULTS AND DISCUSSION

Table 1 shows the summary of the analysis of variance for the evaluations of the fruits after harvest. None of the evaluated variables showed significant interaction with boron doses ($p<0.05$). Different results were found in the literature, in which most of the works study the use of foliar boron in conjunction with zinc.

Table 1. Summary of analysis of variance of the mean fruit weight (FW)- g, fruit diameter (FD)- cm, number of fruits (NF) and fruit length (FL)- cm, in irrigated okra submitted to different doses of boron.

		Mean square			
	DF	FW (g)	FD (cm)	FN	FL (cm)
Doses	5	12,73 ns	0,010 ns	0,38 ns	47,92 ns
Block	1	12,31 ns	0,022 ns	2,08 ns	38,54 ns
Replication	3	7,15 ns	0,005 ns	2,25 ns	57,18 ns
Residue	38	9,09	0,014	3,87	53,94
Total	47				
CV (%)		**19,44**	**9,05**	**56,90**	**59,08**
Mean		**15,51**	**1,30**	**3,46**	**12,43**

*Significant at the 5% probability level by the F test; ns – not significant; DF- degrees of freedom; CV - Coefficient of Variation.

Boron and zinc play an important role directly and indirectly in improving the yield and quality of okra production (JAHAN et al., 2020). The studies found in the literature have resulted in significant interactions between boron doses and the yield variables evaluated (JAHAN et al., 2020; MALIHA et al., 2022; RAHMAN et al., 2020). Table 2 shows the values of the Test of mean for the evaluated variables.

Table 2. Test of mean for the fruit weight (FW)- g, fruit diameter (FD)- cm, number of fruits (NF) and fruit length (FL)- cm, in irrigated okra submitted to different doses of boron.

Boron doses (mL ha^{-1})	FW (g)	FD (cm)	FN	FL (cm)
0	14.77 a	1.27 a	3.75 a	11.00 a
100	14.32 a	1.29 a	3.62 a	11.40 a
200	15.06 a	1.33 a	3.37 a	11.40 a
300	16.59 a	1.30 a	3.37 a	11.57 a
400	14.78 a	1.29 a	3.12 a	11.51 a
500	17.53 a	1.37 a	3.50 a	11.68 a

* Values followed by the same letter did not differ statistically, according to the Tukey test at 5% probability.

For all variables evaluated there was no significant difference between the means for the different doses of boron. However, the averages for the dose of 500 mL ha^{-1} of boron showed better performance for all variables, except for the number of fruits. Maliha et al., (2022) studying the effect of zinc and boron on growth and yield in two okra varieties found the highest result for all of the growth and yield parameters in mixture of 0.3% Zinc with 0.2% Boron. The authors study four treatment: T0 = Control, T1 = 0.2% Zinc, T2 = 0.3% Zinc, T3 (mixture) = 0.2% Zinc + 0.2% Boron and T4 (mixture) = 0.2% Zinc + 0.3% Boron. The authors also found the maximum results for fruift length (16.3 cm), fruit girth (2.1cm), fruit number (33.2) and single fruit weight (34.3 g) from those plots which were treated with T4.

Jahan et al., (2020) found significant variation for single fruit weight, fruit length, Fruit Diameter and Number of Fruits $Plant^{-1}$ as influenced by different Zn and B application. For all the parameters studied, the mixture with the highest concentrations of zinc and boron showed the best results.

Rahman et al., (2020) observed no significant variation among de different doses of boron in fruit girth. However, the best results of number of fruits per plant (18.51) and fruit length (16.83 cm) was found in the highest doses of boron (0.3 % Borax). There was no significant variation among the treatments in fruit girth of okra due to foliar application of borax.

Arya et al., (2021) evaluated different doses of boron under two types of irrigation, conventional and drip irrigation. The results of the study revealed that under drip irrigated condition,

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foliar application of KAU multi mix (Sampoorna, 0.5%) resulted in greater fruit length, fruit weight and fruit yield. However, under conventional irrigation, foliar application of micronutrients did not produce any yield advantage over treatments without foliar application.

CONCLUSION

Boron doses had no significant effect on the yield of irrigated okra with drip irrigation.

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