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SUSTAINABLE WASTEWATER TREATMENT IN PROTECTED IRRIGATED RADISH CULTIVATION

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1 ABSTRACT

The sustainable treatment of wastewater can be an alternative to irrigated agriculture, aiming to mitigate the effects of water scarcity in regions that suffer with this issue. This study aimed to evaluate the effect of sustainable treatment of wastewater on the irrigation of radish cultivated in greenhouses. The study was conducted at the Federal University of Campina Grande, Campina Grande, PB, Brazil. The experimental design was randomized blocks a 3x3 factorial scheme, with the factors being three qualities of water (water treated by wetland, water treated by wetland + UASB and control treatment (water from the local supply system)) and three micro-irrigation systems (subsurface drip, surface drip and micro sprinkler), with four replications. Waters treated by sustainable systems such as wetland and wetland + UASB, were not considered suitable for irrigation of leafy crops according to the guidelines of CONAMA resolution 357/2005. The sustainable treatment wetland + UASB and drip irrigation showed the best results in growth and production of radish. The radish root diameters were within the range considered ideal by the consumer market. Further studies with combinations of sustainable water treatment systems are needed aiming to frame the treated wastewater quality to the requirements of CONAMA resolution 357 for irrigation of leafy crops.

Keywords: reactor UASB, wetland, *Raphanus sativus*, reuse, microirrigation.

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TRATAMENTO SUSTENTÁVEL DA ÁGUA RESIDUÁRIA NO CULTIVO DE RABANETE IRRIGADO EM AMBIENTE PROTEGIDO

2 RESUMO

O tratamento sustentável das águas residuárias pode ser uma alternativa para a agricultura irrigada, visando mitigar os efeitos da escassez hídrica em regiões que sofrem com esta problemática. Objetivou-se com este estudo avaliar o efeito do tratamento sustentável de água residuária no cultivo de rabanete irrigado em ambiente protegido. O trabalho foi conduzido na Universidade Federal de Campina Grande, Campina Grande, PB, Brasil. O delineamento experimental foi blocos casualizados em esquema fatorial 3x3, sendo os fatores: três qualidades de água (água tratada por *wetland*, água tratada por *wetland*+UASB e tratamento testemunha (água do sistema de abastecimento local)) e três sistemas de microirrigação (gotejamento subsuperficial, gotejamento superficial e microaspersão, com quatro repetições. As águas tratadas por sistemas sustentáveis como *wetland* e *wetland*+UASB, não foram consideradas próprias para irrigação de culturas folhosas conforme as diretrizes da resolução do CONAMA 357/2005. O tratamento sustentável *wetland*+UASB e irrigação por gotejamento evidenciaram os melhores resultados em crescimento e produção de rabanete. Os diâmetros das raízes do rabanete ficaram dentro da faixa considerada ideal pelo mercado consumidor. São necessários mais estudos com combinações de sistemas sustentáveis de tratamento de água visando enquadrar a qualidade da água residuária tratada nas exigências da resolução CONAMA 357 para irrigação de culturas folhosas.

Palavras-chave: reator UASB, *wetland*, *Raphanus sativus*, reúso, microirrigação.

3 INTRODUCTION

Treatment for the sustainability of wastewater reuse is a viable alternative, with sustainable technologies as UASB reactors and wetland being proven to be suitable solutions by several studies developed especially in developing countries such as India, Brazil, Mexico and Colombia (LETTINGA, 2008; KHAN et al., 2011; DANTAS et al., 2014; MATOS et al., 2015; SILVA et al., 2017). Khan et al. (2014) affirm that these technologies in the treatment of wastewater, follow the quality standards with the rigors required by the current legislation in India. In Brazil, there is no specific legislation for water reuse in agriculture, however the state law of Ceará Nº 16,033, of 2016 is considered the most up-to-date and strict regarding the classification of water for agricultural reuse.

Batista, Oliveira and Mesquita (2014) reported that from an environmental point of view, the use of microirrigation is considered more sustainable for irrigation with wastewater due to the high application efficiency, the low risk of contamination of agricultural products and operators in the field, the minimization of runoff risks, the reduction of percolation and accumulation of salts close to the root system, and the prevention of aerosol dispersion.

The artificial wetland (built) is a system that remains partially or totally flooded throughout the year, taking advantage of natural processes to remove pollutants from the effluent, improving its physical quality through filtration, sedimentation and volatilization; reducing chemical concentrations due to processes of adsorption, oxidation, reduction, precipitation and chelation; and biological enhancement due to degradation and absorption of microorganisms, decay of pathogens, extraction of by plants, among others. In wetlands, the most important process that improves water quality and regulates nitrogen and phosphorus removal is the direct absorption by macrophyte plants (KHAN et al., 2014).

The Upflow Anaerobic Sludge Blanket (UASB) reactors present high efficiency, generally they are used in primary processes for the stabilization of the initial organic matter. The liquid effluents are directed by gravity and must pass through a coarse solids retention system, in some cases, nutrients (P and N) must be added so that the liquid would be pumped into the UASB sludge blanket reactor (LETTINGA, 2008).

Wastewater when treated regardless of the treatment system, it is considered to have high potential for application via the irrigation system because it has macro and micronutrient contents, which favor the growth and productivity of irrigated crops (KHAN; MEHROTRA; KAZMI, 2015; MATOS et al., 2016; SILVA et al., 2017).

Javarez Junior, Ribeiro and Paula Junior (2010) and Mendes, Bastos and Souza (2016) reported that the use of wastewater treated by sustainable technologies in agricultural crops, has contributed to the reduction and control of environmental pollution, becoming a viable practice in view of the availability of nutrients for agricultural crops, especially vegetables that are highly demanding in fertilizers.

Matos et al. (2015), evaluating the growth and production of radish irrigated with treated wastewater, observed an increase in productivity, without compromising the physicochemical characteristics of the roots, especially their sanitary quality.

The cultivation of radish in countries stands out for presenting attractive characteristics, such as short cycle and rusticity, with the harvest performed from 25 to 35 days after sowing, it offers a quick financial return, besides providing a fast and nutritious food for families (PULITI et al., 2009).

Given the relevance of the theme, the objective of this study was to evaluate the effect of a sustainable wastewater treatment on the cultivation of irrigated radish in a greenhouse.

4 MATERIAL AND METHODS

4.1 Description of the experimental area

The experiment conducted in a greenhouse belonging to the Federal University of Campina Grande, Campina Grande, PB, Brazil, near the sustainable treatment station, located at the geographical coordinates 7º 12 '88 ” S and 35 ° 54' 40” W and altitude average of 532 m, in the period from April to May 2014.

The substrate used was made of a material of a vertisol litholic eutrophic, with a sandy-loam texture, with the following chemical and physical characteristics: pH 7.04; phosphorus 4.97 mg100 g^{-1}; potassium 0.25; sodium 0.20; calcium 3.55; magnesium 3.10; aluminum 0.0; hydrogen 0.0 mmolc dm^{-3}; organic matter 0.96%; bulk density 1.33 g cm^{-3}; sand 85.05; silt 8.04, and clay 6.91%, according to the Brazilian Agricultural Research Corporation (Embrapa) (2014) methodology.

The radish cultivar used was the Crimson *Gigante* of short cycle. The seedlings were produced in polyethylene trays of 128 cells filled with commercial substrate Plantmax®. The transplant was performed using a seedling per pot, at 10 days after sowing, when they had four definitive leaves.

4.2 Treatments and experimental design

The sustainable treatments consisted of a UASB type reactor and a wetland natural treatment system. The adopted statistical design was randomized blocks, with four replications, so that the studied factors were arranged in a 3x3 factorial scheme, that were, three water qualities (water treated by wetland - WET, water treated by wetland + UASB reactor (WET + UASB) and control treatment with water from the local supply system - AAP) and three micro-irrigation systems (subsurface drip, surface drip and micro-sprinkler).

Each experimental unit was composed of a vase with holes in the bottom, containing a 1 cm layer of crushed stone No. 1, covered with a geotextile blanket to facilitate drainage; the pots were filled with about 65 kg of substrate.

4.3 Irrigation and management system

A pressurized irrigation system equipped with three 0.5 CV centrifugal pumps was used, each control head was equipped with a screen filter with a capacity of five m^3 h^{-1} and a Bourdon type pressure gauge.

For the drip irrigation system, a self-compensating Rain Bird hose with a flow rate of 2.3 L h^{-1} was used. The micro sprinkler Hadar 7110 used had an orange nozzle with a nominal flow of 75 L h^{-1}.

For the irrigation management of the Crimson *Gigante* radish cultivar a daily irrigation shift was per fixed, the irrigation depth was calculated based on the crop evapotranspiration (ETc),that was obtained from the readings of 36 drainage lysimeters installed in the greenhouse. The daily ETc was calculated from the average balance of the entry and exit of water, according to Equation 1.

$$ETc = I - D \qquad (1)$$

Where:
ETc - Crop evapotranspiration, in mm day^{-1};
I - Irrigation depth applied by irrigation (entry of water), in mm day^{-1}; and,
D - Drainage of the irrigation depth on the lysimeter (exit of water), in mm day^{-1}.

4.4 Variables analyzed

The waters treated by sustainable systems were analyzed for pH, Biochemical Oxygen Demand (BOD), Suspended Solids (SS), Dissolved Solids (DS), Total Iron (Fe), Total Manganese (Mn), Total Calcium ($Ca^{2+),}$ total magnesium (Mg^{2+}), in addition to the fecal coliforms expressed in Colony Forming Units (CFU mL^{-1}), according to the methodology proposed by Embrapa (1997) and American Public Health Association (APHA) (2005). All parameters were determined three times during the radish cultivation cycle.

At 35 days after transplant, the following variables were analyzed: number of leaves by means of direct counting, leaf area according to Equation 2, diameter of the tuberous root with the aid of a digital caliper, tuberous root volume measured by immersing the root in a beaker with water, and fresh weight of the tuberous root with the aid of a precision scale.

$$AF = C * L * f \qquad (2)$$

Where:
AF - Leaf area, in cm^2;
C -Length of the leaf, in cm;
L - Width of the sheet, in cm; and,
f - Correction factor (0.57), dimensionless, (MATOS *et al.*, 2015).

4.5 Statistical analysis

The variables related to culture were statistically analyzed by the F test, with the analyzes unfolding whenever the interaction was significant, with the comparison of means by the Tukey test ($p \leq 0.05$), with the Sisvar software (FERREIRA, 2014).

5 RESULTS AND DISCUSSION

5.1 Water quality in a sustainable system

The parameters of the quality of the wastewater treated by the sustainable system are shown in Table 1. It is noted, that the parameters pH, suspended solids, dissolved solids, calcium, total nitrogen, sodium, potassium, chloride, and Sodium Adsorption Ratio (SAR)–were classified as acceptable for irrigation purposes, that means that they are within the standards established by Ayers and Westcot (1999).

Table 1. Main parameters of wastewater and drinking water quality, and classification of the irrigation water quality according to Ayers and Westcot (1999).

Parameters	**Wetland**	**Wetland+ UASB**	**Potable water - AAP**	**Classification Ayers and Westcot (1999)**
Hydrogenionic Potential (pH)	8.09	8.09	6.83	6.50–8.50
Suspended Solids (mg L^{-1})	300.00	330.00	0.00	295.6–522.8
Dissolved Solids (mg L^{-1})	1370.00	1310.00	49.00	500–2000
Iron (mg L^{-1})	5.30	5.10	0.00	5.00
Manganese (mg L^{-1})	0.56	0.75	0.00	0.20
Calcium (mg L^{-1})	3.59	2.86	1.73	0–200
Magnesium (mg L^{-1})	4.07	4.34	3.14	-
Biochemical Oxygen Demand - BOD (mg L^{-1})	318.00	345.00	10.00	10–30
Total Coliforms - TC (CFU 100 mL)	7200.00	6500.00	15.00	0–10^3
Electric conductivity -EC (dS m^{-1})	7.69	8.31	4.98	0.80–3.00
Water classification	C4	C4	C4	CE > 3 = Severe
Total Nitrogen (meq L^{-1})	5.50	5.60	1.80	0–50
Total Phosphorus (meq L^{-1})	0.03	0.03	0.02	-
Sodium (meq L^{-1})	5.00	5.70	4.80	0–900
Potassium (meq L^{-1})	0.36	0.43	0.10	0–1000
Carbonates (meq L^{-1})	1.12	5.28	0.00	-
Bicarbonates (meq L^{-1})	2.42	2.15	0.82	-
Chlorides (meq L^{-1})	8.25	6.85	6.82	0–100
Sodium Adsorption Ratio-SAR	3.31	3.22	3.10	3–9

BOD-Biochemical Oxygen Demand; C4- water with very high salinity (EC between 2.25 and 5.00 dS m^{-1} at 25°C)

However, it is worth noting that the pH values, suspended solids (SS), dissolved solids (SD) and iron represent a severe to moderate risk of dripper obstruction, according to the guidelines presented by Nakayama and Bucks (1991). These results are consistent with those obtained by Silva *et al.* (2017) that observed that the wastewater treated by wetland and wetland + UASB presented serious risk of dripper clogging.

The concentrations of calcium, magnesium and potassium found in the treated wastewaters show potential and significant saving capacity with the reuse of this water for crops fertigation purposes (Table 1). The sodium content found in the treated wastewaters was 19% higher than the value obtained for drinking water, indicating the need for care with the reuse of these waters, since they were classified as C4 (high salinity level) (Table 1).

The cultivation of radish irrigated with water that has a high level of salinity requires some care such as the application of leaching water depths. According to Ayres and Westcot (1999), radish crops are moderately sensitive to salinity, with a threshold of 1.2 dS m^{-1}

The biochemical oxygen demand (BOD), total coliforms (TC), electrical conductivity (EC) and manganese (Mn) obtained in this work are above the recommendations of Ayers and Westcot (1999) (Table 1). These parameters are above those recommended, which makes it possible to affirm that further studies are needed with combinations of others sustainable wastewater treatment systems, aiming to meet the requirements of CONAMA resolution 357/2005 for irrigation of leafy crops. It is important to highlight and that these values fit as low emitters clogging risk. It is also noted that the BOD concentrations are directly proportional to the amount of solids and nitrogen present in the waters.

The count of total coliforms (TC) was higher than the limits established for water for agricultural reuse, which is a maximum of 1000 NMP 100 mL^{-1}. This result is similar to those obtained by Mendes, Bastos and Souza (2016). Fact that can be justified by the high pH and BOD concentration.

According to CONAMA resolution 357/2005 (BRASIL, 2005), for the irrigation of vegetables that are eaten raw and fruits that develop close to the soil and that are eaten raw without removing the film, the thermotolerant coliforms should not be exceeded 200 thermotolerant coliforms per 100 mL. In view of this resolution, it is observed that the wastewaters that have undergone the treatments with wetland and wetland + UASB had a number of coliforms higher than acceptable, and; therefore, cannot be used for irrigation.

The treated wastewater when compared to drinking water presents considerable differences in all parameters analyzed, showing that even though the wastewater undergoes sustainable treatment, the treatment options adopted have low efficiency (around 50 to 60%) as stated by Zhang, Wang and Wang (2013).

5.2 Effects of the treated wastewater and irrigation systems on the radish crops

The summary of the analysis of variance for the number of leaves (NF), leaf area (AF), root diameter (D. Root), root volume (V. Root) and fresh root weight (PF. Root) of radish depending on the treated wastewater, water, and the irrigation systems are shown in Table 2.

Table 2. Summary of analysis of variance for the variables analyzed from the radish as a function of the treated wastewater, water, and irrigation systems.

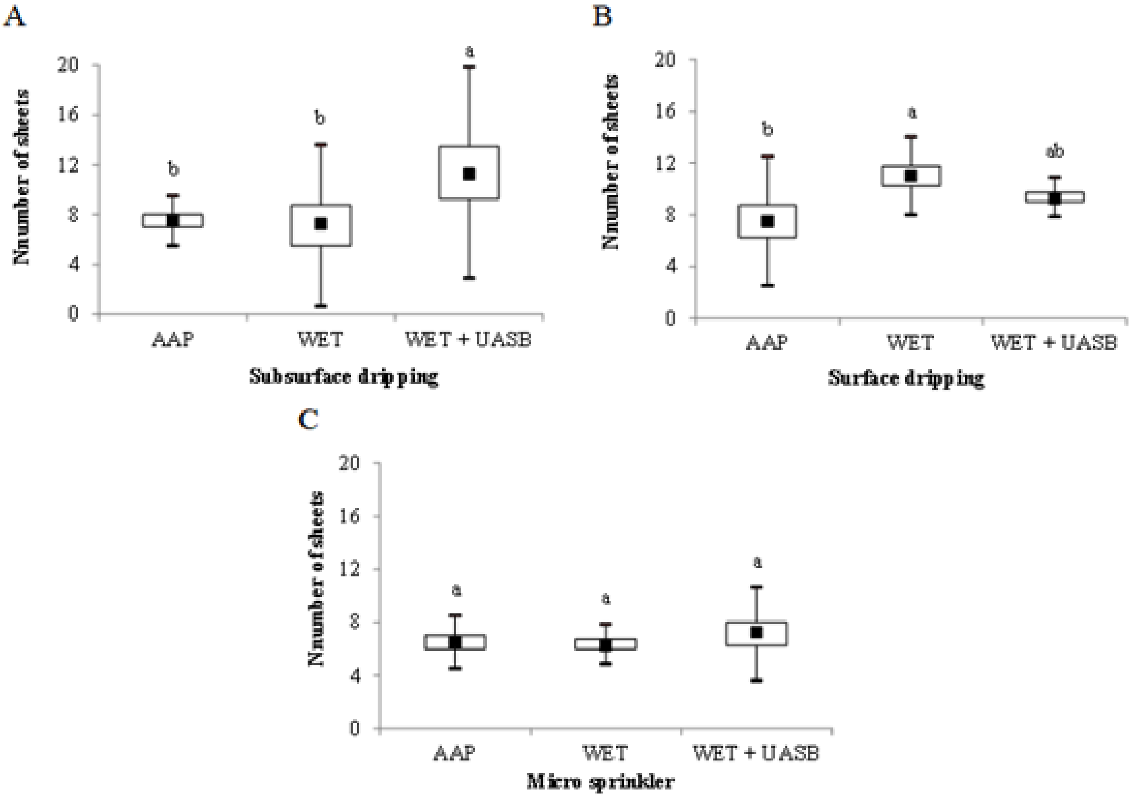
Variation Source	DF	NF	AF (cm^2)	D. Root (mm)	V. Root (ml)	PF. Root (g)
Sustainable Water Treatment (SW)	2	13.02^{**}	611029.84^{**}	83.02^{*}	55.79^{ns}	422.22^{**}
Irrigation Systems (IS)	2	22.02^{**}	305573.68^{**}	93.52^{*}	2714.29^{**}	3041.36^{**}
SW x IS	4	10.19^{**}	324205.88^{**}	277.73^{**}	1635.53^{**}	1533.30^{**}
Residue	25	1.36	24630.98	24.16	87.57	47.42
Overall Average	-	8.19	827.17	39.38	49.3	45.83
CV(%)	-	14.25	18.96	12.48	19.98	15.03
Sustainable Water Treatment (SW)	Medium values (g)					
Supply Water - AAP	-	7.16 b	603.60 c	37.67 b	47.22 a	40.50 b
Wetland	-	8.16 ab	824.76 b	38.08 b	49.16 a	44.77 b
Wetland+UASB	-	9.25 a	1054.88 a	42.41 a	51.52 a	52.22 a
Irrigation Systems (IS)	Medium values (g)					
Micro sprinkler	-	6.67 b	662.53 b	36.91 b	31.94 b	27.52 b
Subsurface dripping	-	8.67 a	839.60 a	38.83 ab	57.63 a	53.52 a
Surface dripping	-	9.25 a	931.06 a	42.41 a	58.33 a	56.44 a

^{ns} - Not significant; * - Significant at 0.05; ** - Significant at 0.01. DF- Degrees of freedom; AF- leaf area; NF-number of leaves; D. Root- root diameter; V. Root- root volume; PF. Root -fresh root weight; CV- Coefficient of variation; AAP- Supply Water.

A significant isolated effect was observed for sustainable water treatment (SW) by the F test at 0.01 for the NF, AF, PF. root and 0.05 for D. root. As for the irrigation systems (IS) factor, there was a significant effect at the level of 0.01 by the F test, for all variables analyzed. There was also interaction between the factors (SW x IS) at the level of 0.01 by the F test, for all variables analyzed (Table 2). These results are similar to those obtained by Matos et al. (2015, 2016), when they studied the production of radish irrigated with treated wastewater.

The unfolding of the interaction between the factors (SW x IS) for the number of leaves of the radish is shown in Figure 1.

Figure 1. Box plot interaction of the sustainable water treatment versus subsurface dripping (A), surface dripping (B) and micro sprinkler (C) for the number of radish leaves at 35 days after transplant.



Box-plot graphs for sustainable water treatment with subsurface dripping show that the average values for the number of leaves were 7.5; 7.3 and 11.3, respectively for AAP, WET and WET + UASB, no statistical difference was observed for the AAP and WET treatments; however, there was a significant difference when compared with the water treated by WET + UASB (Figure 1A).

The average values for the number of leaves when studying the interaction of sustainable water treatment with surface dripping were 7.5; 11.0; and 9.3 for AAP, WET and WET + UASB, respectively; a significant difference was observed at the level of 5% only for wetland treatments compared to AAP (Figure 1B).

There was no significant difference for the interaction sustainable water treatment versus irrigation by micro sprinkler for the variable number of radish leaves, with the observed averages being 6.5; 6.3 and 7.3, it is also noted that these averages are lower than those obtained in the drip irrigation systems (Figure 1C). Possibly, the absence of difference between the different types of water for the micro-sprinkler system, it is associated with the form of water application that simulates an artificial rain, and it is not located with direct contact with the roots of the plants as it occurs in the drip systems.

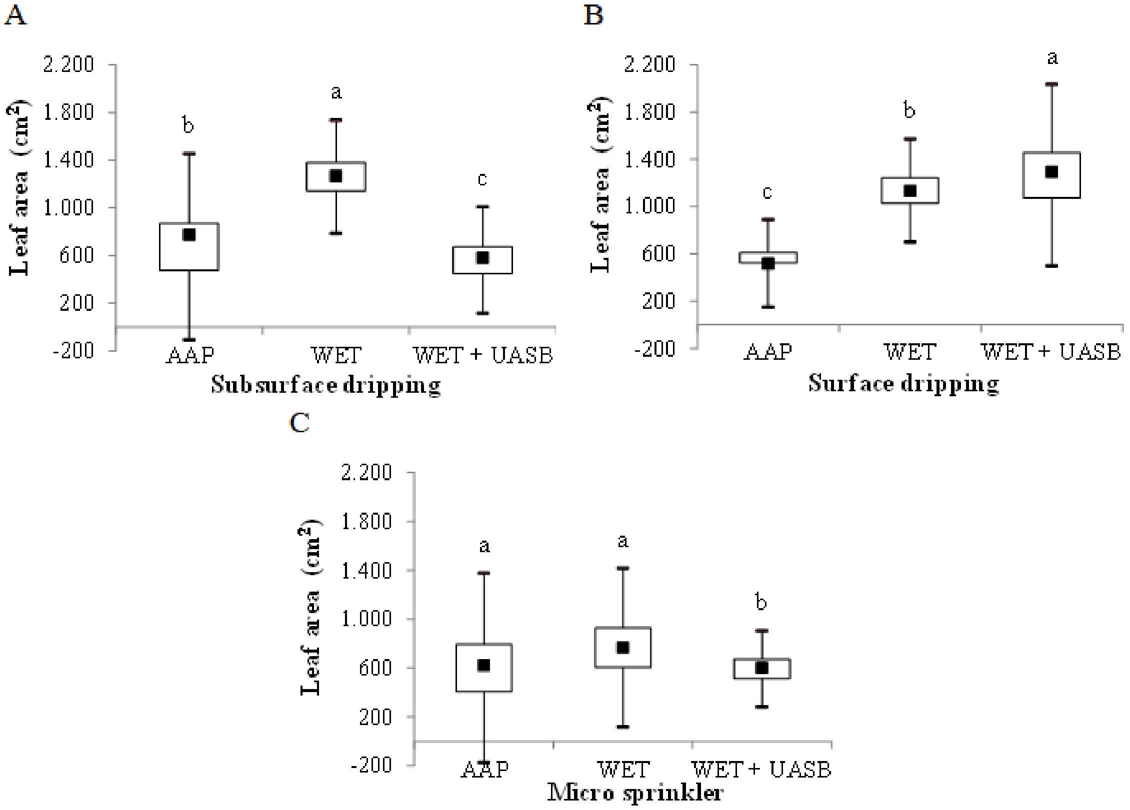
It is also noted that there was a greater discrepancy for the interactions between the maximum value and the other dispersion measures, for the interactions with subsurface and superficial dripping. The interaction for the micro sprinkler was the one that produced less variability in the number of leaves. The great variation observed for the number of leaves in the interactions with the subsurface and surface drip may be associated with the high concentrations of total nitrogen, calcium, potassium and magnesium present in the treated waters. Taiz and Zaiger (2017) states that nitrogen is one of the mineral elements that most influence the growth of plant leaves.

These results are consistent with those observed by Matos et al. (2015) that when researching on growth and production of radish irrigated with wastewater treated in a greenhouse, observed an average of 10 leaves per plant at 35 days after transplanting in the interactions between dripping and water treated by WET + UASB.

Quadros et al. (2010) while studying nitrogen doses in radish applied via fertigation, obtained an average of 21.1 leaves per plant, values higher than those found in this research, showing that the greater the amount of nitrogen available to the plant, the greater its vegetative development. Possibly the amount of total nitrogen available to the plants by the treated wastewater is still considered insufficient, requiring complementary fertilization with nitrogen.

The leaf area of the radish in the different interactions shows great variability, it is also noted that greater distribution of the leaf area of the radish was obtained in the interactions with dripping and sustainable water treatment by WET and WET + UASB, Figure 2; except for the leaf area in the WET + UASB treatment in Figure 2A.

Figure 2. Box plot interaction of the sustainable water treatment versus subsurface dripping (A), surface dripping (B) and micro sprinkler (C) for radish leaf area at 35 days after transplant.



In the interaction for subsurface dripping within each of the sustainable water treatment, it is observed that the treatment with WET was the one that showed the highest averages, corresponding to 1267.5 cm^2, and the treatments with APP and WET + UASB showed reductions of 39 and 54%, respectively, being lower than the WET treatment within the subsurface drip irrigation system (Figure 2A).

The negative values observed for leaf area in the treatment with APP, are due to outliers, that is, possible outliers, due to the values being below or above the detection limit of outliers. This limit is determined through the interquartile range, given by the distance between the first and third quartiles, so the lower limit is determined as follows: lower limit = First Quartile - 1.5 * (Third Quartile - First Quartile).

It can be said in this way, that when the median line is close to the first quartile, the data is positive asymmetric and when the position of the median line is close to the third quartile, the data is negative asymmetric. Thus, it is possible to notice that the leaf area in the APP treatment in the underground drip and in the micro sprinkler the data were negative asymmetric (2A and C).

The interactions for surface dripping inside each sustainable water treatment was the one that showed the highest average for the sustainable treatment of water WET + UASB, corresponding to 1295.0 cm^2, a treatment that provided a large amount of nitrogen, phosphorus, potassium and manganese for the plants throughout the cultivation cycle (Figure 2B).

In Figure 2C, the boxplot of the residues from these analyzes is observed. It can be seen that, for the unfolding of the interaction of the micro sprinkler irrigation system and the treated waters by sustainable treatment WET and WET + UASB, 95% of the residues are contained between 600.0 and 900.0 cm^2 of leaf area. This dispersion of data reveals that the sample size adopted meets the needs of the work. The increase in the sample size would generate results close to those obtained, maintaining the same trend. As for figure 2A, only 75% of the waste is between 477 and 868 cm^2, which reflects an asymmetric trend in the data.

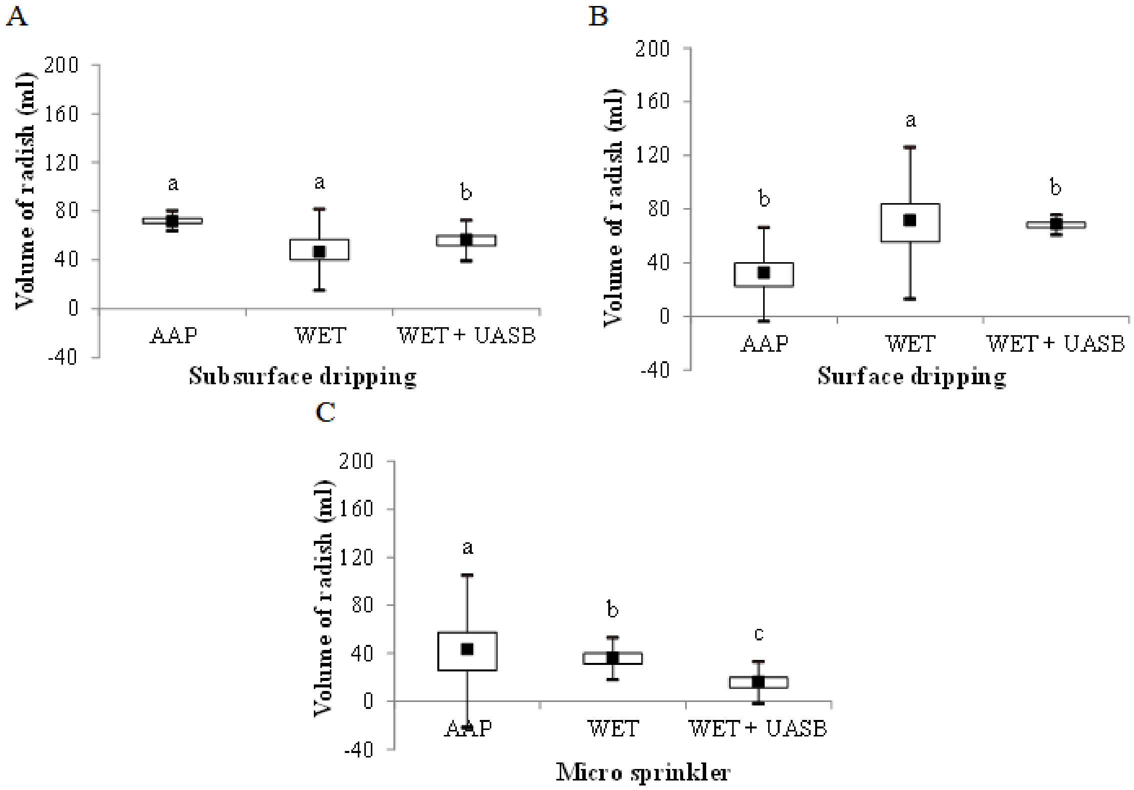
It is also worth noting that the lower and upper limits of those that comprise 25 and 75% of the leaf area values in the different interactions were distant at the upper limit. With this, it can be seen that the averages of leaf areas are discrepant in all treatments, and this discrepancy may be associated with the amount of nutrients present in each water and also with the irrigation system used. This variation in the leaf area is considered acceptable since this variable is directly related to the interception of luminosity, photosynthetic efficiency, evapotranspiration rate and responses to fertilizers and irrigation, so whatever the slight fluctuation in these parameters will influence the leaf area (TAIZ and ZAIGER, 2017).

Matos et al. (2015) by using the same sustainable water treatments, found that in the interaction with the surface drip irrigation system, it was obtained an average radish leaf area superior to the other interactions corresponding to (1,293.3 cm^2). This result is similar to that obtained in the present study.

Maia et al. (2011) when studying the radish under different potassium sources applied in foundation, obtained a leaf area of 441.4 cm^2 plant^{-1}, this result is inferior to those obtained in the present study. The highest values obtained in this study are associated with the amount of potassium present in the water treated by a sustainable system, in addition to the water being applied daily, which provided a supply of daily potassium to the plants, thus favoring the growth of the plants.

The radish root volume for each interaction is shown in Figure 3. There was a significant difference for all the interactions studied, with the lowest values being observed for the interaction with the micro sprinkler irrigation system.

Figure 3. Box plot of the interaction of the sustainable water treatment versus subsurface dripping (A), surface dripping (B) and micro sprinkler (C) for the volume of radish root at 35 days after transplant.



The interaction of the sustainable water treatment within the subsurface dripping showed that the AAP provided the highest average when compared to the waters treated by WET and WET + UASB, corresponding to 72.0 mL of tuberous root (Figure 3A).

It was found that the lower and upper limits that comprise 25 and 75% of the values were very close to the upper and lower limit, showing that the distribution can be considered symmetrical around the average value of the root volume, while the distribution of the volume of root is asymmetrical with concentration to the left of the lowest values for treatment with WET and the right of the highest values to WET + UASB (Figure 3A).

In the interaction of the surface dripping with the treated water, it is noted that the highest averages were obtained in sustainable treatments using wetland and wetland + UASB, corresponding to 71.5 and 70.0 mL of tuberous root volume, respectively (Figure 3B). It is also noticed that in the treatment with WET + UASB the root volume was more homogeneous, when compared to the other water treatments.

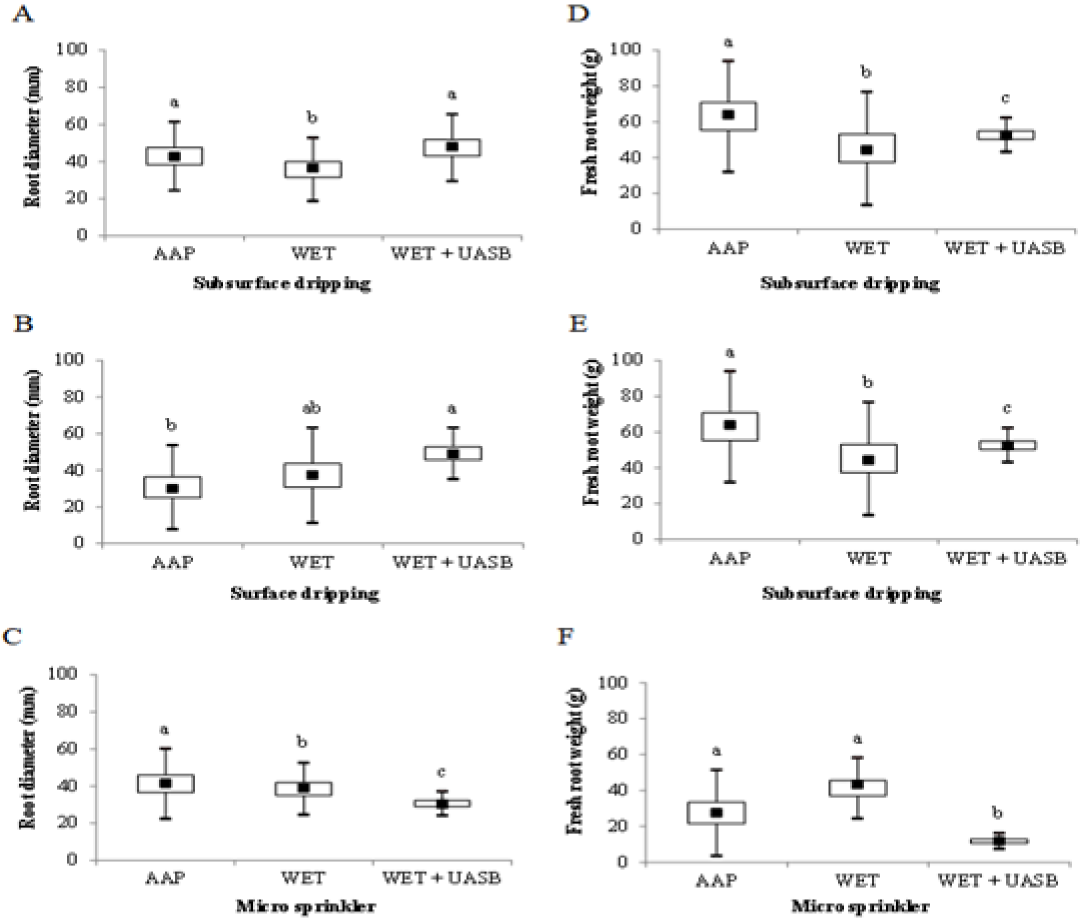
These volumes of radish roots are higher than those found by Silva et al. (2006) and Reis et al. (2012) when studying the radish under organic and conventional fertilization. The highest values observed in the present study are related to the greater supply of nutrients in installments, that is, each irrigation with water treated by a sustainable system. The root volumes obtained are within the acceptable standards for the consumer market. The volume of the radish root is directly related to the quality of the product and its acceptability by the consumer market (FILGUEIRA, 2008).

The volume of radish roots for the interaction between the micro sprinkler irrigation system and the sustainable water treatment showed that there was a difference between each water, with the treated waters having lower averages; however, these were more homogeneous when comparing the 25 and 75 % of values with the upper and lower limit (Figure 3C). There was dispersion only for the micro sprinkler interaction with the AAP in the upper and lower limits, which comprise 75% of the observed averages.

The values of negative minima observed in the root volumes in the superficial drip and in the micro sprinkler (Figures 3B and C) show an asymmetric trend of the data, with outliers, indicating possible discrepancies in the sample, that is, values outside the asymmetric curve. Lima et al. (2017) state that the withdrawal of these outliers generates the overlap of the values of the confidence interval of the standard deviation, thereby reflecting on underestimated or overestimated data, as a result of this, it was decided to leave the outliers, even with negative values.

The maximum values for the radish root diameter in all interactions are within the upper and lower limits, it can be seen that, in all analyzes, 95% of the residues are contained between 7.0 and 65.0 mm in diameter (Figure 4).

Figure 4. Box plot of interaction the sustainable water treatment versus subsurface drip (A), surface drip (B) and micro sprinkler (C) interaction for radish root diameter and subsurface dripping (D), surface dripping (E) and micro sprinkler (F) for fresh weight of radish root at 35 days after transplant.



There was a significant difference at the level of 5% by the Tukey test for the root diameter of the radish as a function of the sustainable water treatment versus the subsurface drip. It is also noted that the root diameters are within the range considered ideal for commercialization (Figure 4A). According to Filgueira (2008), the radish must be harvested with a diameter varying between 20.0 and 50.0 mm, a range that is well accepted by the consumer market.

According to Goes et al. (2011), the high diameter of this tuberous root is related to the greater availability of nutrients provided due to the dynamics of mineralization and decomposition of nutrients made available by irrigation water.

There is a significant difference for the interaction of surface dripping within each treated effluent, noting also that the water treated by WET + UASB was the one with the highest average, 49.0 mm in diameter (Figure 4B). In the water treated by WET + UASB, the highest concentrations of potassium were observed, a fact that justifies the higher averages of diameter. The radish has a short growth period, during which it forms a large amount of mass in the storage organ, which requires a high amount of nutrients, especially nitrogen and potassium (OLIVEIRA et al., 2014), which are needed in greater amount for root formation (ISLAM et al., 2011). Cunha et al. (2017) obtained values of diameter of the tuberous root similar to those obtained in this study, irrigating by drip system.

When the interaction between the micro sprinkler irrigation system and the sustainable water treatment was studied, it was found that there was dispersion between the data; however, the treatment with water treated by WET + UASB was the one that demonstrated lower dispersion values, since that the lower and upper limits that comprise 25 and 75% of the values were very close to the upper and lower limit, making the values of diameter of the tuberous root homogeneous for this treatment (Figure 4C).

This means that the diameters are less discrepant when compared to the AAP and WET treatment; however, it is worth noting the superiority of the AAP treatment for the root diameter (Figure 4C).

Different from what occurs in drip irrigation, which provided greater yields in diameter, since the water layer is applied with low intensity and high frequency in the superficial layer of the soil, making the water more readily absorbed by the plants.

When studying the interaction between the factors for the fresh weight of the commercial radish root, it is noted that there was a discrepancy between the treatments, with 90% of the residues being contained between 20 and 100 g of fresh weight of the radish root (Figure 4D to F).

When analyzing the subsurface dripping interaction within each treated water, it was found that the water treated by AAP and WET + UASB were the ones that showed the highest averages for the fresh weight of the radish root, 64.0 and 53.0 g plant^{-1}, respectively (Figure 4D).

These data are similar to those obtained by Silva et al. (2017) when studying the agronomic performance of radish. The authors also state that when irrigated with nutrient-rich wastewater, the plants perform better in terms of growth and production.

The interaction between the surface dripping factors and the different treated waters showed that the treatments with the sustainable water treatment by WET and WET + UASB were those that showed the greatest dispersion between the data, that is, they represent the interquartile range that is the difference between the third quartile and the first quartile (box size), or even by the amplitude that is calculated by subtracting the maximum value from the minimum value. Although the amplitude is easy to understand, the interquartile range is a more robust statistic for measuring variability since it is not influenced by outliers (Figure 4E).

The range for these treatments were 92 and 42, respectively for WET and WET + UASB, with the average of these treatments for the fresh weight of the commercial root being 69.0 and 70.0 grams per plant, respectively (Figure 4E). According to Klar et al. (2015), for the radish to reach its full development in terms of growth and production, an adequate water and mineral supply is necessary, in order to meet the nutritional absorption of the crop.

Silva et al. (2016) studying the commercial production of radish fertigated with nitrogen in a greenhouse observed that both fertigation with a drip irrigation system and humus fertilization, significantly increased the radish production at 35 days after transplantation, agreeing with the results obtained in the present study.

When evaluating the interaction of the micro sprinkler in each water for the fresh root weight, a smaller amplitude was noticed for the sustainable water treatment by WET and WET + UASB, corresponding to 34.0 and 8.9, respectively, indicating greater homogeneity of the fresh root weight (Fig. 4F).

Rebouças et al. (2010) affirm that the sewage treated by a sustainable system provides nutrients in adequate amounts for the development of the cultures, when compared to the mineral supply by means of foundation fertilization. Rebouças et al. (2010) further reinforce that soils irrigated with treated sewage are capable of supplying the nutritional needs of cowpea, even in the absence of mineral fertilization. This fact corroborates with the data obtained in the present study, since the production of radish with wastewater treated by sustainable means favored the growth and production of the radish, except for the number of leaves.

6 CONCLUSIONS

The waters treated by sustainable systems such as Wetland and Wetland + UASB, are still not considered suitable for irrigating crops according to CONAMA resolution 357 in addition to providing a risk of dripper clogging.

The sustainable treatment wetland + UASB and drip irrigation showed the best results in terms of radish growth and production.

Although water is not recommended for irrigating vegetables, the radish root diameters are within the range considered ideal by the consumer market.

Further studies with combinations of sustainable water treatment systems are needed to meet the requirements of CONAMA resolution 357 to irrigate leafy crops

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