EFFECT OF SILICON ON GROWTH AND ON ACCUMULATION OF IONS IN YOUNG RICE PLANTS SUBMITTED TO SALINE STRESS

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ABSTRACT: Beneficial effects of silicon fertilizing have been observed in many vegetable species, especially when submitted to biotic and abiotic stress. Among the abiotic factors, salinity of the soils has been constituted one of the most serious issues to irrigated agriculture in many areas of the world. This study had as objective to analyze the influence of the silicon in rice plants submitted to crescent levels of salinity. Plants were cultivated in a nutritive solution containing NaCl and Si at a greenhouse from the Biochemistry and Molecular Biology Department, Federal University of Ceará. Adopted experimental outlining was entirely randomized with four repetitions, at a 3 x 3 factorial scheme, being used three NaCl levels (0, 50 and 100 mM) and three Si levels (0, 2 and 4.0 mM). After 15 and 30 days from the beginning of the treatment application it was analyzed: growth and inorganic solute. Salinity reduced plants growth and silicon was able to attenuate this reduction on the intermediate salinity level. Na^+ and Cl^- ions were increased and K^+ and NO_3^- were reduced on leaves and roots of the plants submitted to salinity, with Si content reducing excessive Na^+ and Cl^- accumulation on the shoot of the plants ended the 30 days. Adequate nutrition with Si was able to attenuated the effects provoked by salinity, collaborating to rice plants' tolerance to this stress.

KEYWORDS: Oryza sativa (L.), salinity, Silicon, Stress.

EFEITO DO SILÍCIO NO CRESCIMENTO E NO ACÚMULO DE ÍONS EM PLANTAS JOVENS DE ARROZ SUBMETIDAS AO ESTRESSE SALINO

RESUMO: Efeitos benéficos da adubação com silício têm sido observados em várias espécies vegetais, especialmente quando estas estão submetidas a estresse biótico ou abiótico. Dentre os fatores abióticos, a salinidade dos solos tem se constituído em um dos mais sérios problemas

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para a agricultura irrigada em diversas partes do mundo. Esse estudo teve como objetivo analisar a influência do silício em plantas de arroz submetidas a níveis crescente de salinidade. As plantas foram cultivadas em solução nutritiva contendo NaCl e Si em casa de vegetação pertencente ao Departamento de Bioquímica e Biologia Molecular, da Universidade Federal do Ceará. O delineamento experimental adotado foi o inteiramente casualizado com quatro repetições, em esquema fatorial de 3 x 3, sendo utilizado três níveis de NaCl (0, 50 e 100 mM) e três níveis de Si (0, 2 e 4,0 mM). Após 15 e 30 dias do início da aplicação dos tratamentos analisou-se: crescimento e solutos inorgânicos. A salinidade reduziu o crescimento das plantas e o silício foi capaz de atenuar essa redução no nível intermediário de salinidade. Os íons Na^+ e Cl^-foram aumentados e os teores de K^+ e NO_3^- reduzidos nas folhas e raízes das plantas submetidas a salinidade, com o Si atenuando o acúmulo excessivo de Na^+ e Cl^- na parte aérea das plantas aos 30 dias. Uma nutrição adequada com Si foi capaz de atenuar os efeitos provocados pela salinidade colaborando para tolerância das plantas de arroz a esse estresse.

PALAVRAS-CHAVE*:* Oryza sativa (L.), salinidade, silício, estresse.

INTRODUCTION

Among the annual cultures, rice is one of the most important cereals in the world, for it constitutes the basic diet of over 50% of the world's population with great highlight from the economic and social perspective (Fageria et al., 2007). Just like any other agriculture culture, rice production is influenced by a number of environmental factors. Among the abiotic factors, soil salinity has constituted itself as one of the most serious problems to irrigated agriculture in many areas of the world (Lima Junior et al., 2010).

Elimination of the effects of salinity in the soil and plants by the traditional methods may be temporary and unsatisfactory in regions with limitations regarding available water quantity and quality. Before that, lasting character techniques have been searched, like the selection of species tolerant to salinity (Silva et al., 2000), or the employ of chemical agents (Melloni et al., 2000; Miranda et al., 2002) to protect the plants against the toxic effects of NaCl, as professed by Ahmad (1987), Bradbury & Ahmad (1990) and Liang et al. (1996), when verifying that silicon application stimulated growth of wheat plants, mesquite and barley, cultivated in saline mean.

Silicon is not considered as part of the essential nutrient group or functional, from the physiological point of view, to growth and development of plants, however, its absorptions brings many benefits, especially to rice. This demonstrates the agronomical essentiality of this element for the increase or sustainable productions of this culture (Barbosa Filho et al., 2001).

Therefore, this research aims to evaluate the influence of silicon application on the growth, biochemical and photosynthetic metabolism in rice plants submitted to salinity.

MATERIAL AND METHODS

Rice seeds cv. SCSBRS, were selected and put to germinate between two paper sheets, “germitest” type. The rolls were placed in a BOD germination chamber, and kept at a temperature of 25°C and a photoperiod of 12h. Ten days after sowing, seedlings were transferred to basins containig 10 L of 50% Clark’s nutritive solution to become acclimatized.

After 10 days of acclimatization, plants were transferred to 3 L buckets (two plants/bucket) containing 100% Clark’s nutritive solution, each bucket being considered as a parcel. On this day application of 0, 2 and 4 mM Na_2Si_3 and 0, 50 and 100 mM NaCl was initiated. At 15 and 30 days measurement of plant height was performed, next, plants were separated in shoot and root, being determined foliar area with the area meter “LI 3100 Area Meter” (Li-Cor., In. Lincoln, Nebraska, USA).Collected material was frozen at -20°C and subsequently lyophilized. After this process, dry matter was determined (DM) of the shoot and roots. Lyophilized material was macerated and stored in glass vials at 4°C for further utilization.

The raw extracts were prepared accordingly with the Rinne et al. (2012) method. Contents of Na^+ and K^+ were determined by flame photometry (Malavolta et al., 1997), being performed a read on the flame photometer to each properly diluted extract, Cl^- contents were determined accordingly to the Gaines’ et al. (1984) method and NO_3^- content was determined through the salicylic acid method (Cataldo et al., 1975).

Adopted experimental outlining was entirely randomized with four repetitions, in factorial 3 x 3 scheme, having as treatments the combination of three levels of NaCl (0, 50 and 100 mM) and three levels of SiO_2 (0, 2 and 4 mM). Data were subdued to variance analysis, being the comparison among averages by the Tukey’s test at significance level at 5% performed, with aid of the SISVAR 5.0 program.

RESULTS AND DISCUSSION

On the 15th and 30th days, the DMAP and DMR were significantly affected by the salinity when compared to the control plants at different silicon levels (Figs. 1A, 1B, 1C and 1D). These results show a typical response of glycophytes to salinity of the outer mean, presenting a significant decrease of dry matter of different plants organs (Azevedo Neto et al., 2004).

Application of Si promoted, in conditions of control, and on the lower stress level (50 mM), a gradual increase on DMAP and DMR on both analyzed periods, in a manner that plants under this salinity level and treat with 4 mM of S, presented an increase in DMAP of 57.1% and 37.2% in comparison to plants cultivated on the absence of Si on the 15th and 30th days of stress, respectively. The DMR under these conditions had similar behavior, presenting an increase of 26.1% on the 15th day and a significant increase of 85.8% on the 30th day of salt exposition. Tahir et al. (2006) also observed on wheat culture that the application of silicon increased significantly dry matter and productivity of grains of the culture, both on genotypes cultivated under normal conditions, as on saline conditions, indicating its importance on the mineral nutrition of this plant.

The Foliar Area (FA), characterized as one of the most affected parameters by saline stress, was significantly inhibited by the salinity on both NaCl concentrations and on both analyzed periods of stress, registering reductions of 78% and 76% on the 15th and 30th days, respectively, when compared to the control plants, independently of silicon levels (Figs. 2A and 2B).Reduction of foliar area, under such conditions, is important to the maintenance of the high hydric potential of the plant, obtained through the diminished perspiration (Dantas et al., 2003). Reduction on the FA could be observed in many vegetable species submitted to saline stress, such as cotton (Oliveira et al., 2012), bean (Freitas et al., 2011) and corn (Feijão et al., 2011).

Addition of silicon promoted increase of the foliar area in rice plants only on control conditions, not having significant effect on the saline treatments both on the first 15 days of stress, as on 30 days after (Figs. 2A and 2B). These results corroborate with what was found by Gong et al. (2003), that observed silicon application on wheat cultivated in vases with soil increased its height, foliar area and plant dry matter.

Salinity provoked reduction on the plants' length significantly on both NaCl exposure periods, being more evident when they were submitted to the highest salinity level (100 mM) (Fig. 2C and 2D). Similarly, Rodrigues et al. (2005) working with rice plants of cv. Formoso in a greenhouse, submitted them to the water salinity level of 8,5 dS m^{-1}, and verified reductions of 33.6% on height, when compared to the development of witness plants. It is possible to observe that some of the plants nourished with Si at 4 mM for 30 days were the ones with least decrease on height as the increase of NaCl in the cultivation solution, where at 100 mM these plants presented superior values to the ones non-nourished with this mineral. Reis et al. (2008), during two years of conducting experiments, verified greater height of the rice, cultivar IAC 201, for most of the silicon doses utilized.

At 15 days, as expected, the Na^+ contents were considerably increased by the saline treatments on both studied organs, independently of the Si levels utilized. The increase of this ion occurred from the NaCl at 50 mM application, remaining the same value on the highest salt dose (Figs. 3A and 3B).

It was also observed that under salinity conditions (100 mM), during the first 15 days after the stress application, plants nourished with Si at 4 mM accumulated more Na^+ ions, when compared to the others of the Si treatment (Figs. 3A and 3B).

On the radicular system of rice plants the increase of Na^+ levels were even more significant under saline stress, on both periods, being the average three times superior to the control treatment (Figs. 3B and 4B). This behavior has been confirmed on different literature species, sorghum (Silva et al., 2014), cowpea (Praxedes et al., 2010), cotton (Freitas et al., 2011).On the 30th day, Na^+ contents were gradually increased with increase of salinity in the nutrient solution (Figs. 4A and 4B), meanwhile Si supplementation reduced accumulation of this ion on the shoot of the plants cultivated in a 100 mM of Na^+ solution (Fig. 4A).

Differently of what was observed with the Na^+, saline stress reduced K^+ contents on the leaves and rice roots, both on the 15th day (Figs. 3C and 3D), as on the 30th day (Figs. 4C and 4D). Reductions on the K^+ contents on leaves and roots were also found on corn (Azevedo Neto et al., 2004), sorghum (Netondo et al., 2004) and on jatropha (Silva et al., 2009), submitted to salinity. This is due to physico-chemical similarities of the Na^+ and K^+ions, that make the K^+ transporters may be used to Na^+ absorption when the latter is found in excess on the growth mean, which may result in K^+ deficiency (Maathuis & Amtmann 1999).

The application of Si did not have positive effects for this variable only in the area shoot in the two periods of stress at 50 mM NaCl, where it obtained increases around 25% in relation to the plants without nutrition with silicon. Yin et al. (2013) reported that the short-term application of silicon reduces the Na^+ concentration in the sorghum leaf but does not increase the K^+ content. These studies indicate that silicon may mitigate the adverse effects of salinity, preventing the absorption of Na^+ by the root and / or its transport from roots to shoot.

Chloride (Cl^-) contents on the shoot were not affected by salinity past 15 days of stress (Fig. 3E), except on plants nourished with a higher dose of Si, which presented an increase on this variable. On this period salt effect was more evident on the roots, significantly increasing this ion, independently of the silicon concentration applied (Fig. 3F).

Nitrate (NO_3^-) contents past 15 days were gradually reduced on both plants' organs with the increase of NaCl concentration in the nutritive solution (Fig. 3G and 3H), in the absence or in any levels of silicon applied. Past 30 days, the reduction on the accumulation of NO_3^- in function of salinity occurred on non-supplemented with Si plants (Fig. 4G and 4H).

Past 30 days the chloride contents on both analyzed organs were significantly increased by saline stress (Fig. 4E and 4F), although, on the shoot, the Si reduced significantly these contents on stressed plants on both doses of NaCl. The roots, on the other hand, had no silicon effect on the studied salt concentrations.

CONCLUSION

Salinity reduced the growth of the plants and silicon was able to attenuate this reduction on the intermediate salinity level. Ions Na^+ and Cl^- were increased and K^+ and NO_3^- contents were reduced on leaves and roots of plants submitted to salinity, with Si attenuating the excessive accumulation of Na^+ and Cl^- on the shoot of the plants at 30 days.

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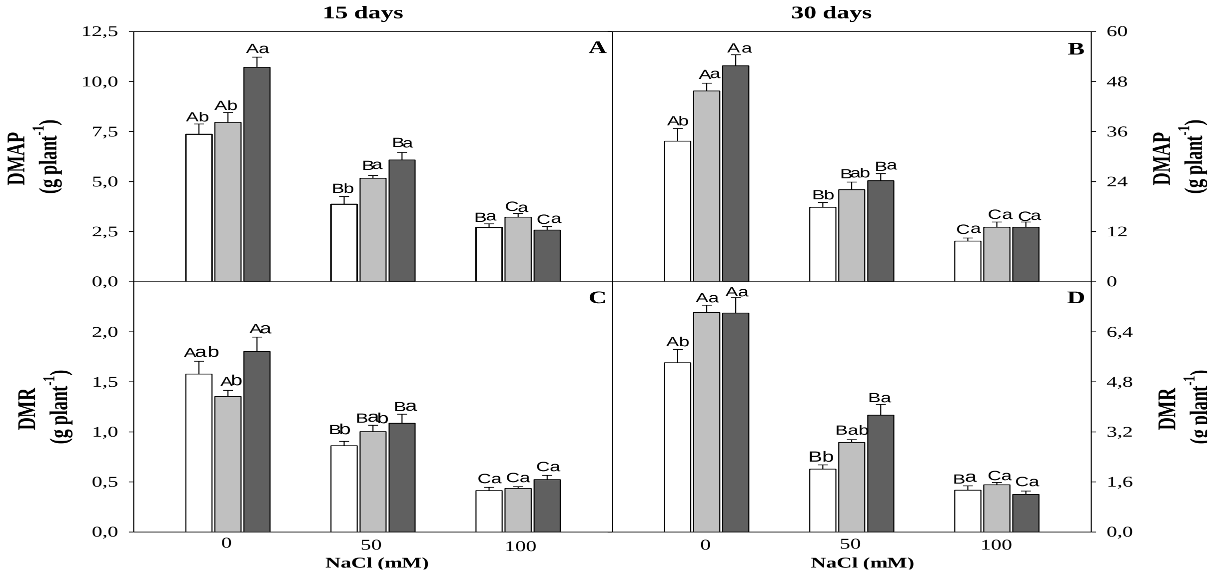

Fig. 1. Dry mass of the shoot (DMAP, A and B) and of the roots (DMR, C and D) of rice plants on 15 and 30 days of stress and nourished with 0 mM of Si ( ), 2 mM of Si ( ) and 4 mM of Si ( ), under different levels of salinity. Capital letter compare levels of NaCl on the same Si level, meanwhile lowercase letters compare Si levels on the same NaCl level. Columns represent average of 4 repetitions and bar the standard error.

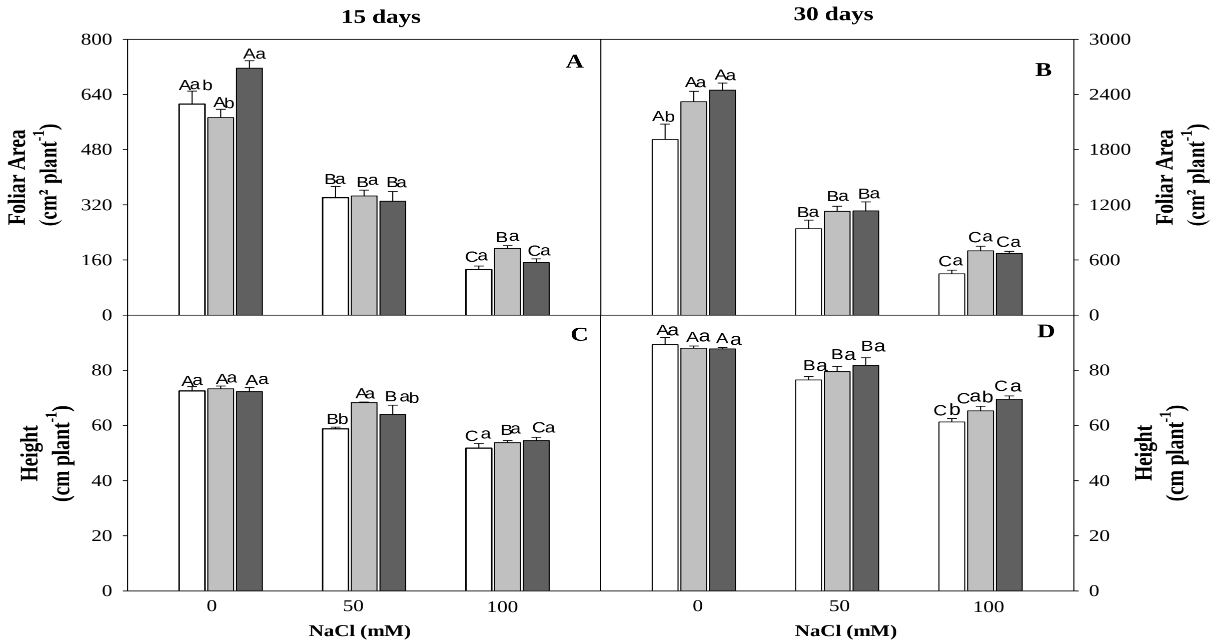

Fig. 2 Foliar area (FA) and Height of rice plants on 15 and 30 days of stress and nourished with 0 mM of Si ( ), 2 mM of Si ( ) and 4 mM of Si ( ), under different levels of salinity. Capital letter compare levels of NaCl on the same Si level, meanwhile lowercase letters compare Si levels on the same NaCl level. Columns represent average of 4 repetitions and bar the standard error.

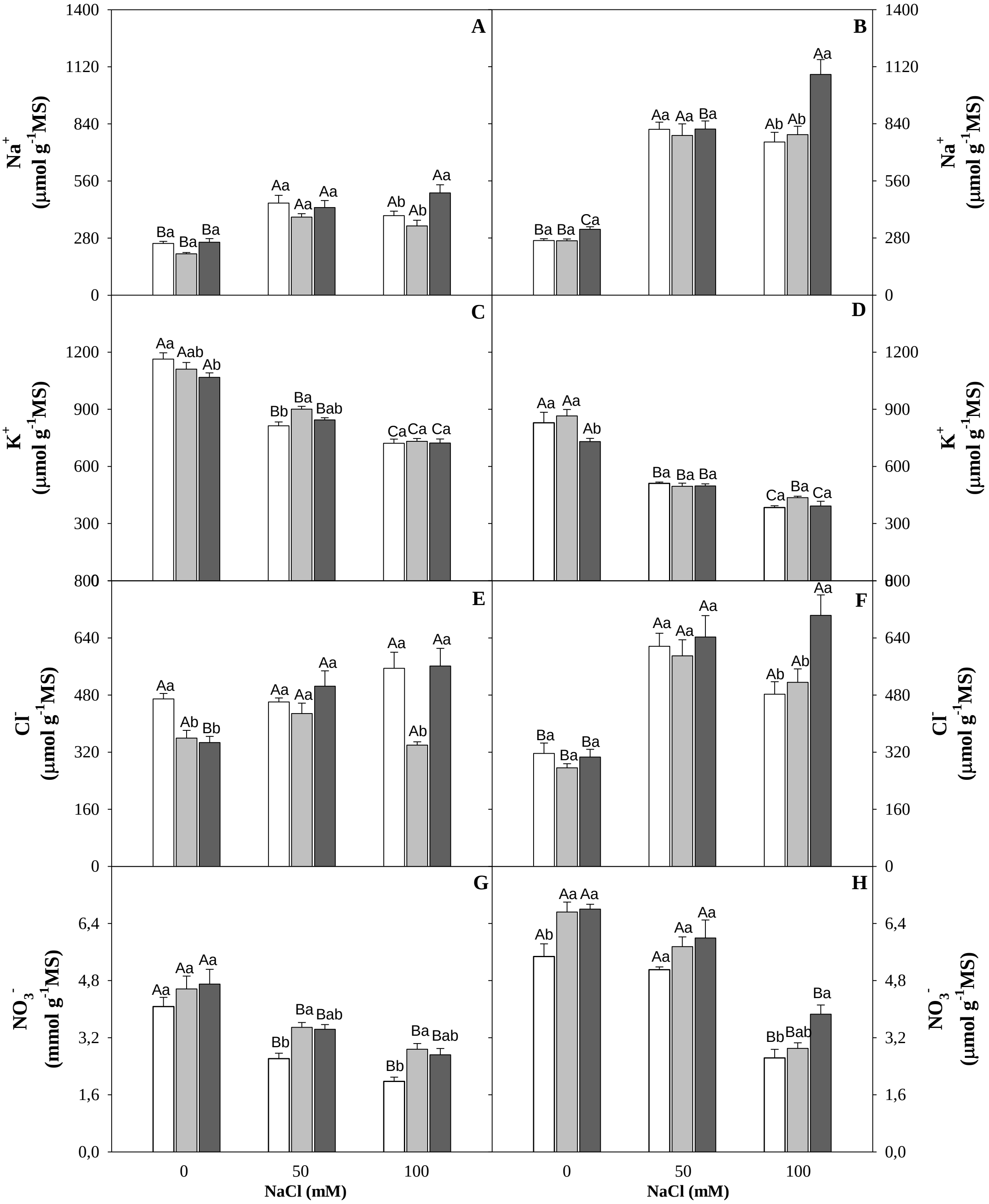

Fig. 3Na^+, K^+, Cl^- and NO_3^- contents on the shoot (A, C, E and G, respectively) and roots (B, D, F and H, respectively) of rice plants on 15 days of stress and nourished with 0 mM of Si (☐), 2 mM of Si (☐) and 4 mM of Si (■), under different levels of salinity. Capital letter compare levels of NaCl on the same Si level, meanwhile lowercase letters compare Si levels on the same NaCl level. Columns represent average of 4 repetitions and bar the standard error

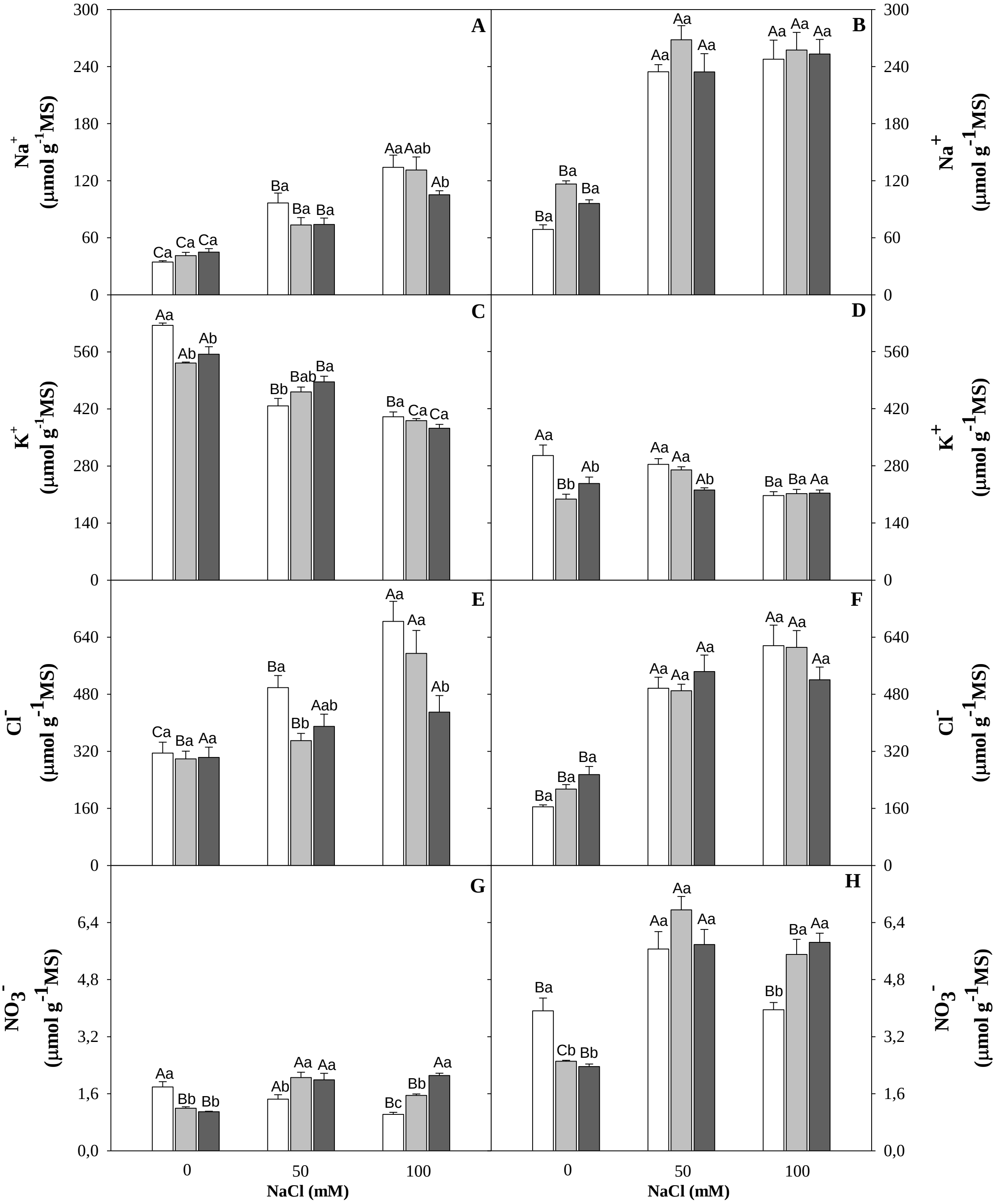

Fig. 4Na^+, K^+, Cl^- and NO_3^- contents on the shoot (A, C, E and G, respectively) and roots (B, D, F and H, respectively) of rice plants on 30 days of stress and nourished with 0 mM of Si (☐), 2 mM of Si (☐) and 4 mM of Si (■), under different levels of salinity. Capital letter compare levels of NaCl on the same Si level, meanwhile lowercase letters compare Si levels on the same NaCl level. Columns represent average of 4 repetitions and bar the standard error.