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EFFECT OF EXOGENOUS SALICYLIC ACID AND SILICON APPLICATION ON SALINITY TOLERANCE OF RICE

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Abstract

Soil salinity remarkably hinders rice growth, development and productivity. The present study was set up to explore the role of exogenous salicylic acid (SA) and silicon (Si) application on the growth and yield performance of two contrasting rice genotypes, namely BRRI dhan41 (salt-tolerant) and BRRI dhan49 (salt-sensitive) under salinity. The experiment was laid out in a randomized complete block design with three replications and four SA and Si treatments such as control (tap water), 100 ppm SA, 100 ppm Si (as $CaSiO_3$) and, co-application of SA and Si (50 ppm each). Results revealed that the maximum plant height (125.2 cm), fresh weight of shoot (267.3 g) and maximum K^+/Na^+ (5.2) were obtained in BRRI dhan49 after sole application of Si under salt stress. Besides, the number of grains per panicle and grains per hill significantly increased in BRRI dhan41 after the sole application of SA (64 and 46%, respectively) and co-application of SA and Si (29 and 21%, respectively), and in BRRI dhan49 with sole SA (182 and 277%, respectively) and Si (75 and 446%, respectively) compared with their respective controls. Besides, we observed that the K^+/Na^+ was increased where the shoot accumulation of Na^+ reduced significantly in both rice varieties after sole and co-application of SA and Si compared with the untreated plants. However, the present findings showed new dimensions regarding the beneficial effects of Si on rice plants which could effectively be utilized to grow and maximize rice production in the saline-prone coastal areas of Bangladesh encountering detrimental effects of salt stress on rice.

Introduction

The currently cultivated rice (*Oryza sativa* L.) varieties are facing significant yield reductions due to the increasing trend of soil salinity in the coastal regions of Bangladesh (Ahmed and Haider, 2014). Though rice has a widespread geographic distribution but the production of rice is very low due to its vulnerability to climate change. In addition to reducing plant growth, photosynthesis, biomass, yield, and water usage efficiency, high salinity also causes physiological drought as well as ion toxicity in plants, which lowers nutrient availability by reducing their osmotic potential (dos Santos *et al.*, 2022; Akram and Ashraf, 2011). Shoot and root growth has been significantly reduced in rice plants due to high osmotic stress (Shrivastava and Kumar, 2015). Salinity reduced the number of spikelets and grains thus causing poor grain yield (Saqib *et al.*, 2012). The most important and injurious effect of salinity is the accumulation of sodium ion (Na^+) and chloride ion (Cl^-) in plant tissues (Nishimura *et al.*, 2011). Wang *et al.* (2019) reported that several adaptation and mitigation strategies have been employed to overcome the harmful effect of high soil salinity in plants. Among them, the exogenous application of salicylic acid (SA) and silicon (Si) already gained considerable attention in alleviating the salinity-induced negative effects. SA is one of the plant growth regulators that provide protection against salinity (Husen *et al.*, 2018). Several morpho-physiological and biochemical processes like growth, ethylene production, photosynthesis, flowering and nitrate metabolism have been reported to be regulated by SA (Hayat *et al.*, 2010).

Besides, Si is known as the second most plentiful element in soil and widely known as beneficial element for plants (Epstein, 1999; Liang *et al.*, 2015). Si application has mitigating effects on salinity-induced negative impacts in different plant species including rice (Somaddar *et al.*, 2022), barley (Khan *et al.,* 2019), wheat (Singh *et al.*, 2022), sorghum (Hurtado *et al.*, 2020). According to Abro *et al.* (2009), application of Si increased plant height in rice and wheat, respectively. Importantly, Si treatment has been reported to reduce Na^+ uptake and enhanced K^+/Na^+ ratio in plants under salinity stress (Garg and Bhandari, 2015). Considering the fact stated above, this study was undertaken to evaluate the effect of foliar application of SA and Si in mitigating the salinity-induced negative impacts in rice.

Materials and Methods

The experiment was carried out at the Field laboratory and Stress Agronomy laboratory, Department of Agronomy and Central laboratory of Patuakhali Science and Technology University, Bangladesh. The experiment area was located at the coordinates of 22°37' N latitude and 89°10' E longitude under Ganges Tidal Floodplain Argo-ecological zone-13. The experiment was carried out in a factorial randomized complete block design (RCBD) where two rice varieties *viz.*, BRRI dhan41 and BRRI dhan49 were used as factor A and exogenous application of 100 ppm SA (salicylic acid), 100 ppm Si (in the form of $CaSiO_3$) and co-application of SA and Si (50 ppm each) as factor B. A control treatment (tap water) was included with factor B to compare the treatment and non-treatment effects on the growth parameters of rice genotypes with three replications. SA and Si solutions were foliar sprayed. A surfactant Tween-20 at concentration of 0.5% (v/v) was added with SA and Si Solution. The exogenous SA and Si application was done two times (60 and 80 days after sowing).

The experiment was set up in plastic pots using the soil culture method and the soil was sandy loam. Urea, triple superphosphate, muriate of potash, gypsum, and zinc sulphate fertilizers were added to the soil according to the recommended dosage (FRG, 2018). Four to five pre-germinated seeds were planted in soil and two seedlings having uniform growth were kept. Subsequently, the soil salinization was introduced using table salt (NaCl) in the form of irrigation water. We used 5.0 g NaCl per liter of tap water to treat the rice plants with saline water having an EC of approximately 9.8-10 dS/m. Saline irrigation was applied six (6) times at 7-day interval starting from 45 days of rice seedlings after sowing. At the same time, the control plants were treated with tap water only.

The important growth and yield attributes like plant height, root length, number of effective tillers, fresh and dry biomass, grain yield, as well as shoot Na^+ and K^+ contents were recorded following the basic principles.

Briefly, the amount of Na^+ and K^+ in the rice shoots was measured following the procedure as described by Krishnamurthy *et al.* (2016). Rice shoot sample of 0.5 g was used for digestion with 10 ml of the di-acid mixture (2:1 of nitric acid and perchloric acid). Then properly digested leaf sample's volume was made up to 100 ml with distilled water in a 100 ml volumetric flask.

After filtering the solution by Whatman filter paper grade-42 the amount of Na^+ and K^+ was measured using a flame photometer (BIOBASE, Model: BK-FP640).

The effects of treatments means were compared using Tukey's honestly significant difference (HSD) using computer based statistical program JMP 8 (JMP®8, SAS Institute Inc., Cary, NC, 1989-2019).

Results and Discussion

Effect of exogenous of SA and Si on different growth characters of rice under salt stress

Plant height and root length

The foliar application of SA and Si significantly enhanced plant height by 28 and 29%, respectively in BRRI dhan49 as compared with control, which were statistically similar (Figure 1A). The lowest plant height (88 cm) was observed in BRRI dhan41 after the co-application of SA and Si which was statistically similar to the control. It was also noticed that plant height of BRRI dhan49 under saline medium increased by 13% while treated with SA alone and no significant difference was observed after sole application of Si and co-application of SA and Si over control (Figure 1A). In case of the salt-tolerant var. BRRI dhan41, root length was significantly increased by 25 and 11% after sole application of SA and Si compared with the control. Contrastingly, in the sensitive BRRI dhan49, the root length reduced significantly by 22% while treated with SA and Si together, and no significant effect was observed due to the sole application of SA and Si over control under saline condition (Figure 1B). Several studies also showed that plant height and root length significantly reduced under salt stress, which was subsequently ameliorated by the application of SA (Jini and Joseph, 2017; Mahdieh *et al.*, 2015; Ali and Mahmoud, 2013).

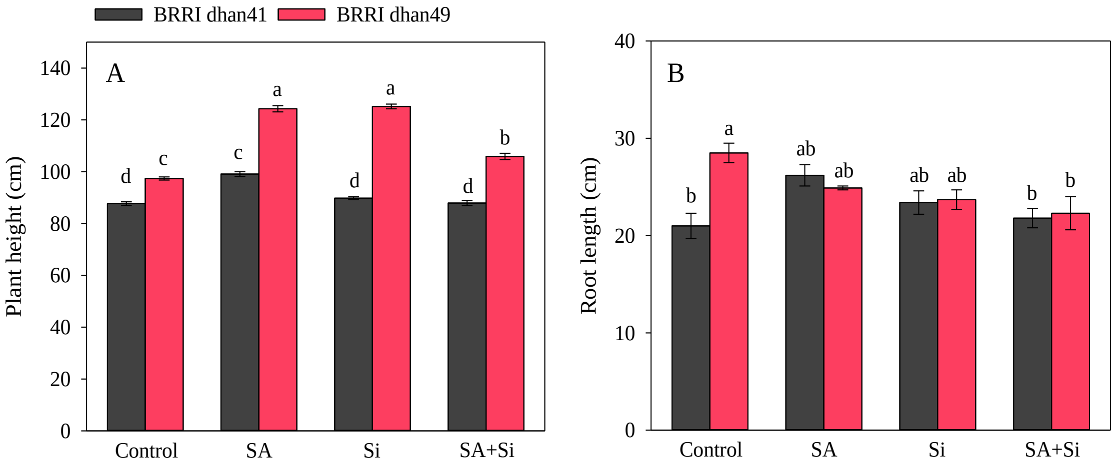

Fig. 1. Effect of salicylic acid (SA) and silicon (Si) on (A) plant height and (B) root length of rice under salt stress (10 mS cm^{-1}).

Effective tillers per hill

The variety BRRI dhan41 had no significant difference in the number of effective tillers per hill after the sole and co-application of SA and Si. Whereas, the sensitive variety BRRI dhan49 remarkably increased effective tillers per hill by 206 and 163%, respectively after sole application of SA, and co-application of SA and Si over control plants under salt stress (Figure 2).

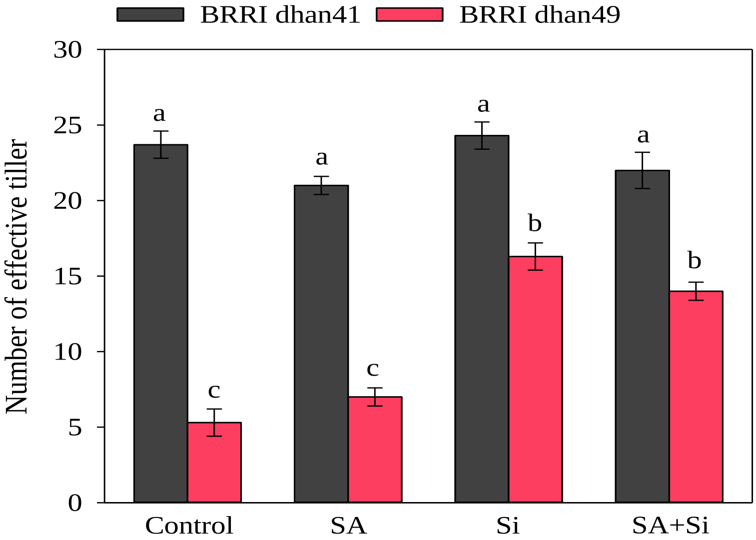

Fig. 2. Effect of salicylic acid (SA) and silicon (Si) on number of effective tiller.

Shoot-root fresh and dry weight

Shoot fresh weight showed a significant improvement by 8 and 39% due to the sole application of Si, and co-application of SA and Si in the tolerant rice var. BRRI dhan41 as compared with the untreated plants (Figure 3A). However, the sensitive var. BRRI dhan49 showed a significant reduction in shoot fresh weight from sole SA application (13%) and combined application of SA and Si (9%) when compared with control plants. However, no significant variation was observed in shoot fresh weight due to the application of Si compared to the control plant. Besides, co-application of SA and Si significantly enhanced shoot dry weight by 27% in BRRI dhan41; whereas, no significant variation was observed in both the rice varieties due to the sole application of SA and Si (Figure 3B). In case of root fresh weight, application of SA and Si significantly reduced root fresh weight by 14 and 19% respectively, while combined application of SA and Si remained statistically similar to the control plants of BRRI dhan41. Likewise, BRRI dhan49 showed significant reduction due to the application of sole SA (28%) while other treatments (Si and, combined SA and Si) statistically similar to the control (Figure 3C). Besides, BRRI dhan41 significantly reduced root dry weight by 27 and 37% after sole application of SA, and combined application of SA and Si, over control. Similarly, in BRRI dhan49, root dry weight was significantly reduced by 28 and 29%, respectively when treated with sole SA and Si. However, no significant difference of root dry weight was found from co-application of SA and Si over control plant (Figure 3D). Several studies also revealed that Si application enhances shoot fresh and dry weight by reducing the salt-induced negative impacts in rice and barley (Farooq et al., 2015; Flam-Shepherd et al., 2018 and Somaddar *et al.*, 2022). However, Mahdieh *et al.* (2015) and Somaddar *et al.* (2022) observed that Si application had no significant effects on the root fresh and dry weight of rice under salt stress, which is consistent with the present findings.

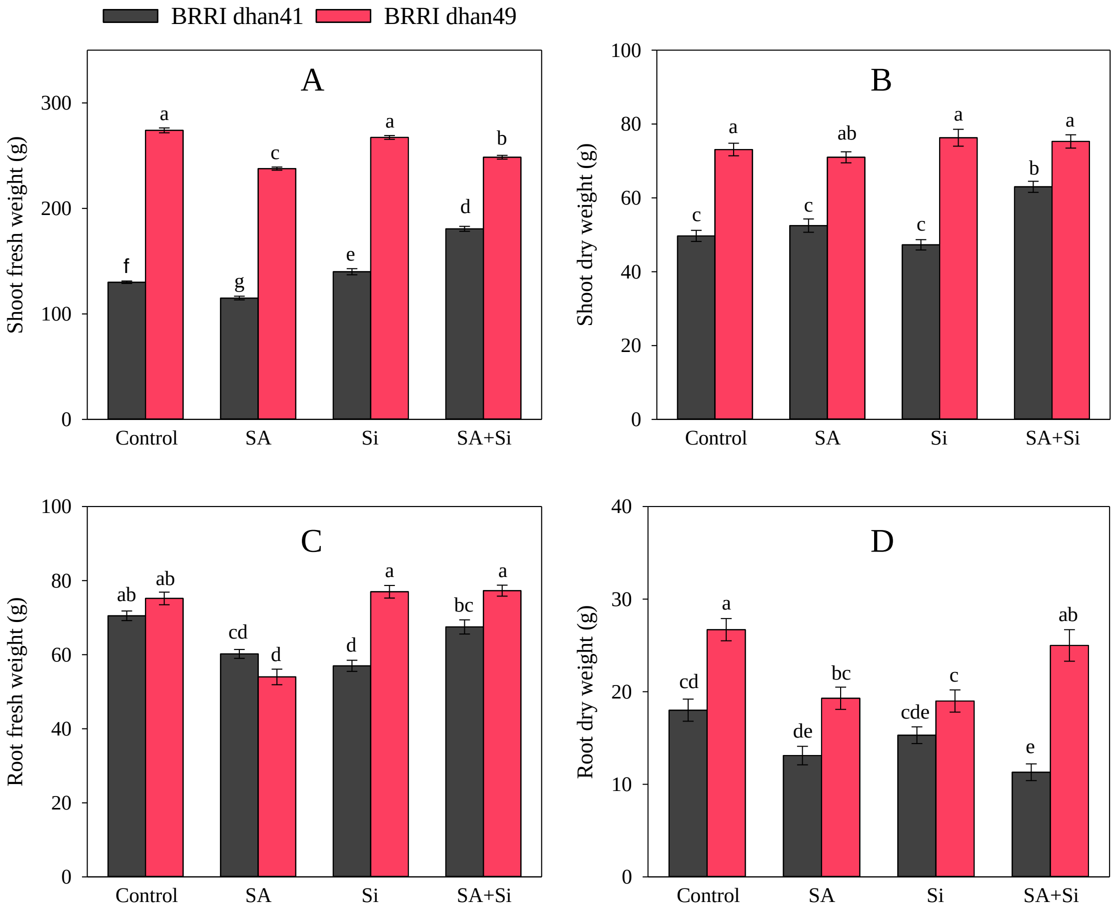

Fig. 3. Effect of salicylic acid (SA) and silicon (Si) on (A) shoot fresh weight, (B) shoot dry weight, (C) root fresh weight and (D) root dry weight.

Effect of SA and Si on yield characters of rice under salt stress

The data revealed that sole application of SA and co-application of SA and Si significantly enhanced the number of grains per panicle by 64 and 29%, respectively in BRRI dhan41. While in BRRI dhan49 remarkably increased by 182 and 75% after treating with sole application of SA and Si respectively, compared with the control plants (Figure 4A). Besides, the number of sterile spikelets was significantly reduced by 26% in BRRI dhan41 after sole application of SA compared with other treatments (Figure 4B). Notably in BRRI dhan49, the number of sterile spikelets remarkably reduced by 23, 38 and 49%, respectively after sole applications of SA, Si, and co-application of SA and Si as compared with the untreated plants under salinity (Figure 4B). It also observed that exogenous application of Si significantly increased thousand grain weight by 15% in BRRI dhan41, whereas, sole application of SA and co-application of SA and Si showed statistically similar results as compared with control (Figure 4C). In case of BRRI dhan49, no significant variation was observed in thousand grain weight under all the treatment combinations compared with the control plants under salinity (Figure 4C). In addition, the number of grains per hill remarkably increased by 46% due to the application of SA in BRRI dhan41 over control plant (Figure 4D). On the other hand, in BRRI dhan49, the number of grains per hill increased significantly by 277, 446 and 118% respectively, due to the sole applications of SA and Si, and, co-application of SA and Si under saline environment over control (Figure 4D).

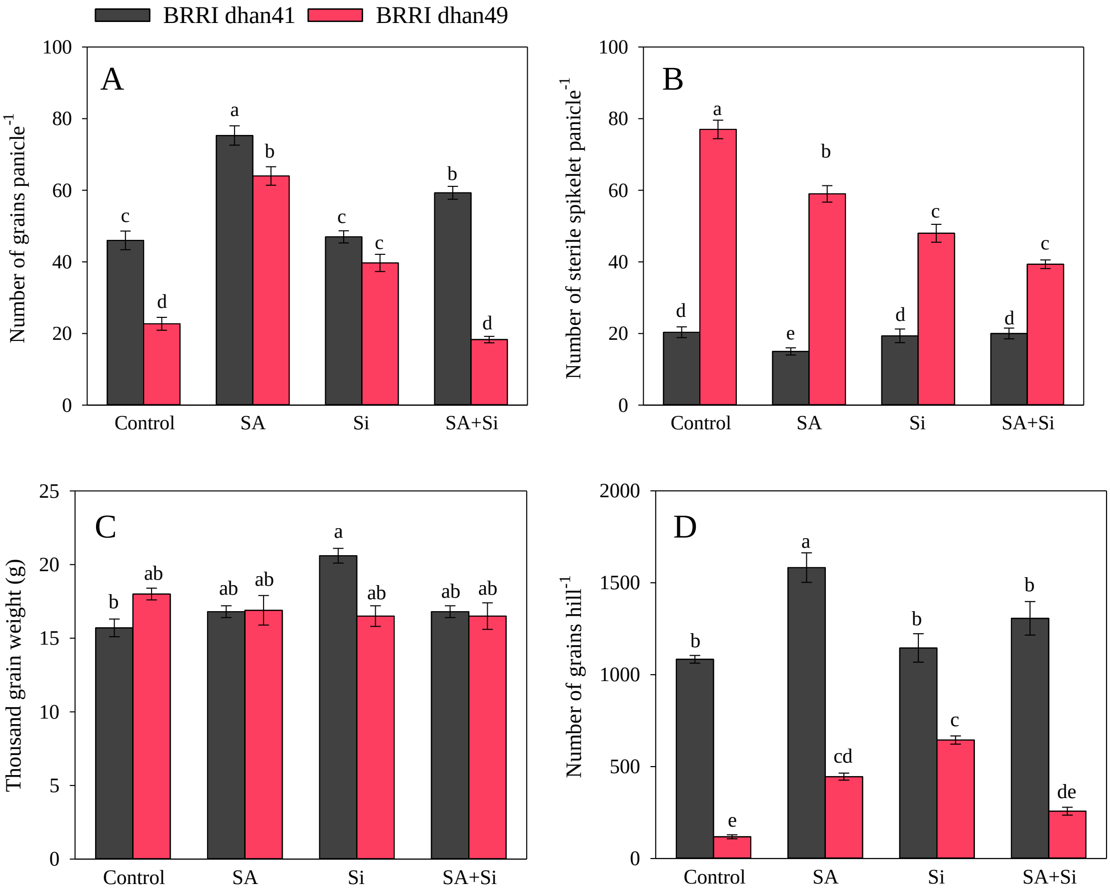

Fig. 4. Effect of salicylic acid (SA) and silicon (Si) on (A) number of grains panicle^{-1}, (B) number of sterile spikelet panicle^{-1}, (C) thousand grain weight and (D) number of grains hill^{-1}.

Likewise, reports from several studies have also highlighted that 1 mM SA application significantly increased different yield attributes of rice such as the number of grains per panicle, thousand grain weight and grain yield under salt stress (Jini and Joseph, 2017). This finding corroborates with the present study.

Effect of exogenous SA and Si on K^+ and Na^+ accumulation in rice under salt stress

Result revealed that exogenous SA, Si, and combined SA and Si application significantly reduced Na^+ accumulation by 25, 34 and 20%, respectively in BRRI dhan41, and by 43, 40 and 23%, respectively in BRRI dhan49 (Figure 5A). Notably, the sole application of SA, and co-application of SA and Si significantly increased K^+ accumulation by 72 and 115%, respectively in BRRI dhan41. While, BRRI dhan49 showed a noticeable increase in K^+ accumulation in shoot after application of SA, Si, and Co-application of SA and Si, which are 29, 46 and 36%, respectively over control plants (Figure 5B). Importantly, the K^+/Na^+ increased significantly in both BRRI dhan41 and BRRI dhan49 after sole application of SA (128 and 124%, respectively), Si (42 and

143%, respectively) and co-application of SA and Si (168 and 76%, respectively) compared with untreated conditions (Figure 5C).

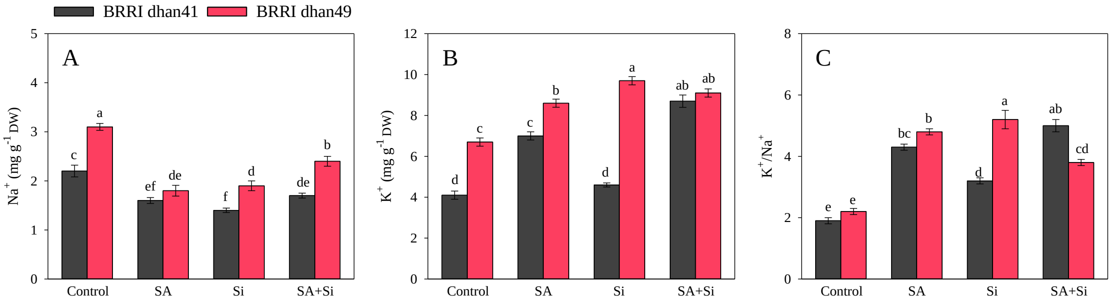

Fig. 5. Effect of salicylic acid (SA) and silicon (Si) on accumulation of (A) Na^+, (B) K^+ and (C) K^+/Na^+ in rice under salt stress.

It has been reported that the Si application in rice reduced the leaf Na^+ while enhanced the levels of K^+ and K^+/ Na^+ (Yan *et al.*, 2020; Somaddar *et al.*, 2022). Liang *et al.* (2007) also reported that Si supplementation reduced the root Na^+ content under salt stress.

Conclusions

The findings of the present study indicated that the application of Si and SA have significant effect in the mitigation of salinity stress. The results suggested that the sensitive var. BRRI dhan49 showed highest plant height and number of effective tillers with the sole and combined application of SA and Si. Besides, different yield attributes such as number of grains per panicle and number of grains per hill showed a significant effect, and the number of sterile spikelets remarkably reduced when applied with SA and Si, particularly in the salt-sensitive BRRI dhan49. The application of SA and Si alone and, SA and Si together significantly reduced Na^+ accumulation in rice leaf of both varieties; while the K^+ content and K^+/Na^+ increased in all the treatment combinations under salinity. However, the present findings showed new dimensions regarding the beneficial effects of SA and Si solely, as well as combinedly on the growth and yield of rice under salinity.

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