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RESEARCH ARTICLE OPEN ACCESS

Lettuce (*Lactuva sativa L.*) Irrigated with Domestic Sewage Treated in Protected Environment

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ABSTRACT

The reuse of wastewater has been a strategy for the scarcity of water resources in arid and semiarid regions and to reduce the impact of this waste in water courses. In view of this, the aim of this work was to evaluate the development and production of “Baba de Verão” Lettuce (*Lactuca sativa L.*) in two cycles submitted to different concentrations of domestic sewage treated (0, 50 and 100%) and three irrigation depths, corresponding to 75, 100 and 125% of the soil moisture in the field capacity in protected environment. The concentrations of domestic sewage treated were prepared using water from the city's supply company and the sewage from the Sewage Treatment Station. The research was conceived in a randomized block design, generating a 3 x 3 factorial, with 5 repetitions. Utisol was used in the 45 pots used to grow the lettuce. It was used a critical tension of -30 kPa to determine the soil moisture critical and apply irrigation depth. The characteristics of leaf number, plant height, fresh weight and dry weight of lettuce were analyzed. Influences of the concentration of domestic sewage and the irrigation depth applied were observed separately, while the interaction did not influence the variables studied in the two crop cycles. The greater irrigation depths and the higher concentrations of domestic sewage provided greater development in the crop.

Keywords: field capacity, tensiometry, wastewater

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I. INTRODUCTION

Brazil has a vast water reserve, but arid and semi-arid regions may suffer from water scarcity during droughts and the use of wastewater has been an alternative, arousing great interest and showing significant research advances in recent years [1].

The use of sewage effluent treated is not a new practice, however, there is a growing interest in the need to reuse it, especially in agriculture [2]. Many recent works have been carried out with the use of sewage effluent treated in the irrigation of several crops, among them radish [3], banana [4], okra [5], lettuce [6] and [7] and pepper [8] and [9].

The use of wastewater has become an interesting option as it reduces contamination by direct discharge of sewage into water bodies, allows more rational use of resources and is an alternative source of water available for agricultural crops [10].

Lettuce is one of the most significant leafy vegetables planted worldwide and consumed throughout the year [11]. Due to its short growing cycle, lettuce is a very nutrient demanding crop, and deficiency of these nutrients has symptoms that can be visually identified as abnormal colour, growth, burning and distortion of plant parts [12]. Thus, in addition to acting as a source of water, domestic sewage treated has the properties of a biofertilizer that can provide mineral nutrition to the crop [13].

The yield of vegetables in protected environment has increased significantly in recent decades. In addition, increase vegetable production has less environmental impact compared to field cultivation [11].

The aim of this work was to evaluate, in two production cycles, the development and yield of “Baba de Verão” Lettuce (*Lactuca sativa L.*) submitted to different concentrations of domestic sewage treated (0, 50 and 100%) and three irrigation depths, corresponding to 75, 100 and 125% of the soil moisture in field capacity, in protected environment.

II. MATERIALS AND METHODS

The experiment was designed for lettuce growing “Baba de Verão” variety submitted to 0, 50 and 100% of domestic sewage treated with three irrigation depths corresponding to 75, 100 and 125% of the soil moisture in field capacity, in a protected environment.

Concentrations of domestic sewage treated were prepared using water from the city's water supply company and the sewage from the Sewage Treatment Station.

The sewage went through two tanks to remove organic matter in the treatment station. The first tank has an anaerobic reactor which is responsible for the removal of 60% of organic matter. The second tank has an aerobic reactor that removes up to 90% of the Biochemical Oxygen Demand. The sewage was collected to dilute the concentrations of the second tank.

The pots used for growing lettuce with a capacity of 21 litres, each containing 15 kg of soil, were arranged on a metal bench inside the protected environment.

The collected soil was classified as Ultisol, put to dry naturally for 72 hours, revolving it twice a day, so that the procedure occurred in a uniform way. Then the soil was sieved and a 1,000 g sample was taken for chemical analysis. After evaluating the result of the soil analysis, the need for liming was observed. The limestone was incorporated in the entire soil volume and then soil saturation was performed in the vessel until water percolation was observed. A period of approximately 90 days was expected before transplanting the lettuce seedlings, time necessary for the soil correction of pH.

After this period, the lettuce was sown on a tray of 150 cells, placing 5 seeds per cell. During this period, water was applied twice a day.

Lettuce seedlings were transplanted fifteen days after germination, when the seedlings had four definitive leaves. Three lettuce seedlings were transplanted into each pot. After seven days of transplanting, thinning was performed, leaving only the most vigorous plant per pot when the differentiation of treatments began. During the first seven days after transplanting, only the water supply was used in all plots.

The research was designed in randomized blocks. The experimental plots consisted of three different concentrations of domestic sewage treated and three irrigation depths, generating a factorial 3 x 3. The determination of irrigation depths was related to soil moisture in field capacity. Five repetitions of each treatment were used, thus totaling nine treatments.

Nine tensiometers were installed in each treatment to monitor soil moisture in randomly chosen vessels. Irrigation was performed when the tensiometer reading indicated the tension corresponding to the moisture below field capacity. The irrigation depth was then applied to elevate this moisture to the field capacity condition of the analyzed treatment.

The water content in the soil under varying tensions was determined to know the timing of irrigation from the tensiometers. Initially, the soil saturation was done by capillarity, immersing a plastic container in the water. After saturated, a tensiometer was inserted into the soil and then the vessel was sealed so that no loss due to evaporation would occur, thus favoring homogeneous reduction of soil moisture. It waited for the percolation to be completed and then the water tension and weight were measured using a digital tensimeter and a balance with semi-analytic accuracy, respectively. These collected data allowed the elaboration of the soil water retention curve (Fig. 1).

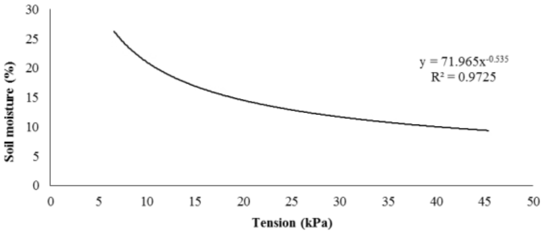

Figure 1 Soil water retention curve used in the experiment

The adopted range for 100% field capacity was 15 kPa to 35 kPa (critical soil moisture accounting for the height of the water column inside the tensiometer). A ratio was made to find the ranges for 75 and 125% of field capacity, being adopted 25 to 60 kPa and 9 to 22 kPa, respectively. The critical soil tension used was -30 kPa [14].

The chemical characteristics of the water supply company and the domestic sewage treated were performed (Table 1).

Table 1 Chemical characteristics of the water supply company (WSC) and the domestic sewage treated (DST)

Characteristics	**WSC**	**DST**
Total Phosphorus, mg L^{-1}	<0.037	2.81
Carbonates, mg L^{-1}	<5.2	<5.2
Bicarbonates, mg L^{-1}	115.0	275.3
pH	7.2	7.8
Electrical Conductivity, µS cm^{-1}	368	1026
Total Dissolved Solids, mg L^{-1}	206.3	574.6
Nitrate, mg L^{-1}	10.1	2.2
Nitrite, mg L^{-1}	<0.01	0.2
Ammoniacal Nitrogen, mg L^{-1}	0.1	11.7
Potassium, mg L^{-1}	1.8	15.8
Calcium, mg L^{-1}	57.0	40.9
Sodium, mg L^{-1}	39.1	52.4
Magnesium, mg L^{-1}	8.9	8.9
SAR	6.8	10.5
Sulfates, mg L^{-1}	64.0	85.0
Chloredis, mg L^{-1}	43.6	92.1

Leaf number (obtained by counting), plant height (with the aid of a 50 cm millimeter ruler, the distance from the surface of the soil to the top of the largest leaf was checked), fresh weight (weighed just after harvesting, which was done by cutting the plant close to the ground). After determining of fresh weight, the samples were placed in an oven at 65^{o}C for 72 hours. After this period the dry weight of the lettuce was determined and with these data, the analysis of variance (ANOVA) was performed for randomized blocks. Then, the degrees of freedom of treatments were unfolded to verify the effects of effluent concentration, irrigation depths and the interaction between them under the analyzed variables. The statistical program SISVAR 5.6 was used to carry out statistical analyzes [15].

III. RESULTS AND DISCUSSION

It was observed in Table 2 that both for the concentration of domestic sewage treated and irrigation depth applied, there was a significant effect at least 5% probability by the F test for leaf number, plant height, fresh weight and dry weight. The interaction between the concentration of domestic sewage treated and irrigation depth treatments did not show significance for leaf number, plant height, fresh weight and dry weight of lettuce.

Table 2 Analysis of variance of the first lettuce production cycle for leaf number (LN), plant height (PH), fresh weight (FW) and dry weight (DW)

	DF	**Average square**			
		LN	**PH**	**FW**	**DW**
Conc.	2	8.7**	17.1**	60.8*	1.2*
Irriga.	2	11.3**	50.4**	132**	2.6**
Inter.	4	0.6^{ns}	3.1^{ns}	3.5^{ns}	0.1^{ns}
Treat.	8	5.3**	18.4**	49.9**	0.9**
Block	4	22.5**	24.4**	239**	4.7**
Resid.	32	1.5	3.1	13. 6	0.3
CV		8.8	11.4	15.1	15.1

(**) Significant effect at 5% probability; (*) significant at 1% probability; (ns) not significant at 5% probability level by F test. DF: Degree of Freedom; Conc. = concentration of domestic sewage treated; Irriga. = irrigation depth; Inter. = interaction concentration and irrigation depth; Treat. = treatment; Resid. = residue; CV = coeficiente of variation (%).

When performing the Tukey test ($p < 0.05$), the treatment with the highest concentration of domestic sewage treated differed statistically from the concentration that did not contain domestic sewage treated for leaf number, plant height, fresh weight and dry weight of lettuce in the first cycle (Table 3).

Table 3 Tukey test ($p<0.05$) of the first cycle for leaf number (LN, unity), plant height (HP, cm), fresh weight (FW, g plant^{-1}) and dry weight (DW, g plant^{-1}) in relation to the concentration of domestic sewage treated (DST)

	LN	**HP**	**FW**	**DW**
0% DST	13.7 b	14.4 b	22.3 b	3.2 b
50% DST	14.2 ab	15.8 ab	24.8 ab	3.5 ab
100% DST	15.2 a	16.5 a	26.3 a	3.7 a

The averages followed by the same letter do not differ statistically. DST = domestic sewage treated.

The values of leaf number and height of lettuce found in this research were lower than those reported by [16] who observed a decrease in leaf number and height of lettuce at a significance level of 5%, when they applied a solution with 50% of effluent resulting in average values of 21.9 for the leaf number and 21.1 cm for the lettuce height.

Higher values of leaf number and height of lettuce were reported by [17] who observed maximum values for leaf number and lettuce height of 22 and 21 cm, for concentrations of 83.8 and 76.3% of domestic sewage treated, respectively. However, they did not find any significant effect for irrigation depths, differing from the results found in this research.

Results different from those obtained in this research were reported by [18], when they worked with curly lettuce and did not find any statistical difference ($p < 0.05$) for plant height and leaf number using only treated wastewater.

Observing Tukey's test results ($p < 0.05$) in Table 4, it was found that the largest irrigation depth applied (125% of soil moisture in field capacity) was significantly higher than the smallest irrigation depth (75% of soil moisture in field capacity) used in the experiment, differing only plant height for irrigation depths of 100% of soil moisture in field capacity.

Table 4 Tukey test ($p<0.05$) for leaf number (LN, unity), plant height (HP, cm), fresh weight (FW, g plant^{-1}) and dry weight (DW, g plant^{-1}) according to the irrigation depth used in the first lettuce cycle

Irrigation depth	LN	HP	FW	DW
75% SMFC	13.5 b	13.7 c	21.3 b	3.0 b
100% SMFC	14.3 ab	15.5 b	24.8 a	3.5 a
125% SMFC	15.2 a	17.4 a	27.2 a	3.8 a

The averages followed by the same letter do not differ statistically. SMFC = soil moisture of field capacity

For the first lettuce cycle, the irrigation depths applied corresponding to 75, 100, and 125% of the soil moisture in field capacity were 97.6, 125.2; and 198.8 mm.

Results similar to this research were obtained by [19] who found late development for lettuce submitted to irrigation depths of 25 and 50% of the crop evapotranspiration, whereas the irrigation depth corresponding to 125% of the crop evapotranspiration showed better results in relation to lettuce growth.

Analysis of variance of the second cycle of lettuce production for leaf number, plant height, fresh weight and dry weight can be seen in Table 5.

Table 5 Summary of analysis of variance of the second lettuce production cycle for leaf number (LN), plant height (PH), fresh weight (FW) and dry weight (DW)

	DF	Average square			
		LN	PH	FW	DW
Conc.	2	17.3**	18.7**	293**	3.5**
Irriga.	2	28.5**	24.9**	904**	10.9**
Inter.	4	1.0ns	4.1ns	3.9ns	0.05ns
Treat.	8	11.9**	12.9**	301**	3.6**
Block	4	37.0**	34.5**	576**	7.0**
Resid.	32	3.2	2.6	44.7	0.5
CV		10.9	10.5	23.6	23.6

(**) Significant effect at 5% probability; (*) significant at 1% probability; (ns) not significant at 5% probability level by F test. DF: Degree of Freedom; Conc. = concentration of domestic sewage treated; Irriga. = irrigation depth; Inter. = interaction concentration and irrigation depth; Treat. = treatment; Resid. = residue; CV = coeficiente of variation (%).

For the second crop cycle, similar results to the first cycle were obtained, because both for the concentration of domestic sewage treated and for the irrigation depth applied there was a significant effect at least 5% probability by the F test for leaf number, plant height, fresh weight and dry weight of lettuce. The interaction of these two factors did not show significance for any of the evaluated characteristics. Similar to the first cycle, the treatment and the block showed statistical difference ($p < 0.01$) (Table 5).

It was verified that the concentration of domestic sewage treated was maintained with the pattern observed in the first lettuce production cycle, in which the treatment that obtained 100% of sewage differed statistically from that which received 100% of water from the supply company in all analyzed variables (Table 6).

Table 6 Tukey test ($p<0.05$) of the first cycle for leaf number (LN, unity), plant height (HP, cm), fresh weight (FW, g plant^{-1}) and dry weight (DW, g plant^{-1}) in relation to the concentration of domestic sewage treated (DST)

	LN	HP	FW	DW
0% DST	15,1 b	14,3 b	24,0 b	2,6 b
50% DST	16,4 ab	15,1 ab	28,1 ab	3,1 ab
100% DST	17,3 a	16,5 a	32,8 a	3,6 a

The averages followed by the same letter do not differ statistically. DST = domestic sewage treated.

As occurred in the first cycle for the isolated effect of the irrigation depths applied on the leaf number, plant height, fresh weight and dry weight of the lettuce, in the second cycle larger irrigation depths applied provided higher values for all evaluated variables (Table 7).

Table 7 Tukey test ($p<0.05$) for leaf number (LN, unity), plant height (HP, cm), fresh weight (FW, g plant^{-1}) and dry weight (DW, g plant^{-1}) according to the irrigation depth used in the second lettuce cycle

Irrigation depth	LN	HP	FW	DW
75% SMFC	14.7 b	13.9 b	20.1 c	2.2 c
100% SMFC	16.7 a	15.5 a	29.4 b	3.2 b
125% SMFC	17.4 a	16.5 a	35.5 a	3.9 a

The averages followed by the same letter do not differ statistically. SMFC = soil moisture of field capacity

For the second cycle of lettuce crop production, the irrigation depths applied corresponding to 75, 100 and 125% of the soil moisture in field capacity were 108.2, 141.7 and 222.4 mm, values higher than those applied in the first lettuce production cycle in this research.

The low yield of lettuce can be explained by the high values of nitrate found in the water of the supplying company and high values of pH, bicarbonates, phosphorus, total dissolved solids and ammonium nitrogen found in the domestic sewage treated, because according to [21], pH values above 7.5, bicarbonate above 120 mg L^{-1} and ammonium nitrogen above 5 mg L^{-1} can cause damage to the development of vegetables. These authors also reported that Salt Adsorption Ratio values higher than 6.0 can cause sodicity problems in the soil, thus reducing soil permeability and, consequently, reducing crop development.

IV. CONCLUSION

Domestic wastewater can reduce the use of better quality water in agriculture, being a source of nutrients for crops and becoming an alternative to reduce the environmental impact caused by the excessive use of chemical fertilizers.

This research is a valuable support for future research related to crop yields with the reuse of wastewater.

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