Production of parsley in hydroponic conditions under isosmotic brackish nutrient solutions

Produção da salsa em condições hidropônicas sob soluções nutritivas salobras isosmóticas

Juliana Bezerra Martins[1]* [iD], José Amilton Santos Júnior[2] [iD],
Fernando José da Silva Júnior[2] [iD], Gerônimo Ferreira da Silva[2] [iD], Salomão de Sousa Medeiros[3] [iD]

[1]Universidade Federal Rural de Pernambuco/UFRPE, Dois Irmãos, Recife, PE, Brasil
[2]Dom Manuel de Medeiros, Dois Irmãos, Recife, PE, Brasil
[3]Ministério da Ciência, Tecnologia, Inovações e Comunicações, Instituto Nacional do Semiárido, Campina Grande, PB, Brasil
*Corresponding author: julianaabmartins@gmail.com
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ABSTRACT

Brackish waters may vary in their chemical compositions, interfering with different plant responses to stress; therefore, the present study aimed to evaluate the production components of parsley plants subjected to levels of electrical conductivity in nutrient solutions with an initial ECns of 1.58 dS m^{-1}, which was solubilized in water with the following water electrical conductivity configurations (ECw): 0.12 (control), 1.12, 2.12, 3.12, 4.12 and 5.12 dS m^{-1}, resulting in six isosmotic levels (EC$_{ns}$ = 1.7, 2.7, 3.7, 4.7, 5.7 and 6.7 dS m^{-1}) in an interaction with four types of salt: NaCl, CaCl$_2$, MgCl$_2$ and KCl. The experimental design was completely randomized in a factorial scheme with five replicates. Two strategies were used to restore the volume consumed by the parsley plants, and the replacement was made with municipal-supply water (ECa = 0.12 dS m^{-1}) in the first strategy and with the respective brackish waters in the second strategy. The total fresh and dry weights of the shoots and roots were evaluated as well as the total dry mass percentage of the shoots and roots. The responses of the plants to the different cationic natures was more evident at the highest levels of electrical conductivity tested, and the use of municipal-supply water to replace the evapotranspired depth mitigated the deleterious effects of salinity. In addition, greater reductions were observed in the fresh and dry mass when the replacement of the volume consumed was with the brackish waters.

Index terms: *Petroselinum crispum*; salinity; cationic nature; hydroponics.

RESUMO

As águas salobras podem apresentar variação na sua composição química, interferindo em diferentes respostas das plantas frente ao estresse, então, o presente trabalho objetivou-se em avaliar os componentes de produção da salsa submetida a níveis de condutividade elétrica da solução nutritiva inicialmente com CE$_{sn}$ = 1,58 dS m^{-1} que foram solubilizados em águas com a seguinte configuração de condutividade elétrica da água (CE$_a$): 0,12 (controle); 1,12; 2,12; 3,12; 4,12 e 5,12 dS m^{-1} resultando em seis níveis isosmóticos (CE$_{sn}$ = 1,7; 2,7; 3,7; 4,7; 5,7 e 6,7 dS m^{-1}) em interação com quatro tipos de sais NaCl, CaCl$_2$, MgCl$_2$ e KCl. O delineamento experimental foi inteiramente casualizado, em esquema fatorial com cinco repetições. Foram utilizadas duas estratégias para reposição do volume consumido pelas plantas de salsa, no primeiro experimento, a reposição foi com água de abastecimento municipal (CE$_a$ = 0,12 dS m^{-1}), e no segundo com as respectivas águas salobras Foram avaliadas a massa fresca e seca total, da parte aérea e da raiz, bem como o percentual de massa seca total da parte aérea e da raiz. A resposta das plantas às diferentes naturezas catiônicas foi mais evidente nos maiores níveis de condutividade elétricas testados e o uso de água de abastecimento na reposição da lâmina evapotranspirada mitigou os efeitos deletérios da salinidade, além disso foram verificadas maiores reduções nas massas frescas e secas quando a reposição do volume consumido foi com as águas salobras.

Termos para indexação: *Petroselinum crispum*; salinidade; natureza catiônica; hidroponia.

INTRODUCTION

Parsley is an herb in the Apiaceae family, and its leaves are widely used in cooking, either cooked or raw. It is also considered an important source of vitamins; in addition, it has compounds such as flavonoids, carotenoids and ascorbic acid (Maodaa et al., 2016), which are bioactive compounds with antioxidant capacity that have been associated with the protection of human health against chronic degenerative diseases (Lako et al., 2007; Reis et al., 2015).

Studies on parsley have mainly focused on its use as a source of food and its effects on human health (Snoussi et al., 2016; Nirumand et al., 2018). However, research related to its production is still scarce, especially in the Brazilian semiarid region.

In this region, underground waters, which are sometimes the only water available for agriculture, are characterized by a high salt content (Montenegro et al., 2013), which is a limiting factor for irrigated agriculture, since salinity interferes with the physiological and biochemical functions of plants, causing a reduction in the production and yield of crops (Torres et al., 2014; Munns; Gilliham, 2015).

Specifically, regarding the salinity of the waters in the Brazilian semiarid region, Holanda et al. (2016) commented that most of the sources contain salts of different natures (Ca^{2+}, Mg^{2+}, K^+, Na^+, CO_3^-, HCO_3^- and Cl^-) in different quantities, which, depending on the agricultural use, may result in precipitation reactions that limit the absorption of some nutrients by plants, antagonistic interactions among nutrients during absorption by roots and alterations of the solution pH (Santos et al., 2017).

In this context, the use of brackish waters in agricultural production requires the utilization of adequate cultivation techniques and forms of management that are important, such as hydroponic cultivation (Santos Júnior et al., 2015), and strategies of brackish water use to replace the water metabolized by plants (Bione et al., 2014).

Compared to cultivation in soil, in hydroponic cultivation, the energetic reordering of water potential due to the absence of a soil matrix favors the use of brackish waters in the production process, leading to more expressive results for the same level of salinity (Santos Júnior et al., 2015).

Even in the context of hydroponic cultivation, strategies using brackish water to prepare and replace the evapotranspired nutrient solution with waters of different levels of electrical conductivity (Freitas et al., 2014; Campos Júnior et al., 2018) can further mitigate the effects of salts on plants (Guedes et al., 2015), in addition to rationalizing the use of waters with different salt contents, increasing the water supply (Santos Júnior et al., 2016).

In short, the production of leafy vegetables in hydroponic systems using brackish waters to prepare and manage nutrient solutions has been studied and recommended by different authors (Rebouças et al., 2013; Souza Neta et al., 2013; Bione et al., 2014; Santos Júnior et al., 2015; Silva et al., 2015), who indicated a good yield, early harvest and the reduced use of pesticides among other advantages. In addition, under hydroponic cultivation conditions, physical changes occur in the energy levels. Due to the absence of soil, the matrix potential tends to be zero, making the osmotic influence decisive on the total potential (Santos Júnior et al., 2015).

Given the above, the present study aimed to evaluate the production components of *Petroselinum crispum* plants subjected to isosmotic levels of electrical conductivity of brackish nutrient solutions prepared in waters salinized by NaCl, $CaCl_2$, $MgCl_2$ and KCl.

MATERIAL AND METHODS

Study location

Two experiments were conducted between October 2017 and February 2018 in a protected environment at the Federal Rural University of Pernambuco (UFRPE), Recife – PE, Brazil (8°01'07" S, 34°56'53" W and mean altitude of 6.5 m) with the following dimensions: 6.0 m wide, 18.0 m long, 4.0 m on the right and 5.5 m on the highest part of the structure. The roof covering consisted of a transparent, low density, polyethylene blanket that was treated against the effects of ultraviolet rays.

During the experiments, inside the protected environment, the mean maximum and minimum temperatures were 37.5 °C and 31 °C, respectively, with mean maximum and minimum relative air humidity values of 62.5% and 45.3%, respectively. Both measurements were taken using a digital thermometer. There was no negative interference of the climate on plant development.

Treatments, design and experimental structure

A completely randomized experimental design, analyzed in a 6x4 factorial scheme with five replicates, was adopted to test six levels of electrical conductivity of the nutrient solutions (EC_{ns}): 1.7 (control, without salt), 2.7, 3.7, 4.7, 5.7 and 6.7 dS m^{-1}; the solutions were obtained by adding NaCl, $CaCl_2$, $MgCl_2$ and KCl, the four cationic natures of salt.

The control treatment (EC_{ns} = 1.7 dS m^{-1}) was obtained by adding the fertilizer salts to municipal-supply water (EC_w = 0.12 dS m^{-1}). For the EC_{ns} levels of 2.7, 3.7, 4.7, 5.7 and 6.7 dS m^{-1}, the waters were initially prepared by diluting increasing quantities of NaCl, $CaCl_2$, $MgCl_2$ and KCl in municipal-supply water (EC = 0.12 dS m^{-1}), establishing the following levels: 1.12, 2.12, 3.12, 4.12 and 5.12 dS m^{-1}. These waters were stored in 90 L tanks, and then the fertilizers were solubilized in the quantities of fertilizers used recommended by Furlani et al. (1999) for leafy vegetables. The experiments differed only by the

water used to replenish the individual tanks of nutrient solution, whose volume was naturally reduced by the consumption of plants, i.e., municipal-supply water (ECw = 0.12 dS m^{-1}) was used in the first cycle, and the respective brackish waters used to prepare the nutrient solution were used in the second cycle.

The hydroponic system adopted consisted of 6-m-long and 100-mm-diameter gutters made of PVC pipes with 60-mm-diameter holes every 0.14 m. On both ends, elbows were installed, and one elbow was connected to a faucet to guarantee the formation of a nutrient solution film inside the pipe, which was level and 0.4 m high (Santos Júnior et al., 2016); in these tubes, drilled circular 60-mm-diameter "cells" were spaced evenly every 7 cm. The cells corresponded to the experimental plots, and each tube corresponded to a treatment (Figure 1).

Figure 1: Low-cost hydroponic system.

Cultivation conduction and nutrient solution management

Parsley (*Petroselinum crispum*), cv. Graúda portuguesa, was the reference crop. The seeds were sown in October 2017 (first experiment) and December 2018 (second experiment) in 180-mL disposable plastic cups that were perforated at the bottom and lower third of the sides; the cups were filled with coconut fiber for the sowing of 45 seeds without thinning. In the first ten days after sowing (DAS), the substrate

moisture was maintained with two daily applications of 20 mL of water with a low salt concentration (EC = 0.12 dS m^{-1}).

For the management of the nutrient solution, a closed system was adopted, i.e., the nutrient solution was prepared only once at the beginning of the experiment; twice a day (7:00 and 15:00 h), 20 L of nutrient solution was applied in the pipes, and the surplus returned to the tank through hoses. The level in this tank was replenished every seven days using municipal-supply water or brackish water in the first and second cycles, respectively. Variations in the EC_{ns} and the nutrient solution pH (pH_{ns}) were monitored every two days in the 90 L tanks, and regarding the phytosanitary aspects of the crop, there was no incidence of pests or diseases during the cultivation cycles.

At the end of each cycle (50 DAS), the following variables were evaluated: the total fresh matter (TFM), the shoot fresh matter (SFM) and the root fresh matter (RFM), which were collected and weighed on a 0.01 g precision scale; the plants were cut close to the substrate, and the shoot and root were weighed separately, after which a sum of the two parts was taken to obtain the total matter. Posteriorly, the materials were separately identified in paper bags that were properly identified and dried in a forced-air oven at 60 °C until a constant weight was obtained for later obtaining the total dry matter (TDM), the shoot dry matter (SDM) and the root dry matter (RDM). These results were used to calculate the %SDM, %RDM and %TDM by relating the dry matter to the fresh matter using the following equation: %DM = (dry matter / fresh matter) x 100.

The results were subjected to analysis of variance by an F test. The levels of the nutrient solution electrical conductivity (quantitative factors) were compared by regression analysis, whereas the cationic natures of the water (qualitative factors) were compared by a test of means (Tukey). All the analyses were conducted at the 0.05 probability level using a statistical program (Ferreira, 2011).

RESULTS AND DISCUSSION

A trend of reduction was observed in the EC_{ns} when municipal-supply water was used in the replacement for all the levels studied, especially 5.7 dS m^{-1} and 6.7 dS m^{-1}, both in the nutrient solution prepared with KCl, compared with the initial values (Figure 2A).

Under replacement with brackish water, there was an increasing trend, especially from 35 DAS at levels higher than 3.7 dS m^{-1}, particularly in the solutions prepared with KCl and MgCl$_2$, both at a level of 6.7 dS m^{-1} (Figure 2B), compared with the initial EC$_{ns}$. In general, the reduction observed in the EC$_{ns}$ under replacement with municipal-supply water can be attributed to the dilution of salts caused by the addition of water with few minerals (0.12 dS m^{-1}). Conversely, the increase observed under replacement with brackish water was due to the supply of salts upon replacement, which was also observed by Campos Júnior et al. (2018), who worked with rockets and used brackish water in the replacement of the evapotranspirated volume.

Regarding the pH$_{ns}$, under replacement with municipal-supply water, compared with the initial values in the treatment based on KCl, there were reductions up to 15%, at an EC of 1.7 dS m^{-1}, reaching a value of 5.5 at the end of the cycle (50 DAS) (Figure 3A).

Under replacement with brackish water, the highest variations in the pH$_{ns}$ occurred in the treatment of 3.7 dS m^{-1} in the solution prepared with KCl, showing a maximum reduction of 11.47% (Figure 3B). For the pH$_{ns}$, the variations did not exceed the range from 5.5 to 6.5 cited by Silva et al. (2018), which may be attributed to the cationic nature of the salts (except MgCl$_2$), originating from the reactions of strong acids with strong bases, which did not cause abrupt changes in the pH, even with the increase in EC$_{ns}$.

Individually, the treatments caused significant differences ($p < 0.05$) in the total fresh matter (TFM), shoot fresh matter (SFM) and root fresh matter (RFM) under replacement with municipal-supply water. The interaction between the treatments significantly ($p < 0.05$) influenced the TFM and SFM under replacement with municipal-supply water (Table 1).
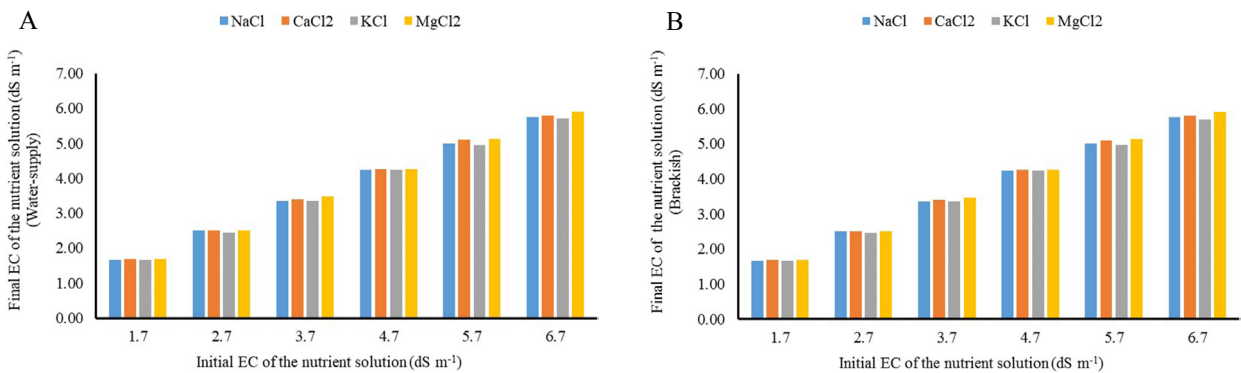
Figure 2: Electrical conductivity of the nutrient solution under replenishment with municipal-supply water (A) and brackish water (B) for the parsley plants (cv. Graúda portuguesa) cultivated with low-cost hydroponics.
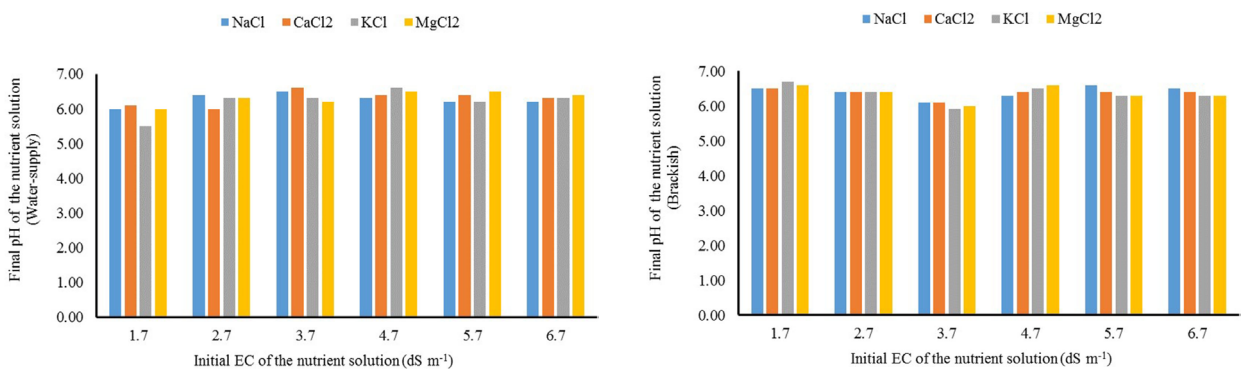
Figure 3: The pH of the nutrient solution under replenishment with municipal-supply water (A) and brackish water (B) for parsley plants (cv. Graúda portuguesa) cultivated with low-cost hydroponics.

Table 1: The total fresh matter (TFM), shoot fresh matter (SFM) and root fresh matter (RFM) results of parsley plants, cv. 'Graúda Portuguesa', exposed to isosmotic brackish nutrient solutions prepared in waters with different cationic natures and responses with municipal-supply water.

	EC of the nutrient solution (dS m^{-1})						
	1.7	2.7	3.7	4.7	5.7	6.7	
[1]TFM (g) – Municipal-supply (EC$_{ns}$: $p<0.05$, CN: $p<0.05$; EC$_{ns}$vsCN: $p<0.05$, CV = 4.63%)							
NaCl	69.56a	58.37a	48.69a	38.72a	35.41a	29.84a	$y=-7.9271^{**}x + 80.059$, $R^2 = 0.9662$
CaCl$_2$	65.18a	52.43b	44.51bc	34.97bc	25.08b	20.41b	$y=-9.0126^{**}x + 78.283$, $R^2 = 0.9875$
MgCl$_2$	62.51a	46.92c	42.83c	34.55c	26.15b	21.93b	$y=-7.814^{**}x + 71.967$, $R^2 = 0.9659$
KCl	69.20a	54.41b	46.71ab	38.05ab	35.00a	29.89a	$y=-7.5269^{**}x + 77.156$, $R^2 = 0.9425$
[1]SFM (g) – Municipal-supply (EC$_{ns}$: $p<0.05$, CN: $p<0.05$, EC$_{ns}$vsCN: $p<0.05$, CV = 4.95%)							
NaCl	49.58a	42.92a	36.62a	28.83a	26.67a	23.01a	$y =-5.4111^{**}x + 57.332$, $R^2 = 0.9701$
CaCl$_2$	47.01a	38.86b	33.08b	27.25a	18.56b	16.33b	$y = -6.2894^{**}x + 56.597$, $R^2 = 0.9855$
MgCl$_2$	45.73a	33.94c	32.87b	27.05a	20.61b	18.15b	$y = -5.2489^{**}x + 51.77$, $R^2 = 0.949$
KCl	49.95a	40.61ab	35.21a	28.45a	26.98a	22.78a	$y = -5.2429^{**}x + 56.017$, $R^2 = 0.9515$
RFM (g) – Municipal-supply (EC$_{ns}$: $p<0.05$, CN: $p<0.05$, EC$_{ns}$vsCN: $p>0.05$, CV = 10.88%)							
	NaCl	CaCl$_2$	MgCl$_2$	KCl			$y = 0.9543^{**}x + 86.048$, $R^2 = 0.9727$
	11.99a	10.25c	9.42d	11.04b			

[1]Different letters in the column indicate significant differences between the cationic natures at the 0.05 probability level by the test of means (Tukey). EC$_{ns}$: electrical conductivity of the nutrient solution; CN: cationic nature; CV : coefficient of variation.

In the interaction between the treatments under replacement with municipal-supply water, there was a linear reduction in the TFM as a function of the EC$_{ns}$ levels, but as the salinity increased from 2.7 dS m^{-1}, the TFM was 24.40% higher than that of the plants under NaCl and MgCl$_2$; the analysis demonstrates the difference in the effect of different salts on plants (Table 1).

Reductions in the SFM under replacement with municipal-supply water were observed; in addition, compared with CaCl$_2$ and MgCl$_2$, a difference ($p<0.05$) in the effect of the salts was found from 2.7 dS m^{-1}, especially in the SFM of the plants under NaCl and KCl (Table 1).

In the same way, there were reductions in the RFM under municipal-supply water, which, in spite of not having been significantly influenced in the interaction between the treatments, showed more expressive results when cultivated in solutions based on NaCl and KCl (Table 1).

There were greater losses of TFM, SFM and RFM in the plants exposed to salinity induced by divalent cations under replacement with municipal-supply water, which may be related to the higher speed of absorption of monovalent cations compared to divalent cations (Abrahão; Bôas; Bull, 2014).

Individually, the treatments caused significant differences ($p<0.05$) in the total fresh matter (TFM), shoot fresh matter (SFM) and root fresh matter (RFM) under replacement with brackish water. The interaction between the treatments significantly ($p<0.05$) influenced the RFM under replacement with brackish water (Table 2).

Under replacement with brackish water for the TFM and SFM, differences ($p<0.05$) between the cationic nature were observed with NaCl, in which the plants cultivated under NaCl presented more expressive results. In addition, there were linear reductions with the increase in salinity regardless of the cationic nature used in the nutrient solution (Table 2).

Table 2: The total fresh matter (TFM), shoot fresh matter (SFM) and root fresh matter (RFM) results of parsley plants, cv. 'Graúda Portuguesa', exposed to isosmotic brackish nutrient solutions prepared in waters with different cationic natures and responses with brackish water.

	EC of the nutrient solution (dS m⁻¹)						
	1.7	2.7	3.7	4.7	5.7	6.7	
TFM (g) – Brackish (EC_{ns}: p<0.05, CN: p<0.05, EC_{ns}vsCN: p>0.05, CV = 4.46%)							$y=-5.0017^{**}x + 58.511$, $R^2 = 0.9932$
		NaCl	CaCl₂	MgCl₂	KCl		
		38.34a	36.87b	37.44ab	37.35ab		
SFM (g) – Brackish (EC_{ns}: p<0.05, CN: p<0.05, EC_{ns}vsCN: p>0.05, CV = 5.54%)							$y = -4.2546^{**}x + 48.918$, $R^2 = 0.9937$
		NaCl	CaCl₂	MgCl₂	KCl		
		31.88a	30.47b	31.26ab	30.58b		
¹RFM (g) – Brackish (EC_{ns}: p<0.05, CN: p<0.05, EC_{ns}vsCN: p<0.05, CV = 4.71%)							
NaCl	8.24a	7.37a	6.75a	6.06a	5.33ab	5.00a	$y = -0.6574^{**}x + 9.2195$, $R^2 = 0.9888$
CaCl₂	8.46a	7.42a	6.39a	5.63a	5.35a	5.17a	$y = -0.6691^{**}x + 9.2137$, $R^2 = 0.9227$
MgCl₂	8.34a	7.35a	6.47a	5.83a	4.75b	4.29b	$y = -0.8197^{**}x + 9.6145$, $R^2 = 0.9917$
KCl	9.03a	8.17a	6.86a	6.17a	5.50a	4.86ab	$y = -0.8443^{**}x + 10.311$, $R^2 = 0.9825$

¹Different letters in the column indicate significant differences between the cationic natures at the 0.05 probability level by the test of means (Tukey). EC_{ns}: electrical conductivity of the nutrient solution; CN: cationic nature; CV : coefficient of variation.

Reductions in TFM and SFM in leafy vegetables under salt stress in hydroponic systems have also been found by other authors; for instance, similar results were reported in coriander (Rebouças et al., 2013) and basil (Bione et al., 2014), confirming that salinity causes disorders in plant metabolism, leading to the restriction of growth and the loss in yield (Silveira et al., 2016). However, despite the decrease in production with increasing salts, satisfactory fresh mass values reaching 50 g of parsley were observed.

For these two variables, it is interesting to note that under replacement with brackish water, under high EC_{ns}, the osmotic effect can be more deleterious than the ionic effect with respect to the production of crops.

For the RFM, a significant response to the interactions between the treatments (p<0.05) was only observed under replacement with brackish water, from 5.7 dS m⁻¹, which was different from the other plant parts (Table 2). It is worth pointing out the difference (p<0.01) of 17% in the RFM of the plants exposed to CaCl₂ and MgCl₂, which may be related to the lower absorption of Mg because it has a very high hydration energy, which causes its attraction to binding sites in the plasma membrane to

be particularly low, leading to low rates of absorption of this nutrient by plants (Marschner, 1986).

The EC_{ns} caused significant differences (p<0.05) in the total dry matter (TDM), the shoot dry matter (SDM) and the root dry matter (RDM) and in the percentages of total dry matter (%TDM), the shoot dry matter (%SDM) and the root dry matter (%RDM) under replacement with municipal-supply water. The interaction between the factors had a significant influence (p<0.05) on the TDM, SDM, RDM and %RDM. In addition, the %SDM was also affected (p<0.05) by the cationic nature (Table 3).

There was a linear reduction in the TDM with the increase in EC_{ns} under replacement with municipal-supply water. However, the difference between the effect of the salts was only observed from 4.7 dS m⁻¹, with more expressive results related to NaCl and KCl than to CaCl₂ and MgCl₂, whose mean difference reached 29.45% at an EC_{ns} of 6.7 dS m⁻¹ (Table 3).

A linear reduction was also found in the SDM as the EC_{ns} increased under replacement with municipal-supply water. Analogously, different responses to the cationic nature were observed when municipal-supply water was used in the replacement, also from 4.7 dS m⁻¹, especially under NaCl and KCl, compared to CaCl₂ and MgCl₂ (Table 3).

Table 3: The total dry matter (TDM), shoot dry matter (SDM) and root dry matter (RDM) and the percentages of total dry matter (%TDM), the shoot dry matter (%SDM) and the root dry matter (%RDM) results of parsley plants, cv. 'Graúda Portuguesa', exposed to isosmotic brackish nutrient solutions prepared in waters with different cationic natures and responses with municipal-supply water.

	EC of the nutrient solution (dS m^{-1})	
	1.7	2.7	3.7	4.7	5.7	6.7	
[1]TDM (g) – Municipal-supply (EC$_{ns}$: $p<0.05$, CN: $p<0.05$, EC$_{ns}$vsCN: $p<0.05$, CV = 5.66%)
NaCl	11.78a	9.00a	7.92a	7.34a	6.64a	5.16a	$y=-1.1646^{**}x + 12.865$, $R^2 = 0.9256$
CaCl$_2$	10.22a	8.71a	7.63a	6.90ab	4.42b	3.64b	$y= -1.3286^{**}x + 12.5$, $R^2 = 0.9773$
MgCl$_2$	10.43a	8.87a	7.83a	5.50b	4.56b	3.96b	$y= -1.3603^{**}x + 12.572$, $R^2 = 0.9731$
KCl	10.69a	8.94a	7.81a	7.07a	6.50a	5.08a	$y=-1.0317^{**}x + 12.015$, $R^2 = 0.9707$
[1]SDM (g) – Municipal-supply (EC$_{ns}$: $p<0.05$, CN: $p<0.05$, EC$_{ns}$vsCN: $p<0.05$, CV = 5.69%)
NaCl	8.36a	7.53a	6.83a	6.45a	5.85a	4.47a	$y =-0.7106^{**}x + 9.5661$, $R^2 = 0.9672$
CaCl$_2$	8.14a	7.12a	6.73a	6.25a	4.00b	3.35b	$y = -0.9654^{**}x + 9.9865$, $R^2 = 0.9361$
MgCl$_2$	8.24a	7.66a	6.86a	4.74b	4.00b	3.53b	$y = -1.0471^{**}x + 10.236$, $R^2 = 0.9573$
KCl	8.56a	7.34a	6.82a	6.34a	5.73a	4.42a	$y = -0.7431^{**}x + 9.6562$, $R^2 = 0.9675$
[1]RDM (g) – Municipal-supply (EC$_{ns}$: $p<0.05$, CN: $p<0.05$, EC$_{ns}$vsCN: $p<0.05$, CV = 5.98%)
NaCl	2.60a	1.77a	1.08a	0.88a	0.79a	0.69a	$y = -0.3626^{**}x + 2.8245$, $R^2 = 0.8311$
CaCl$_2$	2.07a	1.59ab	0.90a	0.65a	0.41a	0.29b	$y = -0.3626^{**}x + 2.5078$, $R^2 = 0.9290$
MgCl$_2$	2.18a	1.20b	0.96a	0.76a	0.56a	0.43b	$y = -0.3106^{**}x + 2.3194$, $R^2 = 0.8403$
KCl	2.13a	1.59ab	0.99a	0.82a	0.77a	0.66a	$y = -0.2851^{**}x + 2.3576$, $R^2 = 0.8508$
\multicolumn{7}{l}{%TDM (%) – Municipal-supply (EC$_{ns}$: $p<0.05$, CN: $p>0.05$, EC$_{ns}$vsCN: $p>0.05$, CV = 14.63%)}	$y = 0.5209^{**}x + 13.547$, $R^2 = 0.816$
%SDM (%) – Municipal-supply (EC$_{ns}$: $p<0.05$, CN: $p<0.05$, EC$_{ns}$vsCN: $p>0.05$, CV = 8.06%)	
	NaCl	CaCl$_2$	MgCl$_2$	KCl			$y = 0.9557^{**}x + 13.941$, $R^2 = 0.9724$
	17.97ab	18.64a	16.35b	18.87a			
[1]%RDM (%) – Municipal-supply (EC$_{ns}$: $p<0.05$, CN: $p<0.05$, EC$_{ns}$vsCN: $p<0.05$, CV = 9.74%)
NaCl	13.88a	9.91a	9.03a	9.06a	9.20a	10.15ab	$y = 0.5121^{**}x^2 – 4.8949x + 20.235$, $R^2 = 0.9217$
CaCl$_2$	11.43a	11.06a	8.07a	8.54a	7.30b	8.47b	$y = 0.2625^{**}x^2 – 2.9367x + 16.083$, $R^2 = 0.8369$
MgCl$_2$	13.17a	9.62a	9.51a	10.29a	10.71a	12.02a	$y = 0.4718^{**}x^2 – 4.0116x + 18.037$, $R^2 = 0.8041$
KCl	12.42a	11.63a	8.74a	8.64a	9.66a	10.94a	$y = 0.4641^{**}x^2 – 4.2816x + 18.781$, $R^2 = 0.8652$

[1]Different letters in the column indicate significant differences between the cationic natures at the 0.05 probability level by the test of means (Tukey). EC$_{ns}$: electrical conductivity of the nutrient solution; CN: cationic nature; CV : coefficient of variation.

Under replacement with municipal-supply water, there were losses up to 73.46%, 85.99%, 80.27% and 69.01% in the RDM of the plants exposed to the nutrient solutions based on NaCl, $CaCl_2$, $MgCl_2$ and KCl, respectively, within the salinity range from 1.7 dS m^{-1} to 6.7 dS m^{-1}. Regarding the cationic natures of the water, higher results were found for NaCl and KCl, and lower results were observed for $MgCl_2$ and $CaCl_2$ at levels of 2.7 and 6.7 dS m^{-1}, respectively (Table 3).

The similar behaviors for these two salts (NaCl and KCl) may be related to the fact that K and Na have a common absorption mechanism that is regulated by their concentrations in the nutrient solution. Thus, high K levels can modify Na uptake and transport and limit the toxic damage of this nutrient (Schachtman; Schroeder, 1994).

For the % TDM and % SDM, under replacement with municipal-supply water, there was a linear increase with the increase in nutrient solution electrical conductivity, with gains of 14.67% for the %TDM and 22.66% for the %SDM. Nonetheless, only the %SDM demonstrated a significant influence (p<0.05) on the cationic nature, with higher gains in the solutions based on KCl (Table 3).

The %RDM showed minimum values of 8.53%, 7.86%, 9.50% and 8.90% in the solutions based on NaCl, $CaCl_2$, $MgCl_2$ and KCl, respectively. In relation to the cationic nature, from 5.7 dS m^{-1}, less expressive results were observed in the solutions based on $CaCl_2$.

The EC_{ns} caused a significant difference (p<0.05) in the total dry matter (TDM), the shoot dry matter (SDM) and the root dry matter (RDM) and in the percentages of the total dry matter (%TDM), the shoot dry matter (%SDM) and the root dry matter (%RDM) under replacement with brackish water. The cationic nature had a significant influence (p<0.05) on the TDM, SDM and %RDM (Table 4).

There was a linear reduction in the TDM with the increase in EC_{ns} under replacement with brackish water regardless of the type of salt, which individually demonstrated more expressive values in the solutions based on NaCl. The use of brackish water in the replacement resulted in a relative loss estimated at 42.23% within the studied interval of the EC_{ns}.

A linear reduction was also found in the SDM as the EC_{ns} increased and under replacement with brackish

Table 4: The total dry matter (TDM), shoot dry matter (SDM) and root dry matter (RDM) and the percentages of total dry matter (%TDM), the shoot dry matter (%SDM) and the root dry matter (%RDM) results of parsley plants, cv. 'Graúda Portuguesa', exposed to isosmotic brackish nutrient solutions prepared in waters with different cationic natures and responses with brackish water.

EC of the nutrient solution (dS m^{-1})				
TDM (g) – Brackish (EC_{ns}: p<0.05, CN: p<0.05, EC_{ns}vsCN: p>0.05, CV = 7.82%)				y=-0.8089**x + 10.699, R^2 = 0.9969
NaCl	$CaCl_2$	$MgCl_2$	KCl	
7.54a	7.27ab	7.31ab	7.10b	
SDM (g) – Brackish (EC_{ns}: p<0.05, NC: p<0.05, EC_{ns}vsCN: p>0.05, CV = 8.66%)				y = -0.74**x + 9.648, R^2 = 0.9972
NaCl	$CaCl_2$	$MgCl_2$	KCl	
6.78a	6.49ab	6.54ab	6.35b	
RDM (g) – Brackish (EC_{ns}: p<0.05, CN: p>0.05, EC_{ns}vsCN: p>0.05, CV = 6.64%)				y = -0.0689**x + 1.0475, R^2 = 0.9891
%TDM (%) – Brackish (EC_{ns}: p<0.05, CN: p>0.05, EC_{ns}vsCN: p>0.05, CV = 9.43%)				y = 0.4586**x + 17.766, R^2 = 0.8931
%SDM (%) – Brackish (EC_{ns}: p<0.05, CN: p>0.05, EC_{ns}vsCN: p>0.05, CV = 10.87%)				y = 0.5326**x + 19.11, R^2 = 0.8825
%RDM (%) – Brackish (EC_{ns}: p<0.05, CN: p<0.05, EC_{ns}vsCN: p>0.05, CV = 9.53%)				y = 0.332**x + 10.569, R^2 = 0.9765
NaCl	$CaCl_2$	$MgCl_2$	KCl	
11.76bc	12.32ab	12.61a	11.15c	

[1]Different letters in the column indicate significant differences between the cationic natures at the 0.05 probability level by the test of means (Tukey). EC_{ns}: electrical conductivity of the nutrient solution; CN: cationic nature; CV : coefficient of variation.

water, and among the cationic natures studied, the plants cultivated with NaCl were shown to be less sensitive to the salinity increase of the nutrient solution.

This may be related to the fact that the root system has proteins that are present in the plasmalemma of epidermal cells and can exclude Na^+ from the cytosol to the outside; also, when this is carried out, it may lead to the deposition of this ion in the xylem, and consequently, transpiration flow may favor the transfer of Na^+ to the shoots. Therefore, this transport system can be directly involved with mechanisms that regulate the transport and distribution of this ion in the plant (Silveira et al., 2016).

Under replacement with brackish water, there was an estimated reduction of 6.02% in the RDM per dS m^{-1} (Table 4). However, for the %TDM, there was a linear increase with the increment in nutrient solution electrical conductivity, with gains of 10.74%; in the same way as the %SDM, there were also linear increments as the salinity increased under replacement with brackish water (11.51%) (Table 4).

Under replacement with brackish water, the plants grown in the solutions containing $CaCl_2$ and $MgCl_2$ showed a higher % RDM, and an increment up to 12.37% was estimated when the %RDM was compared between the plants, at 1.7 and 6.7 dS m^{-1} (Table 4).

In both experiments, there was a tendency of growth in the accumulation of dry mass with the increase in salinity; analogously, an increase in dry matter content in plants under salt stress has also been observed in pepper (Piñero et al., 2014) and lettuce (Pérez-López et al., 2013), which may be attributed to the maintenance of high turgor in the tissues due to efficient stomatal closure (Pirasteh-Anosheh et al., 2016) and consequently greater CO_2 fixation.

CONCLUSIONS

The percentages of shoot and root dry matter increased with increasing electrical conductivity. Greater reductions were observed in the fresh and dry mass when the volume consumed was replaced with brackish water. The use of municipal-supply water mitigated the effects of the salts on the production variables and the dry matter content of the parsley plants. Although reductions were observed with the increment of EC$_{ns}$ in both strategies of replacement, the results of parsley production were satisfactory.

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