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Sources and Levels of Salinity in the Rocket Crop

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ABSTRACT

Understanding the response of the rocket crop to different source and salinity levels allows determining the type and level of salt that can be tolerable even where this factor is limiting. We evaluated the effect of different sources and levels of salinity sodium chloride (NaCl) and potassium chloride (KCl) in rocket. The trial was conducted in a greenhouse, throughout completely randomized design in a 2x6x11 factorial scheme, two salt sources (NaCl and KCl), six salinity levels (0, 0.5; 2.0, 3.5, 5.0 and 6.5 dS m-1) and eleven replications. KCl exceeded the NaCl and both did not affect the leaves immersion.

Introduction

Rocket (Eruca sativa L.), also called Persian mustard or mustard cress, is an annual herbaceous, small herbaceous vegetable belonging to the Brassicaceae family, mainly consumed in salads, which is rich in vitamin C and A, potassium, sulfur, iron, calcium and alpha-linolenic acid (BORGES et al., 2014). It is a fast growing vegetable with short cycle, originated from southern Europe and western Asia. The tender leaves are very appreciated in the form of salad, mainly in the Center-South region of Brazil (SALLES et al., 2017).

Several adverse environmental factors may be detrimental to the cultivation of this crop. In addition, salinity is one of the abiotic stresses limitation that most affect the yield of this crop, which may interfere with growth and cause changes in the quality of the plant product, due to differences in concentration and ionic composition of the saline farming environments. On the other hand, the rocket under moderate salt stress limits its growth, development and productivity, however, in extreme cases the salinity can lead to the plant to death (SOBHANIAN et al., 2011).

The usage of saline water in agriculture, must be done in rational and economic viable agronomic management, starting with the selection of the variety up to the irrigation water management (doses, irrigation intervals and irrigation water needs of the crop) and the quality of its products, without providing minimum risks of salinization to soils (MEDEIROS et al., 2007).

According to Nawaz et al. (2014) simultaneous stresses seriously compromise all metabolisms of the plant, and growth is severely impaired in the presence of the salinity factor. Thus, forms of coexistence have been studied, and the cultivation of tolerant species is the most outstanding and recommended by professionals in soils degraded by the effect of salinization (PENELLA et al., 2016).

According to Kaiser et al. (2016), salinity has a major impact on agricultural production worldwide, making it more difficult in the arid and semi-arid regions, with long periods of drought, high rates of evaporation and large occurrences of flat soils. In these regions, generally, surface water is scarce, making groundwater essential for agriculture.

Saline stress subjects the plants to adverse conditions, where plants promote the reduction of energy expenditure and consequently, as an adaptive strategy, plants have their growth influenced negatively (LIU & JIANG, 2015).

For Silva et al. (2011) water quality is one of the factors that has a negative effect on the development of crops and affect production, since water is constituent of plant tissues, even making up more than 90% of some plants. Thus, in this way the use of inferior quality water in agriculture, demands rational management, through economically viable alternatives, so that the crop develops to the expected productivity.

In the literature, there are few studies on the behalf of rocket to different sources and levels of salinity, especially when tested under greenhouse conditions, so this study aimed to evaluate the effect of different sources and levels of salinity in the rocket crop evaluating its agronomic attributes.

Material and Methods

The trial was conducted in a greenhouse located at the Faculty of Agricultural Sciences of the Federal University of Grande Dourados, in July and August 2017. The average altitude of the site is 446 m, with a latitude of 22º 11 '45' 'S and longitude 54º 55 '18' 'W. The climate of the region, according to the classification of Köppen (1948), is of the type Cwa (wet mesothermic), with rainy summer and dry winter and with average annual temperature of 22ºC.

To conduct the trial we used Premium seeds variety with 85% germination power and 99% purity, which were submitted to stress with two sources of salinity sodium chloride (NaCl) and potassium chloride (KCl) and six levels of salinity 0; 0.5; 2.0; 3.5; 5.0 and 6.5 dS m-1, corresponding to 0; 0.311; 0.641; 1,282, 1,922 and 2,136 g /l for NaCl and 0; 0.384; 0.718; 1.437; 2,156 and 2,395g/l for KCl. Although the conductivities evaluated are the same, the concentrations to obtain them are different because the sources NaCl and KCl have different molar masses, therefore, the amount of salt used for KCl is higher than NaCl for the same electrical conductivity.

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The trial was based on a completely randomized design in a 2x6x11 factorial scheme, two salt sources (NaCl and KCl), six salinity levels (0, 0.5; 2.0, 3.5, 5.0 and 6.5 dS m-1) and eleven replications. The experimental unit consisted in a soil bag containing a plant. The trial added up132 soil bags, corresponding to 66 for each salinity source and 11 for each salinity level including the control.

The plastic bags were filled with 110g of commercial substrate (soil),classified as neutral salinity for the production of seedlings. After filling the bags with substrate, 50 ml water slide was applied per bag up to the saturation. During the farming period the irrigation water was applied regularly to achieve saturation equivalent to the field capacity, by weight difference. The different levels of salinity wereo btained through the dissolution of sodium chloride (NaCl) and potassium chloride (KCl) in distilled water, adjusting with a benchtop conductivity meter, with automatic temperature correction.

To evaluate the effect of different sources and salinity levels in the agronomic attributes of the crop, we evaluated leaf number, leaf length, fresh and dry leaf mass, leaf area and length of the root system.

To determine of the number of leaves (NF), we performed the harvest at 40 days after sowing, where we counted the green leaves larger than 3.0 cm in length, excluding the yellow and / or dried leaves, from the basal leaves to the last open leaf.

Furthermore, we determined leaf length using a ruler of 30 centimetres, then we stripped all the leaves larger than 3.0 cm in length for leaf area determination (LA) using a LI-COR® leaf area integrator, model LI 3100, by the apparatus once, in numerical order, and the LA values returned were noted by performing all adjustments and cleaning on the surface of the apparatus, in contact with as samples. We estimated the fresh mass of the aerial part by weighing in precision digital scale and then the fresh leaves were conducted to an oven with forced circulation of air to ± 71 ºC, until reached to a constant weight, determined dry mass of the aerial part, expressed in grams. Finally we used the tape measure to determine the of root system length.

The data was submitted to the Shapiro Wilk test to test normality, as well as to analysis of variance, and when significant at the 5% probability level by the F test, a polynomial regression analysis was performed for the quantitative factors and the test of Tukey at the 5% probability level for the qualitative factors, for all variables analysed through the statistical software Assistat 7.7 Beta.

Results and Discussion

According to the analysis of variance (Table 1), we observed that fresh leaf mass, leaf dry mass, leaf index, leaf area and root length were affected by the sources and levels of salinity of the irrigation water containing NaCl and KCl salts , at 1% probability. Contrary we also observed that the irrigation water did not affect the number of leaves (NF). On the other hand, the effect of salinity on the leaf emission of rocket does not affect the inducing organs of the cell division that promote the emission of new leaves in the plant, this is explained by the non-limiting effect of salt on gibberellins. Moreover, Silva (2009) and Silva et al. (2011), working with rocket in hydroponic system NFT, did not observe an effect of the salinity on the number of leaves.Thus, NF can be considered a genetic attribute, varying according to the development of the plant.However, in the hydroponic system, in the NFT system or inert substrate, SOARES et al. (2007) observed that the plant tolerance to salinity is higher for the leaf emission.

Table 1. Summary of variance analysis for fresh mass (FM), leaf area (LA), dry mass (DM) and root length (RL), leaf length (LL) and number of (NF) and salinity levels in rocket.

Mean Squares							
NaCl							
Source of variation	**GL**	**FM**	**LA**	**DM**	**RL**	**LL**	**NF**
Level	5	0,18**	179,24**	0,00083**	45,088**	3,942**	0,364ns
Residual	60	0,003	3,68	0,0002	2,73	0,458	0,558
C1-Linear	1	Ns	**	**	ns	Ns	ns
C2-Quadratic	1	**	**	*	**	**	ns
C3-Cubic	1	**	**	Ns	*	ns	ns
C4-fourth	1	**	**	Ns	ns	*	ns
C5-fith	1	**	**	Ns	ns	*	ns
CV (%)		12,48	18,65	39,08	24,95	14,54	20,53
KCl							
Level	5	1,081**	201,42**	0,005**	36,03**	45,088**	2,072ns
Residual	60	0,013	6,1	0,0005	4,72	2,726	0,791
C1-Linear	1	**	Ns	Ns	**	ns	ns
C2-Quadratic	1	**	**	**	ns	**	*
C3-Cubic	1	ns	**	**	**	ns	ns
C4-fourth	1	**	**	**	ns	**	**
C5-fifth	1	**	**	*	ns	**	ns
CV (%)		16,36	18	38,18	12,94	24,95	21.99
Combined variation							
Level	11	0,793**	208,382**	0,0038**	162,01**	33,95**	1,967**
Residual	120	0,008	4,892	0,003	14,976	1,586	0,594
CV (%)		15,84	18,42	38,87	18,45	22,31	19,71

**Significance at the 1% de probability and ns non - significance.

Additionally, we adjusted the linear correlation models that best fit the study variables. For the fresh mass of the leaves treated with of NaCl, the quadratic, cubic, fourth and fifth equation models were significant at 1% probability with an average coefficient of variation (CV) of 12.48% according to the classification of Pimentel Gomes and Garcia (1998). On the other hand, we observed that LA is be better estimated by the linear, quadratic, cubic, fourth and fifth equation model, with an average coefficient of variation corresponding to 18.65%, a relatively high CV when compared to FM. Despite this CV, the results are reliable and useful for safe inferences for technical and scientific recommendations. In addition, we observed that the DM only fits better the linear and quadratic equation models, presenting a very high CV of 39.08%, showing that making inferences with this CV must admit a variation of 39.08%. On the other hand, we observed that the RL best fits the quadratic and cubic equation models with a high CV of 24.95%, making the results acceptable and applicable. Finally, we observed that LL fits better the quadratic, fourth and fifth equation models, presenting an average CV of 14.54%, and these results are safe to make technical and scientific inferences. The number of leaves was not significant for the source at the dose, so no model fits better to estimate the number of leaves emitted by the plant (Table 1).

On the other hand, for the treatments applied KCl as salt source in the irrigation water, we observed that for fresh mass fits better linear, quadratic, fourth and fifth the equations (Table 1). The leaf area and dry mass did not adjust to the linear equations, while the root growth simultaneously adjusted the linear and cubic equations. We also observed that leaf growth adjusted to the quadratic, fourth and fifth equations. In addition, the combined variation of the sources showed a significant effect on the salinity levels.

Table 2 shows that the increase in the concentrations of salts of irrigation water containing NaCl and KCl provided an increase in fresh mass, leaf index, leaf dry mass, root length and leaf length up to 2.0 dSm -1, what shows the saturation level. From this level, there is a trend of decreasing of the studied variables with the increase of the salinity.

We observed that the irrigated rocket with water containing KCl provided superior results regarding on the agronomic attributes fresh mass, leaf area, leaf dry mass and leaf length at all levels of saline concentration studied, except for leaf length, in which NaCl presented greater root growth in relation to the treatment irrigated with water containing KCl. (Table 2). Analysing the response of the crop in relative terms, it was verified that both sources presented tolerance for even the salinity dSm-1 (salinity threshold-SL), and after this level a decrease occurred.

Oliveira et al. (2011) evaluating the effect of salinity on the performance of two rocket cultivars found that the salinity did not affect the height of the plants initially. But increasing to salinity to 2.1 dS m-1 (21.9 cm) decreased the height, obtaining highest salinity minimum height of of 15.5 cm.

According to Morales et al. (2001), not all parts of the plant are equally affected by salinity, as well, the adaptation to saline stress varies between species and in a same genotype can vary between phonological stages.

Salles et al., (2017) observed that the reduction of the rocket growth under conditions of saline stress is associated to a reduction of the osmotic potential of the plant, and not to the potential of pressure, indicating an osmotic adjustment resulting from the synthesis of compatible solutes.The reduction in the evaluated characteristics possibly dues to the decrease in the osmotic potential caused by the increase of the soluble salts in the soil solution, which makes it difficult for the plants to absorb water.

After the interaction of the concentrations of saline solutions in relation to the yield of fresh mass, leaf area, leaf length, root length, number of leaves and dry leaf mass (Figure 1), we generated the regression equation, according to the best model fit. In the regression equation for fresh mass, we observed that as the salt concentration increased, there was a growth in the fresh mass yield of the leaves, reaching a maximum value of 1.2g of fresh mass for KCl and approximately 0.8g under irrigation with NaCl. After this point, there was a decrease in fresh mass production for both treatments, increasing the salinity level of the irrigation water from the conductivity 2.0 dS m-1 for all treatments.

We also observed that foliar area, leaf length, root length and number of leaves irrigated with saline water containing the NaCl and KCl salts, obtained the same tendency in plot as the fresh mass attribute, as can be seen in Figure 1. Up to the 2.0 concentration dS m-1 occurred a decrease of the productivity in relation to the control. Moreover, at the concentrations of 3.5, 5.0 and 6.5 2 dS m-1 there was a decrease for the evaluated attributes, in which we concluded that 2 dS m-1 is the peak point of tolerance of salinity that the plant can tolerate without reducing productivity.

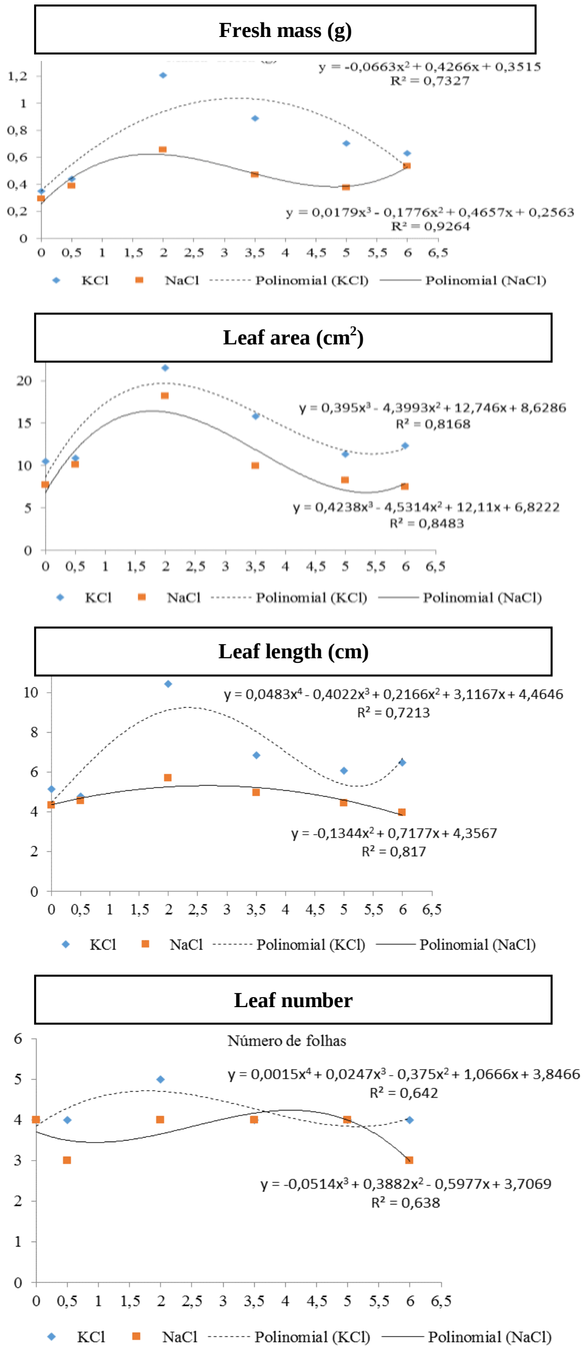
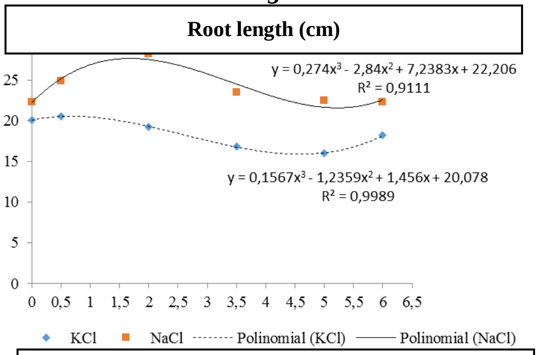


Table 2. Test of means for the evaluated agronomic attributes fresh mass, leaf area, leaf dry mass, root length, leaf length and number of leaves with different salt sources and different levels concentrations.

Condutivity (dSm^{-1})	fress leaf mass (g)		Leaf area (cm^2)		Dry Leaf mass (g)		Root,length (cm)		Leaf length (cm)		Leaf number	
Salts	**NaCl**	**KCl**	**NaCl**	**KCl**	**NaCl**	**KCl**	**NaCl**	**KCl**	**NaCl**	**KCl**	**NaCl**	**KCl**
0	0,293d	0,349d	7,69cd	10,48745c	0,041ab	0,053bc	22,3b	20,0a	4,33bc	5,14bc	4 ns	4 ns
0,5	0,390c	0,441d	10,1b	10,87909c	0,040ab	0,047bc	24,9ab	20,6a	4,54bc	4,76c	4 ns	4 ns
2.0	0,656a	1,211a	18,2a	21,52946a	0,050a	0,065b	28,2a	19,2ab	5,69a	10,4a	4 ns	5 ns
3.5	0,470b	0,888b	9,98bc	15,80945b	0,037ab	0,093a	23,5ab	16,8bc	4,95ab	6,84b	4 ns	4 ns
5.0	0,377c	0,705c	8,25bcd	11,32445c	0,0127b	0,049bc	22,5b	16,0c	4,44bc	6,07bc	4 ns	5 ns
6.5	0,354cd	0,630c	7,52d	12,32582	0,024b	0,030c	22,3b	18,2abc	3,97c	6,47bc	3 ns	4 ns



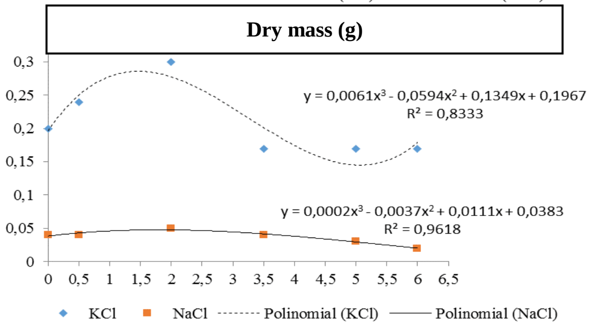


Figure 1. Graphs of interaction between fresh mass, leaf area, leaf length, root length, number of leaves and dry leaf mass of different sources and levels of salt concentration.

Besides all we also remark that although the conductivities evaluated have the same concentrations the amount of salt is different because of their specific mass, therefore the results can also be useful for who do not hat the salt measure equipment only by using scale in g units.

According to Nawaz et al. (2014) under adverse conditions, plants develop forms of adaptation, resulting in biochemical and / or morphological changes. The decrease of the leaf area relates to one of the mechanisms of plant adaptation to saline stress, reducing the transpiration surface. According to Liu; Jiang (2015), about 80% of the reduction of radish growth, caused by salinity, can be attributed to the reduction of leaf expansion and, consequently, to the reduction of light interception, while the other 20% due to the decrease of the stomatal conductance.

The reduction in leaf growth represents a defence mechanism of plants under conditions of water and saline stress, reducing water losses through transpiration (Taiz & Zeiger, 2009). However, it also represents changes in the partition of assimilated photos and reduction in the area destined to the photosynthetic process, which can result in yield losses.

Bione et al., (2014), in a study evaluating the basil production in a hydroponic system under salinity, verified that the fresh and dry mass of the aerial part were linearly reduced with the salinity increase of the brackish waters produced with NaCl, registering for each unit increase in the salinity of these waters (dS m-1) reductions of 7.86%.

Conclusions

We observed an increase in fresh mass, leaf dry mass, leaf area, root growth and leaf length up to 2.0 dS m-1 for NaCl and KCl salts while from 2.0 dSm-1 promoted a yield loss in all the evaluated attributes,

The application of water containing KCl overcame NaCl promoting increase in fresh leaf mass content, leaf dry mass, root length, leaf length and larger leaf area.And we concluded that sources and salinity levels do not affect the number of leaves.

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