ISSN 1808-8546 (ONLINE) 1808-3765 (CD-ROM)

CRESCIMENTO E PRODUÇÃO DA ALFACE MIMOSA UTILIZANDO ÁGUA RESIDÚARIA TRATADA EM FILTROS ANAERÓBIOS VERTICAIS[1]

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1 RESUMO

O presente trabalho teve como objetivo investigar a resposta da cultivar de alface Gabi em campo utilizando água de esgoto tratado em filtros anaeróbios verticais em diferentes proporções. O estudo foi conduzido em campo no Departamento de Engenharia Rural e Socioeconomia (DERS), da Faculdade de Ciências Agronômicas (FCA) - Universidade Estadual Paulista (UNESP), no município de Botucatu - SP, em delineamento inteiramente ao acaso, sendo constituído por cinco tratamentos e cinco repetições. Os tratamentos foram compostos por cinco diferentes composições da lâmina de irrigação preparadas a partir de duas fontes de água, sendo uma de abastecimento (AA) e outra residuária tratada (ART), resultando em: T1 – 100%ART + 0%AA, T2 - 75%ART + 25%AA, T3 - 50%ART + 50%AA, T4 - 25%ART + 75%AA; T5 – 0%ART + 100%AA. Realizaram-se dois ciclos de cultivo de alface durante o período de setembro a dezembro de 2021 e os resultados obtidos foram analisados estatisticamente. Para as variáveis analisadas, foi encontrada diferença significativa pelo teste de Tukey a 5% de probabilidade entre os tratamentos estudados apenas para a massa seca durante o primeiro ciclo de cultivo, sendo que o tratamento T4 (25% ART + 75% AA) apresentou melhor resultado.

Palavras-chave: *Lactuca sativa L.*, reúso, agricultura sustentável, tratamento simplificado

LEROY, K. A.; MACHADO, L. T. S.; TÉLLEZ, H. O.; SÁNCHEZ-ROMÁN, R. M. GROWTH AND PRODUCTION OF MIMOSA LETTUCE USING WASTEWATER TREATED IN VERTICAL ANAEROBIC FILTERS

Recebido em 04/11/2021 e aprovado para publicação em 20/11/2022
DOI: http://dx.doi.org/10.15809/irriga.2022v27n4p856-868

2 ABSTRACT

The present work aimed to investigate the response in field of the lettuce cultivar Gabi using treated sewage water in vertical anaerobic filters in different proportions. The study was carried out at the Department of Rural Engineering and Socioeconomics (DERS), Faculty of Agricultural Sciences (FCA) – São Paulo State University (UNESP), Botucatu - SP, in a completely randomized design, consisting of five treatments and five repetitions. The treatments were composed of five different compositions of the irrigation water depth prepared from two sources, one being tap water (AA) and another treated wastewater (ART), resulting in: T1 – 100%ART + 0%AA, T2 - 75%ART + 25%AA, T3 - 50%ART + 50%AA; T4 - 25%ART + 75%AA; T5 – 0%ART + 100%AA. Two lettuce cultivation cycles were carried out during the period from September to December 2021 and the results obtained were statistically analyzed. For the analyzed variables, a significant difference was found by the Tukey test at 5% probability between the treatments studied only for the dry mass during the first cultivation cycle, and the treatment T4 (25% ART + 75% AA) was that presented best result.

Keywords: Lactuca sativa L., reuse, sustainable agriculture, simplified treatment

3 INTRODUCTION

Originating from wild species in regions of the eastern Mediterranean, lettuce (*Lactuca sativa L.*) is a vegetable belonging to the Asteraceae family, similar to artichoke, chicory, and endive. Lettuce began to be cultivated approximately 4,500 BC. There is evidence of its cultivation in ancient Egypt for animal feed and for extracting oil from its seeds (SANTOS, 2016). This vegetable was brought to Brazil by the Portuguese in the 16th century (TRANI *et al.*, 2014; TAVARES *et al.*, 2005).

Lettuce is considered the most important leafy vegetable worldwide (SALA; COSTA, 2012). This plant is highly desirable to consumers because of its high water content. Furthermore, it provides large amounts of vitamins (A, C, E, B1, B2, and B3) and minerals (phosphorus, iron, calcium, potassium, etc.) (SANTOS, 2016). In Brazil, lettuce is the most consumed leafy vegetable and represents the third largest volume of production, behind only watermelon and tomato (ABCSEM, 2014).

The irrigation sector uses 66.1% of Brazil's freshwater (ANA, 2019). However, according to Federal Law No. 9,433/97, which establishes the National Water Resources Policy, under conditions of scarcity, irrigation ranks third in the order of priority for water use, behind human consumption and animal watering. Therefore, it should not compete with water intended for supply, which will always take priority. In this context, water resources used for irrigation are increasingly scarce and of lower quality. This situation explains the need to adapt existing irrigation techniques to current and future water scarcity conditions (SANTOS, 2019; DUARTE, 2006).

Owing to the current scenario of water scarcity in many places around the world associated with great competition for water resources and the continuous increase in fertilizer prices, the use of water-treated waste in agriculture has become an essential alternative.

This option can be more economical than other costly alternatives, such as desalination or the development of new water sources that involve the construction of dams, reservoirs, and groundwater capture. Furthermore, reusing treated wastewater in agriculture allows for the conservation of drinking water for more demanding purposes, reducing the need for chemical fertilizers through the recycling of nutrients and constituting an effective measure of balanced environmental management of water resources, since it contributes to avoiding or reducing pollution generally caused by the discharge of sewage into bodies of water.

According to Guimarães *et al.* (2018), several studies reported in the literature have demonstrated the agricultural potential of wastewater when properly applied in agriculture. Azevedo and Oliveira (2005) and Leal *et al.* (2007) reported the significant beneficial effects of the reuse of treated wastewater on the production of sugarcane and cucumber, respectively.

While there are several benefits to using wastewater for crop irrigation, it is important to emphasize that when this practice is not performed properly, it can harm human health and the environment. Therefore, the reuse of effluents in soils must be constantly monitored, as improper use can lead to soil and water body contamination, degradation of soil physical characteristics, decreased water absorption capacity by plants, increased toxicity and saline stress in plants, and even worker contamination (BERTONCINI, 2008; QUEIROZ; QUEIROZ; ARAGÃO, 2015).

In view of the above, the present work aimed to investigate the response of the lettuce cultivar Gabi in the field using treated sewage water and vertical anaerobic filters in different proportions.

4 MATERIALS AND METHODS

The experiment was carried out from July to December 2021, in the field, at the Department of Rural Engineering and Socioeconomics (DERS) of the College of Sciences Agronomics (FCA) of São Paulo State University (UNESP) “Júlio de Mesquita Filho”, located in the municipality of Botucatu - SP (2nd floor, 50 ') 4 8" of l at São Paulo State University, São Paulo State University (UNESP) " longitude West and 8 1 7, 7 4 m altitude). The predominant climate of the region, according to the Köppen classification, is of the Cfa type, characterized as warm temperate (mesothermal) humid with rainy summers and dry winters. The location has an average annual air temperature of approximately 20.3°C, with July being the coldest month of the year (17.1°C) and January the hottest month (22°C). The average annual rainfall in the region is 1,428.4 mm, with January being the rainiest month (246.2 mm) and August the driest month (36.1 mm) (CUNHA; MARTINS, 2009).

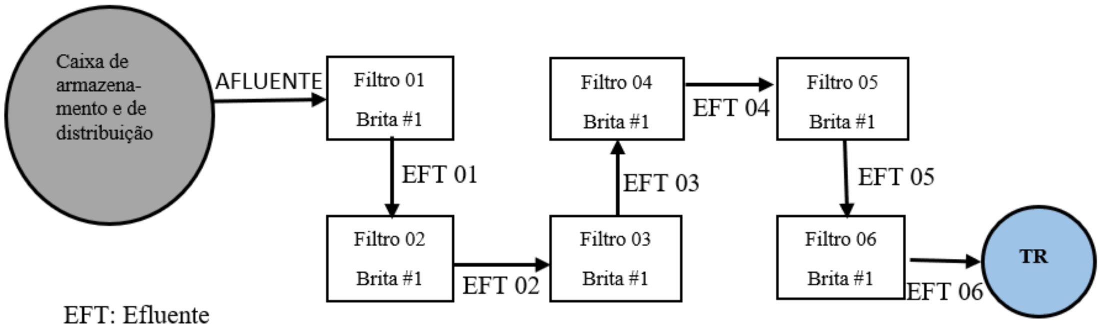
The experiment was carried out with two different water sources, one with wastewater treated with vertical anaerobic filters and the other from a local supply system.

The wastewater used in the experiment, originating from the sewage treatment plant (STP) of the São Paulo State Basic Sanitation Company (SABESP), was transported on demand to the experimental site in a 3,000-L tank on a tanker truck. This water was stored in a 5,000-L polyethylene tank for several weeks before being used in the experiment. This contributed to the sedimentation of dissolved particles in the water, improving its quality.

To treat the effluent used for lettuce irrigation, the treatment system proposed by Pitoro (2019) was adopted. This system consists of six filters manufactured in 200-liter plastic drums, each 0.90 m high and 0.50 m in internal diameter, arranged vertically and filled with #1 crushed stone support material. The six filters were connected in series by a 32 mm rigid PVC pipe, thus maintaining the water flow in vertical and downward directions (Figures 1 and 2).

The wastewater treatment system (STAR) also included a 5,000-liter water tank for receiving and distributing effluent from the Botucatu sewage treatment plant (considered an influent in this study) to the barrels through a 50-mm diameter PVC pipe equipped with a gate valve and a 150-liter water tank for receiving the treated effluent, called the reception tank (TR). The hydraulic retention time in the wastewater treatment system was approximately 4 days throughout the experiment.

Figure 1. Wastewater treatment system layout



Source: Author (2021)

Figure 2. Wastewater treatment system installed at the FCA Campus

Source: Author (2021)

A completely randomized experimental design (CRD) with five treatments (T) and five replicates (R) was used. The treatments consisted of five different percentages of treated wastewater (ART) irrigation depth combined with supply water (AA): T1, 100%ART + 0%AA; T2, 75%ART + 25%AA; T3, 50%ART + 50%AA; T4, 25%ART + 75%AA; and T5, 0%ART + 100%AA. The physicochemical characteristics of the water supply and treated waste used in the experiments are described in Table 1. Each plot consisted of 8 plants, totaling 200 plants in the experimental area.

Table 1. Characterization of treated wastewater and water supply

Parameters	Water type	
	AA	ART
pH	7.4	7.9
Electrical Conductivity (µS.cm $^{-1}$)	49.3	554.9
Total Solids	NR	346.9
Total Soluble Solids	NR	4.6
Total Dissolved Solids	NR	342.3
Total Nitrogen (mg.L $^{-1}$)	13.3	43.0
Total Phosphorus (mg.L $^{-1}$)	1.4	1.9
Potassium (mg.L $^{-1}$)	102.4	81.4
Biological Oxygen Demand (mg.L $^{-1}$)	NR	23.3
Chemical Oxygen Demand (mg.L $^{-1}$)	NR	23.6

AA-Water supply, ART-Treated wastewater, NR: Not performed
Source: Author (2021)

The crop used in the experiment was lettuce, a cultivar called Gabi, belonging to the mimosa group, with a cycle ranging from 60--70 days. It is a large, symmetrical plant with a high leaf volume and a high tolerance to bolting and tip burn and can be grown year-round, especially in summer.

Two cycles were carried out: the first occurred from September 18, 2021, to October 19, 2021, and the second occurred from November 15, 2021, to December 20, 2021. For both cycles, lettuce seedlings were purchased locally. At the time of purchase, the seedlings were 30 days old in the first cycle and 25 days old in the second cycle, both of which corresponded to the days after sowing.

After receiving the seedlings, they were transplanted into seedbeds, which remained in the field for 30 days in the first cycle and 35 days in the second cycle. Each seedbed consisted of two rows of four plants and a row of drip tubing with four emitters.

The fertilizers applied in this research, from transplanting to covering, were determined on the basis of soil analysis and following the recommendations of Trani *et al.* (2014). These authors suggest that mineral fertilization be applied at planting between seven and ten days after transplanting (DAT) in the total area of the beds, according to the soil analysis. The topdressing doses used were 60 kg ha^{-1} N, 15 kg ha^{-1} P_2O_5 and 30 kg ha^{-1} K2O, which were divided into two applications during the lettuce cycle. As topdressing, at 20 DAT during the 1st cycle, 8.35 g of urea (with 46% N), 3.2 g of potassium chloride (with 60% K_2O) and 3.6 g of simple superphosphate (with 21% P) were applied to each bed of the five treatments. In the second cycle, complete fertilization was carried out on the control (T5- 0% ART - 100% AA), with 8.35 g of urea (with 46% N), 3.2 g of potassium chloride (with 60% K2O) and 3.6 g of simple superphosphate (with 21% P) applied at 20 and 32 DAT, and for the compositions with ART, only a single top dressing application was carried out at 20 DAT.

Cultural treatments, such as controlling unwanted plants and applying pesticides to keep the area free of weeds, pests, and diseases, were performed as needed. A neem oil-based insecticide was sprayed every growing season for pest control at approximately 15 DAT at a dosage of 1 mL of solution per liter of water, as recommended by the manufacturer. Granular bait was used to control ants.

To apply different proportions of wastewater, combined with the local water supply, a localized drip irrigation system was installed. The system consisted of two reservoirs with a volumetric capacity of 300 liters, along with two PVC ball valves with a nominal diameter (DN) of 32 mm, one for each reservoir; a peripheral motor pump SOMAR (SHP-35) with 0.5 hp of power; a pressure gauge for monitoring system pressure; a 120 mesh screen filter with a mesh opening equivalent to 125 microns; a discharge line equipped with eight valves, two of which are used to control the possible return of water to the reservoir, one for washing the discharge line and five to control the opening and closing of the main lines; five main lines, all of recycled low-density polyethylene (LLDPE) with a DN of 20 mm; and 11 lateral lines of linear low-density polyethylene (LLDPE) with a DN of 20 mm.

A drip line with four emitters was installed at each site, resulting in a spacing of 0.30 m between emitters, aiming to form a wet band. The emitters used were Amnondrip, self-compensating, with a flow rate of 2.3 Lh^{-1} and an operating pressure of 1--3 bar.

Notably, irrigation, when water sources are used, is carried out individually because of the use of a single motor pump. Thus, the process used was as follows: 1) opening the registers (main lines and reservoir) of four treatments, for example, treatment 1, treatment 2, treatment 3 and treatment 4; 2) turning on the irrigation system; 3) irrigating with supply water according to the demand of each treatment based on time; 4) closing the registers (main lines) with respect to the irrigation time required for each treatment; 5) turning off the irrigation system after irrigating the four treatments; and 6) repeating this procedure for the second water source (treated wastewater) to complete the irrigation of the experimental units.

The evaluations were carried out at 30 DAT in the 1st cycle and 35 DAT in the 2nd cycle, during which the following parameters were analyzed: head diameter, number of leaves, and fresh and dry masses of the aerial parts.

a) Head diameter: the diameter was measured with the aid of a tape;
b) Number of leaves: the number of leaves (NF), considering leaves with a length equal to or greater than 3 cm;
c) Fresh and dry leaf mass: To determine fresh and dry leaf mass, leaves were stored in kraft paper bags to avoid transpiration loss. The fresh leaf mass (FLM) of each plant was subsequently determined by weighing on a precision balance. After determining the fresh leaf mass, the samples were stored in kraft paper bags and placed in a forced-air oven at 65 $^{\circ}C$ for 72 hours until they reached a constant weight. The dry leaf mass (DLM) of each plant was then determined via a precision balance.
d) Productivity: Productivity was calculated on the basis of the fresh mass of the aerial part of the plant and the population of plants per hectare for the proposed spacing.

Statistical analyses were performed via Sisvar 5.6 software, and the means were subjected to Tukey's test at the 5% probability level. The results are presented and interpreted in tables.

5 RESULTS AND DISCUSSION

Tables 2 and 3 show no significant difference ($p>0.05$) between the means of the variables head diameter, number of leaves, and fresh mass of the aerial part in the 1st and 2nd crop cycles due to the addition of different proportions of treated domestic sewage water. Fonteles *et al.* (2015) analyzed the growth and production of two lettuce cultivars using domestic sewage water from the campus of the Federal Rural University of Semi-Arid (UFERSA) and did not find a significant difference in the variables stem diameter, number of leaves, or dry matter of the aerial part.

Table 2. Summary of the analysis of variance of the nondestructive variables at the end of the 1st lettuce (Lactuca sativa L.) cultivation cycle in an experiment conducted at Botucatu, SP, from September to October 2021.

Causes of variation	Average board				
	GL	**A.D**	**NF**	**MFF**	**MSF**
Treatment	4	10.1 ^{NS}	1.9 ^{NS}	292.5 ^{NS}	5.1 *
Residue	24	4.9	5.5	689.7	1.6
CV	(%)	8.7	14.3	17.3	17.5
Treatment		**Average Values**			
T1		27.5 to	15.5 to	87.4 a	5.5 to
T2		29.4 a	17.0 to	103.9 a	7.1 ab
T3		30.1 a	16.5 to	104.7 a	7.5 ab
T4		31.1 a	15.9 a	107.0 a	8.1 b
T5		30.9 a	16.8 a	103.2 a	7.6 ab
Dms		6.4	4.5	44.17	2.4

T1- 100%ART + 0%AA, T2- 75%ART + 25%AA, T3- 50%ART + 50%AA, T4- 25%ART + 75%AA, T5- 0%ART + 100AA

GL- degree of freedom, DC- head diameter (cm), NF- number of leaves, MFPA- fresh mass of the aerial part (g. head $^{-1}$), MSPA- dry mass of the aerial part (g. head $^{-1}$), CV- coefficient of variation, Dms - minimum significant difference.

Note: NS, not significant; *, significant ($p < 0.05$); equal letters in the columns do not differ statistically according to Tukey's test ($p < 0.05$).

Table 3. Summary of the analysis of variance of the nondestructive variables at the end of the 2nd lettuce (Lactuca sativa L.) cultivation cycle in an experiment conducted at Botucatu, SP, from November–December, 2021

Causes of variation	**Average frame**				
	GL	**A.D**	**NF**	**MFF**	**MSF**
Treatment	4	10.1 NS	3.3 NS	392.0 NS	4.1 NS
Residue	24	4.9	16.0	2251.4	8.7
CV	(%)	8.7	15.3	34.1	27.3
Treatment		**Average Values**			
T1		26.1 a	24.7 a	139.4 a	12.1 a
T2		25.1 to	30.2 a	141.7 a	10.5 to
T3		26.0 a	24.2 a	141.6 a	10.8 to
T4		26.4 a	24.1 a	124.9 a	9.6 a
T5		27.3 a	25.1 to	149.1 a	11.0 a
Dms		7.8	9.5	92.0	5.7

T1- 100%ART + 0%AA, T2- 75%ART + 25%AA, T3- 50%ART + 50%AA, T4- 25%ART + 75%AA, T5- 0%ART + 100AA.

GL- degree of freedom, DC- head diameter (cm), NF- number of leaves, MFPA- fresh mass of the aerial part (g. head $^{-1}$), MSPA- dry mass of the aerial part (g. head $^{-1}$), CV- coefficient of variation, Dms - minimum significant difference.

Note: NS, not significant; *, significant ($p < 0.05$); equal letters in the columns do not differ statistically according to Tukey's test ($p < 0.05$).

Similar results were reported by Baumgartner *et al.* (2007) in an experiment evaluating the reuse of effluents from fish and pig farming for irrigating lettuce crops. The authors reported that for the variables head diameter, root length, root mass, total plant mass, fresh mass, and dry mass, no significant difference was detected at the 5% probability level via the F test in relation to the type of wastewater used.

Juchen (2000), evaluating the production of American lettuce fertigated with dairy and meatpacking wastewater, reported no significant difference between treatments in terms of the lettuce head diameter and number of leaves. These results were also reported by Lima *et al.* (2011), who evaluated the production of pumpkin seedlings irrigated with different proportions of treated water from domestic sewage and reported no significant difference between the treatments for most of the variables analyzed.

Tavares *et al.* (2005), examining the effects of irrigation with wastewater from domestic and organic fertilizer applications, reported that the interaction between the two factors was not significant at the 5% probability level. The authors also observed no significant differences at the 5% level for the variables plant height, plant circumference, number of leaves, leaf weight, root weight, total weight, and root diameter. due to the type of water used.

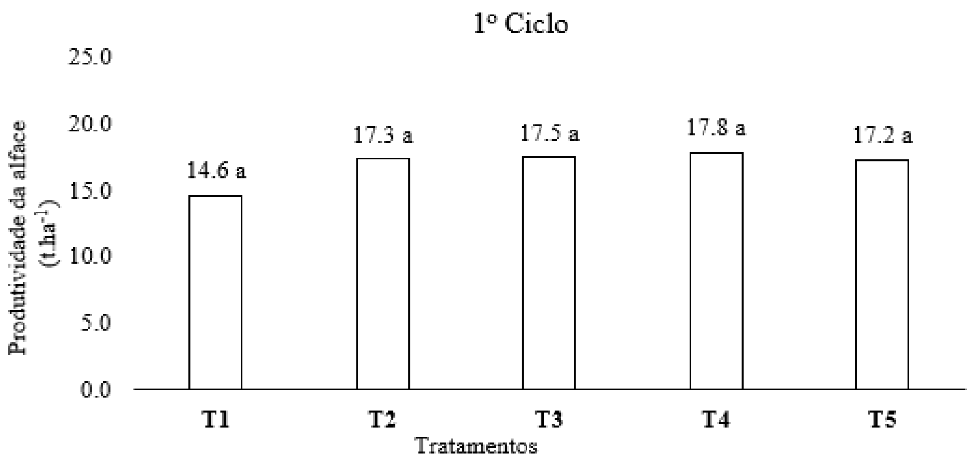
The results of Santos (2019), in an experiment carried out with treated effluent from lettuce cultivation, are contrary to those of the present work, as the author reported that there was a significant difference between the proportions of the irrigation depth for all variables shown in Tables 2 and 3 for wastewater treated by constructed wetlands (ARTAC). Furthermore, the results of the present work do not coincide with those of the work of Baumgartner *et al.* (2005), who, when irrigating lettuce with wastewater from agroindustrial activities, reported differences between treatments in terms of the variables of plant height, head diameter, length of the largest leaf, average number of leaves per plant, fresh mass, dry mass and total plant mass. This could be explained by the origin of the wastewater and/or the treatment system used.

The dry mass of leaves (MSF) in the 1st cycle was the only variable for which a significant difference was verified at the 5% probability level when different proportions of domestic sewage water depth were applied. treated; treatment T4 differed from T1 but did not significantly differ from T5, T3 and T2. The highest average MSF value was found in treatment T4 (25% ART + 75% AA), and the lowest was found in treatment T1 (100% ART + 0% AA). The results indicate that the application of different concentrations of treated domestic effluent did not harm the growth of the lettuce culture, corroborating Baumgartner *et al.* (2007) and Fonteles *et al.* (2015).

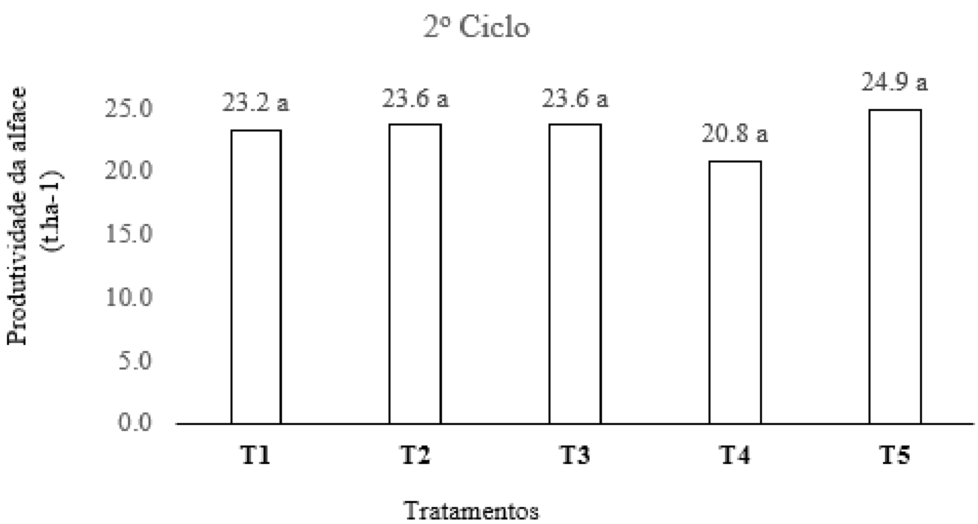
Figure 3 shows the average productivity according to the treatments evaluated during the two cultivation cycles.

Figure 3. Average values of lettuce productivity according to the different treatments evaluated during the 1st ^{cycle} (**A**) and the 2nd ^{cycle} (**B**) of cultivation.

A



B



Averages followed by at least one same letter in the columns for each treatment do not differ from each other at a 5% probability according to the Tukey test.

As shown in Figure 3, the comparison of the productivity averages revealed that there was no significant difference between the treatments evaluated during the two cycles, corroborating the findings of Fonteles *et al.* (2015), who, when evaluating the growth and production of two lettuce cultivars using different dilutions of treated wastewater, did not obtain a significant difference, thus demonstrating the potential for replacing part of the chemical fertilizer application, the technical feasibility of reusing sewage for lettuce irrigation, and the savings in better-quality water. Furthermore, the productivity values obtained in the first cycle were close to the national average of 18.6 t. ha $^{-1}$ reported by Neves *et al*. (2017), referring to the 2016/17 harvest (Figure 3A). With respect to the second cycle, for all the treatments, the productivity obtained was greater than the national average for 2016 (Figure 3B).

Rego *et al.* (2005) studied treated domestic sewage in the production of watermelon, variety Crimson Sweet, under drip irrigation. These authors reported no significant differences between treatments T1 (well water plus recommended fertilizer); T2 (effluent plus recommended fertilizer); T3 (effluent); and T4 (effluent plus half the recommended fertilizer) in terms of productivity and other variables analyzed, demonstrating the possibility of using treated sewage without fertilizer, saving not only fertilizer but also well water, and making irrigation and cultivation less expensive.

6 CONCLUSION

The results obtained demonstrated the possibility of using water wastewater treated in vertical anaerobic filters as a source of water and nutrients for the cultivation of high-quality lettuce for human consumption, reducing fertilization with commercial chemical fertilizers and reducing production costs, increasing the cost of economical irrigation and cultivation.

7 ACKNOWLEDGMENTS

This work was carried out with support from the Improvement Coordination Higher Education Personnel – Brazil (CAPES) – Financing Code 001.

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