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

ABSORÇÃO DE MACRONUTRIENTES E SÓDIO PELO TOMATEIRO SUBMETIDO A IRRIGAÇÃO COM E SEM DÉFICIT HÍDRICO, UTILIZANDO DIFERENTES CONCENTRAÇÕES DE ÁGUA RESIDUÁRIA

FRANCIELLY GUIEIRO GOMES DE SOUSA[2]; RENATA DA SILVA CUBA DE CARVALHO[3]; MARA RÚBIA MENDES DE MELO[4] E HÉLIO GRASSI FILHO[5]

[1] *Trabalho originado da dissertação de mestrado do primeiro autor intitulada: "Irrigação com água residuária em diferentes diluições e disponibilidade para a cultura do tomate cereja"*
[2] *Doutoranda, Departamento de Engenharia Rural, Faculdade de Ciências Agronômicas – FCA – Unesp, Câmpus Botucatu, Avenida Universitária, 3780, CEP 18610-034, Altos do Paraíso, Botucatu-SP, Brasil, fran.engagricola@gmail.com*
[3] *Doutora, Departamento de Engenharia Rural, Faculdade de Ciências Agronômicas – FCA – Unesp, Câmpus Botucatu, Avenida Universitária, 3780, CEP 18610-034, Altos do Paraíso, Botucatu-SP, Brasil, renatacuba@hotmail.com*
[4] *Doutoranda, Departamento de Produção e Melhoramento Vegetal. Faculdade de Ciências Agronômicas (FCA/UNESP – Campus de Botucatu). Rua José Barbosa de Barros, 1780. CEP: 18.610-307, Botucatu-SP - Brasil. mara_mendesmelo@hotmail.com*
[5] *Professor Titular do Departamento de Solos e Recursos Ambientais da Faculdade de Ciências Agronômicas - FCA/UNESP, Campus Botucatu (SP), heliograssi@fca.unesp.br*

1 RESUMO

Perante a grande demanda de água no planeta para o desenvolvimento de atividades econômicas e consumo doméstico, estudos relacionados ao aproveitamento da água residuária no meio agrícola podem ajudar a minimizar problemas de escassez desse recurso. Sendo assim o objetivo do presente trabalho foi avaliar a absorção de macronutrientes e sódio pela cultura do tomate irrigado com e sem déficit hídrico, utilizando água residuária. O experimento foi conduzido em ambiente protegido, o sistema de irrigação foi por gotejamento, e o manejo da irrigação foi baseado na evaporação do tanque classe 'A' instalado dentro do ambiente. Foram determinadas duas lâminas: 70 e 100% da evapotranspiração da cultura, nas quais foram utilizadas água de abastecimento e de esgoto doméstico tratado em quatro diluições: 25, 50, 75 e 100%. Assim, foi possível avaliar a absorção de macronutrientes e sódio, na área foliar e frutos, através de análise química. Os resultados obtidos, indicaram que as plantas irrigadas com déficit hídrico absorveram maior quantidade dos nutrientes N, K, Mg e S. No entanto quanto maior a porcentagem de água residuária na irrigação, maior foi a absorção de sódio pelas plantas e frutos.

Palavras chave: nutrição, reúso doméstico, manejo da irrigação, *Lycopersicon esculentum L.*

SOUSA, F. G. G.; CARVALHO, R. S. C.; MELO, M. R. M.; GRASSI FILHO, H. ABSORPTION OF MACRONUTRIENTS AND SODIUM BY TOMATOES SUBMITTED TO NORMAL AND WATER DEFICIENT IRRIGATION SCHEMES USING VARIOUS CONCENTRATIONS OF WASTEWATER

Recebido em 11/09/2019 e aprovado para publicação em 15/09/2020
DOI: http://dx.doi.org/10.15809/irriga.2021v26n1p65-76

2 ABSTRACT

The high worldwide demand for water use in economic development and domestic consumption has led to studies on the agricultural use of wastewater that can help minimize the problem of scarcity of this resource. This study aimed to evaluate the absorption of macronutrients and sodium from cultivated tomatoes, irrigated with wastewater, under normal and water deficient irrigation schemes. The experiment was conducted in a greenhouse, we used a drip irrigation system that was managed on the basis of evaporation from a Class A tank placed in the experimental area. Two irrigation depths were determined: 70 and 100% of the crop evapotranspiration, supply water, and four dilutions of domestic wastewater were used: 25, 50, 75, and 100%. We evaluated the absorption of macronutrients and sodium via chemical analysis of the leaves and fruits. Results showed that plants irrigated using the water deficit irrigation scheme absorbed more N, K, Mg, and S nutrients. However, the higher the percentage of wastewater used for irrigation, the higher the absorption of sodium by plants and fruits.

Keywords: nutrition, domestic reuse, irrigation management, *Lycopersicon esculentum L*.

3 INTRODUCTION

Mineral nutrients are necessary for plant development, the majority of which are absorbed from the soil by the roots. These elements are divided into two groups, macronutrients and micronutrients, with the former required in greater quantities by plants. The macronutrients used are nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S) (NATH; TUTEJA, 2016).

Sodium (Na), although beneficial to plants in certain amounts, inhibits growth and several physiological processes in excess (ADAMS; SHIN, 2014). Na replaces some of the functions of K in the osmotic process, cell growth, enzymatic activities and protein synthesis; however, the main function of Na is the regulation of turgor pressure and cell expansion (MASER et al., 2002).

However, plants require adequate water availability and quality for nutrient absorption so that their development cycle is efficient and productive (PES; ARENHARDT, 2015). However, access to water resources in desirable quantities and standards is not always possible.

The difficulties caused by water scarcity will increase in the future due to population growth, urbanization, climate change and increasing demand for food, which will further distance supply from demand for water (HUSSAIN et al., 2002). One of the alternatives proposed in studies and research is the use of wastewater to meet not only the water needs of crops but also the availability of nutrients for plants, providing savings in water and fertilizers.

Despite providing countless benefits for the development and productivity of plants, wastewater is still considered a complex resource, as it contains toxic substances that can cause negative impacts on soil properties, groundwater and surface water quality, as well as microbiological risks to public health (ELGALLAL; FLETCHER; EVANS, 2016).

Moreover, tomato farming is considered by producers and researchers to be a high-cost crop that demands water, has high fertilizer requirements, and is susceptible to the development of pests and diseases. However, the amount of nutrients absorbed by tomato plants depends on abiotic and biotic environmental factors (PELUZIO, 1999). Thus, the efficiency of nutrient utilization by tomato plants varies according to the soil type, climatic conditions, cultural practices, irrigation system and management, among other related factors (FAGERIA, 1998).

In this context, the objective of this work was to evaluate the absorption of macronutrients and sodium by irrigated tomato crops, with and without water deficit, via wastewater.

4 MATERIALS AND METHODS

The experiment was carried out in a greenhouse from August to December 2016 in the experimental area of the Department of Rural Engineering, Faculty of Agricultural Sciences of São Paulo State University, Botucatu campus, state of São Paulo (22°51' S, 48°25' W, 762 m). According to the Köppen classification, the climate of the region is of the humid subtropical "Cfa" type (KÖPPEN; GEIGER, 1928).

The Carolina cherry tomato seedlings were grown in trays using commercial substrate. The plants were transplanted 32 days after sowing into 14-liter pots filled with soil.

The initial fertilization was based on the soil analysis, carried out previously and on the volume of soil in the pot, according to the recommendations of Filgueira (2008), with the following applied as initial fertilization: N: 300, P_2O_5: 600 and K_2O: 500 kg.ha^{-1}.

Table 1. Physical and chemical characteristics of the soil used to fill the pots.

Sand		**Clay**		**Silt**					**Soil texture**		
----------(g kg^{-1})----------									Sandy		
861		91		48							
pH	MO	P_{resin}	Al^{3+}	H+AL	K	Here	Mg	SB	CTC	V	S
$CaCl_2$	g dm^{-3}	mg dm^{-3}			mmol$_c$ dm^{-3}					%	mg dm^{-3}
5.6	13	107	0	16	1.5	31	10	42	58	73	8
B		Cu			Fe			Mn		Zn	
----------mg dm^{-3}----------											
0.23		1.4			63			2.8		5.5	

Source: Soil Physics Laboratory and Soil Fertility Laboratory, FCA, UNESP.
MO= Organic matter;
SB = Sum of bases
CEC = Cation exchange capacity

After 30 days of transplanting, top dressing fertilization was carried out weekly, with the application of 3% calcium nitrate and potassium nitrate. Additionally, during the experiment, two foliar fertilizers were carried out with micronutrients: $ZnSO_4$ (0.3%), $MnSO_4$ (0.2%), $MgSO_4$ (0.5%), $NH_4H_2PO_5$ (0.5%) and H_3BO_3 (0.1%). During the development of the plants, two stems were pruned regularly to remove lateral branches.

The experimental design used was split plots in a factorial scheme (5x2), with six replications, with treatments consisting of two soil water depths (L): 100 and 70% crop evapotranspiration replacement (ETc) and five dilutions of wastewater (D) 0, 25, 50, 75 and 100%, totaling 10 treatments.

The wastewater was obtained from a sewage treatment plant (STP) in the city of Botucatu, São Paulo. It was collected and stored in a reservoir at the experimental unit, where it was subsequently distributed and diluted according to each treatment. To determine the water parameters, analyses were conducted according to the methods recommended by the *Standard Methods for the Examination of Water and Wastewater* (APHA, 2012) and standards of the Environmental Company of the State of São Paulo (CETESB) (Table 2).

Table 2. Physicochemical characteristics of wastewater.

Parameters	Unit	Result
Turbidity	(NTU)	1.33
Residue dry	(mg L^{-1})	173
pH		7.47
Total hardness	(mg $CaCO_3$ L^{-1})	56
Hardness Calcium	(mg $CaCO_3$ L^{-1})	42
Magnesium hardness	(mg $CaCO_3$ L^{-1})	11.76
Iron (Fe)	(mg L^{-1})	0.228
Chloride	(mg L^{-1} C)	64.67
Sulfate	(mg L^{-1})	<0.001
Fluoride	(mg L^{-1})	0.0008
Conductivity electrical	(uS/cm)	634.6
Total phosphorus	(mg L^{-1} P)	15.03
Nitrate	(mg L^{-1})	0.083
Nitrite	(mg L^{-1})	0.312
COD	(mg L^{-1})	251.5
BOD	(mg L^{-1})	2.33
OD	(mg L^{-1})	2.51

Source: Department of Chemistry and Biochemistry, Institute of Biosciences – UNESP – Botucatu
COD = Chemical oxygen demand
BOD = biochemical oxygen demand
DO = Dissolved oxygen

The irrigation system used was localized drip irrigation with a self-compensating emitter and a flow rate of 2 Lh $^{-1.}$ Irrigation management was based on reference evapotranspiration (ETo) via the class A tank method, which is located inside the greenhouse. To determine ETo via the class A tank method, a value of 1 was used for the tank coefficient, which was multiplied by the tank evaporation (mm day $^{-1}$).

For the values, crop evapotranspiration (ETc) was calculated according to Equation 1, with irrigation depths established on the basis of the ETc obtained, according to the following treatments: 70% and 100% ETc replacement.

$$ETc = ETo \; x \; Kc \qquad (1)$$

where Etc is the crop evapotranspiration and Kc is the crop coefficient.

The values used as Kc for the tomato crops were obtained from Doorembos and Kassan (1979), with initial, average and final Kc values of 0.5, 0.8 and 1.2, respectively.

During the experiment, the relative humidity and maximum, average, and minimum temperatures of the protected environment were monitored. At the beginning of fruit ripening, the macronutrient and sodium contents of the plant tissue and fruits were analyzed. At the full production and ripening phase, analysis was performed. microbiological analysis of fruits via the Colilert® method (*Standard Methods 9223B: Enzyme Substrate Test)*, a methodology that allows rapid enumeration of coliforms and *E. coli,* developed by

IDEXX Laboratories. It is based on the Defined Substrate Technology (DST) (GROSSI et al.), 2013).

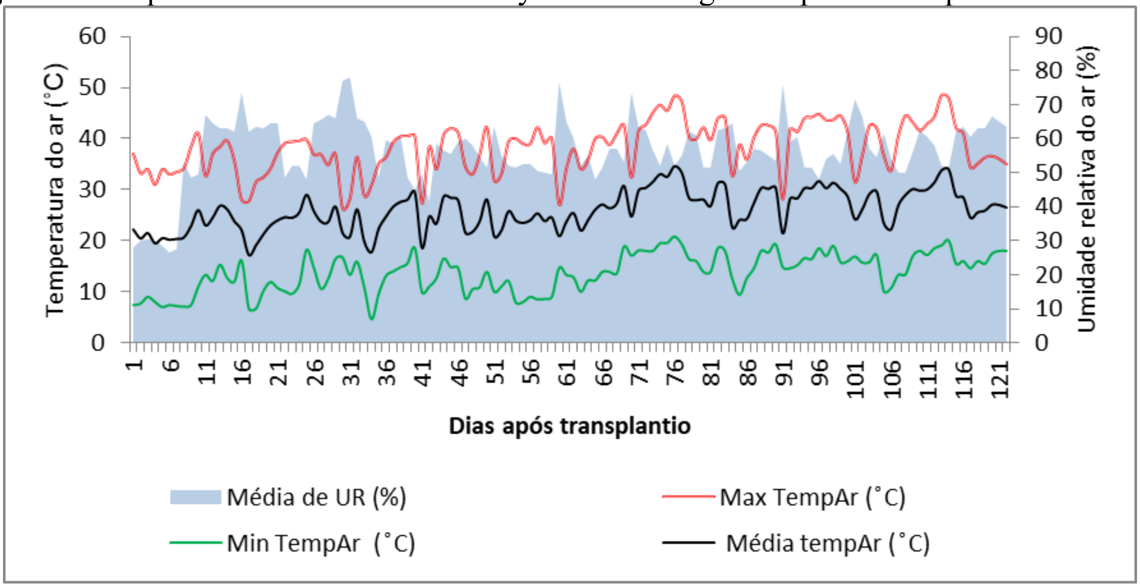
The results obtained were subjected to statistical analysis with the aid of Sisvar software version 5.6 (FERREIRA, 2011), with the averages being subjected to the Tukey test at 0.05 probability.

5 RESULTS AND DISCUSSION

The total irrigation depths applied throughout the experiment were 1184 and 833.13 mm for the 100 and 70% ETc treatments, respectively; thus, the plants had different responses to the availability of water provided.

Figure 1 shows the temperature and relative humidity of the air during cultivation.

Figure 1. Temperature and relative humidity values during the experimental period.



During the crop cycle, the plants are subjected to high temperatures (Figure 1), which is not recommended for tomato plants; therefore, the high temperatures recorded may have influenced nutrient absorption. Tomato plants are demanding in terms of periodicity, as they require mild temperatures during the day and cooler temperatures at night. In Brazil, under high light conditions, the optimal temperatures for tomato cultivation during the day and night should be in the ranges of 21 to 28°C and 15 to 20°C, respectively. Notably, these values may vary depending on the age of the plant and the type of cultivar (FILGUEIRA, 2008).

Thermal stress in plants, due to high temperatures, whether due to chronic or abrupt heating, is considered a limiting factor for their development and productivity (BOYER, 1982), as it interferes with activities such as photosynthesis, transpiration, water dynamics and hormone production (HECKATHORN et al., 2014).

The macronutrient contents of Ca and Mg differed significantly in relation to the dilution and depth factors. P, Na and S had significant influences only on dilution, with interactions occurring between the two factors for the p value (Table 3).

Table 3. Summary of analysis of variance for macronutrients and sodium in tomato leaves at early ripening.

	Mean square			
	Dilution (D)	**Blade (L)**	**Dilution x Slide**	**CV(%)**
Nitrogen (N)	1.82^ns^	1.80^ns^	1.67^ns^	3.91
Phosphorus (P)	0.09**	0.03^ns^	0.04*	3.44
Potassium (K)	8.07^ns^	26.45^ns^	0.82^ns^	6.34
Calcium (Ca)	3.95**	4.05*	0.55^ns^	9,11
Magnesium (Mg)	0.22**	0.13*	0.07^ns^	5.82
Sulfur (S)	0.04*	0.02^ns^	0.01^ns^	5.64
Sodium (Na)	14373808**	325125^ns^	225963^ns^	20.92

(* *) Significant at the 1% level (*) and significant at the 5% level (ns) according to the F test; CV = coefficient of variation.

Table 4 shows the average macronutrient and sodium contents in tomato leaves; a significant difference in sodium content was observed between the treatments.

Table 4. Average levels of macronutrients and sodium in leaves at the beginning of fruit ripening.

Blade	D0%	D25%	D50%	D75%	D100%	Averages
			Treatments			
			Nitrogen (g kg^{-1})			
70% ETc	36.50	38.50	40.00	38.00	38.00	38.20 A
100% ETc	37.50	38.00	37.50	38.00	37.00	37.60 A
Averages	37.00 a	38.25 a	38.75 a	38.00 a	37.50 to	
			Phosphorus (g kg^{-1})			
70% ETc	3.15	2.90	3.25	2.70	2.75	2.95 A
100% ETc	3.05	2.90	2.80	2.80	2.80	2.87 A
Averages	3.10 a	2.90 b	3.03 a	2.75 c	2.77 c	
			Potassium (g kg^{-})			
70% ETc	38.00	39.50	41.00	40.50	37.50	39.33 A
100% ETc	36.00	38.50	37.50	38.00	35.00	37.06 A
Averages	37 to	39.00 a	39.25 a	39.25 a	36.25 a	
			Calcium (g kg^{-1})			
70% ETc	8.50	10.50	9.50	9.50	8.50	9.30 A
100% ETc	8.00	9.50	8.50	9.50	6.50	8.40 B
Averages	8.25 ab	10.00 to	9.00 ab	9.50 a	7.50 b	
			Magnesium (g kg^{-1})			
70% ETc	3.00	2.75	2.80	2.75	2.40	2.74 A
100% ETc	2.90	2.70	2.55	2.55	2.20	2.58 B
Averages	2.95 a	2.73 a	2.68 a	2.65 ab	2.30 b	
			Sulfur (g kg^{-1})			
70% ETc	1.40	1.60	1.70	1.70	1.45	1.57 A
100% ETc	1.40	1.50	1.45	1.65	1.50	1.50 A
Averages	1.40 b	1.55 ab	1.58 ab	1.67 a	1.47 ab	
			Sodium (g kg^{-1})			
70% ETc	0.56	1.35	2.29	3.49	4.99	2.54 A
100% ETc	0.694	1,389	2,674	3,234	5,999	2.798 A
Averages	0.62 d	1.37cd	2.49 bc	3.37 b	5.49 a	

Means followed by different uppercase letters in the column and lowercase letters in the row differ from each other according to the Tukey test at 5% probability.

Sodium was easily absorbed by the plant, and as the concentration of wastewater applied to the soil increased, an increase in sodium content was observed in the tomato leaves.

The presence of excess salts in water and their accumulation in the soil can reduce its osmotic potential, harming crop development due to reduced soil water availability (TELLES; COSTA, 2010). However, salinity, high sodium concentrations, and excess nutrients are characteristics of wastewater that can have adverse effects on soil and crops, so care must be taken with respect to irrigation management.

The sodium content is considered an important factor in water quality; excess sodium causes alkaline soil (KELLEY, 1980). Importantly, the amount of sodium that plants can tolerate depends on the crop or variety.

One of the greatest problems with water reuse in agriculture is the concentration of ions. When salinity increases, the ions present in the water can reach concentrations considered toxic, interfering with the absorption of other nutrients by plants (SOUSA; DUARTE, 2014). According to Almeida (2010), when there is a predominant concentration of Na ions, which induces the exchange of Ca and Mg ions for Na in the soil, degradation, loss of soil structure and permeability can occur.

By competing with potassium, excess sodium absorbed by roots can interrupt photosynthesis, damage plant cell organelles, and interrupt enzyme activities and protein biosynthesis (GUPTA; HUANG, 2014).

With respect to P and Mg, the results indicate that the greater the availability of wastewater is, the lower the absorption of these macronutrients. According to Fageria (2001), this behavior occurs due to the interaction between P and Mg, since this cation participates in the activation of kinase enzymes and most of the reactions that act in the transfer of P.

The macronutrient and sodium contents of the fruits were analyzed. Table 5 shows the analysis of variance, and Table 6 shows the analyzed means (Tukey test) for the data obtained in the analysis of macronutrient and sodium absorption by the fruits.

Table 5. Summary of analysis of variance of macronutrients and sodium in fruits

	Mean square			
	Dilution (D)	**Blade (L)**	**D x L**	**CV(%)**
Nitrogen (N)	5.55^{**}	2.70^{*}	0.28^{ns}	2.98
Phosphorus (P)	0.19^{**}	0.13^{*}	0.03^{ns}	6.06
Potassium (K)	11.61^{**}	6.53^{*}	0.61^{ns}	4.46
Calcium (Ca)	0.033^{ns}	0.033^{ns}	0.033^{ns}	17.67
Magnesium (Mg)	0.02^{**}	0.04^{**}	0.002^{ns}	5.22
Sulfur(S)	0.005^{**}	0.003^{*}	0.001^{ns}	2.82
Sodium (Na)	641333^{**}	40333^{ns}	18666^{ns}	14.22
GL	4	1	4	

$^{(*\ *)}$ Significant at the 1% level $^{(*)\ and}$ significant at the 5% $^{level\ (ns)}$ according to the F test; CV = coefficient of variation.

Table 6. Average levels of macronutrients and sodium in fruits

	Treatments					
Blade	D0 AR	D25 AR	D50 AR	D75 AR	**D100 AR**	**Averages**
			Nitrogen (g kg^{-1})			
70% ETc	26.67	25.33	26.67	24.67	24.33	25.53 A
100% ETc	26.00	24.33	25.67	24.67	24.00	24.93 B
Averages	26.33 a	24.83 b	26.16 a	24.66 b	24.16 b	
			Phosphorus (g kg^{-1})			
70% ETc	2.93	2.67	2.90	2.40	2.57	2.69 A
100% ETc	2.77	2.60	2.53	2.33	2.56	2.56 B
Averages	2.85 a	2.63 abc	2.71 ab	2.36 c	2.57 bc	
			Potassium (g kg^{-1})			
70% ETc	28.00	27.00	27.00	26.00	25.00	26.67 A
100% ETc	27.33	26.33	26.67	25.33	23.00	25.73 B
Averages	27.67 a	26.67 a	26.83 a	25.83 ab	24.00 b	
			Calcium (g kg^{-1})			
70% ETc	1.00	1.00	1.00	1.00	1.00	1 A
100% ETc	1.33	1.00	1.00	1.00	1.33	1.07 A
Averages	1.17 a	1st	1st	1st	1st	
			Magnesium (g kg^{-1})			
70% ETc	1.03	1.03	1.06	1.06	0.93	1.03 A
100% ETc	0.96	1.00	0.93	1.00	0.86	0.95 B
Averages	1.00 to	1.02 a	1.00 to	1.03 a	0.90 b	
			Sulfur (g kg^{-1})			
70% ETc	0.90	0.90	0.93	1.00	0.90	0.93 A
100% ETc	0.90	0.90	0.90	0.93	0.90	0.91 B
Averages	0.90 b	0.90 b	0.92 b	0.97 to	0.90 b	
			Sodium (mg kg^{-1})			
70% ETc	1026.33	959.7	1293	1359	1693	1266.3 A
100% ETc	926.33	1026.33	1493	1426	1826	1339.7 A
Averages	976.33 c	993 c	1393 b	1393 b	1759 a	

Means followed by different uppercase letters in the column and lowercase letters in the row differ from each other according to the TuKey test at 5% probability.

N and N were the macronutrients most abundantly absorbed by the fruits. The irrigation depth significantly influenced N and K absorption; plants irrigated with 70% ETc presented greater absorption of these nutrients.

NO is the nutrient that influences the flavor of the fruit (MONTAGU; GOH, 1990), and K affects the yield, fruit size and soluble solids content (BIDARI; HEBSUR, 2011). Tavallali, Shabnam Esmaili and Karimi (2018), evaluating the interaction between N and K, reported that plants grown with moderate to high doses of K in the soil in the presence of 0 to 150 mg N kg soil^{-1} produced firmer tomatoes.

in K absorption, and an increase in sodium in plants and fruits was observed in relation to the increase in wastewater concentration (Tables 4 and 6). Na stimulates growth by intensifying cell expansion and can also, in part, replace K as an osmotically active solute (TAIZ; ZEIGER, 2013).

An analysis of the data in Table 4 revealed that the leaves contained the greatest amounts of macronutrients and sodium. Maldonado et al. (2017) obtained similar results when evaluating the concentration of nutrients in various parts of a tomato plant, with the macronutrients N, Ca, Mg and S presenting the highest concentrations in the analyses on the basis of the dry weight of the leaves.

In fruit species, in which fruits are frequently removed for commercialization, nutrient replacement should not be performed solely on the basis of soil and leaf analysis since nutrient extraction is constant (SÃO JOSÉ et al., 2014).

In addition to plant nutrition, when wastewater is used, the health of the irrigated crop must be monitored. Microbiological analyses of the fruit indicated that the wastewater did not cause any contamination. The lack of microbiological contamination of the fruit may be due to careful consideration of the experiment, particularly in the selection of the irrigation system used, as drip irrigation prevented the wastewater from coming into direct contact with the tomato plant's aerial parts.

6 CONCLUSIONS

As the concentration of reused water in irrigation increased, there was greater absorption of sodium by plants and fruits; consequently, potassium absorption was inhibited.

Water stress can increase the absorption of some macronutrients by plants.

7 REFERENCES

ADAMS, E.; SHIN, R. Transport, signaling, and homeostasis of potassium and sodium in plants. **Journal of Integrative Plant Biology** , Yokohama, vol. 56, no. 3, p. 231-249, 2014.

ALMEIDA, OA **Irrigation Water Quality** . Cruz das Almas: Embrapa, 2010. Available at: https://www.alice.cnptia.embrapa.br/alice/bitstream/doc/875385/1/livroqualidadeagua.pdf Accessed on: March 11, 2021.

APHA. **Standard Methods for The Examination Of Water And Wastewater** . 22. ed. Washington: American Public Health Association, 2012. 1360 p.

BIDARI, BI; HEBSUR, NS Potassium in relation to yield and quality of selected vegetable crops. **Journal of Agricultural Sciences** , Karnataka, v. 24 , no. 1, p. 55-59, 2011.

BOYER, JS Plant productivity and environment. **Science** , vol. 218, no. 4571 , p. 443-448, 1982.

CETESB. **Water Reuse** . São Paulo: Cetesb, 2021. Available at: https://cetesb.sp.gov.br/aguas-interiores/informacoes-basicas/tpos-de-agua/reuso-de-agua/. Access on : March 12, 2021.

DOORENBOS, J.; KASSAN, AH **Yild response to wet weather** . Rome: FAO, 1979. 193 p. (Irrigation and Drainage Paper, 33).

ELGALLAL, M.; FLETCHER, L.; EVANS, B. Assessment of potential risks associated with chemicals in wastewater used for irrigation in arid and semiarid zones: A review. **Agricultural Water Management** , Amsterdam, v. 177, no. C, p. 419-431, 2016.

FAGERIA, VD Nutrient interactions in crop plants. **Journal of Plant Nutrition** , New York , vol. 24, no. 8, p. 1269-1290, 2001.

FAGERIA, NK Optimization of nutritional efficiency in crop production. **Brazilian Journal of Agricultural and Environmental Engineering** , Campina Grande, v. 2, n. 1, p. 6-16, 1998.

FERREIRA, DF **SisVar ® (Statistical software)** : Analysis of variance system for valanced data . Version 5.6. Lavras: DEX/UFLA, 2011.

FILGUEIRA, FAR **New Manual of Olericulture** : Modern agrotechnology in the production and marketing of vegetables. Viçosa: Editora UFV, 2008. 402 p.

GROSSI, M.; LAZZARINI, R.; LANZONI, M.; POMPEI, A.; MATTEUZZI, D.; RICCO, B. A portable sensor with disposable electrodes for water bacterial quality assessment. **IEEE Sensors Journal** , Piscataway , vol. 13, no. 5, p. 1775- 1782, 2013.

GUPTA, B.; HUANG, B. Mechanism of salinity tolerance in plants: physiological, biochemical, and molecular characterization. **International Journal of Genomics** , London, v. 2014, n. 1, p. 1-18, 2014.

HECKATHORN, SA; SLANG.; MISHRA, S.; BISTA, D. Heat stress and roots. *In* : TUTEJA, N.; GILL, S. (ed .). **Climate Change and Plant Abiotic Stress Tolerance** . Weinheim : Wiley Blackwell, 2014. p. 109-136.

HUSSAIN, I.; RASCHID, L.; HANJRA, MA; MARIKAR, F.; VAN DER HOEK, W. **Wastewater use in agriculture** : review of impacts and methodological issues in evaluating impacts. [*S.l.*]: International Water Management Institute , 2002. (Working Paper, 37).

KELLEY, W. P. **Alkali Soils:** Their Formation Properties and Claims. New York: Reinhold Publishing , 1980.

KÖPPEN, W.; GEIGER, R. **Klimate der Erde** . Gotha: Verlag Justus Perthes , 1928. Wallmap , 150 x 200 cm.

MALDONADO, AJ; ROMENUS, K. A.; DÍAZ, ABM; MENDOZA, AB Macronutrient uptake dynamics in greenhouse tomato crop. **Journal of Plant Nutrition** , New York, vol. 40, p. 1908-1919, 2017.

MASER, P.; HOSOO, Y.; GOSHIMA, S.; HORIE, T.; ECKELMAN, B.; YAMADA, K.; YOSHIDA, K.; BAKKER, EP; SHINMYO, A.; OIKI, S.; SCHROEDER, JI; UOZUMI, N.

Glycine residues in potassium channel-like selectivity filters determine potassium selectivity in four-loop-per-subunit HKT transporters from plants. **Proceedings of the National Academy of Sciences** , Washington, vol. 99, no. 9, p. 6428-6433, 2002.

MONTAGU, KD; GOH, KM Effects of forms and rates of organic and inorganic nitrogen fertilizers on the yield and some quality indices of tomatoes (*Lycopersicon esculentum* Miller). **New Zealand Journal of Crop and Horticultural Science Crop** , United Kingdom, vol. 18, no. 1 , p. 31-37, 1990.

NATH, M.; TUTEJA, N. NPKS uptake, sensing, and signaling and miRNAs in plant nutrient stress. **Protoplasm** , Vienna , vol. 253, no. 3, p. 767-786, 2016.

PELUZIO, JM; CASALI, VWD; LOPES, NF; MIRANDA, GV; SANTOS, GR Behavior of source and sink in tomato plants after apical pruning above the fourth bunch. **Science and Agrotechnology** , Lavras, v. 23, n. 3, p. 510-514, 1999.

PES, LZ; ARENHARDT, MH **Plant Physiology** . Santa Maria: UFSM, 2015. 81 p.

SÃO JOSÉ, AR; PRADO, NB; BOMFIM, MP; REBOUÇAS, TNH; MENDES, HTA Nutrient absorption pattern in Annonaceae. **Brazilian Journal of Fruit Growing** , Jaboticabal, v. 36, n. 1, p. 176-183, 2014.

WJ ; DUARTE, SN **Wastewater** : Treatments and applications in agricultural areas. Piracicaba: FEALQ, 2014. 197 p.

TAIZ, L.; ZEIGER, E. **Plant Physiology** . 5. ed. Porto Alegre: Artmed, 2013. 918 p.

TAVALLALI, V.; SHABNAM ESMAILI, S.; KARIMI, S. Nitrogen and potassium requirements of tomato plants for the optimization of fruit quality and antioxidant capacity during storage. **Journal of Food Measurement and Characterization** , New York, vol. 12, no. C , p. 755- 762, 2018.

TELLES, D. D' A.; COSTA, RP (coord.). **Water Reuse:** Concepts, theories and practices. 2nd ed. Sao Paulo: Blucher, 2010. 408 p.

WHO. **Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture** . Report of a WHO Scientific Group. Geneva: World Health Organization, 2006. v. 2. 22 p.