ISSN 1807-1929
Revista Brasileira de Engenharia Agrícola e Ambiental
Brazilian Journal of Agricultural and Environmental Engineering
v.26, n.1, p.11-20, 2022
Campina Grande, PB – http://www.agriambi.com.br – http://www.scielo.br/rbeaa

DOI: http://dx.doi.org/10.1590/1807-1929/agriambi.v26n1p11-20

Ionic relationships between macronutrients and sodium in parsley under nutrient solutions prepared with brackish water[1]

Relações iônicas entre macronutrientes e sódio pela salsa sob soluções nutritivas preparadas com águas salobras

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HIGHLIGHTS:

Use of water with low electrical conductivity in the preparation of nutrient solutions mitigates the effect of salinity.
Increases in ionic concentration show differences in the efficiency of macronutrient use caused by the cationic natures.
Concentration × cationic nature affects ionic relationships differently, impacting the plant differently.

ABSTRACT: The concentration and nature of ions directly influence ionic relationships between macronutrients and sodium, especially in the context of plants grown under saline conditions. The goal of this study was to analyze the efficiency of use of N, P, K, Ca, Mg, and S, the efficiency of Na accumulation, and the relationships between Ca^{+2}, Mg^{+2}, Na^{+}, and K^{+} after analysis of parsley, cultivar Graúda Portuguesa, plant tissues exposed to nutrient solutions prepared with brackish water with different cationic natures. The treatments consisted of exposing plants to nutrient solutions (EC_{ns} = 1.7, 2.7, 3.7, 4.7, 5.7, and 6.7 dS m^{-1}) prepared with brackish water obtained by solubilizing different salts, NaCl, $CaCl_2.2H_2O$, $MgCl_2.6H_2O$, and KCl in supply water (ECw = 0.12 dS m^{-1}). Two cultivation cycles were conducted, adopting a completely randomized experimental design in both (6 × 4 factorial scheme), with four replicates. The efficiency of the use of macronutrients and sodium accumulation was more affected by the cationic nature of the water at the highest concentration levels. Except for the Ca^{+2} - Mg^{+2} ratio, all other cationic ratios were affected by the increase in the concentration of salts in the nutrient solution.

Key words: *Petroselinum crispum*, hydroponics, salinity

RESUMO: A concentração e natureza dos íons influenciam diretamente as relações iônicas entre macronutrientes e sódio, especialmente no contexto das plantas cultivadas em condições de salinidade. Este estudo foi desenvolvido com o objetivo de analisar a eficiência de uso do N, P, K, Ca, Mg e S e a eficiência de acúmulo de Na, bem como as relações que ocorrem entre Ca^{+2}, Mg^{+2}, Na^{+} e K^{+} após análise do tecido de plantas de salsa, cultivar Graúda Portuguesa, expostas a soluções nutritivas preparadas com águas salobras com diferentes naturezas catiônicas. Os tratamentos consistiram na exposição das plantas a soluções nutritivas (CE_{sn} = 1,7, 2,7, 3,7, 4,7, 5,7 e 6,7 dS m^{-1}) preparadas com águas salobras obtidas mediante a solubilização de diferentes sais - NaCl, $CaCl_2.2H_2O$, $MgCl_2.6H_2O$ e KCl em água de abastecimento (CEa = 0,12 dS m^{-1}). Realizou-se dois ciclos de cultivo, adotando-se em ambos, delineamento experimental inteiramente casualizado (esquema fatorial 6 x 4), com quatro repetições. Verificou-se que a eficiência de uso dos macronutrientes e de acúmulo do sódio foi afetada com maior intensidade pela natureza catiônica da água nos maiores níveis de concentração. Exceto para a razão Ca^{+2} - Mg^{+2}, todas as outras razões catiônicas avaliadas foram afetadas pelo aumento na concentração de sais na solução nutritiva.

Palavras-chave: *Petroselinum crispum*, hidroponia, salinidade

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• Accepted 04 Jul, 2021 • Published 11 Aug, 2021
Edited by: Carlos Alberto Vieira de Azevedo

Introduction

The use of brackish water in the preparation of a nutrient solution in hydroponic vegetable crops has been widely adopted, mainly in semi-arid regions where the water has a high concentration and variability of salts (Martins et al., 2020). Sodium, magnesium, and calcium are the most prevalent ions in waters (Paiva et al., 2021).

In parsley plants exposed to different cationic natures there are changes in production (Martins et al., 2019b), water relationships (Martins et al., 2019a), and photochemical efficiency (Martins et al., 2020). However, studies that address aspects of use efficiency and relationships between nutrients are still scarce.

When plants are grown under saline conditions, use efficiency of these ions is influenced by other factors, such as concentration, ionic nature, and respective relationships (Silva et al., 2018a). The osmotic influence imposed by the increase in concentration compromises the development of plants, causes nutritional imbalances, inhibits photosynthesis, and interferes with ribosomal and protein functions (Nery et al., 2013; Al-shareef & Tester, 2019).

To achieve the appropriate ionic balance (Yang & Kim, 2019), the strategy used in the preparation and replacement of the nutrient solution is essential in the cultivation of crops that are sensitive to salinity.

Thus, the goals of the present study were to analyze the use efficiency of N, P, K, Ca, Mg, and S, the efficiency of Na accumulation, and the relationships that occur between Ca^{+2}, Mg^{+2}, Na^{+}, and K^{+} after analysis of parsley, cultivar Graúda Portuguesa, plant tissues exposed to nutrient solutions prepared with brackish water with different cationic natures.

Material and Methods

This study was conducted between October 2017 and February 2018, in a protected environment in the Department of Agricultural Engineering of the Universidade Federal Rural de Pernambuco (UFRPE), Recife, PE, Brazil (8° 01’ 07” S, 34° 56’ 53” W, and 6.5 m altitude). During the experimental period, the temperature and relative humidity of the air were monitored within the protected environment (Figure 1).

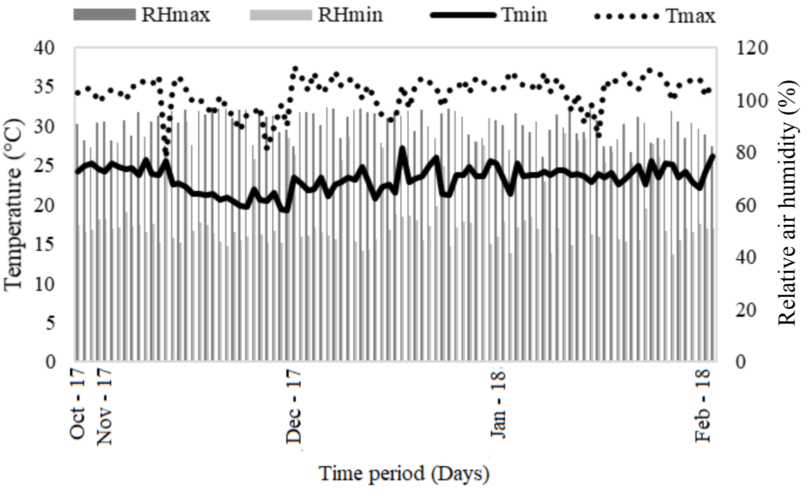
The hydroponic system adopted consisted of PVC tubes with 0.1 m diameter and 6.0 m length, seated horizontally (level) and adapted with circular 0.06 mm-diameter holes, equidistantly spaced every 0.14 m (Santos Júnior et al., 2016). PVC elbows with the same diameter as the tubes were connected to the ends and had valves that allowed a nutrient solution level of 4 cm inside each tube. They were interconnected to the stock reservoir by plastic tubes. The PVC tubes were arranged on a vertical wooden structure.

The evaluated crop was parsley, cultivar Graúda Portuguesa. Sowing was performed in 180 mL disposable plastic cups, with small perforations in the bottom and the bottom third on the sides. The cups were filled with washed coconut fiber. Upon this, 45 seeds were homogeneously deposited and covered with dry coconut fiber. No thinning was conducted, and each disposable cup was considered one parsley bunch. From 10 days after sowing (DAS), irrigation was conducted by spraying water in the morning and afternoon. Next, the cups containing the seedlings were taken to the hydroponic system tubes and the treatments were applied.

The treatments consisted of nutrient solutions prepared with brackish water (EC_{ns} = 1.7, 2.7, 3.7, 4.7, 5.7, and 6.7 dS m^{-1}), salinized by dissolving salts with different cationic natures at the following concentrations: NaCl treatment, 0; 10.95; 21.90, 32.85, 43.80, and 54.75 mmol L^{-1}; $CaCl_2.2H_2O$ treatment, 0; 4.35; 8.70, 13.05, 17.40, and 21.75 mmol L^{-1}; $MgCl_2.6H_2O$ treatment, 0; 3.15; 6.30, 9.44, 12.59, and 15.74 mmol L^{-1}; KCl treatment, 0; 8.59; 17.17; 25.75; 42.92 and 53.65 mmol L^{-1}. Salts were added to water from the UFRPE (electrical conductivity of water - EC_w = 0.12 dS m^{-1}) supply system. The experimental design was a completely randomized, in a 6 × 4 factorial scheme, with four replicates.

Two experiments were conducted with the same treatments and experimental design. As the water consumption by the plants reduced the level of the reservoir, replacement constituted public-supply water from UFRPE (first experiment) and the respective brackish water (second experiment). The electrical conductivity (EC) and pH of the nutrient solution were monitored daily for control and eventual correction, if necessary (Furlani et al., 1999).

The nutrient solutions were prepared only once, before the beginning of each experiment, with the addition of salts to



RHmax and RHmin – Maximum and minimum relative air humidity, respectively; Tmax and Tmin - Maximum and minimum air temperature, respectively

Figure 1. Variation in temperature and relative air humidity of the air in the greenhouse during the experimental period

the water from the UFRPE supply system (EC of 0.12 dS m^{-1}) contained in 90 L reservoirs, observing the relationships of Rhoades et al. (1992) and with the aid of a conductivity meter. The respective salts, i.e., NaCl, $CaCl_2$, $MgCl_2$, and KCl, were individually added in increasing amounts to each of the brackish water treatments, until the EC values were at the pre-established values of 1.12, 2.12, 3.12, 4.12, and 5.12 dS m^{-1}.

Once the brackish waters were prepared, the same quantities of fertilizers (Furlani et al., 1999) were added to each reservoir, namely, 67.5 g calcium nitrate, 45 g potassium nitrate, 36 g magnesium sulfate + micronutrients, and 13.5 g monoammonium phosphate. These quantities corresponded to the following nutrient concentrations in mmol L^{-1}: 13.59 N; 2.37 Ca; 5.50 K; 2.61 P; 1.37 S; 1.48 Mg; and in μmol L^{-1}: 180 B; 30 Cu; 180 Fe; 140 Mn; 8.0 Mo; and 90.0 Zn, which corresponded to conductivity of 1.58 dS m^{-1}. As a result, the final electrical conductivities (EC_{ns}) in the nutrient solutions were 1.7 (control, with no addition of salts), 2.7, 3.7, 4.7, 5.7, and 6.7 dS m^{-1}, respectively.

Regarding nutrient solution management, the protocol used consisted of manual application of 40 L of nutrient solution twice daily to the tubes in the morning (07:00 hour) and afternoon (15:00 hour). Nevertheless, because a closed system was used, the surplus solution in relation to the level inside the pipe, was returned to the solution reservoir through a tube, and the process was repeated daily.

In both experiments, plants were harvested at 50 DAS. The shoots and roots of parsley plants were placed in paper bags and dried in a forced air circulation oven at 65 °C, until a constant weight was reached. The dry mass of shoots and roots was weighed and roots and shoots were ground in a Wiley-type mill. The values for shoot dry mass (SDM) and total dry mass (TDM) hereafter correspond to the average values for four parsley bunches.

The macronutrients P, K, Ca, Mg, S, and the Na ion in the dry matter were removed by wet extraction. For N, sulfuricacid digestion was performed. For the remainder and the Na ion, nitric digestion was performed based on the methodology proposed by Silva (2009). Concentrations of P, K, Na, Ca, Mg, and S were determined based on the methodology proposed by Bezerra Neto & Barreto (2011). P and S concentrations were determined using a UV spectrophotometer. Ca and Mg were determined by atomic absorption spectrophotometry. Na and K were determined by flame photometry. N was determined by the steam drag distillation method (Kjeldahl method).

To quantify the accumulation of macronutrients and Na in the shoots of parsley plants, the obtained concentrations of each macronutrient and Na were multiplied by SDM. The efficiency of use of macronutrients and Na was determined by the ratio between TDM (g) and accumulation of each nutrient in the shoots (g). The interactions between ions were estimated by the ratio of the accumulation values.

The results were subjected to normality and homoscedasticity tests and an analysis of variance was conducted. The EC of the nutrient solution was submitted to regression analysis, whereas the cationic natures were compared with a mean comparison test (Tukey) at $p \leq 0.05$. Statistical analyses were conducted with SISVAR software.

RESULTS AND DISCUSSION

The EC of the nutrient solution (EC_{ns}) decreased under replacement with the public-supply water (PSW) for all cationic natures studied. The reductions could be attributed to the dilution of salts because the EC of PSW was 0.12 dS m^{-1}, which always led to lower EC_{ns} values than the initial EC. Among the cationic natures studied, a maximum decrease of 15% was observed at values of 5.7 and 6.7 dS m^{-1}. With the replacement with brackish water (BRW) the EC_{ns} increased compared to the initial EC_{ns} for all cationic natures, with maximum increments of 25.70, 38.47, 21.01, and 21.28% when there was a predominance of KCl, $MgCl_2$, NaCl, and $CaCl_2$ in the water, respectively.

The increase in EC_{ns} with replacement using brackish water and the decrease in the EC_{ns} with replacement using the PSW, was also observed by Campos Júnior et al. (2018) who worked with arugula (rocket) and used brakish water in the replacement of the evapotranspirated volume. This increase was caused by the supply of salts that occurs with replacement with brackish water.

For the pH_{ns} under replacement with PSW, in the treatment with preponderance of K^+, there was a maximum reduction of 15%, reaching a value of 5.5 at 50 DAS. There was no correction of pH_{ns} because the variation in this study did not exceed the range of 5.5 and 6.5 suggested by Silva et al. (2018b) as the ideal. However, with replacement by BRW with the preponderance of K^+ there was a decrease of the order of 11.47% because as the plant absorbed potassium, there was a tendency to make H^+ available, which enabled osmotic adjustment.

The estimate of ratios was calculated based on the ratio between the accumulation of ions in the SDM of the bunch (Table 1). It is worth highlighting the interactive effect ($p \leq 0.05$) between the treatments on the SDM of plants with replacement by the PSW and the individual significance ($p \leq 0.05$) of the treatments for plants with replacement using BRW.

In general, for replacement using PSW, the decrease in SDM was linearly proportional to the increase in EC_{ns}, although the rate of reduction relative to dS m^{-1} increase was higher for bivalent cations. The values occurred in the following order: $Mg^{+2} > Ca^{+2} > Na^+ > K^+$ (Table 1). For replacement using BRW, there was a relative linear reduction of 0.7633 g in SDM for each dS m^{-1} increase, and a higher SDM ($p \leq 0.05$) when there was a preponderance of Na^+ in the water (Table 1).

The results illustrated the deleterious effects of increasing salinity in the production of SDM in plants, which occurs because of high concentrations of toxic ions, such as Na^+, caused by salt stress and the concomitant decrease in the availability of essential nutrients. This interferes with the development of plants and accelerates the leaf senescence process and consequently decreases photosynthesis (Zörb et al., 2019). Salinity also interferes with the metabolic and physiological processes, compromising plant mass production. Such reduction has also been observed for rocket by Campos Júnior et al. (2018).

In both strategies of nutrient solution replacement, when there was preponderance of Ca^{+2}, the increase in concentration did not affect ($p > 0.05$) the Na^+/K^+ ratio (Table 1). It was observed that the increase in salinity in the nutrient solution could cause competition in the absorption of Na^+ with that of K^+, Ca^{+2}, and

Table 1. Shoot dry mass (SDM) and Na^+/K^+, Na^+/Ca^{+2}, and Na^+/Mg^{+2} ratios in parsley cultivar Graúda Portuguesa, plants tissues exposed to nutrient solutions prepared with brackish water with a preponderance of Na^+, Ca^{+2}, Mg^{+2}, and K^+ and whose evapotranspired depth was replaced with public supply water (PSW) or brakish water (BRW) in the nutrient solution

	Electrical conductivity of nutrient solutions (dS m^{-1})							
	1.7	2.7	3.7	4.7	5.7	6.7	Equation	R^2
SDM of bunches (g) – Public-supply water (EC_{ns}: $p \le 0.05$; NC: $p \le 0.05$; EC_{ns} x NC: $p \le 0.05$; CV = 5.52%)								
NaCl	8.4750 a	7.5225 a	6.7325 a	6.4275 a	5.9600 a	4.4475 a	$y = -0.7180^{**}x + 9.6098$	0.95
$CaCl_2$	8.2675 a	7.1450 a	6.6525 a	6.3175 a	3.9500 b	3.3575 b	$y = -0.9849^{**}x + 10.084$	0.93
$MgCl_2$	8.1750 a	7.6250 a	6.9725 a	4.7850 b	4.0300 b	3.6500 b	$y = -1.0170^{**}x + 10.144$	0.94
KCl	8.3775 a	7.3475 a	6.9225 a	6.3875 a	5.8150 a	4.5100 a	$y = -0.6991^{**}x + 9.4964$	0.96
SDM of bunches (g) – Brackish water (EC_{ns}: $p \le 0.05$; NC: $p \le 0.05$; EC_{ns} x NC: $p > 0.05$; CV = 8.29%)								
NaCl		$CaCl_2$		$MgCl_2$		KCl		
6.7975 a		6.5450 b		6.5091 b		6.2950 b	$y = -0.7633^{**}x + 9.743$	0.99
Public-supply water - Na^+/K^+ (EC_{ns}: $p \le 0.01$; NC: $p \le 0.01$; EC_{ns} x NC: $p \le 0.01$; CV = 16%)								
$CaCl_2$	0.3250 a	0.2775 b	0.2760 b	0.2625 b	0.2795 b	0.2525 b	$\bar{Y} = 0.2788$	
KCl	0.2982 a	0.3140 b	0.2977 b	0.2945 b	0.3057 b	0.3010 b	$\bar{Y} = 0.3018$	
$MgCl_2$	0.3667 a	0.2982 b	0.2810 b	0.2725 b	0.3062 b	0.3727 b	$^{1}y= 0.0157^{**}x^2 - 0.1306^{ns}x+0.5419$	0.98
NaCl	0.3712 a	0.4630 a	0.6125 a	0.8740 a	1.014 a	1.4805 a	$y = 0.2132^{**}x + 0.0923$	0.93
Brackish water - Na^+/K^+ (EC_{ns}: $p \le 0.01$; NC: $p \le 0.01$; EC_{ns} x NC: $p \le 0.01$; CV = 12.26%)								
$CaCl_2$	0.3067 a	0.2912 b	0.3230 b	0.3222 b	0.3420 b	0.3440 b	$^{1}y = 0.0096^{*}x + 0.2810$	0.91
KCl	0.3517 a	0.2655 b	0.2217 c	0.1922 c	0.1840 c	0.1775 d	$y = -0.0327^{**}x + 0.3695$	0.83
$MgCl_2$	0.2965 a	0.2537 b	0.2197 c	0.2130 c	0.2242 c	0.2557 c	$^{1}y = 0.0099^{*}x^2 - 0.0914^{**}x +0.4249$	0.99
NaCl	0.3472 a	0.4292 a	0.6740 a	0.8792 a	1.1510 a	1.4027 a	$y = 0.2185^{**}x - 0.1038$	0.98
Public-supply water – Na^+/Ca^{+2} (EC_{ns}: $p \le 0.01$; NC: $p \le 0.01$; EC_{ns} x NC: $p \le 0.01$; CV = 35.36%)								
$CaCl_2$	0.6547 a	1.1587 a	1.4185 a	1.7982 a	1.9450 a	2.6215 a	$y = 0.3592^{**}x + 0.0908$	0.97
KCl	0.6807 a	0.4907 b	0.4502 c	0.3715 c	0.3480 c	0.2750 c	$^{1}y = -0.0724^{ns}x + 0.7403$	0.91
$MgCl_2$	0.5762 a	0.7230 b	0.8095 b	0.8625 b	0.9995 b	1.0850 b	$^{1}y = 0.0979^{**}x + 0.4315$	0.98
NaCl	0.5285 a	0.4192 b	0.3177 c	0.2545 c	0.2435 c	0.2135 c	$^{1}y = -0.0619^{**}x + 0.5894$	0.9
Brackish water – Na^+/Ca^{+2} (EC_{ns}: $p \le 0.01$; NC: $p \le 0.01$; EC_{ns} x NC: $p \le 0.01$; CV = 36.99%)								
$CaCl_2$	2.3175 a	1.3315 b	0.8997 b	1.2722 b	0.7892 b	0.8307 c	$\bar{Y} = 1.2401$	
KCl	0.7552 a	2.6475 a	2.4667 a	2.1957 b	2.1765 a	2.2957 b	$\bar{Y} = 2.0895$	
$MgCl_2$	2.6752 a	1.4460 b	1.1110 b	0.9407 b	0.9937 b	1.0097 c	$^{1}y = 0.1389^{**} - 1.4483^{**}x+4.5903$	0.94
NaCl	2.8197 a	2.5197 a	3.3957 a	4.3750 a	2.9487 a	7.2200 a	$y = 0.2437^{**}x^2 - 1.3537x+4.5558$	0.68
Public-supply water – Na^+/Mg^{+2} (EC_{ns}: $p \le 0.01$; CN: $p \le 0.01$; EC_{ns} x CN: $p \le 0.01$; CV = 28.20%)								
$CaCl_2$	2.6185 a	2.1580 b	2.1327 c	2.1735 b	2.2155 b	1.8980 b	$^{1}y = 0.0176^{**}x^2 - 0.244^{ns}x+2.8648$	0.64
KCl	2.6855 a	3.7755 a	4.6082 b	6.8737 a	9.5337 a	15.038 a	$y = 2.3230^{**}x - 2.6709$	0.89
$MgCl_2$	2.7342 a	2.2265 b	1.9542 c	2.5035 b	2.4465 b	2.6500 b	$^{1}y = 0.0789^{**}x^2 - 0.6400^{ns}x+3.4860$	0.58
NaCl	3.1190 a	4.5542 a	6.7605 a	8.7210 a	10.383 a	13.440 a	$y = 2.0302^{**}x - 0.6969$	0.99
Brackish water – Na^+/Mg^{+2} (EC_{ns}: $p \le 0.01$; CN: $p \le 0.01$; EC_{ns} x CN: $p \le 0.01$; CV = 43.37%)								
$CaCl_2$	3.4692 a	2.9645 a	3.1212 b	3.1057 b	3.0807 b	2.6437 c	$^{1}y = -0.0069^{ns}x^2 - 0.0502^{ns}x+3.4174$	0.58
KCl	4.0752 a	4.2655 a	4.5867 b	5.2887 b	6.1477 a	6.6572 b	$^{1}y = 0.5502^{ns}x + 2.8592$	0.96
$MgCl_2$	3.1752 a	2.3747 a	2.0577 b	1.9012 b	1.9917 b	2.2777 c	$\bar{Y} = 2.2797$	
NaCl	3.6712 a	4.7117 a	7.5750 a	10.913 a	8.2840 a	19.208 a	$y = 2.6211^{**}x - 1.9481$	0.76

EC_{ns} - Electrical conductivity of the nutrient solution; CN - Primary cationic nature of water. Different letters in the column indicate significant differences between cationic natures at $p \le 0.05$ according to the Tukey test. For SDM under replacement with brackish water, different letters in the rows indicate significant differences between the cationic natures at $p \le 0.05$ according to the Tukey test. **, *, ns - Significant at $p \le 0.01$ and $p \le 0.05$, and not significant by F test, respectively; [1] After the interaction began, there was no significant EC_{ns} within the respective CN

Mg^{+2}, which could lead to nutritional imbalances. According to Butcher et al. (2016), sodium has a considerable negative impact on plant growth and development compared to other cations because of its ability to induce Ca^{+2} and K^+ deficiencies.

However, under replacement with PSW, the predominance of K^+ in water did not affect ($p > 0.05$) the Na^+/K^+ ratio, nor was there an adequate adjustment of the equation. For replacement using BRW, a successive increase in K^+ concentration led to a reduction of Na^+ in plant tissues. According to Julkowska & Testerink (2015), because of the physico-chemical similarities between Na^+ and K^+, Na^+ tends to replace K^+ at its usual binding sites and impairs cell biochemistry; however, when K^+ concentrations increase, the cytotoxic effects of Na^+ caused by salinity stress can be mitigated.

When there was a predominance of Mg^{+2} in the water, the Na^+/K^+ ratio was minimal (0.2703 and 0.2139) at an EC_{ns} of 4.16 and 4.61 dS m^{-1} (Table 1) with replacement with PSW and BRW respectively. However, for replacement using BRW, even with the increase in EC_{ns}, the average Na^+/K^+ ratio was 0.2438. However, when there was a prevalence of Na^+ in the water, this ratio increased at rates of 0.213 and 0.218 per dS m^{-1} added to the solution with replacement by PSW and BRW, respectively (Table 1).

The Na^+/K^+ ratio in the tissues of plants grown under saline conditions is an indicator of antagonism between these ions and it is important to quantify the level of competition between ions for plasmalemma absorption sites and to indicate increased K^+ efflux from the roots in the growing medium because of disturbances to membrane integrity (Inocêncio & Carvalho, 2013).

According to the data, the increase in EC_{ns} accentuated the increase in the Na^+/K^+ ratio according to the prevalence of the cationic nature in this study in the following order: $Na^+ > Mg^{+2} > Ca^{+2} = K^+$ and $Na^+ > Ca^{+2} = Mg^{+2} > K^+$ under replacement with PSW and BRW, respectively (Table 1).

In both forms of replenishment, the water with an cationic predominance of K^+ exhibited a decrease in the Na^+/K^+ ratio. However, the increase in the concentration of Ca^+ and Mg^+ did not influence ($p > 0.05$) the Na^+/K^+ ratio, despite the greater influence on the increase of EC_{ns} for Mg^+ and Ca^+ for replacement with PSW and BRW, respectively.

In both replacement strategies, the prevalence of K^+ and Mg^{+2} in the water did not affect ($p > 0.05$) the Na^+/Ca^{+2} ratio in plant tissues. The regression equations showed that, under the prevalence of K^+, none of the parameters of the adjusted equations was significant ($p > 0.05$); however, under the prevalence of Mg^{+2} there was an increase of 0.0979 for each dS m^{-1} and a minimum (0.8150) at the EC_{ns} of 5.21 dS m^{-1}, for replacement with PSW and BRW, respectively (Table 1).

Regarding the predominance of Na^+ in the water and replacement with PSW, the increase in EC_{ns} did not affect ($p > 0.05$) the Na^+/Ca^{+2} ratio, although there was no significant adjustment ($p > 0.05$) after the split analysis, the increase in EC_{ns} implied a reduction of 0.0619 for each dS m^{-1} increment in the Na^+/Ca^{+2} ratio. On the other hand, although an adequate R^2 was not verified, under replacement with the respective brackish water, the Na^+/Ca^{+2} ratio was minimal (2,675) under EC_{ns} of 2.77 dS m^{-1}.

The predominance of Ca^{+2} increased ($p \leq 0.01$) the Na^+/Ca^{+2} ratio at rates of 0.3592 for each dS m^{-1} increment for replacement with PSW. It is likely that the greater accumulation of Na^+, to the detriment of Ca^{+2}, may be associated with competition between Ca^{+2} and Mg^{+2}, which consequently favored the absorption of Na^+, which under these conditions was favored because it was monovalent and absorbed more than ions with a higher valence, such as Ca^{+2} and Mg^{+2}. However, the use of BRW for replacement did not affect ($p > 0.05$) the Na^+/Ca^{+2} ratio with a predominance of Ca^{+2} in the water.

For replacement with BRW, the Na^+/Ca^{+2} ratio was not affected ($p > 0.05$) when Ca^{+2}, Mg^{+2}, and K^+ were predominant in the water, even with an increase in the EC_{ns}. The input of salts resulting from this replacement strategy likely led to precipitation processes in salts in different ionic forms, affecting the absorption, and consequently, not influencing the Na^+/Ca^{+2} ratio in plant tissues (Table 1).

When the influence of the different cations was analyzed considering each EC_{ns}, the Na^+/Ca^{+2} ratio varied more sharply with the increase in concentration and replacement with PSW, which promoted a greater accumulation of Na^+, to the detriment of Ca^{+2}, when there was a greater amount of $Ca^{+2} > Mg^{+2} > K^+ > Na^+$ in the water. For replacement with BRW, this was $K^+ > Na^+ = Ca^{+2} = Mg^{+2}$ (Table 1).

The Na^+/Mg^{+2} ratio did not vary with an increase in concentration when there was a predominance of Ca^{+2} and Mg^{+2} in the water, under both evapotranspired depth replacement strategies. However, the regression equations showed there were limitations regarding the adjustment and significance of the parameters. When Na^+ was predominant, there were linear increments in the Na^+/Mg^{+2} ratio at rates of 2.0302 and 2.6211 per dS m^{-1} under replacement with PSW and BRW, respectively, reaching a ratio of 19.2 at the EC_{ns} of 6.7 dS m^{-1} (Table 1).

When there was a predominance of K^+ in the water and replacement with PSW, the increase in the Na^+/Mg^{+2} ratio was 2.3230 for each dS m^{-1}, whereas the increase in EC_{ns} did not affect ($p > 0.05$) the Na^+/Mg^{+2} ratio for replacement with BRW (Table 1). It can be inferred that the prevalence of K^+ and Na^+ favored the absorption of Na^+ to the detriment of Mg^{+2} because monovalent cations are absorbed more rapidly by the roots than bivalent cations. Therefore, K^+ strongly competed with the absorption of calcium and magnesium (Silva & Trevizam, 2015). The results for the Na^+/Mg^{+2} ratio at each EC_{ns} were similar for the different cations. In the replacement with both PSW and BRW, there was a higher Na^+/Mg^{+2} ratio, with predominance of $Na^+ = K^+ > Ca^{+2} = Mg^{+2}$ in the waters (Table 1).

In both replacement strategies, there was no influence of the interaction between treatments for the Ca^{+2}/Mg^{+2} ratio. For replacement with PSW, the estimated relative increase in this ratio was 0.4046 for each dS m^{-1}, with the highest mean Ca^{+2}/Mg^{+2} ratio observed in the cultivated plants tissues when there was a higher amount of $Ca^{+2} > K^+ > Na^+ = Mg^{+2}$ in the water. When the replacement was performed with BRW, the Ca^{+2}/Mg^{+2} ratio was minimal (2.755) at the estimated EC_{ns} of 5.64 dS m^{-1}, and the order of the means as a function of the ionic predominance did not change compared to that for replacement with PSW (Table 2).

For the Ca^{+2}/K^+ ratio, replacement with PSW resulted in linear increments of 0.0791 and 0.0227 under the presence of Ca^{+2} and Na^+, respectively (Table 2), and a decrease of 0.0217 and a minimum level (0.2025 under 2.82 dS m^{-1}) with predominance of K^+ and Mg^{+2} in the water, respectively. When replacement was performed with BRW, the Ca^{+2}/K^+ ratio was at a maximum (0.2289), relatively, under the EC_{ns} estimated at 5.4 dS m^{-1}. However, there was a higher Ca^{+2}/K^+ ratio when there was a prevalence of $Ca^{+2} > Mg^{+2} = Na^+ > K^+$ in the water.

After the analysis of the influence of cations on the Ca^{+2}/K^+ ratio at each EC_{ns}, in general, the highest values were obtained under predominance of bivalent cations, especially Ca^{+2}, and these differences intensified with increases in concentration.

Considering that the estimate of use efficiency is also based on TDM, it is worth noting that the interactive effect of the increase in EC_{ns} and CN caused ($p \leq 0.01$) linear reductions in TDM when replacement was performed with PSW. A comparison of CN at each EC_{ns} showed that, under higher concentrations, significant differences ($p \leq 0.05$) in TDM were caused by CN. When the replacement was with BRW, the relative reduction in TDM occurred at a rate of 0.8089 g per dS m^{-1}, and lower damage ($p \leq 0.05$) was observed under the predominance of K^+ (Table 3).

The efficiency of use of all nutrients and accumulation of Na^+ was influenced ($p \leq 0.01$) by the increase in EC_{ns} and the predominant cationic nature for nutrient solution replacement with both PSW and BRW. The interaction between EC_{ns}

Table 2. Ca^{+2}/Mg^{+2} and Ca^{+2}/K^{+} ratios in the tissues of parsley plants, cultivar Graúda Portuguesa, exposed to nutrient solutions prepared with brackish water having a predominance of Na^{+}, Ca^{+2}, Mg^{+2}, and K^{+} and whose evapotranspired depth was replaced with public-supply water or the respective brackish water in the nutrient solution

	Electrical conductivity of nutrient solutions (dS m^{-1})							
	1.7	2.7	3.7	4.7	5.7	6.7	Equation	R^2
Replacement with public-supply water - Ca^{+2}/Mg^{+2} (EC$_{ns}$: $p \le 0.01$; CN: $p \le 0.05$; EC$_{ns}$ x CN: $p > 0.05$; CV = 27.35%)								
CaCl$_2$		KCl		MgCl$_2$		NaCl		
3.3533 a		2.6262 b		2.0467 c		2.2072 c	$y = 0.4046^{**}x + 0.8593$	0.97
Replacement with brackish water - Ca^{+2}/Mg^{+2} (EC$_{ns}$: $p \le 0.01$; CN: $p \le 0.05$; EC$_{ns}$ x CN: $p > 0.05$; CV = 42.10%)								
CaCl$_2$		KCl		MgCl$_2$		NaCl		
3.2004 a		2.1947 b		1.8433 b		2.0272 b	$y = -0.0878^{*}x^2 + 0.9908^{**}x - 0.0394$	0.92
Replacement with public-supply water - Ca^{+2}/K^{+} (EC$_{ns}$: $p \le 0.01$; CN: $p \le 0.01$; EC$_{ns}$ x CN: $p \le 0.01$; CV = 20.66%)								
CaCl$_2$	0.2122 a	0.3172 a	0.3892 a	0.4585 a	0.5460 a	0.6147 a	$y = 0.0791^{**}x + 0.0908$	0.99
KCl	0.2015 a	0.1522 b	0.1332 b	0.1092 c	0.1060 c	0.0825 d	$y = -0.0217^{**}x + 0.2217$	0.92
MgCl$_2$	0.2097 a	0.2147 b	0.2247 b	0.2342 b	0.3017 b	0.4055 b	$y = 0.0129^{**}x^2 - 0.0729^{ns}x + 0.3055$	0.97
NaCl	0.1922 a	0.1935 b	0.1937 b	0.2222 b	0.2470 b	0.3135 c	$y = 0.0227^{**}x + 0.1316$	0.79
Replacement with brackish water - Ca^{+2}/K^{+} (EC$_{ns}$: $p \le 0.01$; CN: $p \le 0.01$; EC$_{ns}$ x CN: $p > 0.05$; CV = 49.63%)								
CaCl$_2$		KCl		MgCl$_2$		NaCl		
0.0346 a		0.0951 c		0.2012 b		0.1685 b	$y = -0.008^{**}x^2 + 0.0864^{**}x - 0.0044$	0.86

EC$_{ns}$ - Electrical conductivity of the nutrient solution; CN - Cationic state; For Ca^{+2}/Mg^{+2} ratio, different letters in the row compare CN, and for the Ca^{+2}/K^{+} ratio, different letters in the column indicate significant differences between CN at $p \le 0.05$ according to the Tukey test. **, *, ns - Significant at $p \le 0.01$, $p \le 0.05$, and not significant, respectively

and CN did not influence ($p > 0.05$) the use efficiency of the macronutrients N, Ca, and S, when the evapotranspired depth was replaced with BRW (Table 3).

Nitrogen use efficiency (NUE) was influenced ($p \le 0.05$) by the interaction between treatments with the replacement by PSW and by the individual factors with replacement by BRW (Table 3). For replacement with PSW, a linear reduction was estimated as 0.0664, 0.0492, 0.0665, and 0.0407 for each dS m^{-1} increment under the predominance of Ca^{+2}, K^{+}, Mg^{+2}, and Na^{+} in the water, respectively.

In this case, the response of the plants to the increase in salt concentration, in the form of osmotic adjustment, was associated with a limited absorption of NO$_3^-$ and its accumulation in vacuoles (Ding et al., 2010). Additionally, the competition between Cl$^-$ and NO$_3^-$ for the same carrier is a factor that directly affected NUE because N absorption and use efficiency depends on the level of availability of this nutrient in the cultivation medium (Beche et al., 2014).

However, for replacement with PSW, by analyzing the differences caused by CN at each EC$_{ns}$, it was evident that NUE was only influenced from 4.7 dS m^{-1}, with significant damage ($p \le 0.01$) recorded under the predominance of bivalent cations. For replacement with BRW, the relative linear decrease was estimated at 0.0257 per dS m^{-1} increment, with the highest use efficiencies with the predominance of MgCl$_2$ and NaCl (Table 3).

There was also an influence ($p \le 0.01$) of the interaction between the factors on phosphorus use efficiency (PUE) in the two replacement strategies. Additionally, linear reductions were estimated for each dS m^{-1} increase under the prevalence of Ca^{+2} (at rates of 0.4083 and 0.1722), Mg^{+2} (at rates of 0.3252 and 0.1839), and Na^{+} (at rates of 0.3555 and 0.2869 mg g^{-1}) for replacement with PSW and BRW, respectively (Table 3). For replacement with PSW and the prevalence of K^{+} in the water, there was no adequate adjustment of PUE with an increase in EC$_{ns}$; however, for replacement with BRW, a minimum PUE (1,7719) occurred under the EC$_{ns}$ at 4.7 dS m^{-1}.

According to Prado (2008), the presence of K and P causes direct effects on the production of crops, especially those subjected to unfavorable conditions, promoting adaptation mechanisms with greater translocation of carbohydrates to the roots, minimizing root damage. Consequently, a better PUE is observed in the presence of K^{+}. Zambrosi et al. (2012) stated that under conditions of P deficiency caused by the presence of salts in the nutrient solution, changes in the activity of enzymes occur, which contribute to more efficient use of P through recycling, reduction of consumption, and use of other fractions of this nutrient.

Potassium use efficiency (KUE) was also influenced ($p \le 0.01$) by the interaction between treatments in both replacement strategies. For replacement with PSW, the estimated reduction for each dS m^{-1} increment was 0.0612, 0.0713, and 0.0606 under a predominance of Ca^{+2}, Mg^{+2}, and K^{+} in the water, respectively, at a minimum (0.346) under EC$_{ns}$ of 5.5 dS m^{-1} when there was predominance of Na^{+}. For replacement with BRW, the estimated reductions were 0.0407 and 0.0260 per dS m^{-1} increment when there was a predominance of Mg^{+2} and K^{+} in the water, respectively. In the analysis of the KUE, there were no significant effects ($p > 0.05$) when Ca^{+2} and Na^{+} were prevalent in the water (Table 3).

Despite the antagonism between the two cations (K^{+} and Na^{+}), the KUE obtained a higher yield in the presence of Na^{+}, demonstrating the efficiency of parsley in absorbing K^{+} even under adverse conditions. Consequently, it is a crop rich in K^{+} (Al-Yousofy et al., 2017), hence absorbing more K^{+} (Araújo et al., 2014).

The interaction between factors affected ($p \le 0.01$) the efficiency of use of Ca^{+2} (replacement with PSW), Mg^{+2} (replacement with PSW and BRW), S (replacement with PSW), and the accumulation efficiency of Na^{+} (replacement with PSW and BRW), whereas the individual factors influenced ($p \le 0.01$) the efficiency of use of Ca^{+2} and S when the replacement was performed with BRW (Table 4).

Table 3. Total dry mass (TDM) and NPK use efficiency in parsley plants, cultivar Graúda Portuguesa, exposed to nutrient solutions prepared with brackish water with a preponderance of Na^+, Ca^{+2}, Mg^{+2}, and K^+ and whose evapotranspired depth was replaced with public-supply water or the respective brackish water used to prepare the nutrient solution

	Electrical conductivity of nutrient solutions (dS m^{-1})							
	1.7	2.7	3.7	4.7	5.7	6.7	Equation	R^2
Replacement with public-supply water – Total dry mass, TDM (g) (EC_{ns}: $p \leq 0.05$; NC: $p \leq 0.05$; EC_{ns} x CN: $p \leq 0.05$; CV = 5.66%)								
$CaCl_2$	10.22 a	8.71 a	7.63 a	6.90 ab	4.42 b	3.64 b	$y = -1.3286^{**}x + 12.50$	0.9773
KCl	10.69 a	8.94 a	7.81 a	7.07 a	6.50 a	5.08 a	$y = -1.0317^{**}x + 12.015$	0.9707
$MgCl_2$	10.43 a	8.87 a	7.83 a	5.50 b	4.56 b	3.96 b	$y = -1.3603^{**}x + 12.572$	0.9731
NaCl	8.36 a	7.53 a	6.83 a	6.45 a	5.85 a	4.47 a	$y = -1.1646^{**}x + 12.865$	0.9256
Replacement with brackish water – Total dry mass, TDM (g) (EC_{ns}: $p \leq 0.05$; CN: $p > 0.05$; EC_{ns} x CN: $p \leq 0.05$; CV = 7.82%)								
$CaCl_2$		KCl		$MgCl_2$		NaCl		
7.27 ab		7.10 b		7.31 ab		7.54 a	$y = -0.8089^{**}x + 10.699$	0.9969
Replacement with public-supply water - Efficiency of use of nitrogen, NUE (g mg^{-1}) (EC_{ns}: $p \leq 0.01$; CN: $p \leq 0.01$; EC_{ns} x CN: $p \leq 0.01$; CV = 14%)								
$CaCl_2$	0.4740 a	0.3630 a	0.3262 a	0.3167 a	0.1557 b	0.1357 b	$y = - 0.0664^{**}x + 0.5740$	0.92
KCl	0.5442 a	0.4207 a	0.3595 a	0.3417 a	0.3430 a	0.2497 a	$y = - 0.0492^{**}x + 0.5833$	0.86
$MgCl_2$	0.4995 a	0.3952 a	0.3457 a	0.2450 b	0.1812 b	0.1827 b	$y = -0.0665^{**}x + 0.5874$	0.94
NaCl	0.5111 a	0.4162 a	0.3525 a	0.3782 a	0.3737 a	0.2462 a	$y = -0.0407^{**}x + 0.5507$	0.78
Replacement with brackish water - Efficiency of use of nitrogen, NUE (g mg^{-1}) (EC_{ns}: $p \leq 0.01$; CN: $p \leq 0.05$; EC_{ns} x CN: $p > 0.05$; CV = 9.14%)								
$CaCl_2$		KCl		$MgCl_2$		NaCl		
0.2904 b		0.2920 b		0.3062 a		0.3135 a	$y = -0.0257^{**}x + 0.4086$	0.98
Replacement with public-supply water - Efficiency of use of phosphorus, PUE (g mg^{-1}) (EC_{ns}: $p < 0.01$; CN: $p < 0.01$; EC_{ns} x CN: $p < 0.01$; CV = 14.56%)								
$CaCl_2$	2.9672 a	2.3975 a	2.1070 b	2.1052 b	1.0537 c	0.9157 b	$y = -0.4083^{**}x + 3.6392$	0.92
KCl	3.2950 a	2.7012 a	2.7550 a	2.8182 a	3.1015 a	2.4872 a	$\bar{Y} = 2.0728$	
$MgCl_2$	2.9132 a	2.3830 a	2.0730 b	1.6675 b	1.3115 c	1.3610 b	$y = -0.3252^{**}x + 3.3173$	0.94
NaCl	3.2808 a	2.5188 a	2.1005 b	2.0025 b	1.8970 b	1.1850 b	$y = -0.3555^{**}x + 3.6571$	0.9
Replacement with brackish water - Efficiency of use of phosphorus, PUE (g mg^{-1}) (EC_{ns}: $p \leq 0.01$; CN: $p \leq 0.01$; EC_{ns} x CN: $p \leq 0.01$; CV = 10.94%)								
$CaCl_2$	3.0155 a	2.7687 a	2.5777 a	2.4125 a	2.1782 a	2.1977 a	$y = -0.1722^{**}x + 3.2481$	0.95
KCl	2.6795 a	2.0677 b	1.7897 b	1.8825 b	1.8992 a	2.1185 a	$y = 0.0952^{**}x^2 - 0.8920^{**}x + 3.8614$	0.94
$MgCl_2$	2.9675 a	2.4090 b	2.1267 b	1.9975 b	1.8922 a	2.0160 a	$y = -0.1839^{**}x + 3.0073$	0.73
NaCl	2.9497 a	2.9202 a	2.4360 a	2.2307 a	1.8190 a	1.6432 b	$y = -0.2869^{**}x + 3.5381$	0.96
Replacement with public-supply water - Efficiency of use of potassium, KUE (g mg^{-1}) (EC_{ns}: $p \leq 0.01$; CN: $p \leq 0.01$; EC_{ns} x CN: $p \leq 0.01$; CV = 14.70%)								
$CaCl_2$	0.4898 a	0.3890 a	0.3598 a	0.3533 a	0.1903 b	0.1820 b	$y = -0.0612^{**}x + 0.5843$	0.91
KCl	0.5233 a	0.3208 b	0.2373 b	0.1883 b	0.1778 b	0.1200 c	$y = -0.0713^{**}x + 0.5605$	0.84
$MgCl_2$	0.4988 a	0.3403 b	0.2735 b	0.1928 b	0.1668 b	0.1948 b	$y = -0.0606^{**}x + 0.5323$	0.81
NaCl	0.5178 a	0.4000 a	0.3278 a	0.3890 a	0.4035 a	0.3283 a	$y = 0.0099^{*}x^2 – 0.1089^{**}x + 0.646$	0.6
Replacement with brackish water - Efficiency of use of potassium, KUE (g mg^{-1}) (EC_{ns}: $p \leq 0.01$; CN: $p \leq 0.01$; EC_{ns} x CN: $p \leq 0.01$; CV = 11.42%)								
$CaCl_2$	0.3527 a	0.3355 a	0.3495 a	0.3170 a	0.2835 a	0.3157 a	$\bar{Y} = 0.3256$	
KCl	0.3377 a	0.2347 c	0.1840 c	0.1592 c	0.1257 c	0.1230 c	$y = -0.04073^{**}x + 0.3651$	0.87
$MgCl_2$	0.3492 a	0.2805 b	0.2390 b	0.2142 b	0.2130 b	0.2127 b	$y = -0.0260^{**}x + 0.3606$	0.79
NaCl	0.3532 a	0.3347 a	0.3325 a	0.3202 a	0.3190 a	0.3135 a	$\bar{Y} = 0.3286$	

For TDM and N use efficiency, under replacement with brackish water, different letters in the row indicate significant differences between the cationic natures; different letters in the column indicate significant differences between the cationic natures at $p \leq 0.05$ according to the Tukey test; EC_{ns} - Electrical conductivity of the nutrient solution; CN - Cationic nature; **, *, ns - Significant at $p \leq 0.01$, $p \leq 0.05$, and not significant according to the F test, respectively

Calcium use efficiency (CaUE) was reduced at rates of 0.3692, 0.2024, 0.3639, and 0.2700 per dS m^{-1} increment when there was prevalence of Ca^{+2}, K^+, Mg^{+2}, and Na^+, respectively, under replacement with PSW. However, it is worth noting that the prevalence of Na^+ and K^+ in the water favored ($p \leq 0.01$) CaUE, especially when the different cationic natures are compared at each EC_{ns} tested (Table 4).

When replacement was performed with BRW, the relative reduction was equal to 0.3214 for each dS m^{-1} increment. The highest values of CaUE occurred when there was a predominance of $K^+ = Na^+ > Mg^{+2} = Ca^{+2}$ in the water. The antagonism between Ca^{+2} and Mg^{+2} may explain the lower CaUE in water with high concentrations of $MgCl_2$; however, lower CaUE was possibly associated with the deactivation of its action because of the ratio between ions or its precipitation in the form of oxalate or calcium phosphate (Tomaz et al., 2003).

Magnesium use efficiency (MgUE) was influenced ($p \leq 0.05$) by the interaction between factors with both replacement strategies (Table 4). Linear reductions per dS m^{-1} increment of 0.4907 and 0.3102, and 0.4354 and 0.3421 were estimated when there was preponderance of Ca^{+2} and Mg^{+2}, respectively, for replacement with PSW and BRW, respectively.

Under the prevalence of K^+ in water, MgUE was minimal (3.9031) under an EC_{ns} estimated at 3.38 dS m^{-1} for replacement with PSW. However, when the replacement was with BRW, there was no significant effect ($p > 0.05$). When there was a prevalence of Na^+ in the water, the was no significant effect ($p > 0.05$) in either replacement strategy for MgUE (Table 4).

Table 4. Use efficiency of Ca^{+2}, Mg^{+2}, S, and Na^+ in parsley plants, cultivar Graúda Portuguesa, exposed to nutrient solutions prepared with brackish water with a predominance of Na^+, Ca^{+2}, Mg^{+2}, and K^+ and whose evapotranspired depth was replaced with public-supply water or the respective brackish water used to prepare the nutrient solution

	Electrical conductivity of nutrient solutions (dS m^{-1})							
	1.7	2.7	3.7	4.7	5.7	6.7	Equation	R^2
Replacement with public-supply water - Efficiency of use of calcium, CaUE (EC_{ns}: $p \le 0.01$; Cn: $p \le 0.01$; EC_{ns} x Cn: $p \le 0.01$; CV = 17.82%)								
$CaCl_2$	2.3515 a	1.2305 b	0.9262 b	0.7737 b	0.3455 b	0.3285 c	$y = -0.3692^{**}x + 2.5434$	0.84
KCl	2.5997 a	2.1280 a	1.8107 a	1.7190 a	1.7072 a	1.4535 a	$y = -0.2024^{**}x + 2.7533$	0.87
$MgCl_2$	2.4015 a	1.5785 b	1.2247 b	0.8342 b	0.6300 b	0.5012 c	$y = -0.3639^{**}x + 2.7235$	0.91
NaCl	2.6922 a	2.0742 a	1.6930 a	1.7610 a	1.6372 a	1.0507 b	$y = -0.2700^{**}x + 2.9521$	0.86
Replacement with brackish water - - Efficiency of use of calcium. CaUE (EC_{ns}: $p \le 0.01$; Cn: $p \le 0.05$; EC_{ns} x CN: $p > 0.05$; CV = 32.80%)								
$CaCl_2$		KCl		$MgCl_2$		NaCl		
1.2962 b		1.9913 a		1.4656 b		1.7619 a	$y = -0.3214^{**}x + 2.9788$	0.76
Replacement with public-supply water - Efficiency of use of magnesium, MgUE (EC_{ns}: $p \le 0.01$; Cn: $p \le 0.01$; EC_{ns} x Cn: $p \le 0.01$; CV = 27.47%)								
$CaCl_2$	3.9532 a	3.0225 a	2.7800 b	2.9450 b	1.4830 c	1.4092 c	$y = -0.4907^{**}x + 4.6597$	0.87
KCl	4.7115 a	3.8525 a	3.6725 a	4.3572 a	5.5980 a	6.1655 a	$y= 0.2288^{**}x^2 - 1.5454^{ns}x + 6.5127$	0.92
$MgCl_2$	3.7260 a	2.5242 a	1.9647 b	1.8995 b	1.3405 c	1.4015 c	$y = -0.4354^{**}x + 3.9714$	0.84
NaCl	4.3830 a	3.9410 a	3.5995 a	3.8505 a	4.1397 b	2.9867 b	$\breve{Y} = 0.3817$	
Replacement with brackish water - Efficiency of use of magnesium, MgUE (EC_{ns}: $p \le 0.01$; Cn: $p \le 0.01$; EC_{ns} x Cn: $p \le 0.01$; CV = 20.51%)								
$CaCl_2$	4.0035 a	3.4285 a	3.3762 a	3.0652 b	2.5355 a	2.4300 a	$y = -0.3102^{**}x + 4.4427$	0.95
KCl	3.9177 a	3.7762 a	3.8165 a	4.3727 a	4.1972 b	4.6320 b	$\breve{Y} = 3.9520$	
$MgCl_2$	3.7662 a	2.6105 b	2.2232 b	1.9312 c	1.8957 a	1.8585 a	$y = - 0.3421^{**}x + 3.8179$	0.75
NaCl	3.6727 a	3.6777 a	3.7447 a	3.9787 a	2.0915 a	4.3177 b	$\breve{Y} = 3.5805$	
Replacement with public-supply water - - Efficiency of use of sulfur, SUE (EC_{ns}: $p \le 0.01$; Cn: $p \le 0.01$; EC_{ns} x Cn: $p \le 0.05$; CV = 14.72%)								
$CaCl_2$	10.805 a	7.3252 b	6.4427 b	6.4035 b	3.4620 c	3.2297 b	$y = -1.4145^{**}x + 12.2189$	0.9
KCl	11.795 a	9.0942 a	8.0235 a	7.8105 a	7.7615 b	5.8477 a	$y = -0.9700^{**}x + 12.6428$	0.84
$MgCl_2$	10.539 a	7.7477 b	6.9977 b	4.9000 c	3.9540 c	4.1157 b	$y = -1.3028^{**}x + 11.8475$	0.9
NaCl	11.573 a	9.7722 a	8.3767 a	10.413 a	10.436 a	7.2772 a	$y = -0.49862^{**}x + 11.7358$	0.36
Replacement with brackish water - - Efficiency of use of sulfur, SUE (EC_{ns}: $p \le 0.01$; Cn: $p \le 0.05$; EC_{ns} x CN: $p > 0.05$; CV = 8.73%)								
$CaCl_2$		KCl		$MgCl_2$		NaCl		
7.2995 a		7.6212 a		6.8879 b		6.5562 b	$y = -0.3503^{**}x + 8.5625$	0.86
Replacement with brackish water - - Efficiency of use of sodium, NUEa (EC_{ns}: $p \le 0.01$; Cn: $p \le 0.01$; EC_{ns} x Cn: $p \le 0.01$; CV = 19.21%)								
$CaCl_2$	1.5100 a	1.4305 a	1.3142 a	1.3922 a	0.6792 a	0.7580 a	$y = -0.1696^{**}x + 1.8930$	0.75
KCl	1.4737 a	1.0470 b	0.7965 c	0.6385 b	0.5932 a	0.3977 b	$y = -0.1971^{**}x + 1.6524$	0.91
$MgCl_2$	1.3642 a	1.1435 b	0.9850 b	0.7095 b	0.5455 a	0.5275 a	$y = -0.1787^{**}x + 1.6296$	0.96
NaCl	1.4257 a	0.8722 b	0.5395 d	0.4447 b	0.3972 a	0.2247 b	$y = -0.2150^{**}x + 1.5537$	0.85
Replacement with brackish water - - Efficiency of use of sodium, NUEa (EC_{ns}: $p \le 0.01$; Cn: $p \le 0.01$; EC_{ns} x Cn: $p \le 0.01$; CV = 12.42%)								
$CaCl_2$	1.1185 a	1.1657 a	1.0930 a	0.9947 a	0.8510 a	0.9282 a	$y = -0.0569^{**}x + 1.2645$	0.77
KCl	1.1092 a	0.8852 b	0.8365 b	0.8287 b	0.6835 b	0.6985 b	$y = -0.0762^{**}x + 1.1603$	0.85
$MgCl_2$	1.1067 a	1.1082 a	1.0867 a	1.0110 a	0.9522 a	0.8550 a	$y = -0.0515^{**}x + 1.2363$	0.89
NaCl	1.0877 a	0.7797 b	0.4960 c	0.3642 c	0.2827 c	0.2232 c	$y = -0.1699^{**}x + 1.2524$	0.90

Different letters in the rows for CaUE and SUE, under replacement with brackish water, indicate significant differences between the cationic natures at $p \le 0.05$ according to the Tukey test; Different letters in the column indicate significant differences between cationic natures at $p \le 0.05$ according to the Tukey test; EC_{ns} - Electrical conductivity of the nutrient solution; **, *, ns - Significant at $p \le 0.01$, $p \le 0.05$, and not significant, respectively

MgUE was sensitive to increases in the concentration of salts when they were $CaCl_2$ or $MgCl_2$. The ionic competition between Ca^{+2} and Mg^{+2} and the saturation of the solution with an increased concentration of Mg^{+2} may also have led to precipitation (Gransee & Führs, 2013). In the present study, there were no symptoms of Mg^{+2} deficiency or toxicity, but the observed situations of precipitation suggest that ionic saturation may have caused nutrient imbalances in the solution.

For replacement with PSW, the interaction between factors affected ($p \le 0.01$) sulfur use efficiency (SUE), notably when there was predominance of Ca^{+2}, K^+, Mg^{+2} and Na^+ in the water, with linear reductions of 1.4145, 0.9700, 1.3028 and 0.4986, respectively, for each dS m^{-1} increment. Thus, the predominance of bivalent cations led to greater sensitivity ($p \le 0.01$) in SUE.

A relative reduction of 0.3503 per dS m^{-1} increment was observed in SUE when the replacement was performed with PSW. Notably, under preponderance of K^+ and Ca^{+2} in the water, there was higher SUE suggesting the importance of maintaining adequate levels of NPK in the nutrient solution for better utilization and preferential sulfur absorption, as highlighted by Soares et al. (2017).

Na^+ use efficiency (NaUE) was also sensitive ($p \le 0.01$) to the interaction between factors in both nutrient solution replacement strategies. However, contrary to that observed for the other cations, NaUE was higher when there was predominance of bivalent cations in the water (Table 4). However, in all types of cationic predominance in water, there was linear reduction of NaUE, which could be attributed to ionic competition in the nutrient solution, and the movement of Na^+ into vacuoles in the context of osmotic adjustment.

In general, the presence of macronutrients and sodium in the shoots of parsley was influenced by the ionic relationship established in the nutrient solution, the saturation of certain cations in the solution, and the response of the crop to salinity in the form of osmotic and ionic adjustment.

Conclusions

1. Except for the Ca^{+2}/Mg^{+2} ratio, all other cationic ratios evaluated were affected by the increase in the concentration of salts in the nutrient solution.

2. Monovalent cations (K^+ and Na^+) and bivalent cations (Ca^{+2} and Mg^{+2}) showed similar behavior in relation to the efficiency of nutrient use.

3. The efficiency of macronutrient use and sodium accumulation were affected at a greater intensity by the cationic predominance of the water at the highest salt concentration.

4. Replacement with public-supply water mitigated the effect of salts on the ratios between cations, as well as on the efficiency of the use of macronutrients and sodium.

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