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Growth, biomass production and ions accumulation in *Atriplex nummularia* Lindl grown under abiotic stress

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A B S T R A C T

Atriplex nummularia is a halophyte of great importance in the recovery of saline soils and is considered as a model plant to study biosaline scenarios. This study aimed to evaluate biometric parameters, biomass production and the accumulation of ions in *A. nummularia* grown under abiotic stresses. Cultivation was carried out in a Fluvic Neosol for 100 days, adopting two water regimes: 37 and 70% of field capacity. Plants were irrigated with saline solutions containing two types of salts (NaCl and a mixture of NaCl, KCl, $MgCl_2$ and $CaCl_2$) at six levels of electrical conductivity: 0, 5, 10, 20, 30 and 40 dS m^{-1}, arranged in a 6 x 2 x 2 factorial with 4 replicates, forming 96 plots. At the end of the experiment, plants were divided into leaves, stem and roots, for the determination of fresh matter (FM), dry matter (DM) and estimated leaf area (LA), besides the contents of Ca^{2+}, Mg^{2+}, Na^+, K^+ and Cl^-. The type of salt did not influence plant growth or biomass production; however, it influenced the levels of Ca^{2+}, Mg^{2+}, Na^+ and Cl^- in the leaves and Mg^{2+}, K^+ and Cl^- in the roots. Increase in salinity reduced the contents of Ca^{2+}, Mg^{2+}, Na^+, K^+ and Cl^- for all treatments.

Palavras-chave:
extração de sais
estado nutricional
halófitas
semiárido Brasileiro

Crescimento, produção de biomassa e acumulação de íons em *Atriplex* cultivada sob estresses abióticos

R E S U M O

A *Atriplex nummularia* é uma halófita de grande importância na recuperação de solos salinos razão por que é bastante utilizada como planta modelo em condições biossalinas. O objetivo deste estudo foi avaliar parâmetros biométricos, produção de biomassa e a acumulação de íons em *A. nummularia* cultivada sob estresses hídrico e salino. Realizou-se o cultivo em Neossolo Flúvico durante 100 dias sob duas condições de umidade do solo: 37 e 70% da capacidade de campo. As plantas foram irrigadas com soluções salinas obtidas a partir de dois tipos de sais (NaCl e uma mistura de NaCl, KCl, $MgCl_2$ e $CaCl_2$) preparadas em seis condutividades elétricas: 0; 5; 10; 20; 30 e 40 dS m^{-1} e dispostas em arranjo fatorial 6 x 2 x 2 com 4 repetições, totalizando 96 parcelas. Por ocasião da colheita as plantas foram fracionadas em folhas, caule e raiz e determinadas a massa fresca (MF), a massa seca (MS) e a área foliar (AF); foram determinados os teores de Ca^{2+}, Mg^{2+}, Na^+, K^+ e Cl^-. O tipo de sal não influenciou o crescimento nem a produção de biomassa; contudo, influenciou nos teores de Ca^{2+}, Mg^{2+}, Na^+ e Cl^- nas folhas e nos teores de Mg^{2+}, K^+ e Cl^- da raiz. O aumento da condutividade elétrica reduziu o conteúdo de Ca^{2+}, Mg^{2+}, Na^+, K^+ e Cl^- em todos os tratamentos.

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Introduction

Plants belonging to the Chenopodiaceae family are well adapted to saline and water stress (Glenn et al., 2012; Nedjimi, 2014; Souza et al., 2014) and can serve as an alternative for the production of palatable biomass in arid regions, where the environmental conditions are unfavorable for most crops (Silveira et al., 2009). Thus, plants in the *Atriplex* genus have become the target of many studies involving tolerance to salinity and drought (Nedjimi, 2014; Walker et al., 2014).

Atriplex nummularia, for instance, can be cultivated in arid regions with mean annual rainfall from 200 to 400 mm. In addition, this halophyte has high capacity to explore groundwater and can reach up to 10 m below the surface (Norman et al., 2010).

In the field, the production of palatable dry matter of *A. nummularia* can range from 0.5 t ha^{-1} $year^{-1}$ in salinized areas to 12 t ha^{-1} $year^{-1}$ when irrigated, and the crop can reach productions of about 15-20 t ha^{-1} $year^{-1}$ (Ben Salem et al., 2010). Soil texture, water availability and salinity are among the factors that can influence crop production (Barrett-Lennard, 2003; Ben Salem et al., 2010).

Atriplex nummularia is considered as a salt accumulator (Souza et al., 2011). The main ions accumulated by plants in the *Atriplex* genus are chloride and sodium (Flowers & Colmer, 2008) and some species accumulate these ions in specialized compartments, such as trichomes and microvesicles. Its high value as a palatable source of minerals, antioxidants and proteins, besides the high contents of S, Mg, Ca and P in the leaves, justifies its indication for the diet of ruminants (Ben Salem et al., 2010).

Studies involving controlled salinity conditions, such as those conducted by Khedr et al. (2011), Bouchenak et al. (2012), Glenn et al. (2012) and Nedjimi (2014), have used NaCl in the elaboration of the saline treatments, promoting conditions different from those found by plants in the field. It is essential to conduct researches involving saline stress with solutions elaborated from other types of salts and ionic species that simulate the actual conditions found by plants in the irrigation water or in the soil solution (Matinzadeh et al., 2013; Belkheiri & Mulas, 2013; Walker et al., 2014).

This study aimed to evaluate development, biomass production and accumulation of ions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+} and Cl^{-}) in *A. nummularia* plants cultivated under conditions of water stress (soil water content at 37 and 70% of field capacity) and saline stress, using solutions containing sodium chloride and a mixture of salts, including calcium, magnesium, sodium and potassium.

Material and Methods

The soil used in the experiment was collected in the rural area of the municipality of Pesqueira-PE, Brazil, specifically in the 'Nossa Senhora do Rosário' settlement, at the geographic coordinates of 8° 34' 11" S and 37° 48' 54" W, in the layer of 0-30 cm and classified as non-saline, non-sodic Fluvic Neosol (EMBRAPA, 2013). The soil was air-dried, pounded to break up clods, homogenized and sieved through a 4-mm grid, preserving its microaggregates.

For soil chemical characterization (Table 1), the following parameters were determined in air-dried fine earth (ADFE): pH_{H20} in the proportion of 1:2.5 (soil:water) and the exchangeable cations Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}, extracted using 1 M ammonium acetate (Thomas, 1982). The saturation extract was obtained through the preparation of the saturation paste (Richards, 1954), measuring its electrical conductivity (EC) and pH. Cation exchange capacity (T) was determined using the index cation method (Richards, 1954). Based on the results obtained in the exchange complex, the values of sum of bases (SB) and the Exchangeable Sodium Percentage (ESP) were calculated.

For physical characterization (Table 2), the ADFE was analyzed for granulometry and clay dispersed in water through the hydrometer method, calculating the degree of clay dispersion and flocculation. Soil bulk density was determined using the graduated cylinder method and soil particle density, the volumetric flask method (EMBRAPA, 1997). Field capacity and permanent wilting point were determined based on the soil-water retention curve (SWRC). Total porosity was estimated using the values of soil bulk and particle density.

The experiment was carried out in a greenhouse for a period of 100 days, using *A. nummularia* plants cultivated in pots with capacity for 10 kg of soil, with one plant per pot.

After transplantation, plants were subjected to two gravimetric water contents in the soil: 0.17 g g^{-1} (-0.06 MPa) equivalent to 70% of field capacity, and 0.09 g g^{-1} (-0.52 MPa) equivalent to 37% of field capacity. These water contents were selected based on the soil-water retention curve (SWRC).

In order to guarantee genetic uniformity, clones of a single plant, produced from stem cuttings, were used in the

Table 1. Initial chemical characteristics of the Fluvic Neosol used to fill the pots in the greenhouse experiment

Variables	Values
Saturation extract	
pH_{se}	8.17
EC (dS m^{-1})	1.17
Exchange complex	
$pH_{(1:2.5)}$	7.70
Ca^{2+}($cmol_c$ kg^{-1})	5.53
Mg^{2+}($cmol_c$ kg^{-1})	2.22
Na^{+}($cmol_c$ kg^{-1})	0.26
K^{+}($cmol_c$ kg^{-1})	0.50
SB ($cmol_c$ kg^{-1})	8.51
ESP (%)	3.00

pH_{se}: pH - Determined in the saturation extract; ESP - Exchangeable sodium percentage; SB - Sum of bases; EC - Electrical conductivity

Table 2. Initial physical characteristics of the Fluvic Neosols used to fill the pots in the greenhouse experiment

Sand			Silt	Clay	CDW	Ds	Dp	DF	DCD	TP	FC	PWP
Fine	Coarse	Total								%		
g kg^{-1}						g cm^{-3}					g g^{-1}	
435	17	452	386	162	117	1.36	2.66	0.28	0.72	49.57	0.24	0.05

CDW - Clay dispersed in water; Dp - Soil particle density; Ds - Soil bulk density; DCD - CDW/Clay; DF: (1 – DCD); DCD – Degree of clay dispersion; DF - degree of flocculation; TP - Total porosity experiment. The stem cuttings were transplanted to pots 90 days after propagation with standardized height of 19 cm; during the cultivation, the seedlings were not subjected to any fertilization and were irrigated with only tap water.

Initially, plants were irrigated for 20 days with only distilled water and the electrical conductivity was gradually increased in order to avoid osmotic shock on the transplanted plants. During the experiment, the water content in the pots was maintained through daily weighings performed in the late afternoon, for the equilibrium of the desired water content, compensating the losses through evaporation.

The solutions used in the experiment were elaborated with two types of salts, one composed only of NaCl and the other composed of a mixture of salts with proportions similar to that of an artesian well, located close to the soil-sampling site. These solutions were prepared with six values of electrical conductivity: 0, 5, 10, 20, 30 and 40 dS m^{-1} (Silveira et al., 2009; Belkheiri & Mulas, 2011).

Plant height was periodically measured for growth evaluation at 45, 65 and 85 days after transplantation (DAT). At 100 DAT, plants were cut close to the soil surface, divided into leaves and stems, weighed and the fresh matter was determined. Roots were collected through washing in running water until the complete removal of soil; then, they were dried in paper towel and the fresh matter was determined. For dry matter determination, leaves, stems and roots were placed in a forced-air oven at 65 °C until constant weight.

Leaf area was estimated based on the leaf disc method (Souza et al., 2012b). Leaf discs with known area were collected using a leaf-disc sampler (Area = 1 cm^2), placed in paper packages, dried in an oven (65 °C for 72 h) and weighed separately, per plant. Leaf area was estimated through Eq. 1:

$$LA = \frac{(DML + DMD) \times KAD}{DMD} \quad (1)$$

where:

LA - estimated leaf area (cm^2);

DML - dry mass of leaves (g);

DMD - dry mass of discs (g); and

KAD - known area of the collected leaf disc, in this case 1.0 cm^2.

Leaves, stems and roots were ground in a Wiley-type mill and the nitric-perchloric digestion was performed (Silva et al., 2008). The contents of Na^+ and K^+ were determined through flame emission photometry and the contents of Ca^{2+} and Mg^{2+} through atomic absorption spectrophotometry. Chloride was determined through extraction in water and titration with $AgNO_3$ (Malavolta et al., 1989).

The treatments were arranged in a randomized block design, with four replicates (blocks), in a 2 x 2 x 6 factorial, with two soil water contents (37 and 70% of field capacity), two saline solutions (NaCl and a mixture of NaCl, KCl, $MgCl_2$ and $CaCl_2$) and six levels of electrical conductivity (0, 5, 10, 20, 30 and 40 dS m^{-1}). The data were subjected to the assumptions of normality and analysis of variance. For quantitative variables, equations of regression models were adjusted and, for the variables that did not fit to the models, the mean and the standard deviation were used to present the data.

Results and Discussion

For plant height, measured at 45, 65 and 85 days after transplantation, there was significant difference for the interaction Water content x Electrical conductivity (Figure 1). There was no significant effect on plant growth, according to the analysis of variance, with respect to the type of salt.

Plant height decreased with the increase in electrical conductivity for both water contents; at the highest EC level, plants at 70% FC were 20% shorter than plants in the control, while plants at 37% FC showed higher reduction (22%), due to the water stress.

At 85 DAT, plants under EC of 5 dS m^{-1} showed mean increment of 62 cm at 70% FC, while plants at 37% FC grew 31 cm in the same period (Figure 1C); in this case, the reduction of 50% in plant height can be attributed to the water stress.

The biomass production of leaves, stems and roots showed significant effects, according to the analysis of variance, for the interaction Water content x Electrical conductivity (Table 3).

Leaf fresh and dry matters were the most affected variables in the plants (Table 3). Plants subjected to 70% FC and EC of 40 dS m^{-1}, for instance, suffered reduction of 94% in leaf biomass, compared with the control. For plants under water stress (37% FC), this reduction was equal to 91%, while for both water contents, the highest leaf biomass production was observed in plants under EC of 5 dS m^{-1}.

According to Flowers & Colmer (2008), this reduction in dry biomass production in halophytes occurs when plants are

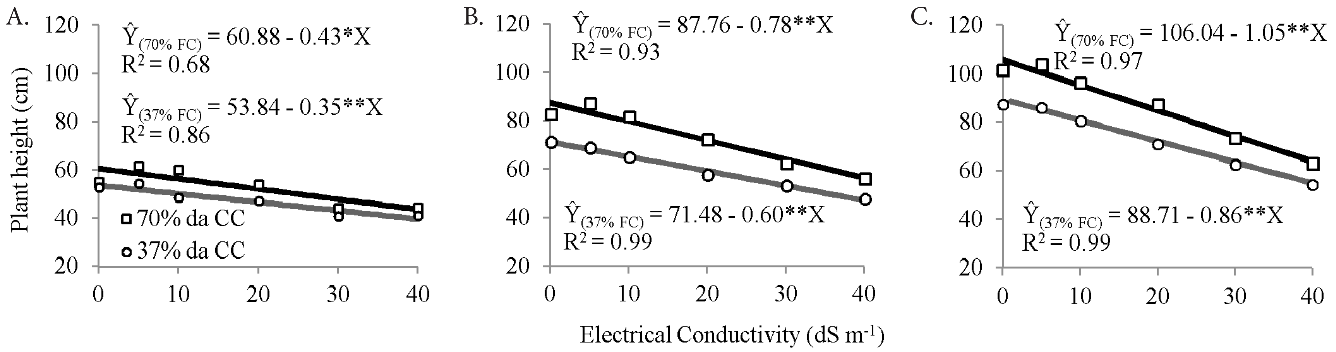


Figure 1. *Atriplex nummularia* plant height at 45 (A), 65 (B) and 85 (C) days after transplantation as a function of the electrical conductivity level of the irrigation water at the water contents of 70 and 37% of field capacity (FC)

Table 3. Mean production (n = 4) of fresh and dry matter (g) of leaves, stems and roots of *Atriplex nummularia* 100 days after transplantation as a function of the level of the electrical conductivity (EC) of the irrigation water, at the water contents of 70 and 37% of field capacity

EC ($dS\ m^{-1}$)	Fresh matter						Dry matter					
	Leaves		Stems		Roots		Leaves		Stems		Roots	
	70	37	70	37	70	37	70	37	70	37	70	37
	%											
0	47.40	35.18	56.68	31.94	17.45	14.39	10.6	7.8	29.2	16.5	5.5	4.1
5	58.07	38.16	56.22	29.69	18.51	18.12	12.3	7.9	30.3	15.0	6.3	4.8
10	50.04	32.01	44.14	19.03	17.15	14.11	11.3	6.8	24.2	10.0	5.5	3.7
20	25.17	9.82	19.43	8.43	12.89	6.38	6.4	2.6	10.7	4.7	3.5	2.1
30	8.55	2.31	10.50	4.54	8.80	3.28	2.5	0.7	5.8	2.5	2.5	1.4
40	3.27	3.15	8.22	5.01	7.99	4.68	1.1	0.9	4.4	2.9	2.3	1.6

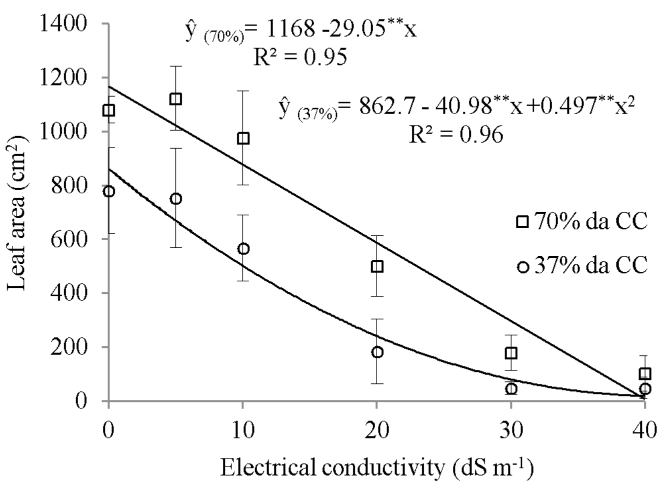
exposed to very high levels of salinity, 250 mmol of NaCl. In a study conducted by Hassine & Lutts (2010), the concentration of 160 mmol of NaCl stimulated the increase in dry biomass production in the shoots of *Atriplex halimus*, while the water stress of -0.64 MPa reduced it to half, compared with the control treatment and the saline stress.

Plants under water stress showed lower biomass production for all the EC levels (Table 3). Water stress was the most limiting factor for leaf and stem production at all the EC levels below 30 $dS\ m^{-1}$; however, for values equal to or higher than 30 $dS\ m^{-1}$, salinity became the greatest limitation (Table 3).

For root fresh and dry biomass, water stress reduced the production for all the EC levels, except 5 $dS\ m^{-1}$. However, the highest reductions occurred due to the saline stress. Belkheiri & Mulas (2013) observed higher reduction in root biomass in plants under saline stress, in comparison to its combination with water stress. Saline stress seems to be the factor with the highest influence on root production (Silveira et al., 2009).

Leaf area showed significant effect only for the interaction Water content x Electrical conductivity. The type of salt did not cause significant difference (Figure 2).

Leaf area decreased with the increment in EC, except for the level of 5 $dS\ m^{-1}$, which showed the highest leaf area compared



Vertical bars indicate the mean standard deviation

Figure 2. *Atriplex nummularia* leaf area as a function of the level of electrical conductivity of the irrigation water, 100 days after transplantation, at the water contents of 70 and 37% of field capacity

with the control. The reduction in the photosynthetically active area due to salinity also leads to the reduction in carbon fixation (Flowers & Colmer, 2008) and, consequently, in biomass production and plant height (Figures 1 and 3; Table 2). Belkheiri & Mulas (2013) reported increase in leaf area of *Atriplex nummularia* irrigated with NaCl solution at the EC levels of 0, 10, 30, 40, 60 and 80 $dS\ m^{-1}$, after 10 days of treatment; however, at 20 days, all the plants under EC higher than 30 $dS\ m^{-1}$ reduced their leaf area compared with the others. Even halophytes, such as *A. nummularia*, can suffer deleterious effects due to the intensity of the stress and the exposure time (Kachout et al., 2009).

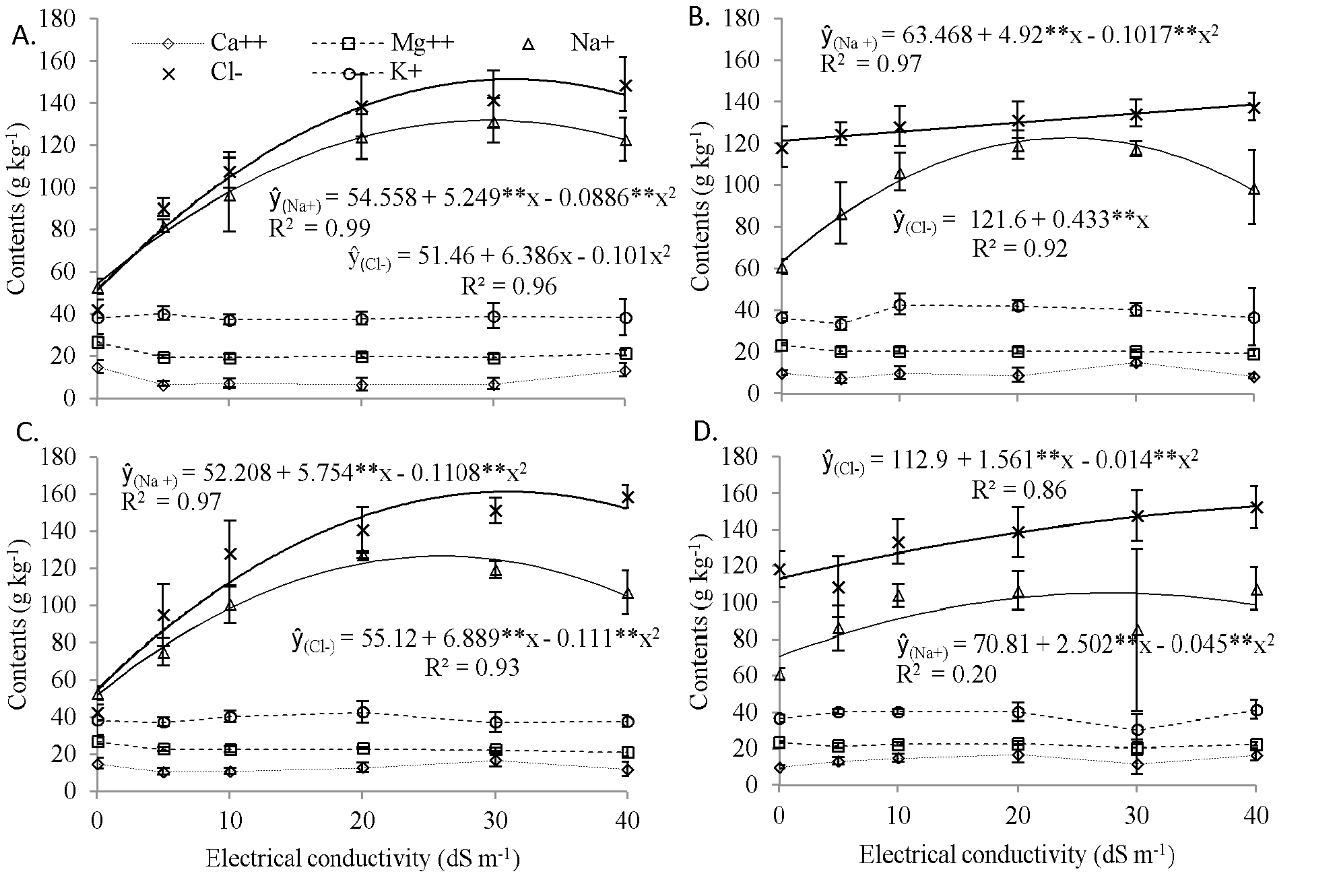
The leaf contents of Ca^{2+}, Mg^{2+}, Na^{+} and Cl^{-} showed significant difference for the interaction Water content x Electrical conductivity; the type of salt also caused significant difference (Figure 3).

The elements with higher accumulation in the leaves of *Atriplex nummularia* were chloride and sodium, respectively. Chloride contents increased with the increment in EC at both water contents and for both type of salt (Figures 3A, B, C and D). Higher chloride contents in response to the increase of EC in *A. nummularia* plants have been reported in other studies, such as Souza et al. (2012a) and Nedjimi (2014).

Increase in Na contents until the EC of 30 $dS\ m^{-1}$ were observed in the leaves, for the treatments with NaCl (Figure 3A and B). Hussin et al. (2013) observed similar behavior within the same EC range (~0, 2.5, 5, 10 and 15 $dS\ m^{-1}$) after 84 days of treatment. Plants subjected to EC higher than 30 $dS\ m^{-1}$ reduced Na^{+} contents with the increase in electrical conductivity.

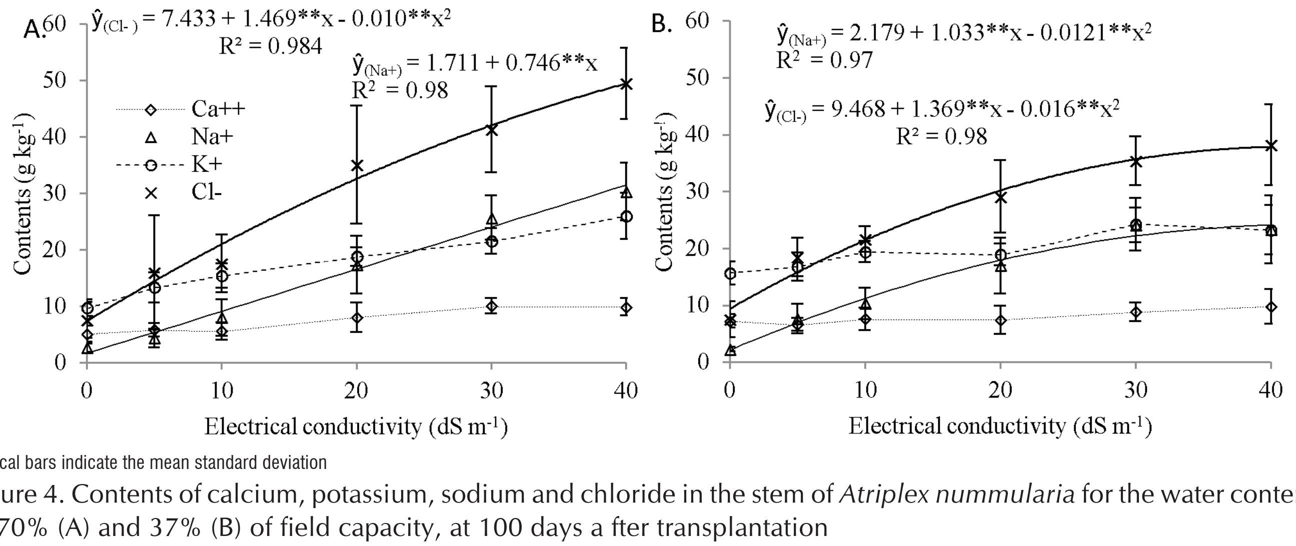
In the evaluation of the phytoextraction potential of *A. nummularia* with respect to Na^{+}, Souza et al. (2012a) observed 124.73 $g\ kg^{-1}$ of Na^{+} in the leaves of plants cultivated for 134 days in saline, sodic soil. Bazihizina et al. (2012) observed 45.9 $g\ kg^{-1}$ of Na^{+} in the leaves of *A. nummularia* under saline stress of 1500 mmol (150 $dS\ m^{-1}$) of NaCl after 21 days. In the present study, the highest Na^{+} content (131 $g\ kg^{-1}$) was observed in plants under 70% FC and EC of 30 $dS\ m^{-1}$. This value is consistent with previous studies and corroborates the accumulation of this element in the leaves of this species (Souza et al., 2012a; Bazihizina et al., 2012).

The contents of Ca^{2+}, Na^{+}, K^{+} and Cl^{-} in the stem of *Atriplex nummularia* were significant for the interaction Water content x Electrical conductivity, but not significant for the type of salt (Figure 4).



Vertical bars indicate the mean standard deviation

Figure 3. Contents of calcium, magnesium, potassum, sodium and chloride in the leaves of *Atriplex nummularia* irrigated with NaCl (A and B) and a mixture of salts (C and D) at 70 and 37% of the field capacity, at 100 days after transplantation



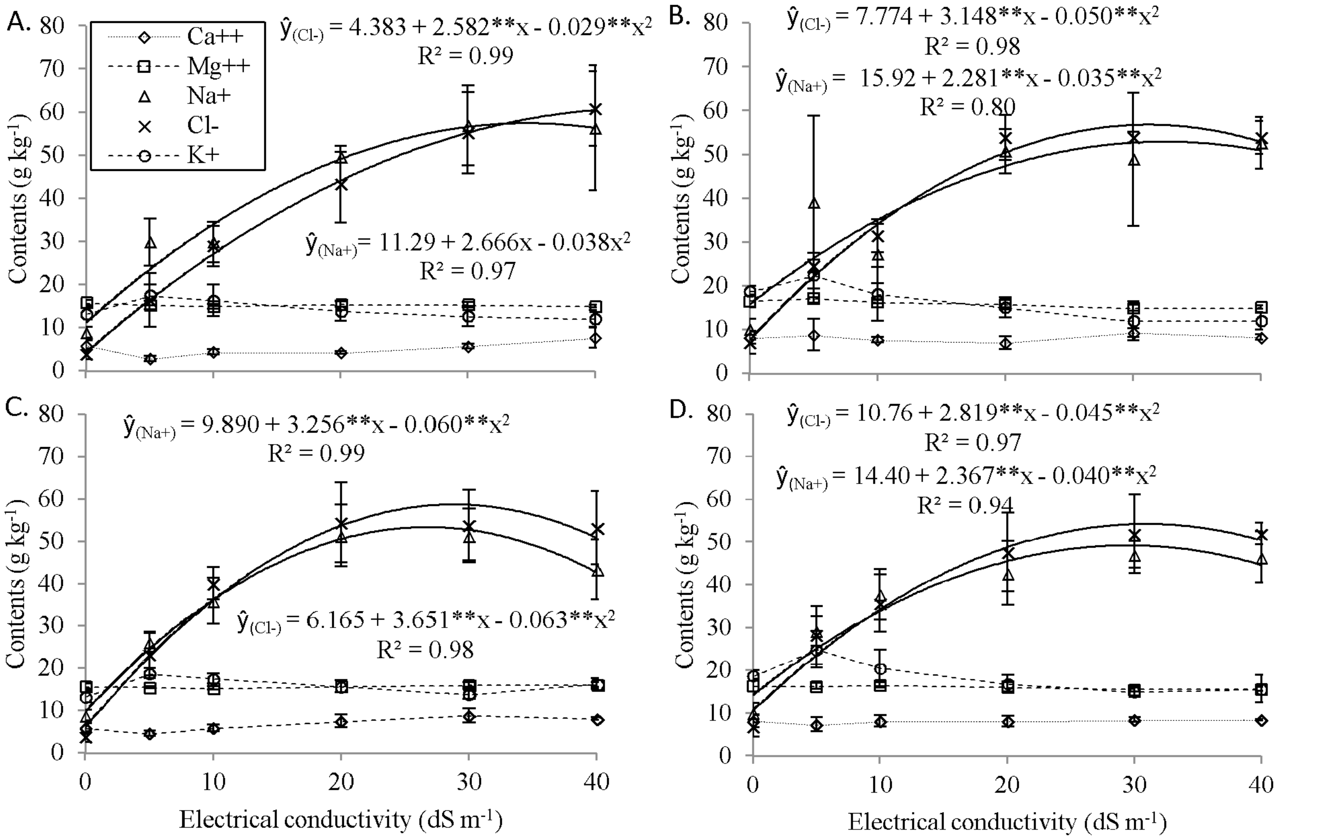
Vertical bars indicate the mean standard deviation

Figure 4. Contents of calcium, potassium, sodium and chloride in the stem of *Atriplex nummularia* for the water contents of 70% (A) and 37% (B) of field capacity, at 100 days a fter transplantation

In the stem, the contents of chloride, sodium and potassium were higher with the increase in EC. Chloride was the element found in highest amounts, followed by potassium and sodium. Plants subjected to 70% FC showed higher sodium contents for the last two levels of EC, in comparison to those under water stress. Water stress reduced the contents of all the elements in plant stems, except for calcium, which was higher for the first EC levels.

For the contents of sodium, leaves and stems showed significant effect for the interaction Water content x Electrical conductivity; there was significant effect of type of salt on leaves and roots (Figure 5).

While in the stems, Na^+ contents in plants under 37% FC decreased for the EC levels of 30 and 40 dS m^{-1} (Figure 5D), the same reduction in Na^+ content was observed in the roots, between the type of salt, decreasing for the mixture. Although it showed a behavior similar to that of the EC from 0 to 20 dS m^{-1}, for the EC levels of 30 and 40 dS m^{-1}, the values were different, with higher contents in plants irrigated with NaCl, which showed a response similar to that reported by Nedjimi (2014), who observed increasing contents as a function of the increment in electrical conductivity.



Vertical bars indicate the mean standard deviation

Figure 5. Contents of calcium, magnesium, potassium, sodium and chloride in roots of *Atriplex nummularia* irrigated with NaCl (A and B) and a mixture of salts (C and D) at 70 and 37% of field capacity at 100 days after transplantation

Table 4. Contents (g plant^{-1}) of Ca^{2+}, Mg^{2+}, Na^{+}, K^{+} and Cl^{-} in *Atriplex nummularia* plants 100 days after transplantation

FC (%)	EC (dS m^{-1})	NaCl Ca^{2+}	NaCl Mg^{2+}	NaCl Na^{+}	NaCl K^{+}	NaCl Cl^{-}	Mixture Ca^{2+}	Mixture Mg^{2+}	Mixture Na^{+}	Mixture K^{+}	Mixture Cl^{-}
70	0	0.34 ± 0.07	0.89 ± 0.20	0.69 ± 0.06	0.74 ± 0.13	0.77 ± 0.11	0.34 ± 0.07	0.89 ± 0.20	0.69 ± 0.06	0.74 ± 0.13	0.77 ± 0.11
	5	0.28 ± 0.03	0.95 ± 0.12	1.27 ± 0.11	1.03 ± 0.04	1.80 ± 0.50	0.34 ± 0.17	0.93 ± 0.35	1.27 ± 0.39	1.08 ± 0.39	1.84 ± 0.38
	10	0.26 ± 0.03	0.78 ± 0.17	1.47 ± 0.32	0.96 ± 0.11	1.82 ± 0.18	0.28 ± 0.16	0.74 ± 0.43	1.49 ± 0.64	1.03 ± 0.58	2.02 ± 0.68
	20	0.14 ± 0.02	0.35 ± 0.11	1.18 ± 0.13	0.64 ± 0.12	1.45 ± 0.18	0.19 ± 0.13	0.36 ± 0.30	1.14 ± 0.60	0.63 ± 0.46	1.33 ± 0.89
	30	0.09 ± 0.03	0.19 ± 0.12	0.67 ± 0.31	0.39 ± 0.19	0.78 ± 0.36	0.11 ± 0.07	0.18 ± 0.12	0.52 ± 0.60	0.32 ± 0.31	0.69 ± 0.79
	40	0.07 ± 0.02	0.13 ± 0.10	0.40 ± 0.20	0.26 ± 0.11	0.43 ± 0.26	0.07 ± 0.03	0.13 ± 0.06	0.34 ± 0.18	0.27 ± 0.11	0.51 ± 0.21
37	0	0.23 ± 0.04	0.56 ± 0.13	0.56 ± 0.21	0.60 ± 0.14	0.69 ± 0.11	0.23 ± 0.04	0.56 ± 0.13	0.56 ± 0.21	0.60 ± 0.14	0.69 ± 0.11
	5	0.21 ± 0.01	0.53 ± 0.08	1.01 ± 0.17	0.69 ± 0.11	1.29 ± 0.18	0.22 ± 0.10	0.46 ± 0.22	0.87 ± 0.37	0.68 ± 0.27	1.20 ± 0.56
	10	0.19 ± 0.01	0.43 ± 0.03	1.03 ± 0.04	0.65 ± 0.04	1.27 ± 0.06	0.18 ± 0.10	0.33 ± 0.25	0.84 ± 0.42	0.55 ± 0.29	1.07 ± 0.56
	20	0.06 ± 0.02	0.15 ± 0.03	0.47 ± 012	0.29 ± 0.08	0.53 ± 0.11	0.09 ± 0.10	0.16 ± 0.23	0.46 ± 0.52	0.30 ± 0.32	0.57 ± 0.65
	30	0.05 ± 0.05	0.08 ± 0.14	0.21 ± 0.10	0.15 ± 0.14	0.27 ± 0.13	0.05 ± 0.02	0.07 ± 0.06	0.20 ± 0.18	0.16 ± 0.11	0.27 ± 0.23
	40	0.04 ± 0.05	0.08 ± 0.19	0.25 ± 0.07	0.19 ± 0.14	0.38 ± 0.38	0.06 ± 0.18	0.09 ± 0.36	0.24 ± 0.64	0.18 ± 0.63	0.25 ± 0.94

FC - Field capacity

The contents of chloride and sodium in the roots showed similar behavior; in plants irrigated with NaCl, the contents were slightly higher compared with plants irrigated with a mixture of salts. In addition, there was a stabilization of the values for the EC levels of 20, 30 and 40 dS m^{-1}, regardless of the type of salt. This behavior was similar for both water regimes. Thus, despite being a halophyte, *Atriplex nummularia* has a limit for the accumulation of the ions chloride and sodium in the roots (Belkheiri& Mulas, 2013).

In the study conducted by Silveira et al. (2009), roots of *Atriplex nummularia* under saline stress showed the highest contents of potassium compared with the other plant parts, decreasing with the increment in electrical conductivity. Bouchenack et al. (2012) observed similar behaviors between leaf and root contents. However, in the present study, leaf contents were higher than root contents.

Based on the values of dry matter and contents of the elements in the three plant parts, the contents of Ca^{2+}, Mg^{2+}, Na^{+}, K^{+} and Cl^{-} were estimated, which reduced with the increment in electrical conductivity (Table 4). This reduction in the contents of these ions occurred as a response to the reduction of biomass production, which is characteristic of plants cultivated under very high electrical conductivity (Belkheiri & Mulas, 2013).

Conclusions

1. The type of salt does not interfere with plant growth; however, water stress reduces plant height at all the levels of

electrical conductivity and is more pronounced for the highest levels of electrical conductivity

2. The electrical conductivity of 5 dS m^{-1} stimulates the increase in biomass production, growth and leaf area, and is the level of best adaptability, even under water stress conditions.

3. The contents of calcium, magnesium, sodium and chloride in the leaves of *Atriplex nummularia* and the contents of magnesium, potassium and chloride in the roots are influenced by the type of salt in the environment.

4. The increase in electrical conductivity reduced the contents of Ca^{2+}, Mg^{2+}, Na^{+}, K^{+} and Cl^{-} in all the treatments.

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