GROWTH OF IRRIGATED HERBACEOUS COTTON WITH DOMESTIC SEWAGE WATER TREATED[1]

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ABSTRACT: The objective of this work was to evaluate the development of herbaceous cotton plants (cultivar BRS 335), irrigated with treated domestic sewage. For this, an experiment was carried out in a randomized block design, in a 3 x 2 factorial design, with six replicates, three treated effluent (0%, 50% and 100%) and two management conditions (with or without fertilization phosphate). The height and diameter of the plants were evaluated throughout the development cycle at 27, 44, 64 and 78 days after germination (DAG), with three plants in each subplot the data were submitted to analysis of variance, analysis of regression and multiple comparison test. It was verified that the treatments irrigated with waste water (T3 - 100% treated domestic sewage water and T2 - 50% supply water + 50% treated domestic sewage), was higher than T1 (100% water supply); there was no significant effect on the interaction of treatments with fertilization with phosphorus, however fertilization with phosphorus alone had a positive and significant effect.

KEYWORDS: *Gossypium hirsutum* L., plant development, water reuse

CRESCIMENTO DE ALGODOEIRO HERBÁCEO IRRIGADO COM ÁGUA DE ESGOTO DOMÉSTICO TRATADO

RESUMO: Objetivou-se com este trabalho foi avaliar o desenvolvimento de plantas de algodão herbáceo (cultivar BRS 335), irrigadas com esgoto doméstico tratado. Para isso, um experimento foi realizado em um delineamento em blocos ao acaso, em um projeto fatorial 3 x 2, com seis repetições, três efluentes tratados (0%, 50% e 100%) e duas condições de manejo (com ou sem fosfato de fertilização). A altura e o diâmetro das plantas foram

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avaliados ao longo do ciclo de desenvolvimento aos 27, 44, 64 e 78 dias após a germinação (DAG), com três plantas em cada subparcela, os dados foram submetidos à análise de variância, análise de regressão e teste de comparação múltipla. Verificou-se que os tratamentos irrigados com águas residuais (T3 - água de esgoto doméstica tratada a 100% e água de abastecimento de T2 a 50% + 50% de esgoto doméstico tratado) foi maior que T1 (100% de abastecimento de água); não se constatou efeito significativo na interação dos tratamentos com a adubação com fósforo, no entanto a adubação com fósforo isoladamente apresentou efeito positivo e significativo.

PALAVRAS-CHAVE: *Gossypium hirsutum L.*, desenvolvimento de plantas, reuso de água

INTRODUCTION

Inappropriate conventional farming practices tend to compromise existing natural resources. Part of the world has faced problems of drinking water shortages, which can lead to competition for this resource; in many cases there is plenty of water, but it is of poor quality because of man-made pollution. Without the adoption of measures to mitigate this problem, such as sanitation and proper treatment of water used in cities, the volume of good quality water will progressively reduce.

The cotton crop (*Gossypium hirsutum*) contributes significantly to the Brazilian economy. Brazil stands out on the world scene as one of the main producers of cotton fiber, with a planted area of 1.39 million hectares and a production of 1.95 million tons of feather in the 2011/2012 harvest (CONAB, 2013).

Currently one of the alternatives for sustainable use of wastewater to reduce problems in the environment is to use it in a planned and correct way in agricultural areas. The management of these waters and the use in fertirrigation of agricultural crops can make possible the increase of productivity and quality of harvested products and reduction of environmental pollution (CHEVREMONT et al., 2013).

In the arid and semi-arid regions, the water reuse is important, given the pre-existing scarcity of this resource; in the Brazilian semi-arid, the exploitation of quality water is more problematic, since the lithosphere is formed by 70% of crystalline rocks and the climate reduces the area of the lithosphere destined to the water storage, besides the water deficit, frequent in these regions, causes the upward flow of the salts to the soil surface.

The criteria for use of effluents for irrigation were developed by the World Health Organization (WHO), based on epidemiological evidence, being recommended the parasitological limit of 1 helminth egg per liter of effluent and a more flexible bacteriological limit of 1000 fecal coliforms per 100 mL for unrestricted irrigation, that is, for those cultures to be consumed raw (WHO, 1989).

Many studies have been carried out around the world where the planned reuse of water is a reality, in order to evaluate the potential and actual risks involved in the use of wastewater (BLUMENTHAL et al., 2000). Irrigation with wastewater significantly influenced the growth of cotton plants, regarding to the rate of emergence, germination percentage, plant height, stem diameter, number of leaves, leaf area and dry mass of shoot, with the increase in the proportion of domestic effluent (SOUSA NETO et al., 2012).

MATERIAL AND METHODS

The study area is located in the municipality of Apodi, in the middle west of Rio Grande do Norte, more precisely in the Milagre Settlement Project, whose geographical coordinates are 5° 35' 18.82" S and 37° 54' 08.48" W and an altitude of 109 m. It is inserted in the geoenvironment Chapada do Apodi, which is a formation of sedimentary origin in its western portion and extends along the border between the states of Rio Grande do Norte and Ceará, in northeastern of Brazil.

The area presents a flat relief with a dominant slope of less than 2%. The soils that cover the area are HABITAL CHEMISTRY Ta Eutrophic, according to the Brazilian Soil Classification System (SANTOS et al., 2013).

According to the classification of Köppen, the climate of the region is of the type BSw'h', characterized by being warm and semiarid with average annual temperature of 28.5 °C, with rainy season being delayed for autumn; the rainfall regime is on average around 717.9 mm per year (IDEMA, 2013).

The water used in the experiment came from the treatment system of the Milagre Settlement Project, since in this settlement there is a domestic effluent treatment system, which was implemented through a research project carried out by the Federal Rural University of the Semi-Arid-UFERSA and financed by the National Council of Scientific and Technological Development - CNPq, in conditions apt to work the reuse, whose composition is detailed in Table 1.

Before the implementation of the experiment, the treatments were randomized into plots subdivided by the SISVAR program - computer statistical analysis system (FERREIRA, 2011); the experiment was set up in a randomized block design, in a 3 × 2 factorial design, with six replicates, corresponding to three treated effluent (0%, 50% and 100%) and two management conditions (with or without phosphorus fertilization), totalizing 36 experimental plots.

After physical and chemical characterization of the soil (Table 2 and Table 3, respectively) according to EMBRAPA (2011) and subsequent preparation of the area, the phosphorus fertilization was defined for the subplots with this management condition, aiming at obtaining a high yield of the crop and applied in the planting groove and calculated according to Ribeiro (1999), based on the results obtained in the depth 0.00 to 0.20 m and added to the soil and incorporated in the first 5.0 cm of depth.

Afterwards, irrigation was carried out with the water supply in all treatments in order to leave it close to the field capacity for the sowing of cultivar BRS 335, with 10 seeds per linear meter being sowing at a standard depth of 3 cm of the soil surface and alternating on the sides of the irrigation furrow, in double rows (1.10 m × 1.5 m × 0.1 m) (Figure 1A, B and C), totaling a population of 125,000 plants per hectare; at 10 days after planting, when the germination stabilized, irrigation was started with the water for each treatment.

The following irrigations after germination were performed based on crop evapotranspiration (ETc), calculated as a function of the reference evapotranspiration (ETo) according to the Penman-Monteith equation parameterized by the FAO (Allen et al., 2006) using station data climatic system belonging to the National Institute of Meteorology - INMET (Apodi-RN) and the crop coefficient which was determined for the four stages of crop growth, in the conditions of the Chapada do Apodi-RN (BEZERRA et al., 2012).

For the evaluation of the growth and stem diameter, three plants in each subplot were measured and identified so that the measurements always occurred in the same plants, being this variables measured along the cycle of the crop in four distinct times, at 27, 44, 64 and 78 days after germination.

The data obtained from the quantitative variables accumulation of growth and stem diameter were submitted to analysis of variance by the F test, up to 5% probability. The means were compared using the Tukey's test at 5% probability, using the computer program SAEG 9.1 (SAEG, 2007).

RESULTS

The growth response of herbaceous cotton (cultivar BRS 335) to the irrigation with treated domestic sewage is presented in Tables 4 and 5, in which it is verified that treated domestic sewage (T3 - 100% sewage water treated and T2 - 50% supply water + 50% treated domestic sewage) promoted significant differences, at 1% probability, for the variables: plant height and stem diameter (Tables 4 and 5). In the different harvest times, there were increases in the plants submitted to the treatments that contained waste water (T1 and T2), when they were compared with the treatment containing water of supply (T1). These effects can be explained by the high doses of nitrogen and high organic matter present in irrigation water (treated sewage).

The results obtained in this research are similar to those verified for the BRS 200 Marrom, cultivated in pots, by Figueiredo (2003), as well as those observed by Bezerra et al (2005) studying the effect of wastewater and biosolids on the growth and development of BRS Rubi colored cotton.

When we compared only the growth of plants in treatments that contained wastewater, we verified that there is no significant difference in the first harvest at 27 days after germination, however we verified differences in the measurements following at 44, 64 and 78 DAG (Figure 2). This can to be explained as a function of the nutritional requirements of the crop to increase during the cycle for its growth, mainly by nitrogen (N), which was only supplied in treatments T3, which was irrigated with 100% treated domestic sewage.

When comparing the stem diameter in treatments irrigated with wastewater, we noticed a difference only in the first harvest at 27 days after germination, however we verified differences in the measurements following at 44, 64 and 78 DAG (Figure 3). This can be explained in function of the initial requirements of potassium (K^+) in this crop is high, being responsible for stem growth, and it was not fully supplied by water containing only 50% of wastewater (T2).

At the end of the cycle, a stabilization was observed in the growth. This response is absolutely normal, since the senescence of the crop begins, and the vegetative cycle of the cotton varies from 100 to 130 days, depending on cultivar. In the cultivar BRS Verde, Fideles Filho et al. (2005) observed that the stabilization of leaf area growth occurred in the period between 80 and 90 days after sowing.

The increase in growth in the high concentration of domestic effluent interval (between treatments T2 and T3) was lower when compared to the increase in the range of the lowest concentration of domestic sewage (between treatments T1 and T2) suggesting that fertirrigation with 50% of wastewater from the total evapotranspiration of the crop is already approaching the maximum yield.

However, when the effect of the presence or absence of fertilization with phosphorus (P) is analyzed, a positive and significant effect is observed (Table 6). This shows that wastewater already contained enough of the nutrients necessary for the development of the crop; P was not enough to show a significant response, this can be explained by the interaction that exists in the absorption of phosphorus with other elements, mainly with nitrogen (N), which was absent in treatment with water supply.

CONCLUSIONS

Treated domestic sewage has a fertilizer effect on the cotton crop, making it an alternative input for production.

The height of the plant and the stem diameter of the cotton plants respond positively to the fertigation with treated domestic sewage.

The use of 50% of cotton crop evapotranspiration by fertigation with treated domestic sewage water to replace good quality water leads to cotton development to satisfactory parameters under semi-arid conditions, as evidenced by the developmental evolution.

The domestic sewage treated in the cultivation of the cotton in substitution of the water of good quality, does not bring any damage to the development of the culture.

Phosphorus fertilization proved to be significant in the development of cotton plants, however, there was no variation in the interaction with the presence or absence of wastewater in the fertirrigation.

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Table 1. Physical-chemical and biological characteristics of the waters used.

Characteristics	Water Wastewater	Water Supply
pH...	7,34	6,96
Electric conductivity (dS m^{-1})	1,10	0,09
Thermotolerant coliforms (NMP 100 mL^{-1})	$9,8x10^3$	0
Chemical Oxygen Demand (mg L^{-1})	80	-
Biochemical oxygen demand (mg L^{-1})	27	-
Total solids (mg L^{-1})	655	-
Suspended solids (mg L^{-1})	44,0	-
Total phosphor (mg L^{-1})	7,8	-
Total nitrogen (mg L^{-1})	54,1	-
Potassium (mg L^{-1})	23,7	11,5
Total iron (mg L^{-1})	0,48	0,26
Manganês total (mg L^{-1})	0,13	0,05
Total manganese (mg L^{-1})	0,08	0,2
Copper (mg L^{-1})	0,04	0,03
Sodium (mmolc L^{-1})	7,03	0,46
Calcium (mmolc L^{-1})	1,21	0,17
Magnesium (mmolc L^{-1})	0,76	0,28

Table 2. Soil chemical characteristics of the experimental area

Depth	pH[1]	CE	O.M.[2]	P[3]	K^+	Na^+	Ca^{2+}	Mg^{2+}	Al^{3+}	(H+Al)	SB	CTC	V	m	PST
m	água	dS/m	g.Kg^{-1}	-------mg.dm^{-3}-----			------------------$cmol_c.dm^{-3}$------------------						-----%------		
0,0-0,2	6,6	0,12	5,88	7,0	162,3	21,53	2,76	0,73	0,00	0,77	4,00	4,77	84	0	2
0,2-0,4	6,05	0,05	2,97	6,7	128,5	34,5	2,50	2,16	0,05	1,15	5,14	6,29	82	1	2

[1] The pH in water was determined potentiometrically in the suspension whose soil-liquid ratio was 1: 2.5 and the EC in the same proportion directly with the potentiometer.
[2] Oxygen Matter determined by oxidation with 0.020 mol L^{-1} potassium dichromate and determined by titration with ammoniacal ferrous sulfate 0.005 mol L^{-1}.
[3] P, K and Na, using the Mehlich-1 extractor; 1N KCl for Ca, Mg and Al; Calcium acetate at pH 7.0 for H + Al; DTPA solution (pH = 7.3); Cu, Fe, Mn and Zn extracted with mixed extractive solution and available B was extracted with HCl (0.05M), in the ratio of 1: 2 soil / extractant

Table 3. Physical soil characteristics of the experimental area.

Depth (m)	Sand[1]	Silte	Clay	Textural Classification	Dp[2]	Sd	TP	Humidity in Tensions (in KPa)			Water Availability		
								10	33	1500	Ѳa[3]	Ѳt	Ѳrs
	...........kg.kg^{-1}..........				--.kg.dm^{-3}--		%				mm.cm^{-1}	mm	mm
0,0-0,2	0,820	0,078	0,102	Free sand	2,77	1,68	36,6	11,85	6,74	3,84	1,34	26,85	13,42
0,2-0,4	0,608	0,070	0,322	Franco sandy clay	2,84	1,73	38,8	11,60	8,86	6,23	0,43	8,78	4,39

[1] The granulometric fractions were determined by the pipette method and expressed in kg kg-1.
[2] The particle density (Sd) determined by the volumetric flask method, the soil density (Dp) by the volumetric ring method and the total porosity (TP) based on the values of Sd and Dp.
[3] Total water availability (Ѳa), total water storage capacity (Ѳt) and actual water storage capacity (Ѳrs) according to terms described by Bernardo (2005)

Figure 1. Detail of an experimental plot with a detailed view of irrigation in the planting grooves (A) and cotton cultivation in double spacing (B) and (C).

Table 4. Mean values of plant height data of herbaceous cotton (cultivar BRS 335) irrigated with different doses of treated domestic sewage.

Treatments	Days after germination (DAG)			
	27	44	64	78
	--cm--			
T1	18,78Bc	37,72Cb	51,92Ca	54,00Ca
T2	30,06Ac	71,39Bb	89,14Ba	90,44Ba
T3	35,58Ad	80,28Ac	98,31Ab	105,06Aa

[1] Capital letters (A, B), compare the means of the treatments.
[2] Lower case letters (a, b) compare averages of the same treatment over the course of the development cycle.
[3] T1 - Water supply; T2 - 50% water supply and 50% wastewater; T3 - 100% waste water.

Table 5. Mean values of stem diameter of herbaceous cotton (cultivar BRS 335) irrigated with different doses of treated domestic sewage.

Treatments	Days after germination (DAG)			
	27	44	64	78
	--mm--			
T1	3,87Cc	6,11Bb	7,24Ba	7,98Ba
T2	5,70Bc	9,89Ab	10,70Ab	11,81Aa
T3	6,79Ac	10,44Ab	11,15Aab	11,40Aab

[1] Capital letters (A, B), compare the means of the treatments.
[2] Lower case letters (a, b) compare averages of the same treatment over the course of the development cycle.
[3] T1 - Water supply; T2 - 50% water supply and 50% wastewater; T3 - 100% waste water.

Table 6. Summary of analysis of variance of plant height (H) and plant diameter (D), in a scheme of sub-divided plots.

Sources of variation	Degrees of freedom	Mean square	
		H	D
Block	5	124,58	5,33
Treatment (T)	2	20057,04**	190,82**
Residue (A)	10	113,24	1,61
Types of handling	1	539,28*	10,39**
T x M	2	213,90ns	0,023ns
Residue (B)	15	111,80	0,50
Time of evolution (Time)	3	22831,12**	172,52**
T x Time	6	803,05**	3,30**
M x Time	3	17,46ns	0,65ns
T x Time	6	27,28ns	0,22ns
Residue (C)	90	39,78	0,66
CV Plot subdivided (%)		9,92	9,50

** Significant at 1% probability by F test.
* Significant at 5% probability by F test.
ns Not significant at 5% probability by F test.

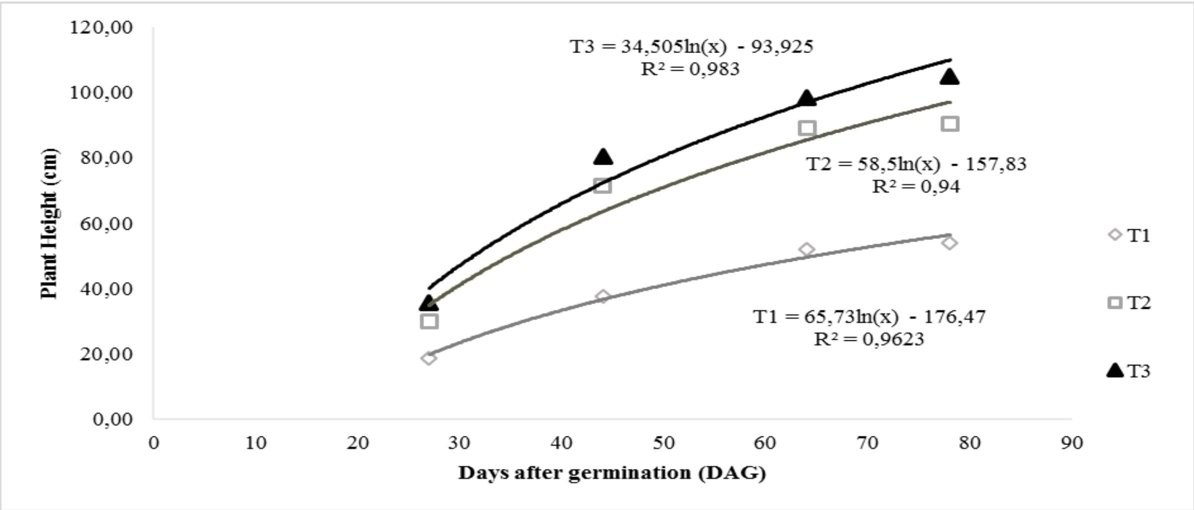

Figure 2. Height of herbaceous cotton plants submitted to different treatments (T3 - 100% treated domestic sewage water and T2 - 50% supply water + 50% treated domestic sewage).

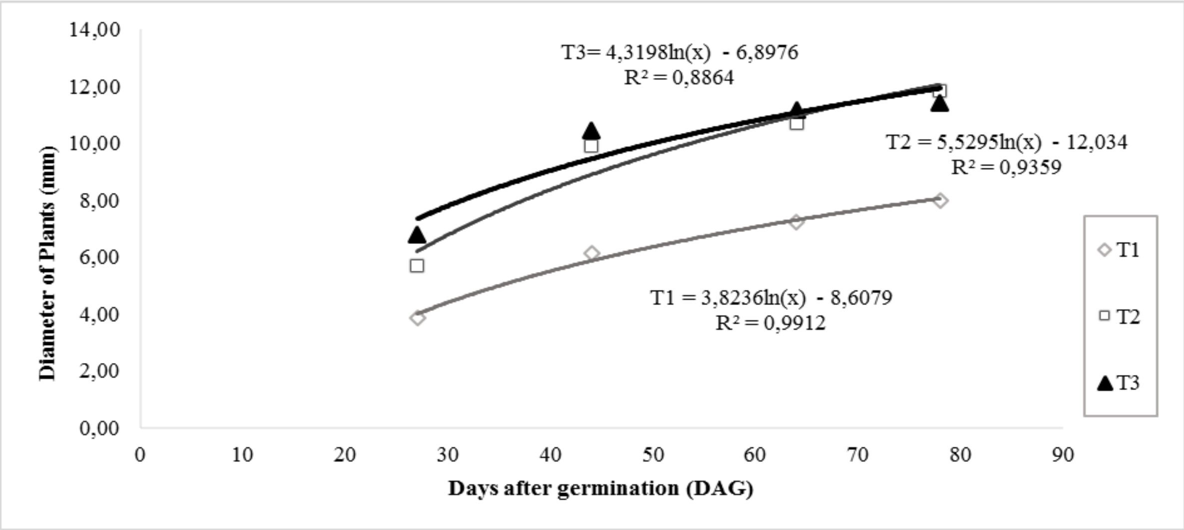

Figure 3. Stem diameter of herbaceous cotton plants submitted to different treatments (T3 - 100% treated domestic sewage water and T2 - 50% supply water + 50% treated domestic sewage).