SALT TOLERANCE OF TWO RICE VARIETIES FOR UPLAND AND IRRIGATED CULTIVATION

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ABSTRACT: Salinity is one of the stresses that most impact world rice production. In this way, understanding how varieties of this crop behave under salt stress can help measure the impact of selection pressure on the formation of varieties with different cultivation recommendations in tolerance to abiotic stresses. In this sense, two rice varieties, one from the irrigated system and the other from the rainfed system, were subjected to salinity treatments (0 and 80 mM NaCl) to assess tolerance. It was also verified if the tolerance related to specific characteristics such as compartmentalization of toxic ions in the stems or even potassium efflux reduction, suggested by some research. The results showed higher tolerance to salinity for the São Francisco variety, recommended for irrigated cultivation, than for the BRS Esmeralda variety, recommended for rainfed cultivation. However, the high tolerance was not related to bigger compartmentalization of toxic ions in the stem or any other plant organ. Despite this, this variety showed more considerable potassium retention in the leaves and stems, even with tremendous pressure to efflux this ion promoted by salinity.
KEYWORDS: Ion accumulation, salinity, *Oryza sativa* L.

TOLERÂNCIA À SALINIDADE DE DUAS VARIEDADES DE ARROZ PARA CULTIVO DE SEQUEIRO E IRRIGADO

RESUMO: A salinidade é um dos estresses que mais impactam a produção mundial de arroz. Desta forma compreender como variedades desta cultura se comportam sob estresse salino pode ajudar a dimensionar o impacto da pressão de seleção para a formação de variedades com distintas recomendações de cultivo em relação à tolerância a estresses abióticos. Neste

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sentido, duas variedades de arroz, uma de sistema irrigado e outra de sequeiro, foram submetidas à salinidade (0 and 80 mM NaCl) para se avaliar a tolerância, e se ela está relacionada a características específicas como a compartimentalização de íons tóxicos no colmo ou mesmo a redução do efluxo de potássio, como sugerido por algumas pesquisas. Os resultados apontaram maior tolerância à salinidade para a variedade São Francisco, recomendada para cultivo irrigado, que para a variedade BRS Esmeralda, recomendada para cultivo de sequeiro. Entretanto, a maior tolerância não pôde ser relacionada a uma maior compartimentalização de íons tóxicos no colmo ou em qualquer outro órgão da planta, apesar disso, essa variedade apresentou maior retenção de potássio nas folhas e colmo mesmo com grande pressão para efluxo desse íon promovido pela salinidade.

PALAVRAS-CHAVE: Acúmulo de íons, estresse abiótico, *Oryza sativa* L.

INTRODUCTION

The plants are subject to several conditions of biotic and abiotic stresses, being quite common the stresses caused by the salinity (soil or irrigation water) and by flooding, which causes hypoxia conditions. These stresses significantly impact the productivity and availability of rice-growing areas worldwide (Pandey *et al.*, 2017). In Brazil, rice varieties are developed for cultivation under dry conditions or in an irrigated system, with most of the rice produced in the country being cultivated under irrigation, which is subject to salinity and hypoxia. Furthermore, approximately one-third of the irrigated areas worldwide, which provide 40% of global food production is affected by salinization (El-mageed *et al.*, 2018). It is essential to highlight that cytosolic potassium homeostasis and various tissues' ability to retain this ion in plants under stress can be essential for salinity tolerance. However, evidence suggests that an initially stress-induced K^+ efflux is also crucial in mediating plant growth and development under hostile conditions (Shabala, 2017). Nevertheless, K^+ efflux restriction can also be related to abiotic stress tolerance, as shown in mutant Arabidopsis plants (gork1-1) (Wang *et al.*, 2016). Thus, given the above, it was intended to assess whether the tolerance to salt stress is related to the type of cultivation technique for which the rice varieties were selected, the toxic ions compartmentalization in the stems (Peng *et al.*, 2016), and the reduction of the K^+ efflux.

MATERIAL AND METHODS

Rice seeds of varieties São Francisco (SF) and BRS Esmeralda (ES) were provided by the Brazilian Company of Agricultural Research (Embrapa). The SF variety is developed for irrigated cultivation while ES for rainfed or upland cultivation (Castro *et al.*, 2014; EMBRAPA, 2013). Seeds were sown in germitest paper and placed in the BOD chamber under controlled conditions: 30 °C, relative humidity greater than 90%, and a 12-h photoperiod. The seedlings grew in BOD chamber until the coleoptile reached a size of approximately 5 cm, which took ten days. Three ten-day-old seedlings were transferred to each plastic pot (3.0 L) containing modified Clark's nutrient solution (Clark, 1975) Fe–EDTA concentration of 0.076 mM. The nutrient solution had 5.5 ppm or mg L^{-1} of dissolved oxygen. The experiments were carried out under greenhouse conditions: average air temperature of 33 °C during the day and 27 ºC at night, average air relative humidity of 75%, and a 12-h photoperiod. After growing in the greenhouse, plants with twenty-five days old of both varieties were submitted to saline treatments. The experiment was performed in a complete randomized design, in a 2 × 2 factorial scheme, composed of two varieties (SF and ES) and two NaCl levels (0 and 80 mM). Salinity treatments were applied as Lopes *et al.* (2020). The data were subjected to the Shapiro-Wilk test before being subjected to variance analysis (two-way ANOVA). Sidak's test separated the mean treatment values ($p < 0.05$), using the GraphPad Prism 8 program.

The samples were collected ten days after the application of salt stress. The plant material was divided into leaves, stems, and roots. After measuring the fresh mass, the material was kiln-dried in a forced-air circulation oven at 60 °C for 48 h for determining the leaves, stems and root dry mass. The inorganic ions (Na^+, K^+, and Cl^-) were extracted from leaves, stem, and roots, according to Cataldo *et al.* (1975). For this, 50 mg of the dry mass was finely powdered and homogenized with 5.0 mL of deionized water for one hour at 75 ºC. The tubes containing the homogenate were vigorously shaken every 15 min and then centrifuged at 3,000 x g for 10 min. The obtained supernatant was filtered on filter paper and stored at -20 °C. It was then used for Na^+ and K^+ ions determination using flame photometry (Micronal®, model B462, Brazil), according to the methodology described by Malavolta *et al.* (1989), being carried out one read for each ion. The Cl^- content was determined according to the colorimetric method of Gaines *et al.* (1984) with the aid of a spectrometer set at 460 nm and a standard curve with NaCl.

RESULTS AND DISCUSSION

There was a significant interaction between varieties and salinity for growth parameters, except shoot length (Fig. 1). The salinity reduced the dry leaf mass and shoot length in both varieties (Fig. 1a, d). However, it reduced the dry mass of stems and roots only in ES by 34% and 53% (Fig. 1c, d). On the other hand, it reduced the root length only in SF by 15% (Fig. 1e). The salinity damage was more accentuated in ES since all the plants' constituent parts had a significant dry mass reduction. The SF showed more tolerance to salt stress than ES, perhaps by investing less in the growth of stems and roots, considering this variety was selected to produce in an environment with more access to water. Although rice is considered a relatively salt-sensitive crop (Fogliatto *et al.*, 2020), the degree of sensitivity or tolerance is different in distinct varieties.

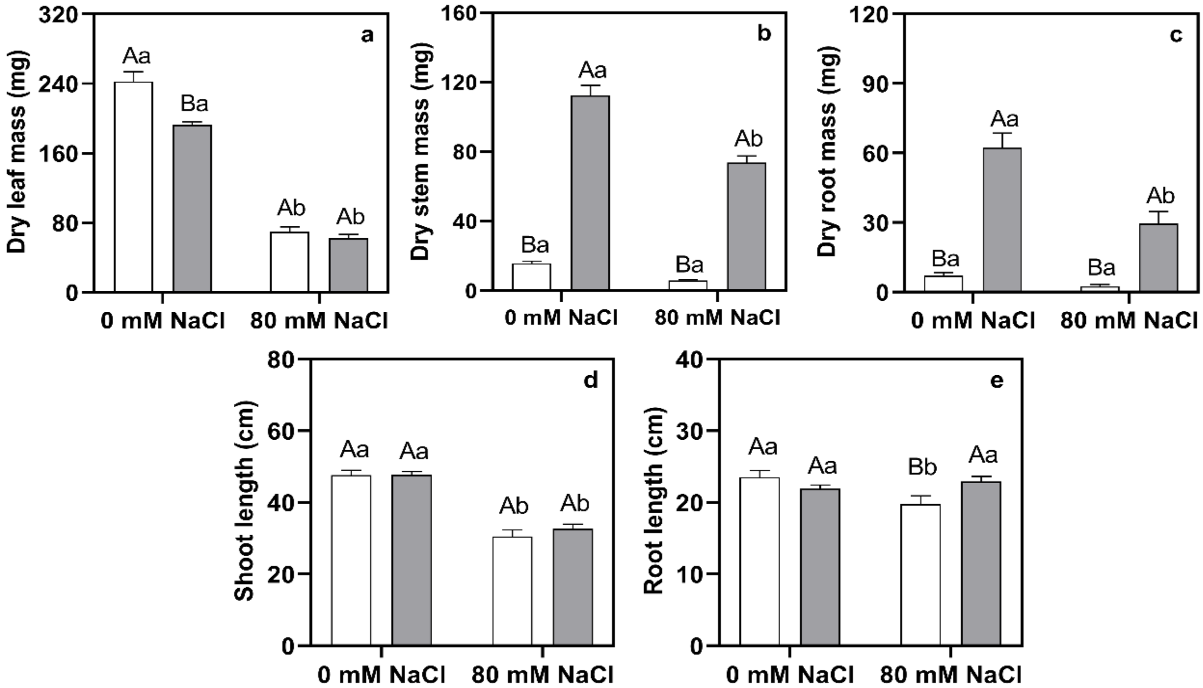

Figure 1. Growth analysis of rice plants var. São Francisco (*white bars*) or BRS Esmeralda (*grey bars*) under no-saline or saline (80 mM NaCl) conditions for ten days. Dry mass of leaves (**a**), stems (**b**), roots (**c**), and shoot (**d**) and root (**e**) length. For each variable, the capital letters and lowercase letters compare the variety and salinity treatments, respectively. All subfigures exhibit a significant interaction between treatments except **d**, according to *F*-test ($p < 0.05$). Error bars represent ± standard error and means represent n = 6.

There was no significant interaction between rice varieties and salinity in the accumulation and distribution of Na^+, Cl^-, and K^+ ions, except for the leaves' K^+ content (Fig. 2). Salinity caused a significant increase in Na^+ and Cl^- in all analyzed plant organs, as in other species (Oliveira *et al.*, 2020), mainly in stems (Fig. 2a-f) (Peng *et al.*, 2016). However, it induced less accumulation of K^+ in all parts of the plant (Fig. 2g-i). The ES showed a higher Na^+ content than SF only in the stems under salt conditions, although SF and ES had a similar accumulation of Na^+ without salinity (Fig. 2a-c). Besides, ES had lower Cl^- content than SF in leaves and roots (Fig. 2d-f) and lower K^+ content in leaves and stems (Fig. 2g-i).

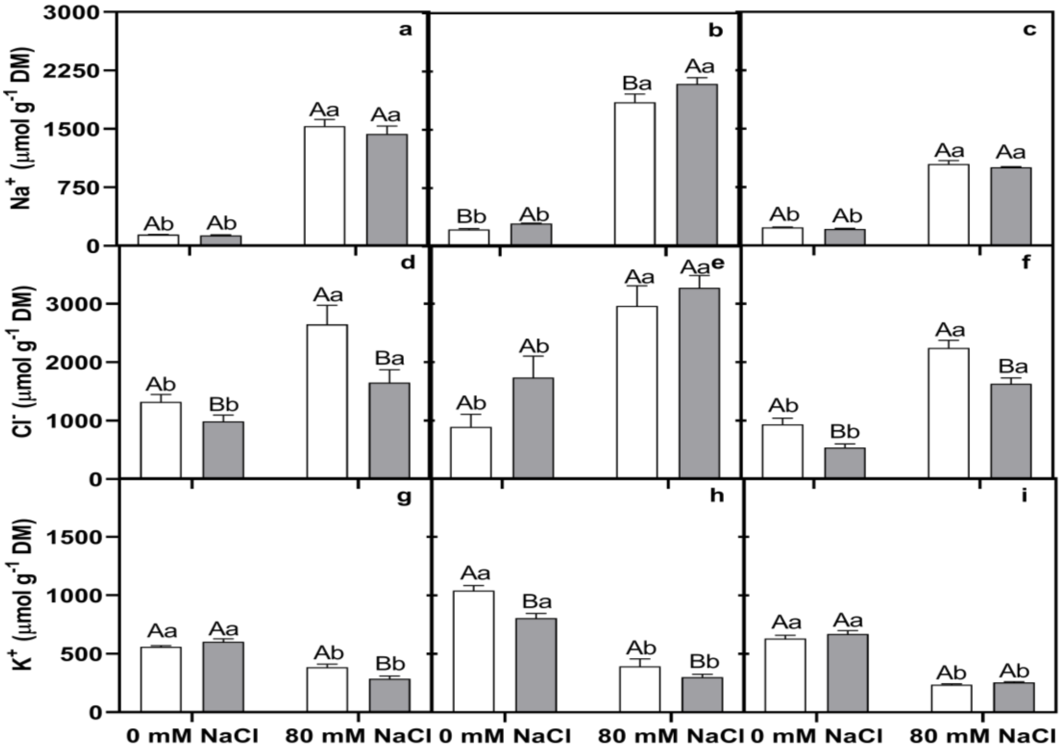

Figure 2. Inorganic ions of rice plants var. São Francisco (*white bars*) or BRS Esmeralda (*grey bars*) under no-saline or saline (80 mM NaCl) conditions for ten days. Na^+ content in leaves (**a**), stems (**b**), and roots (**c**); Cl^- content in leaves (**d**), stems (**e**), and roots (**f**); and K^+ content in leaves (**g**), stems (**h**), and roots (**i**). For each variable, the capital letters and lowercase letters compare the variety and salinity treatments, respectively. All subfigures exhibit a not significant interaction between treatments except **g**, according to *F*-test ($p < 0.05$). Error bars represent ± standard error and means represent n = 6.

The SF was slightly more salt-tolerant than ES, indicating differences in the tolerance that may be linked to phenotypic changes promoted by the pressure of selecting varieties for their type of cultivation. There were no differences in the toxic ions' compartmentalization in the stems. Despite a more significant accumulation of Cl^- in SF's leaves and roots, it did not present any more significant damage than ES. In contrast, the SF showed a significant reduction of the K^+ efflux in leaves and stems, a positive attribute to the abiotic stress tolerance (Wang *et al.*, 2016).

CONCLUSIONS

The SF was slightly more tolerant to salinity than ES, with higher K^+ content in shoot than ES without higher accumulations of toxic ions in the stems or restriction of its contribution to the plant.

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