Research, Society and Development, v. 9, n. 8, e963986535, 2020
(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v9i8.6535

Teores foliares de nutrientes em *Cryptostegia madagascariensis* em diferentes solos salinizados

Leaves contents of nutrients in *Cryptostegia madagascariensis* in different salinized soils

Contenido de nutrientes de la hoja en *Cryptostegia madagascariensis* en diferentes suelos salinizados

Recebido: 09/07/2020 | Revisado: 20/07/2020 | Aceito: 22/07/2020 | Publicado: 03/08/2020

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Research, Society and Development, v. 9, n. 8, e963986535, 2020
(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v9i8.6535

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Resumo

Um experimento foi desenvolvido em abrigo telado com o objetivo de avaliar o estado nutricional de plantas de C. madagascariensis submetidas a diferentes níveis de salinidade e de umidade. Os tratamentos foram arranjados em blocos casualizados, com quatro repetições, seguindo o arranjo fatorial de 4x4x2, correspondendo aos cinco níveis de salinidade ou incubações (0,3; 1,0; 2,0 e 4,0 dS m-1), quatro teores de umidade (20% da CC; 40% da CC; 70% da CC e 110% da CC) mantidos até o final do ensaio e com dois tipos de solos (Neossolo Flúvico e Vertissolo). Incialmente, foram utilizados dois solos sendo um Neossolo Flúvico e um Vertissolo. As amostras foliares foram analisadas para determinação dos teores de N, P, K e Na. Os solos foram acondicionados em vasos com capacidade de 21 litros, onde em cada vaso continha 19 Kg de solo e 4 plantas por parcela, em blocos casualizados com 4 repetições. Após a emergência, 10 dias após a semeadura (DAS), realizou-se o desbaste, deixando quatro plantas por vaso. Decorrido 152 dias após a semeadura foram retiradas amostras de tecido vegetal (folhas) para as análises químicas. Ao final do experimento foram avaliadas criteriosamente as seguintes variáveis foliares: Nitrogênio (N); Fósforo (P), Potássio (K) e Sódio (Na). O aumento da umidade em ambos os solos sob crescimento das plantas jovens elevou os teores de sódio e reduziu os teores de potássio no tecido vegetal decorrentes do excesso de sódio nos dois solos em função da salinidade e umidade.

Palavras-chave: Bioinvasora; Composição foliar; Salinidade; Nutrientes; Estresse hídrico.

Abstract

The species *C. madagascariensis* occurs in humid and arid areas, thus, the species has been standing out as an invasive plant. An experiment was developed in greenhouse with the objective of evaluating the leaf contents (nutritional status) of plants of these invasive plants subjected to different levels of salinity and humidity. The treatments were arranged in randomized blocks, with four repetitions, following the factorial arrangement of 4x4x2, corresponding to the five levels of salinity or incubations (0.3; 1.0; 2.0 and 4.0 dS m^{-1}), four moisture contents (20% of CC; 40% of CC; 70% of CC and 110% of CC) maintained until the end of the test and with two types of soils (Floss Neossol and Vertisolo). Initially, two soils were used, a Floss Neossol and a Vertisol. Leaf samples were analyzed to determine the levels of N, P, K and Na. The soils were placed in pots with a capacity of 21 liters, where each pot contained 19 kg of soil and 4 plants per plot in randomized blocks with 4 repetitions. After elapsed 152 days after sowing, samples of plant tissue (leaves) were taken for chemical analysis. At the end of the experiment, the following leaf variables were carefully evaluated: Nitrogen (N); Phosphorus (P), Potassium (K^+) and Sodium (Na^+). The increase in humidity in both soils under growth of young plants increased sodium levels and reduced potassium levels in plant tissue resulting from excess sodium in the two soils as a function of salinity and humidity.

Keywords: Bioinvasive; Leaf composition; Hydrical stress; Nutrients; Salinity.

Resumen

Las especies *Cryptostegia madagascariensis* ocurre en áreas húmedas y áridas, la especie se ha destacado como una planta invasora. Se realizó un experimento en un refugio selectivo (invernadero) con el objetivo de evaluar el contenido de las hojas (estado nutricional) de las plantas de estas plantas invasoras sometidas a diferentes niveles de salinidad y humedad. Los tratamientos se organizaron en bloques aleatorios, con cuatro repeticiones, siguiendo la disposición factorial de 4x4x2, correspondiente a los cinco niveles de salinidad o incubación (0.3; 1.0; 2.0 y 4.0 dS m-1), cuatro contenido de humedad (20% del CC; 40% del CC; 70% del CC y 110% del CC) mantenido hasta el final de la prueba y con dos tipos de suelo (Neossolo Flúvico y Vertisolo). Inicialmente, se utilizaron dos suelos, un Floss Neossol y un Vertisol. Se analizaron muestras de hojas para determinar los niveles de N, P, K y Na. Los suelos se colocaron en macetas con una capacidad de 21 litros, donde cada maceta contenía 19 kg de suelo y 4 plantas de *C. madagascariensis* en bloques al azar con 4 repeticiones. Se analizaron muestras de hojas para determinar los niveles de N, P, K y Na. Al final del experimento, se evaluaron cuidadosamente las siguientes variables foliares: nitrógeno (N); Fósforo (P), Potasio (K) y Sodio (Na). El aumento de la humedad en ambos suelos bajo el crecimiento de plantas jóvenes de *C. madagascariensis* aumentó los niveles de sodio y redujo los niveles de potasio en el tejido vegetal debido al exceso de sodio en ambos suelos debido a la salinidad y la humedad.

Palabras clave: Bioinvasivo; Composición de la hoja; Estrés hídrico; Salinidad; Nutrientes.

1. Introduction

Invasive plants have high growth capacity, dispersion, greater number of seeds, high germination rate, being able to modify the composition, structure or function of the ecosystem (Souza et al., 2011; Sousa et al., 2016). The presence of a resistance mechanism to stress situations can give invasive plants greater potential for establishment, bearing in mind that other ecosystems, such as semiarid regions or wetlands, can be affected by these species. The response to the stress situation varies according to the intrinsic characteristics of the species (Taiz et al., 2017; Medeiros et al., 2019).

The response of plants to water deficit varies according to the species, intensity and genetics of the plant, which can cause several morphophysiological changes, as a decrease in turgor and reduction in the size of the leaves, as well as cell growth, cell wall synthesis. Nitrogen and chlorophyll metabolism can be affected (Souza et al., 2011a). In this type of condition, vegetables trigger physiological mechanisms that allow them to escape or tolerate this abiotic condition (Mendes et al., 2011; Mesquita et al., 2020).

In addition to the morphological changes, physiological and metabolic adjustment provide osmotic balance of plants, assisting the transport of water and nutrients to expanding cells. This process depends on a difference in water potential between the roots and the expanding tissue, requiring the water potential of the expanding tissue to be less than the water potential of the root (Pedrotti et al., 2015; Medeiros et al., 2018).

Salinity is one of the factors that most limit growth and plant mineral nutrition in regions with low water availability, due to the reduction of the osmotic potential in the root environment, effectively reducing the activity of ions in solution and altering the absorption processes, transport, assimilation and distribution of nutrients in the plant (Brito et al., 2015; Nolan et al., 2017; Taiz et al., 2017).

The high concentration of salts is considered a stressor for plants, for presenting osmotic activity, retaining water, in addition to the action of ions on the protoplasm and the impact on plants mineral nutrition (Leão et al., 2011; Taiz et al., 2017).

The soils of the semiarid region, due to the high evaporation rate and low rainfall, they present, in general, high concentrations of solubles salts, according to Mesquita et al. (2020). The problem of soil salinization makes areas and perimeters of this region unfeasible (Yang et al., 2011; (Souza et al., 2011), leading to degradation and increase in abandoned areas, in addition to hindering natural regeneration, reduce biodiversity and provide opportunities for the entry and monodominance of invasive plants in these sites (Vieira et al., 2012).

Some invasive plant species tolerate a higher level of soil salinity, as example, *Parkisonia aculeata* L. (Fabaceae) (Medeiros et al., 2018) and *Calotropis procera* (Aiton) W.T. Aiton (Apocynaceae). Another species that, due to the strong presence in salines environments, It is suggested that it tolerates high levels of salinity is *Cryptostegia madagascariensis,* according to studies of Cruz et al. (2016) and Sousa et al. (2016).

Even in the face of this serious problem with invasion of this species and little is known about the behavior of this species, being even more scarce studies with this taxon in the Brazilian semiarid, which makes it of fundamental importance to know, with scientific support, the autoecology of this invader and know the balance of nutrients, so that it is possible to subsidize public policies aimed at the control and recovery of areas invaded by *Cryptostegia madagascariensis* in referred context. Given the above, The present study aimed to evaluate the effect of salinity and different water regimes on the leaf composition of young plants of *C. madagascariensis* cultivated in two types of soils during the 152 DAE.

2. Material and Methods

The experiment was conducted at the Plant Ecology Laboratory (LEV), Department of Phytotechnics and Environmental Sciences (DFCA), Center of Agrarian Sciences (CCA) – Campus II – Federal University of Paraíba (UFPB), Areia-PB, referring to the period from August 2016 to January 2017. The location of the experiment is located in the following Geographic Coordinates: 6°57’58,2” and South Latitude; 35° 42’ 56,6” of Longitude West of Greenwich, at 518 meters altitude, and is inserted in Brejo Paraibano Microregion.

The maximum and minimum temperatures and the maximums values and of minimums for relative humidity were recorded by the digital thermometer, being collected daily at 9:00 hours. For the average relative humidity of the air it was determined through an arithmetic average between the maximum and minimum humidity.

Table 1 shows the monthly average values of the maximum temperatures, minimum and relative humidity of the maximum, minimum and average air in the LEV/CCA/UFPB, Areia-PB, during the months of conducting this experiment.

Research, Society and Development, v. 9, n. 8, e963986535, 2020
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Table 1. Mediums monthly values of temperature and relative humidity of the air inside the greenhouse of the Laboratory of Plant Ecology. Areia-PB, 2017.

Dada	2016					2017
	August	**September**	**October**	**November**	**Dcember**	**January**
	Mean temperature (°C)					
Maximum	25.8	26.3	27.1	28.0	28.5	32.0
Minimum	24.5	25.2	26.0	26.7	27.1	28.8
Mean relative humidity of air (%)						
Maximum	75.1	71.3	69.8	63.6	66.5	66.5
Minimum	67.0	61.2	62	58.9	61.5	46.9
Mean of Day	71	66.2	66	61.2	64	56.7

Average annual data collected in the experimental period. Source: Researcher data.

Fruits of *C. madagascariensis*, when they had dehiscence, were collected manually in the canopy of individuals from an existing population at Fazenda Triunfo, located in the municipality of Ibaretama-CE, in the coordinates 05º 27′ 27,2″ S and 94º 76′ 65,2″ W. The farm has a total area of 740 ha, of which approximately 100 ha are occupied by the invasive alien species.

The collection of fruits in the matrices was done at random, traversing the area invaded by the referred species. The fruits were collected in August 2016. After being collected, these were packed in plastic bags and later transported to the LEV/CCA/UFPB, in Areia - PB.

Substrates consisted of a clay-silt-free texture Vertisol and a Fluvial Neossol with Areia Franca texture, both without pH correction and without the addition of fertilizers or organic matter. The two soils were collected at a depth of 0-20 cm, the Vertissolo was collected on the farm of Senhor Severino Cruz in the municipality of Alagoa Grande-PB, in geographic coordinates 07º 05’ 20’’S, and 35º 38’ 06’’O and average altitude of 143 meters and the Floss Neossolo in the agricultural area located in the Gruta Funda of the municipality of Algodão de Jandaira-PB, in the coordinates 06º51’11,3’’S, 35º55’51,5’’W and average altitude of 407± 3 m. Both soils were under invasion by another invasive species, such the *Prosopis juliflora*, *Parkisonia aculeata* and thre *Calootropis prucera*.

After collecting the two soils for physical-chemical and salinity analysis, the samples were transported to the laboratory DSER/CCA/UFPB in order to untangle and dry them. The samples of each soil after being passed through a 2 mm mesh, were physically characterized and regarding fertility, using the methodologies compiled by Embrapa (2018). Were also characterized regarding the salinity of the saturation extract as Richards (1954), whose results are indicated in the (Table 2).

Table 2. Physical, chemical properties and salinity attributes of Vertisolo and Floss Neossol collected in the municipalities of Alagoa Grande-PB and Cotton of Jandaira-PB. Areia-PB, 2017.

Physical Attributes		
	Vertisolo	**Neosol**
Sand (g kg^{-1})	370	872
Silte (g kg^{-1})	283	85
Clay (g kg^{-1})	347	43
Soil density (kg dm^{-3})	1.59	1.75
Particle density (kg dm^{-3})	2.65	2.80
Total porosity (m^3 m^{-3})	2.80	37.5
Textural classification	Franco-Silty clay	Franca Sand
Fertility Attributes		
	Vertisolo	**Neosol**
Hp (1:2.5 water)	6.10	6.88
P (mg dm^{-3})	11.0	174
Ca^{2+} ($cmol_c$ dm^{-3})	9.15	3.25
Mg^{2+} ($cmol_c$ dm^{-3})	13.15	1.5
K^+ (mg dm^{-3})	0.30	0.49
Na^+ ($cmol_c$ dm^{-3})	0.43	0.31
SB ($cmol_c$ dm^{-3})	22.73	5.55
Al^{3+} ($cmol_c$ dm^{-3})	0	0
(H^++Al^{3+}) ($cmol_c$ dm^{-3})	4.06	0.5
CEC ($cmol_c$ dm^{-3})	26.79	6.05
V (%)	84.85	91.74
SOM (g kg^{-1})	20.02	7.7
Salinity Attributes		
	Vertisolo	**Neosol**
ECs (dSm^{-1})	0.79	0.49
Hp	5.83	7.05
Ca^{2+} ($cmol_c$ dm^{-3})	1.25	1.87
Mg^{2+} ($cmol_c$ dm^{-3})	3.75	4.00
K^+ (mg dm^{-3})	0.53	0.88
Na^+ ($cmol_c$ dm^{-3})	11.94	5.41
Cl^- ($cmol_c$ dm^{-3})	6.75	5.75
CO_3^2($cmol_c$ dm^{-3})	0	0

Atributos da Salinidade		
	Vertisolo	**Neosol**
HCO_3^-($cmol_c$ dm^{-3})	4.06	0.5
SO_4^{-2} ($cmol_c$ dm^{-3})	-	-
SAR	8.47	3.84
PES%		
PSI	10.11	4.23

Hp = *hydrogen potential;* SB = sum of bases; CEC = cation exchange capacity; V% = base saturation; SOM = soil organic matter; ECs = Electric Contiguity of Soil; SAR = Sodium adsorption ratio; PES = percentage of exchangeable sodium; *Average data collected at 153 days after emergency*. Source: Researcher data.

Chemical analyzes were used to determine the electrical conductivity of soils, of pH, potential acidity and the levels of P^-, K^+, Na^+, H^+; Al^{3+}, Al^{3+}, Ca^{2+}, Mg^{2+}, CTC, base saturation and organic matter (EMBRAPA, 2018). The physical characteristics determined in the two soils before the experiment were: granulometric composition and clay dispersed in water by the pipette method; soil density (test tube method) and particle density (volumetric flask method); the total porosity was calculated, as well as the textural classification (EMBRAPA, 2018) and whose values are shown in Table 2.

The experiment was conducted in a screened environment at the Plant Ecology Laboratory, where the plants of *C. madagascariensis* were grown in 128 plastic pots with a capacity of 21 liters (dm^{-3}) with 4 repetitions, being placed in each pot 19 kg of the substrate, dry and saline. Before the salinization of the substrates, they were passed through a 8 mm mesh sieve and, then set to dry, as recommended by Medeiros et al. (2018).

The substrates, after drying, were placed in the pots which were separated into four batches, each lot being irrigated with water containing the following values of electrical conductivities of the irrigation water: 0.3 (average electrical conductivity of tap water used in the experiment); 1.0; 2.0 and 4.0 d Sm^{-1}. The electrical conductivity levels of the water used for soil salinization were obtained by diluting the Sodium Chloride salts with 70%, Calcium Chloride 20% and Magnesium Chloride in the proportion of 10% in tap water and the measurements made with a portable conductivimeter as they also proceeded Medeiros et al. (2011) and Medeiros et al. (2019).

Before sowing, the seeds were removed from the capsule that surrounds them and no physical or chemical treatment was needed to accelerate its germination. For each vase, were used 10 seeds, which were placed on the substrate at an average depth of 1.5 cm, using as a cover a light layer of the substrates, in order to favor the emergency. Before sowing, the soil was moistened so that there was a better accommodation of the soil particles in the pots and adequate sowing conditions in order to obtain greater homogeneity in the vigor of the seeds. After the emergence stabilized, the seedlings were thinned 10 days after sowing, with four more vigorous seedlings remaining in each pot. The four plants were maintained until the end of the trial (152 days), with 4 plants per pot, with 32 pots for each repetition, with 4 repetitions totaling 128 pots.

During the sowing period until the end of the seedling phase, all pots remained close to field capacity (CC). After the seedling phase (30 days after germination), were initiated treatments with different water regimes, constituting the maintenance of soil moisture at four levels, namely: N1 (20% of CC); N2 (40% of CC); N3 (70% of CC) and; N4 (110%, flooded), maintained until the end of the test. From then on, soil moisture controls were performed three times a week, consisting of replacing evapotranspirated water through the weight difference measured by the digital scale between the weighing days, as recommended by Medeiros et al. (2019).

The determination of the water volume to raise the soils to field capacity and saturation were carried out in extra pots in the test which were drilled on the lower side and a plastic hose was attached. For determine of field capacity (gravimetric method) the hose attached to the pot was connected to a pet bottle, then water was added until drainage started, being considered as a volume of water to raise the dry soil to the field capacity of the retained water, when the drainage ceased (Souza et al., 2011b). To determine the saturation of the soil, the end of the hose remained facing upwards, with water being added until its level in the hose was equal to the level of the soil in the pot, being considered as volume of water to raise the dry soil to water saturation. Added

The experimental design used was in randomized blocks, with four replications. To assess soil fertility after planting, treatments consisted of soil salinity levels (0.3; 1.0; 2.0 and 4.0 dS m^{-1}) and soil moisture (20% of CC; 40% of CC; 70% of CC and 110%, flooded) in the two types of soils studied (Vertisol and Floss Neossol) where they were distributed in a factorial scheme with four levels of soil water and four levels of electrical conductivity of the soil saturation extract according to the factorial scheme studied throughout the work (4 x 4 x 2).

After 152 days after sowing, the plants were collected, separating the aerial part (leaves) from the stems, and placed to dry in a forced air circulation oven, at a temperature of 65 ºC, until they reach constant weight. After drying the leaves, the procedures for analysis of leaf contents began.

To prepare the extracts, the crushed leaf dry mass was digested using sulfuric acid, hydrogen peroxide, sodium and copper and selenium sulfates (Tedesco et al., 1995) to determine the levels of N, P, K and Na. With the extracts, the determination of leaf contents was made following the methodologies described by Miyazawa et al. (1999): steam distillation to nitrogen; phosphorus blue spectrophotometry for phosphorus; flame emission photometry for potassium and sodium.

The results were submitted to analysis of variance, the level of significance being determined by the "F" test and the means compared by the Tukey test at 5% probability. Quantitative variables (Salinity) were subjected to polynomial regression analysis (Banzatto e

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Kronka, 2013). For data processing, software was used the SISVAR (Barbosa & Maldonado JÚNIOR, 2015).

3. Results and Discussion

These results derive from the analysis of the leaf material of young plants of C. madagascariensis evaluated after the period of 152 days of planting the plants in two types of soil and different levels of salinity and humidity.

In table 3, observes the isolated effects of the electrical conductivity of irrigation water (CEai), of moisture and soils under study, as well as the interaction between these factors on the fertility of these soils and leaf levels in the initial growth of plants of *C. madagascariensis.*

The electrical conductivity of irrigation water, humidity and soil types positively affected nutrient levels such as N. Leaves and P. Leaves, respectively by the interaction with three factors - double interaction, assessed at levels of 1 and 5% probability by the Tukey test. Seen, the interaction C x MOISTURE x SOIL did not show significant effects for the contents of K^+ and Na^+ in leaves of this invasive plant, simultaneously.

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Table 3. Summary of mean squares and regression analysis for leaf Nitrogen content in leaves (N. Leaves), Phosphorus on Leaves (P. Leaves), Potassium in leaves (K. Leaves) and Sodium in Leaves (Na. Leaves) of the plants of Cryptostegia madagascariensis for the purposes of Salinity (CEai), Soil Moisture (M) and Soil Types (S) evaluated in the 152 DAE period. Areia-PB, 2017.

V.F	DF	N.Leaves	P. Leaves	K. Leaves	Na. Leaves
CEai (C)	3	5.386^{ns}	8.727^{**}	27.561^{ns}	0.045^{*}
MOISTURE (U)	3	124.04^{**}	20.665^{**}	801.093^{**}	3.102^{**}
SOIL (S)	1	597.75^{**}	98.280^{**}	271.066^{**}	0.176^{**}
C x MOIST	9	34.512^{**}	5.640^{**}	31.723^{*}	0.040^{**}
C x SOIL	3	15.489^{ns}	10.588^{**}	42.588^{*}	0.015^{ns}
MOIST x SOIL	3	63.634^{**}	6.814^{**}	63.363^{*}	0.510^{**}
C x MOIST x SOIL	9	24.477^{*}	6.517^{**}	24.250^{ns}	0.016^{ns}
BLOCK	3	59.744	0.199	826.53	0.042
Erro	93				
Regression					
E. Linear	1	12.808^{ns}	6.0941^{**}	75.6021^{*}	4.5148^{**}
E. Quadratic	1	66.9533^{*}	34.5544^{**}	522.808^{**}	4.1565^{**}
E. Cubic	1	28.0489^{ns}	67.6014^{**}	49.1254^{*}	0.4707^{**}
Regression Deviation	1	0.0001	0.000012	0.00001	0.00001
Erro	93	10.7339	0.096	13.8847	0.012
C.V%		14.24	12.37	29.34	11.14
Total	127				

F.V= Variation fator; DF = Degree of freedom; CV = Coefficient of variation; Ns=not significant; (*) and (**) respectively significant at the levels of 1 and 5% probability by the Tukey test; DF= degree of freedom; CV= coefficient of variation; LE=Linear Effect; QE= Quadratic effect; CE= Cubic effect; RD= Regression deviation; Erro= residue; (—) = without adjustment for polynomial models (Regression); Source: Researcher data.

The nitrogen content in the leaves of *C. madagascariensis* was positively influenced by independent factors alone (Salinity, humidity and soils) and also by the interaction Salinity x Humidity x Soils, and expresses statistical superiority in the treatments at the level of significance of 1% ($P < 0.01$) of probability by the F test (Table 3).

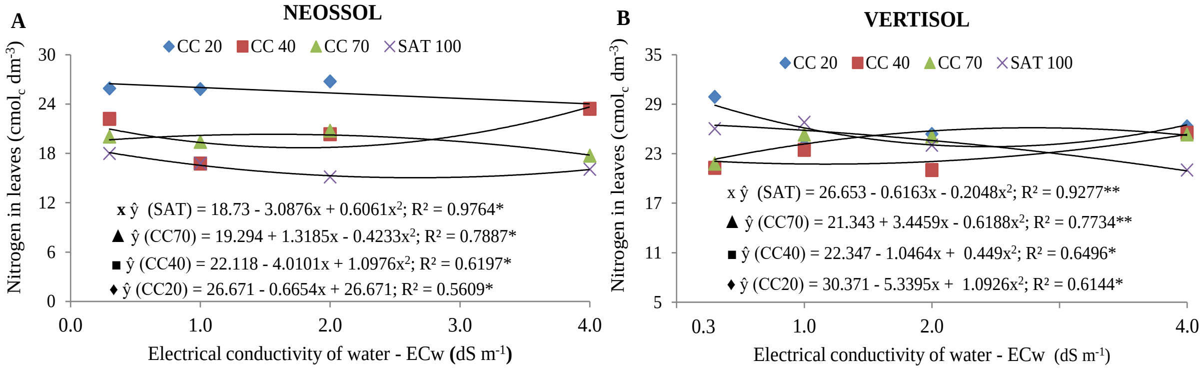
Action of isolated effects and interaction had a positive influence on phosphorus levels in leaves of young ornamental plants (*C. madagascariensis*), expressing statistical superiority of 1% ($P < 0.01$) of probability by the F test (Table 3).

Behavior of the data regarding the accumulation of potassium in the plant tissue (leaves) was significantly affected by the Soil Humidity x Soil interaction, and expresses statistical superiority in treatments at the 5% significance level ($P < 0.01$) of probability by the F test (Table 3).

The superiority of sodium in the leaves even with the high water condition in relation to the two types of soils and other cations present (Table 2), where this element in the soil can result in adsorption to the exchange complex with negative reflexes in the dispersion of clays and loss from physical quality to water and nutrient dynamics.

Despite the expressive superiority of leaf nitrogen in plants of *C. madagascariensis* treated in the Floss Neossol at a humidity of 20% in relation to the saturated soil (110%) and with increasing levels of soil salinity (Figures 1A and 1B), it is observed that this parameter was linearly inhibited in the order of 26.47 to 24.01 cmolc.dm^{-3}, corresponding to the lowest and the highest level of salinity (0.3 and 4.0 dS m^{-1}), respectively.

Figure 1. Leaves nitrogen contentes (N) of the young plants of *Cryptostegia madagascariensis* evaluated in two soils under different levels of salts present in the irrigation water and different humidity conditions, Areia-PB, 2017.



Source: Researcher data.

On saturated soil (110%), the leaves contents of N were significantly reduced of 17.85 to 16.07 cmol$_c$.dm^{-3}, in function of the stress caused by the increasing salinity of irrigation water from 0.3 to 4.0 dS^{-1}. This decrease caused a 9.29% inhibition in the total nitrogen content in plants with an increase in the soil's salt content and an increase in moisture until saturation, simultaneously, as shown in (Figure 1A).

Based on the aforementioned (Figure 1B), the treatments evaluated in Vertisolo submitted to different saline levels and increases in soil moisture, responded quadratically as to the accumulation of nitrogen in the leaves. Despite the positive effects influenced by the interaction Salinity x Moisture x Soils in the field capacity at the level of 20% humidity, the leaf N content showed a sharp decline from 28.87 to 26.48 cmolc.dm^{-3} with increasing character soil saline (0.3 to 4 dS m^{-1}), respectively. Compared to the 40 and 70% humidity, the data behaved in a similar way to the previous situation, where the minimum and maximum levels of nitrogen in the dry leaf mass of the plants varied of 21.73 and 26.15 $cmol_c.dm^{-3}$ in the estimated doses of the electrical conductivity of the irrigation water of 1.16 and 2.77 dS m^{-1}, with coefficient of determination of 64.96 and 77.34%, simultaneously.

It is possible to state that the plants tested in the Floss Neossol showed a process of growth inhibition and consequently a decline in the N content in the leaves with an increase in the saline character of the soil and an increase in water conditions until soil saturation (110%). It can be considered that this ornamental plant in this type of soil presented characteristics of salt toxicity or ionic imbalance regarding the values of leaf N, not tolerating the studied salinity levels. Under these conditions, the plant has an osmotic response, reducing the water potential of its cells, where the turgor pressure is effectively reduced. Thus, the water potential of the plant becomes relatively negative to that of the soil, thus ensuring water absorption (Vasconcelos et al., 2010; Taiz et al., 2017). However, if compared to Vertisolo, under the same conditions, probably, the plants resisted more due to the increase in metabolic activities, mainly under water conditions of 40 and 70%, respectively. These variations in the amount of nitrogen accumulated in plants may be due to the type of plant species, type of microbial symbiosis, salinity, water conditions and age of the plant, all of which must be considered so that it can have a significant effect on the accumulation of plant tissue nutrients (Rozane et al., 2013). However, (Pasiecznik et al., 1993), observed significant increases in the nutrient status of soil with mesquite for four years, assuming that this occurred due to a deficit of water in the soil or due to salinity limiting nitrogen fixation.

Despite the accumulation of phosphorus in the leaf biomass of *C. madagascariensis* present different behavior between treatments with different water limitations and with elevated soil salinity, drastic differences were found in both the Floss Neossolo and Vertisolo (Figure 2A and 2B).

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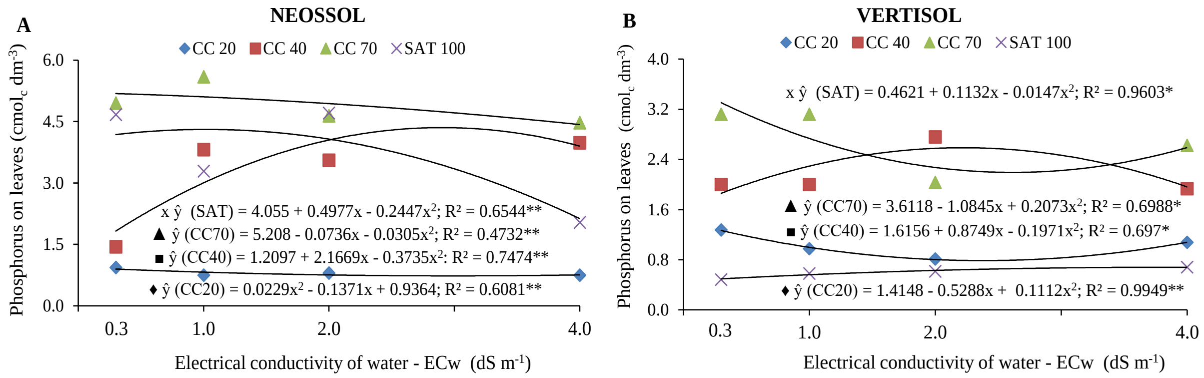
Figure 2. Phosphorus contents (P) in Leaves of young plants of *Cryptostegia madagascariensis* evaluated in the soil under supplementary irrigation with different levels of salts present in the irrigation water and different field capacity conditions, Areia-PB, 2017.



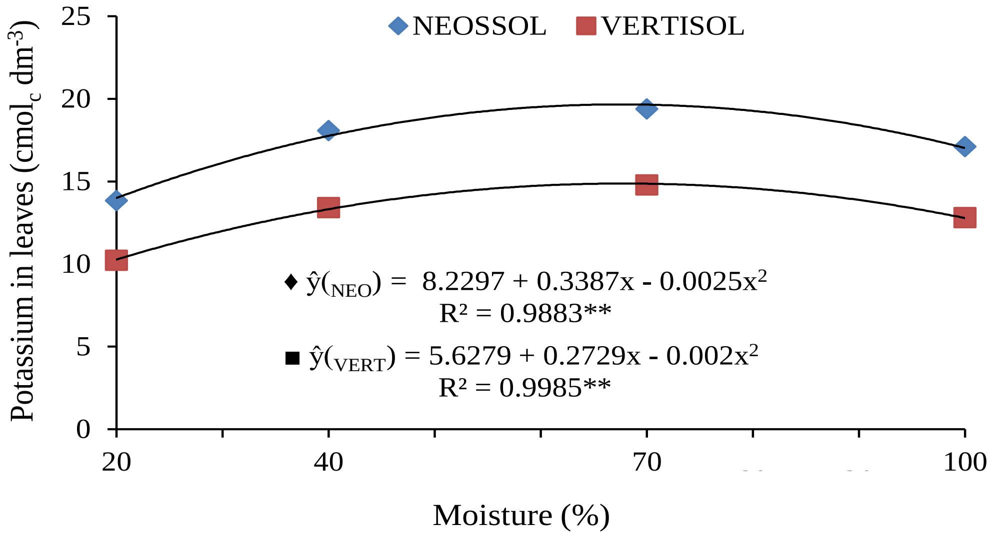
Source: Researcher data.

The lowest values of phosphorus in the plant tissue of *C. madagascariensis*, in Floss Neossol, can be affected by the increase in salinity of irrigation water in the field capacity of 20%, with values ranging from 0.91 to 0.75 cmolc.dm^{-3}, corresponding to the lowest and highest water salinity of 0.3 and 4.0 dS m^{-1} (Figure 2A). Despite the expressive superiority of the field capacity between 20 and 70%, the highest values of leaf P tested in the same conditions, that is, with the increase in the saline character of irrigation water and different limitations regarding water content until soil saturation (110%), oscillated in the order of 5.18 to 4.42 cmolc.dm^{-3}, referring to the estimated dose of 0.3 and 4.0 dS m^{-1}). This decrease caused significant losses for each unit value, being inhibited the increase of the P content in the leaves from the initial water salinity of 0.3 dS m^{-1}. Probably the excess of salts reduced the development of plants, due to the increase in energy that needs to be released to absorb water from the soil (Medeiros et al., 2018).

There is a significant variation in the Vertisol on the levels of P in the leaf dry mass at the end of the experiment for the effect of different water regimes and increased water salinity (Figure 2B). Contrasting behavior is observed between water regimes 40 and 70% as well as 20 and SAT 110%, respectively. In this sense, the lowest P values in the leaves ranged from 0.49 to 0.67 cmolc.dm^{-3}, in the estimated doses of 0.3 and 4.0 dS m^{-1}, respectively, in supersaturated soil, in the water regime of 110% (Saturated Soil). On the other way, in the field capacity in the order of 70% (CC70%), the highest values of P in leaf dry matter were found at the end of the experiment, where these levels ranged from 3.31 to 2.58 cmolc.dm^{-3}, corresponding to lower and higher salinity (0.3 and 4.0 dS m^{-1}). Comparatively to the two different situations, this decrease caused a 22.05% inhibition in the total phosphorus content of the plants with an increase in the saline content of the soil, as seen in (Figure 2B). When comparing the two conditions, there is an expressive superiority in the accumulation of P in the plants, however, the drastic reduction of the P content in the plants or inhibition, can be caused by the degenerative effects or indirect effects of the saline ions present in the soil (Abdel Latef, 2010; García et al., 2011; Sousa et al., 2016).

The plants of *C. madagascariensis* evaluated in the period of 152 DAS and considering that there was homogeneity in the vigor of these plants in the greenhouse test, had potassium content increased quadratically from 14.10 to 19.87 cmolc.dm^{-3} as the maximum estimated value, and as such, they were evaluated in a Floss Neossol at the maximum estimated field capacity of 73.71%, with a decrease of this nutrient in the leaves after that point (Figure 3). This decrease was drastically affected by the increase in field capacity from 70 to 110%, with a percentage decline of K^+ in the leaves of 13.28%.

Figure 3. Leaves potassium contents (K) of young plants of *Cryptostegia madagascariensis* evaluated in two soils and different water regimes. Areia-PB, Brasil, 2017.



Source: Researcher data.

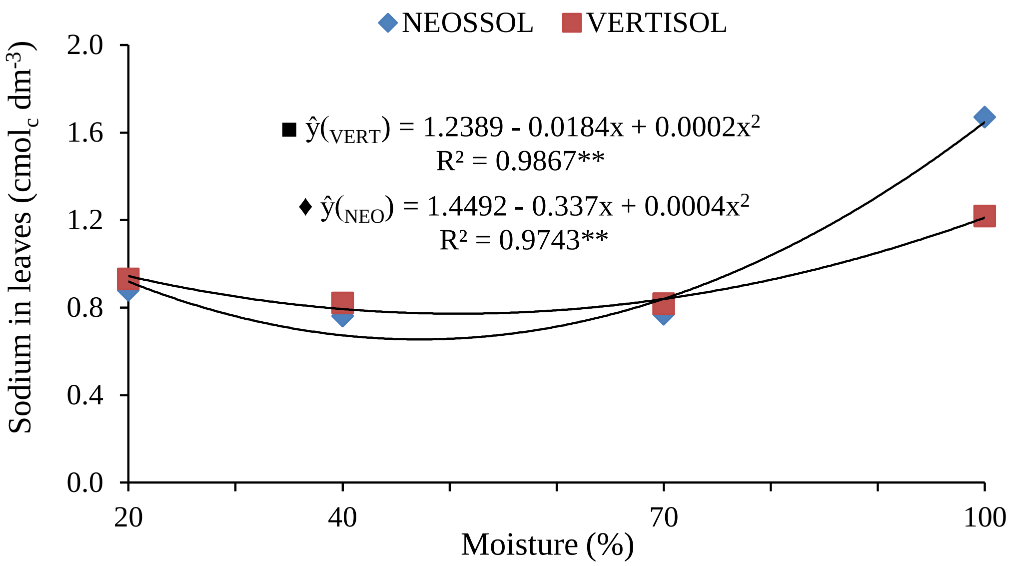
However, the parameters evaluated in the Vertisol (Figure 3) resulted in greater efficiency of the plants in the supply of leaf potassium in the order of 15.16 cmolc.dm^{-3}, referring to the maximum estimated field capacity of 74.75%. Comparing the two soils, simultaneously, the plants obtained a percentage yield of 23.69% in the foliar potassium supply.

An important adaptive mechanism of invasive plants under excess water in different soils is the reduction of photosynthetic processes and the transport of organic solutes, consequently impairing the efficiency of allocation of this nutrient via leaf (Sucre & Suáres, 2011).

The results of Na^+ in the leaf dry matter of young plants of *C. madagascariensis* referring to the Fluvic Neossol and Vertisol adjusted to the quadratic polynomial regression models, with a determination coefficient of 99.17% and 99.85%, respectively (Figure 4). Analyzing the data of the Floss Neossol, the Na^+ levels were increased from 0.91 to 2.15 cmolc.dm^{-3}, in the estimated field capacity of 20 and 110%, respectively. This is because the irrigation of plants with different water regimes increased or favored a percentage increase of sodium in the leaves in the order of 57.67%.

At comparing the data of the Floss Neossol in relation to Vertisol data, the plants provided a quadratic increment (99,85%) in the sodium content in the leaves from 0.81 to 0.92 cmolc.dm-3 due to the gradual increase in the field capacity of 20% until the soil saturation, that is, 110% (Figure 4). In this sense, under such a condition, it is convenient that the plants consequently reduce the loading of Na^+ and Cl^- in the xylem and water conservation in the tissues to ensure some vital functions.

Figure 4. Leaves sodium contents (Na^+) of young plants of *Cryptostegia madagascariensis* evaluated in two soils and different water regimes, Areia-PB, 2017.



Source: Researcher data.

The two soils behaved similarly in relation to the accumulation of Na^+ via the leaf, promoting distribution of assimilates, greater allocation of this Na^+ nutrient by plants in the leaves and, above all, greater efficiency in water absorption. In view, the plants provided an improvement in the conditions regarding osmotic regulation for root growth, under water stress conditions (Souza et al., 2011a). Thus, the salts dissolved in the soil solution cause changes in the physiological processes of the crops, with a consequent reduction in their growth and productivity (Birk et al., 2010; Holanda Filho et al., 2011).

Similar behavior was obtained by Schossler et al. (2012) and Menezes et al. (2019) after finding inhibition of the growth of the neem invasive plant (*Azadirachta indica* A. Juss) under saline soil conditions and different irrigation regimes. These results are also in line with Asik et al. (2009) at concluding that humus and humic acid reduced the damaging effects of sodium chloride, at levels of 0, 15, 30 and 60 mM, on the growth and production of *Tritucum*.

4. Conclusions and Suggestions

The increase in water salinity and humidity levels until saturation increased the salinity of the two soil types, mainly in the water regime of 70% of the CC in the two studied soils

For the contents K, P and Na in plants leaves of *C. madagascariensis* of both studied soils there was a significant reduction in their values in relation to those initially verified in all salinity and humidity conditions tested under abiotic stresses.

The increase in the saline content of the waters increased the saline character of the two soils studied, however, it did not hinder the initial growth of young plants of *C. madagascaraiensis* at 152 days, which indicates that the species is tolerant to salinity, which may explain, in part, the success of this species in colonizing saline areas representing an ecological advantage of the same.

Author's contributions

All authors contributed equally to the production of the manuscript.

Declaration of conflicting interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The study was supported by Productivity Grants from the Brazilian National Research Council (CNPq).

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