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RESEARCH ARTICLE

TREATED DOMESTIC EFFLUENT AND LEVELS OF BORON ON GROWTH AND FLOWERING OF SUNFLOWER

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ABSTRACT

The expansion of oilseed cultivation under semiarid conditions is related to the use of alternative water and efficient fertilization management. Thus, the aim of this study was to evaluate the growth and flowering of sunflower (EMBRAPA 122-V2000) irrigated with treated domestic effluent under different doses of boron (B). Hence, this study tested the application of five B doses (0 - control, 1.0, 2.0, 3.0 and 4.0 mg kg^{-1} applied as basal dose in the form of boric acid) in plants irrigated with two types of water (treated domestic effluent and public-supply water). These treatments were arranged in a completely randomized design, analyzed in a 5 x 2 factorial scheme, with three replicates, totaling 30 experimental units. Statistical analysis included analysis of variance and regression analysis for the quantitative factor and test of Tukey for the qualitative factor at 0.05 probability level. It was found that the interaction between boron doses and type of water had an influence on stem diameter in all stages of the cycle until flowering; the beginning of flowering, number of petals and capitulum internal diameter were not influenced by boron doses or types of water used in irrigation; however, the plants showed a maximum external diameter of the capitulum under the dose of 1 mg kg^{-1} of boron, applied as basal fertilization, regardless of the type of water used in irrigation.

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INTRODUCTION

The expansion of irrigated crops in arid and semiarid regions of the planet is evidently limited by water availability. Nobre *et al.* (2010) comment that urbanization, agricultural expansion, industrialization and environmental degradation contribute to the reduction of this water supply, in both quantity and quality. In terms of numbers, taking the Brazilian state of Paraíba as an example, it is observed a water potential of only 1,320 m^3 person^{-1} year^{-1}, a very low value that alerts for the imminent scarcity of drinking water, including for human supply (Santos *et al.*, 2006). One of the alternatives to increase water supply is through the use of treated domestic effluents in irrigation. In Latin America, for example, more than 500,000 ha are irrigated with domestic effluent, mostly without treatment, highlighting the Mexico City, where 108 m^3 s^{-1} are used for the irrigation of various crops. A large part of this volume (3.4 km^3 per year) does not receive any treatment (91.8%) and are used in 26 irrigation districts (Cavallini, 2002). Among other benefits, water reuse promotes greater water availability and allows the recycling of macro and micronutrients such as boron (B), for example. In studies on the B content in the domestic effluent, Sandri *et al.* (2006) observed mean content of 0.3 mg L^{-1}, a mean value that does not pose any restriction to its application in irrigation according to the Brazilian legislation (CONAMA, 2005), because the maximum limit recommended for Class-1 irrigation water is 0.5 mg L^{-1}. B is the micronutrient most required by the sunflower crop (Viana *et al.*, 2012), one of the species most susceptible to B deficiency, since absence of this nutrient limits its production (Krudnak *et al.*, 2013), because B plays an important role in flowering, pollen tube growth, fruiting processes and hormonal activity, as well as in many other physiological processes of the plant, such as the transport of sugars, synthesis of cell wall and metabolism of carbohydrates and nitrogen (Ouzounidou *et al.*, 2013). Given its wide adaptability to different edaphoclimatic conditions with little influence of latitude, altitude and photoperiod on its yield (Aquino *et al.*, 2011), the sunflower crop has gained

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importance in all regions of Brazil. Its main uses include floriculture (Santos Júnior *et al*., 2014), human food (Porfírio *et al*., 2014) and bioenergy (Gomes *et al*., 2012), besides being used as forage in the production of silage (Mesacasa *et al*., 2012) and acting in mycorrhizal colonization and recycling of nutrients, favoring other subsequent crops. Considering the previously mentioned aspects, this study aimed to evaluate growth and flowering components of sunflower cv. EMBRAPA 122-V2000 irrigated with treated domestic effluent and subjected to different B doses.

MATERIALS AND METHODS

The experiment was carried out under greenhouse conditions in the period from April to July, at the Academic Unit of Agricultural Engineering of the Center of Technology and Natural Resources (CTRN) of the Federal University of Campina Grande (UFCG), in Campina Grande-PB, Brazil (7°12'52" S; 35°54'24" W; 550 m). The experimental design was completely randomized, analyzed in a 5 x 2 factorial scheme with three replicates, totaling 30 experimental units. Treatments consisted of application of five B doses (0 - control, 1.0; 2.0; 3.0 and 4.0 mg kg^{-1}, using boric acid as a source, incorporated into the soil as basal fertilization) and two types of irrigation water (treated domestic effluent and public-supply water). The studied cultivar was EMBRAPA 122-V2000, whose seeds were provided by EMBRAPA Soybean, Dourados-MS. The seedlings were produced in the same area of the experiment, in PVC tubes filled with commercial substrate, under daily irrigations, through the application of 10 mL twice a day of the water corresponding to the respective treatment. At 25 days after sowing (DAS), the seedlings were transplanted to the definitive experimental units, polyethylene pots with an outlet for drainage at the bottom and volumetric capacity of 6 L, which were filled with 200 g of crushed stone nº 1, Nylon screen and 8 kg of soil. The utilized soil material was classified as sandy loam Regolithic Neosol, non-saline and non-sodic (Table 1), and was collected in the superficial layer (0-20 cm) from nearby district of São Jose da Mata, Campina Grande-PB. Mineral fertilizations were performed as basal applications, in all pots, following the recommendations of Novais *et al*. (1991), using the doses of 300, 100, 150 and 40 mg kg^{-1} of soil of P_2O_5, N, K_2O and S, respectively. The domestic effluent utilized was obtained at the Campus I of the UFCG, collected using a motor pump set, filtered in fine sand and stored in a PVC barrel in an amount sufficient for the entire experiment. The waters (public-supply and treated domestic effluent) applied in the experiment were characterized according to the methodology proposed by EMBRAPA (1997), and the results are presented in Table 2.

As to irrigation management, after transplantation, the volume of water (treated domestic effluent and public-supply water, according to the treatment) was calculated to maintain the soil at pot capacity, by daily applying the consumed value, calculation based on the water balance (volume applied - volume drained) + 5% of leaching fraction. Irrigation was suspended eight days before harvest.The following growth variables were measured at 39, 46 and 53 DAS: stem length (SL), considering the distance from the base of the plant, close to the soil surface, to the bifurcation of the last leaf; stem diameter (SD), using a digital caliper always at 5 cm from the soil surface; and the number of leaves (NL), by counting leaves whose midrib length was longer than 3 cm and were healthy and photosynthetically active. As to the flowering variables, the number of days from sowing to the beginning of flowering (BF) was measured, which occurred when plants were in the stage R_4 (Castiglioni *et al*., 1997). When the capitulum had 100% of its petals open, the number of petals (NP) was counted and the capitulum external (CED) and internal (CID) diameters were measured, based on the arithmetic mean of the measurements performed at two positions of the capitulum (horizontal and vertical). The obtained results were subjected to analysis of variance, comparing the quantitative factor through polynomial regression and the qualitative factor through amean test (Tukey) at 0.05 probability level. All analyses were performed using a statistical program (Ferreira, 2011).

RESULTS AND DISCUSSION

Based on the results of the analysis of variance, the factor types of irrigation water, B doses and the interaction between treatments did not affect significantly ($p>0.05$) the number of leaves in any evaluation period (Table 3).Studies conducted by Martin *et al*. (2014) analyzing the efficiency of B and Ca application, via leaves and soil, in the sunflower cv. Agrobel did not observe a significant effect of B on the number of leaves, as well as Euba Neto *et al*. (2014), working with the cultivar Hélio 863 with B doses of 0, 0.50, 1.00 and 2.00 mg dm^{-3}, also did not verify significance, as in the present study. It is worth mentioning, as a record of observations in the experimental period, that in older leaves of the plants except in plants under B dose of 0 mg kg^{-1} irrigated with domestic effluent and under dose of 1 mg kg^{-1} irrigated with public-supply water, there were symptoms of B toxicity such as chlorosis and necrosis, as observed in studies conducted by Lima *et al*. (2013) and Euba Neto *et al*. (2014), suggesting that there is a narrow range between deficiency and toxicity, which was also observed by Foloni *et al*. (2010), who studied sunflower growth under B fertilizations and concluded that, although sunflower is relatively demanding (Steiner; Lana, 2013), but it is not tolerant to high B doses, especially when highly soluble sources are used, such as boric acid.With regard to stem length, the interaction between treatments and B doses did not influence significantly ($p>0.05$) this variable (Table 3), as also observed by Santos *et al*. (2015), who studied the growth of sunflower cv. Hélio 358, as a function of P and B supply, and did not observe significant effects of the isolated factor B on stem length in the interval of 0 to 2 kg ha^{-1} of B. These results do not agree with the evaluations of Lima *et al*. (2013) in the cultivation of sunflower, cv. Catissol 01, under field conditions applying 1.0, 2.0, 3.0, 4.0 and 5.0 kg ha^{-1} of B as basal dose observed significant effects of B doses on stem length. Similar results were found by Bonacin *et al*. (2009), who worked with the cultivar EMBRAPA 122-V2000 under B doses of 0, 1.0, 2.0, 3.0 and 4.0 kg ha^{-1}.However, plants irrigated with the different types of water showed significant differences ($p<0.05$) in terms of stem length, at 39 DAS (Table 4); in plants irrigated with domestic effluent, stem length was, on average, 7.06 cm greater than in plants irrigated with public-supply water, with means of 49.68 and 42.62 cm, respectively (Figure 1). Similar results were observed by Andrade *et al*. (2012), who studied the growth of ornamental sunflower in an organic production system and irrigated with treated domestic effluent and observed at 38 DAS, mean values of 48.28 and 39.46 cm for plants irrigated with treated domestic effluent and water from the municipal supply system, respectively.

Table 1. Physical and chemical characteristics of the soil* used in the experiment

Characteristic	Unit	Value	Characteristic	Unit	Value
Granulometry			Organic matter	$g\ kg^{-1}$	0.34
Sand	%	82.19	Nitrogen	$g\ kg^{-1}$	0.02
Silt	%	12.76	Available P	$mg\ kg^{-1}$	0.88
Clay	%	5.05	pH (H_2O)	-	6.12
Density			$CE_{1:2.5}$	$dS\ m^{-1}$	0.16
Apparent	$kg\ dm^{-3}$	1.66	Saturation extract		
Particle	$kg\ dm^{-3}$	2.81	Calcium	$mmol_c\ L^{-1}$	2.1
Porosity	%	40.92	Magnesium	$mmol_c\ L^{-1}$	1.9
Exchange complex			Sodium	$mmol_c\ L^{-1}$	2.0
Calcium	$cmol_c\ kg^{-1}$	1.68	Potassium	$mmol_c\ L^{-1}$	0.2
Magnesium	$cmol_c\ kg^{-1}$	1.27	Carbonate	$mmol_c\ L^{-1}$	0.0
Sodium	$cmol_c\ kg^{-1}$	0.06	Bicarbonate	$mmol_c\ L^{-1}$	2.8
Potassium	$cmol_c\ kg^{-1}$	0.07	Chloride	$mmol_c\ L^{-1}$	2.8
Sum of bases	$cmol_c\ kg^{-1}$	3.08	Sulfate	$mmol_c\ L^{-1}$	Absent
Hydrogen	$cmol_c\ kg^{-1}$	1.20	SAR	$(mmol\ L^{-1})^{0.5}$	1.42
Aluminum	$cmol_c\ kg^{-1}$	0.0	EC_{se}	$dS\ m^{-1}$	0.67
T	$cmol_c\ kg^{-1}$	4.28	pH_{se}	-	5.6
Qualitative $CaCO_3$	-	Absent			
Organic carbon	$g\ kg^{-1}$	0.20			

*Determined according to the methodologies recommended by EMBRAPA (1997)

Table 2. Physico-chemical characterization* of the treated domestic effluent (TDE) and the public-supply water (PSW) used in irrigation

Water	pH	EC($dS\ m^{-1}$)	P	K	N	Na	Ca	Mg	Zn	Cu	Fe	Mn	SAR
			mg L^{-1}										$(mmol\ L^{-1})^{0.5}$
TDE	7.45	1.84	3.59	31.6	28.6	147.6	81.2	39.5	0.01	0.08	0.001	0.02	3.36
PSW	7.5	0.38	nd	5.47	nd	35.6	20.0	15.8	nd	nd	nd	nd	1.45

*According to EMBRAPA (1997). nd – not determined

Table 3. Summary of the ANOVA for the number of leaves (NL), stem length (SL) and stem diameter (SD) of sunflower cv. EMBRAPA 122-V2000, irrigated with two types of water under different doses of boron along the crop cycle

Source of Variation	DF	Mean square								
		Number of leaves			Stem length			Stem diameter		
		39DAS#	46DAS	53DAS	39DAS	46DAS	53DAS	39DAS	46DAS	53DAS
Dose of Boron (B)	4	2.58^{ns}	3.61^{ns}	1.08^{ns}	65.85^{ns}	58.14^{ns}	126.36^{ns}	0.19^{ns}	0.46^{ns}	0.57^{ns}
Type of Water (W)	1	2.7^{ns}	1.2^{ns}	0.03^{ns}	384.492^{**}	286.44^{ns}	105.28^{ns}	2.488^{**}	0.06^{ns}	2.319^{**}
Interaction B x W	4	4.45^{ns}	3.78^{ns}	12.11^{ns}	45.063^{ns}	140.37^{ns}	148.84^{ns}	1.553^{**}	1.616^{**}	1.462^{**}
Residual	18	2.71	5.30	0.048	50.65	72.14	98.68	0.44	0.46	0.40
CV	(%)	9.60	10.56	9.360	15.44	11.80	9.510	9.32	7.25	6.07

* and ** significant at 0.05 and 0.01 probability level by F test, respectively. ns - Not significant at 0.05 probability level. # DAS – days after sowing.

Table 4. Means for the follow-up analysis of the significant interaction between B doses and types of water related to stem diameter (SD) of sunflower cv. EMBRAPA 122-V2000 irrigated with two types of water under different doses of boron

Type of water (W)	Doses of boron – mg B kg^{-1}				
	0	1	2	3	4
	39 DAS# (mm)				
Treated Domestic Effluent	7.69a	6.75a	7.02a	7.39a	8.46a
Public-supply water	6.68a	7.41a	7.17a	6.66a	6.51b
	46 DAS (mm)				
Treated Domestic Effluent	10.05a	8.74b	9.25a	9.26a	10.01a
Public-supply water	9.25a	10.41a	9.25a	8.77a	9.27a
	53 DAS (mm)				
Treated Domestic Effluent	11.00a	10.37b	10.60a	10.75a	10.95a
Public-supply water	9.68b	11.54a	9.66a	9.57a	10.04a

DAS – days after sowing. Means followed by the same letter in columns do not differ significantly at 0.05 level of probability

Table 5. Summary of the ANOVA for the beginning of flowering (BF), number of petals (NP), capitulum internal (CID) and external diameter (CED) of sunflower cv. EMBRAPA 122-V2000, irrigated with two types of water under different doses of boron

Source of Variation	DF	Mean Square			
		BF	NP	CID	CED
Dose of Boron (B)	4	10.250^{ns}	5.533^{ns}	0.675^{ns}	7.687^{**}
Linear Regression	1	24.066^{ns}	0.266^{ns}	1.320^{ns}	16.537^{**}
Quadratic Regression	1	4.761^{ns}	12.190^{ns}	0.017^{ns}	3.986^{**}
Type of Water (W)	1	13.333^{ns}	0.300^{ns}	0.252^{ns}	3.816^{ns}
Interaction B x W	4	18.583^{ns}	24.633^{ns}	1.213^{ns}	4.128^{ns}
Residual	18	10.466	22.500	0.684	1.794
CV	(%)	6.10	23.29	13.76	8.02

* and ** significant at 0.05 and 0.01 probability level by F test, respectively. ns - not significant at 0.05 probability.

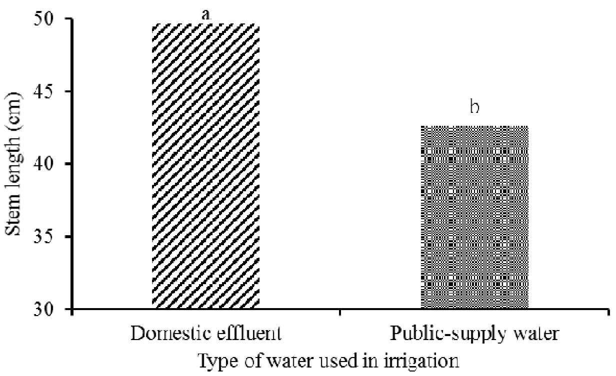

Figure 1. Stem length of sunflower cv. EMBRAPA 122-V2000, at 39 days after sowing irrigated with two types of water under different doses of boron

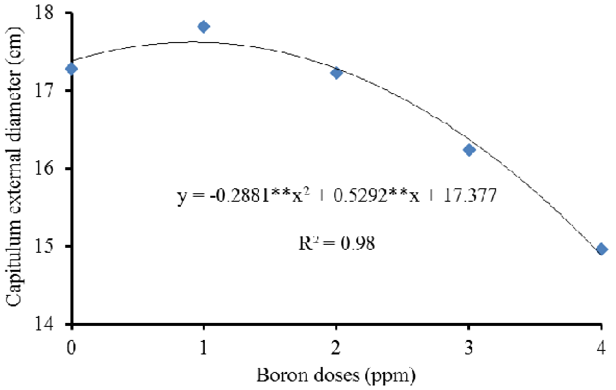

Figure 2. Mean external diameter of the capitulum of sunflower cv. EMBRAPA 122-V2000 irrigated with two types of water under different doses of boron

The mean stem length of sunflower was not influenced ($p>0.05$) by the B doses, individually; on the other hand, the type of water influenced the behavior of this variable individually at 39 and 53 DAS and the interaction between treatments promoted significant differences ($p<0.05$) in all evaluation periods. According to the follow-up analysis of the interaction between treatments for stem diameter, at 39 DAS, plants irrigated with domestic effluent showed higher values of mean stem diameter at the doses of 0, 3 and 4 mg kg^{-1}; thus, when irrigated with treated domestic effluent, there were decreases of 8.74, 9.74 and 3.0% in mean stem diameter in the comparison between plants without B addition (control) and those under doses of 1, 2 and 3 mg kg^{-1}, respectively, and an increase of 10.28% in mean stem diameter between plants under B dose of 4 mg kg^{-1} and control plants (Table 4). At 46 DAS, plants cultivated without the addition of B doses (control) and under doses of 3 and 4 mg kg^{-1} showed better results under irrigation with treated domestic effluent (Table 4). For the irrigation with treated domestic effluent, the mean stem diameter of plants under the dose of 0 mg kg^{-1} was 7.4, 9.57 and 6.5% higher than that of plants under the doses of 1, 2 and 3 mg kg^{-1}, respectively. However, plants under the dose of 4 mg kg^{-1} showed a mean stem diameter 1.76% higher than that of plants cultivated without the addition of B doses.At 53 DAS, plants irrigated with domestic effluent and cultivated without the addition of B (control) showed a mean stem diameter about 2.85% higher than that of plants under the dose of 1 mg kg^{-1}; 3.62% higher than that of plants under 2 mg kg^{-1} and 2.57% higher than that of plants under 3 mg kg^{-1} of B. However, plants under 4 mg kg^{-1} of B showed a mean stem diameter about 1.04% higher in relation to the control. Considering the mean B content observed in Regolithic Neosol, 0.65 mg kg^{-1} in the 'Zona da Mata' and 'Agreste' Pernambucano (Lima *et al.*, 2007) and 0.61 mg kg^{-1} in the municipality of Esperança-PB (Menezes *et al.*, 2008), as well as the mean B content in the domestic effluent, 0.3 mg L^{-1} (Sandri *et al.*, 2006), the fact that the domestic effluent promotes better results as the cycle advances, regardless of the tested B dose, can be associated with the natural leaching due to the great mobility of B in the soil (Communar & Keren, 2007), since it was applied only as basal fertilization. The supply through the use of domestic effluent in the irrigation of plants may have replenished the possible loss through leached B. It should be pointed out that, in the case of plants irrigated with public-supply water, the dose of 1 mg B kg^{-1} promoted better values of stem diameter. This behavior was observed in all evaluation periods for this type of water. Based on this result, the dose of 1 mg, B kg^{-1} behaved as the optimal point in the B deficiency-toxicity relationship in sunflower. Similar results were also obtained in studies conducted by Marchetti *et al.* (2001) and Malavolta *et al.* (1997).

As to the flowering variables, the types of water used in irrigation, the different doses of B and the interaction between the tested factors did not influence significantly ($p>0.05$) the behavior of the beginning of flowering, mean number of petals and mean internal diameter of the flower; however, B doses significantly ($p<0.01$) influenced the mean external diameter of the capitulum (Table 5). According to EMBRAPA (2006), the cultivar Embrapa 122-V2000 is indicated for the South and Central regions of Brazil, and the beginning of flowering normally occurs between 53 and 60 DAS and maturation between 85 and 100 DAS, a result consistent with that observed in the present study, in which the beginning of flowering occurred on average at 53 DAS, for the control dose, and at 55, 52, 52 and 51 DAS, for the doses of 1, 2, 3 and 4 mg kg^{-1}, respectively, indicating that the tested doses, although showing moderate symptoms of toxicity, did not compromise the beginning of flowering. As to internal diameter of the capitulum, the mean results obtained in the present study agree with those reported by Queiroga (2011), who studied the response of the sunflower crop (cv. H-251) to B doses (0, 0.5, 1.0, 2.0 and 3.0 kg ha^{-1}) and also did not observe a significant effect on the mean internal diameter of the flower.The mean external diameter of the capitulum was not significantly ($p>0.05$) influenced by the type of water used in irrigation or by the interaction between treatments; however, the increasing doses of B significantly ($p<0.05$) influenced the behavior of this variable. Based on the regression equation (Figure 3), it was estimated that the highest external diameter of the capitulum (17.8 cm) was obtained at the dose of 1 mg kg^{-1}, i.e., this dose behaved as an inflection point, from which lower or higher B values cause a decrease in the mean external diameter of the capitulum (Figure 2). Similar behavior was also observed by Malavolta *et al.* (1997), who claim that B levels in the soil below 0.5 mg kg^{-1} and above 1.0 mg kg^{-1} can promote deficiency and toxicity, respectively, in the sunflower crop, which is sensitive to the variation of this nutrient.

Conclusion

The utilization of treated domestic effluent in the irrigation of the plants promotes increment in stem length; about the stem diameter, when the domestic effluent in irrigation was used, the more expressive results were observed in plants in the absence of boron application, however, in plants irrigated with public-supply water, the best results were obtained at a boron dose of 1 mg kg^{-1}. The interaction between boron doses and type of water influences stem diameter in all stages of the crop cycle until flowering. The beginning of flowering, number of petals and internal diameter of the capitulum are not influenced by boron doses or types of water used in irrigation; however, the plants showed a maximum external diameter of the capitulum under the dose of 1 mg kg^{-1} of boron, applied as basal fertilization, regardless of the type of water used in irrigation.

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