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Research Article

BOTANY

Effect of selenium nanoparticles on the growth traits of rice (*Oryza sativa* L.) plants under salinity stress

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KEY WORDS

Rice, salinity, selenium nanoparticles, growth traits, crop productivity

ABSTRACT

Salt stress is among the most prevalent abiotic stresses which affect plant growth and yield. The application of nanoparticles can enhance growth and saline resistance of plants. The objective of this work was to mitigate the negative influence of salinity on the growth of two rice (*Oryza sativa* L.) genotypes using selenium nanoparticles (Se-NPs). Two rice genotypes (Sakha 101 and Giza 179) were subjected to salt stress (150 and 250 mM NaCl) and treated with Se-NPs (10 and 20 mg/L). Results revealed that the treatment of the two rice genotypes with 150 and 250 mM NaCl inhibited the growth traits including shoot length, root length, dry weights of root and shoot, fresh weight of shoot of both rice genotypes, as compared to control. However, Se-NPs (10 and 20 mg/L) treatment enhanced the growth criteria of both rice genotypes under salinity conditions. Overall, the application of Se-NPs improved the growth characteristics and minimized the damaging impact of salinity stress on rice plants.

Introduction

High salinity generates osmotic stress through extreme ion aggregations **(Hasanuzzaman et al., 2019)**. Overproduction of reactive oxygen species (ROS) results in the generation of malondialdehyde (MDA), adversely influencing cell metabolism and physiological processes **(Sachdev et al., 2021)**. Salt stress also affects photosynthesis process and chlorophyll pigments **(Ali et al., 2004)**. Plants primarily respond to salinity-induced oxidative stress by a variety of defense mechanisms, including ion compartmentalization, photosynthesis regulation and induction of enzymatic (peroxidase (POX), catalase (CAT), and ascorbate peroxidase (APX)) and nonenzymatic (ascorbic acid, phenolics and flavonoids) antioxidants **(El-Esawi et al., 2018)**. Moreover, to cope with the severe harmful influences of high concentration of salts in the agricultural soil, various strategies have been applied to further enhance salt stress resistance in plants, including application of nanotechnology **(Kurt and Ateş, 2024)**.

Nanotechnology serves as a highly effective strategy to improve the growth of plants **(Kurt and Ateş, 2024)**. Selenium (Se) is considered as a vital component for higher plants, contributing to their nutrition and metabolism **(Hu et al., 2013)**. Various researches indicated that Se can improve the growth of plants, mainly under abiotic stress, where it manages the water content of plants and functions as an antioxidant, thereby improving plant resistance to abiotic stress **(Hu et al., 2013; Mozafariyan et al., 2016)**. Selenium nanoparticles (Se-NPs) have been effectively used to improve plant growth and mitigate the harmful impacts of environmental stresses **(Kiumarzi et al., 2022)**.

Rice (*Oryza sativa* L.) is the primary food source for the global population **(Fukagawa and Ziska, 2019)**, making it an essential cereal crop for assuring worldwide food security. Rice production is adversely affected by environmental factors, including salinity stress **(Korres et al., 2022)**. Therefore, effective technologies should be adopted to enhance rice production to meet the growing population needs. Hence, the purpose of this study was to assess the role of selenium nanoparticles in alleviating the negative impacts of salinity on the growth criteria of two rice genotypes in Egypt.

Materials and methods

Cultivation and treatment of rice plants

Rice seeds (cv. Sakha 101 and Giza 179) were sanitized by soaking them in a solution of 10% (v/v) sodium hypochlorite for 5 min, followed up by multiple rinses with distilled water. Two concentrations of Se-NPs (10 and 20 mg/L) were prepared. The seeds of rice cultivars were then primed with each Se-NPs concentration as well as with distilled water (control group) for 24h at room temperature. After priming, the seeds were cultivated in plastic pots (20 seeds/pot) filled with 24 kg of 2:1 clay: sandy soil. After 30 days of germination, each rice cultivar was subjected to 9 treatments as follows: (1) control (distilled water), (2) 150 mM NaCl, (3) 250 mM NaCl, (4) 10 mg/L Se-NPs, (5) 10 mg/L Se-NPs + 150 mM NaCl, (6) 10 mg/L Se-NPs+ 250 mM NaCl, (7) 20 mg/L Se-NPs, (8) 20 mg/L Se-NPs+ 150 mM NaCl, (9) 20 mg/L Se-NPs+ 250 mM NaCl. Each treatment was represented by three replicates. The plants were irrigated with saline solutions (150 and 250 mM NaCl) and sprayed with the two concentrations of Se-NPs twice per week for one month. After 60 days of growth, plants were collected from each treatment and used for the growth traits analyses.

Growth parameters

The collected plants were thoroughly rinsed several times with tap water. The lengths of root and shoot (cm) were determined. The dry weight (g) and fresh weight (g) of the whole plant were also assessed. Dry weight was determined after drying plant samples in an oven at 65°C for 3 days.

Statistical analysis

The present data were analyzed statistically using CoStat edition 6.311. All comparisons were accomplished using one-way analysis of variance (ANOVA), followed by multiple range of Duncan's test. Values were represented as means ± standard errors and differ significantly at $p \leq 0.05$.

Results and Discussion

Salinity stress is a destructive ecological problem which represents one of the reasons for minimizing the growth and productivity of agricultural crops **(Majeed and Muhammad, 2019).** It significantly affects rice production and yield **(Korres et al., 2022)**. Nanotechnology approach is currently used to minimize the potential harm caused by salinity stress. The present study assessed whether Se-NPs could alleviate the negative effects of salinity stress on rice plants. The results showed that salinity stress (150 and 250 mM) reduced the shoot fresh weight of Sakha 101 and Giza 179 **Fig. (1)**. The ratios of reduction were 19% and 36% for Sakha 101 and 13% and 23.5% for Giza 179, respectively, as compared to control. On the other hand, application of 10 mg/ L and 20 mg/ L of Se-NPs improved the shoot fresh weight of salt-stressed Sakha 101 and Giza 179 plants. The ratios of improvement were 26% and 42.8% for Sakha 101 and 19.6% and 38.7% for Giza 179, respectively, in response to the treatment of plants with 150 mM NaCl. Moreover, the ratios of improvement were 31.9% and 53.8% for Sakha 101 and 18.7%, 43% for Giza 179, respectively, in response to the treatment with 250 mM NaCl. In addition, the application of 10 mg/ L and 20 mg/ L of Se-NPs significantly enhanced the shoot fresh weight by 17% and 29.6% of Sakha 101 and by 15% and 34.6% for Giza 179 plants in comparison to control. In agreement with our results, **Çelik et al. (2019)** demonstrated that salinity decreased the fresh weight of leaves of rice plants.

Salinity stress (150 and 250 mM) reduced the shoot dry weight of Sakha 101 and Giza 179 as represented in **Fig. (2)**. The ratios of reduction were 19.9% and 38.7% for Sakha 101 and 11% and 22% for Giza 179, respectively, as compared to non-stressed samples. In contrast, the application of 10 mg/ L and 20 mg/ L of Se-NPs improved the shoot dry weight of salinity-stressed Sakha 101 and Giza 179 plants. The ratios of improvement were 26.7% and 36% for Sakha 101, and 17.8% and 36% for Giza 179, respectively, in response to 150 mM NaCl treatment. Moreover, the ratios of improvement were 34.9 % and 60% for Sakha 101 and 16.8% and 45% for Giza 179, respectively, in response to 250 mM NaCl treatment. In addition, the application of 10 mg/ L and 20 mg/L Se-NPs significantly enhanced the shoot dry weight by 17% and 27.8% for Sakha 101 and by 14.8 % and 38% for Giza 179 plants as compared to control.

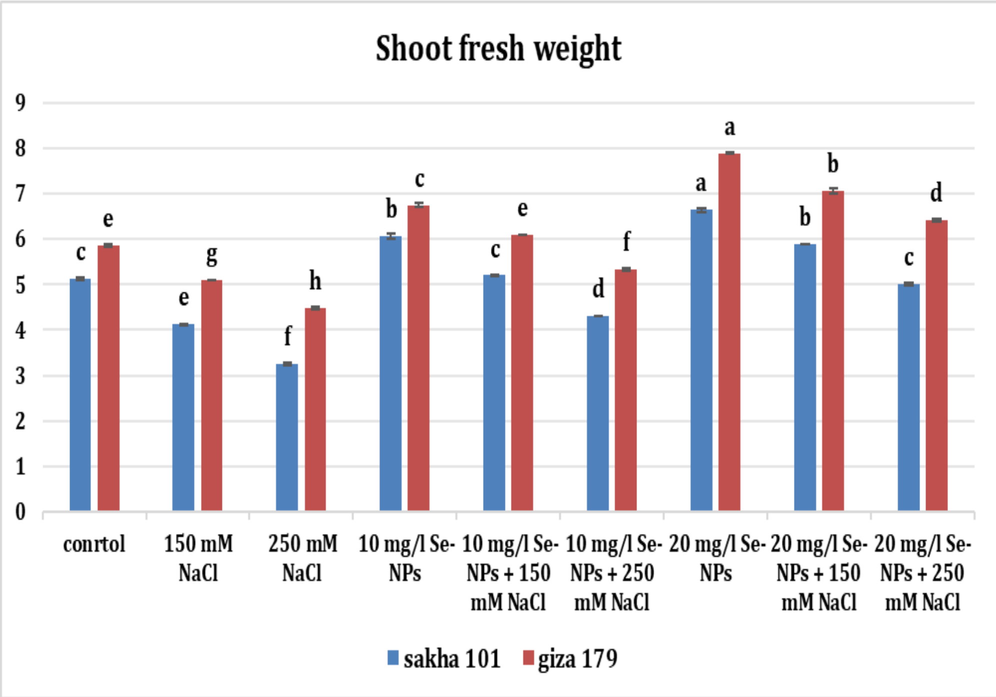

Fig. (1): Impact of foliar application of Se-NPs on shoot fresh weight of rice plants (Sakha 101 and Giza 179) subjected to different levels of salinity. Different letters above bars refer to significant differences.

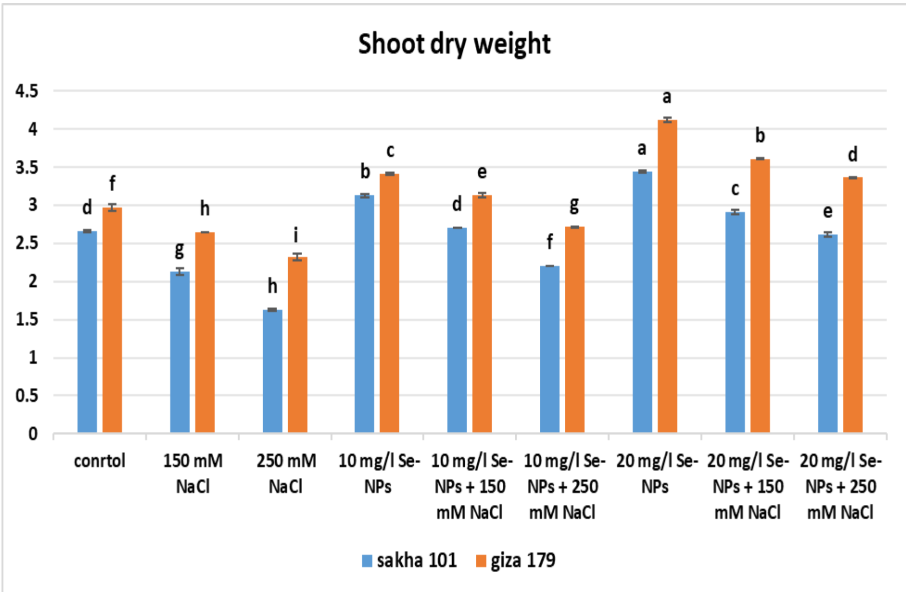

Fig. (2): Influence of foliar application of Se-NPs on shoot dry weight of rice plants (Sakha 101 and Giza 179) exposed to different salinity levels. Different letters above bars refer to significant differences.

In concordance with our findings, **Elsheery et al. (2025)** revealed that SeNPs application improved shoot fresh and dry weights of faba bean plants under salinity stress.

Treatment with 150 and 250 mM NaCl caused reductions in the root dry weight of Sakha 101 and Giza 179, as represented in **Fig. (3)**. However, the application of 10 mg/L and 20 mg/L of Se-NPs improved the root dry weight of salinity-stressed Sakha 101 and Giza 179 plants. The ratios of improvement were 29.6% and 51.8% for Sakha 101, and 41% and 68.6% for Giza 179, respectively, in response to the treatment with 150 mM NaCl. Furthermore, the ratios of improvement were 50% and 75% for Sakha 101 and 50% and 78.6% for Giza 179, respectively, in response to the treatment with 250 mM NaCl. In addition, the application of 10 mg/L and 20 mg/ L of Se-NPs significantly enhanced the root dry weight by 21.7 % and 30% for Sakha 101 and by 31.9% and 58% for Giza 179 plants compared to control.

Salinity stress (150 and 250 mM NaCl) reduced the shoot length of Sakha 101 and Giza 179 as represented in **Fig. (4**). However, the application of 10 mg/ L and 20 mg/ L of Se-NPs improved the shoot length of stressed Sakha 101 and Giza 179 plants. The ratios of improvement were 11.9% and 28.5% for Sakha 101 and 12.5 % and 25 % for Giza 179, respectively, in response to the treatment with 150 mM NaCl. The ratios of improvement were also 12.6% and 31% for Sakha 101 and 12% and 25.5% for Giza 179, respectively, in response to the treatment with 250 mM NaCl. In addition, the application of 10 mg/L and 20 mg/ L of Se-NPs significantly enhanced the shoot length by 8.6% and 21.7% for Sakha 101 and by 12% and 22% for Giza 179 plants as compared to control.

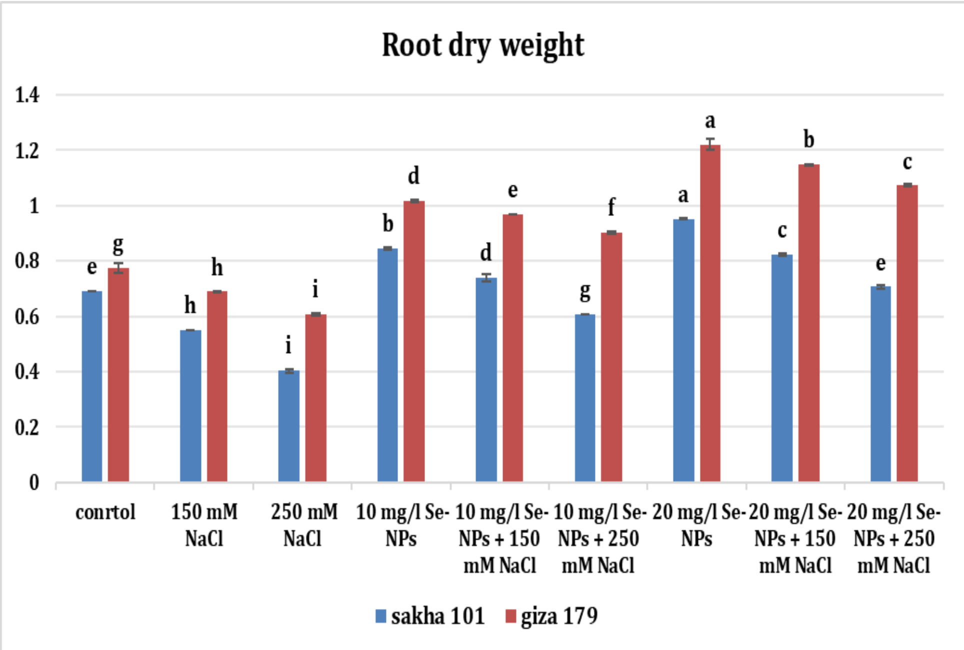

Fig. (3): Influence of application of Se-NPs on root dry weight of rice plants (Sakha 101 and Giza 179) exposed to different salinity levels. Different letters above bars refer to significant differences.

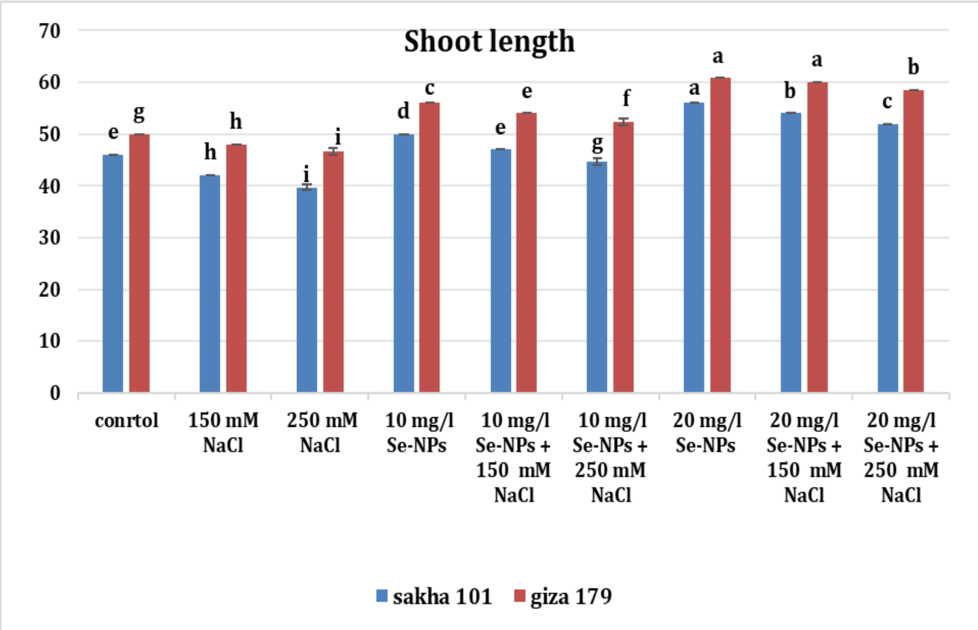

Fig. (4): Impact of foliar spray of Se-NPs on shoot length of rice plants (Sakha 101 and Giza 179) exposed to different salinity levels. Different letters above bars refer to significant differences.

As represented in **Fig. (5)**, salt stress (150 and 250 mM NaCl) also reduced the root length of Sakha 101 and Giza 179. However, the application of 10 mg/L and 20 mg/L of Se-NPs improved the root length of Sakha 101 and Giza 179 plants exposed to salinity levels (150 and 250 mM NaCl). Moreover, the application of 10 mg/L and 20 mg/L of Se-NPs significantly enhanced the root length of Sakha 101 and Giza 179 plants as compared to control.

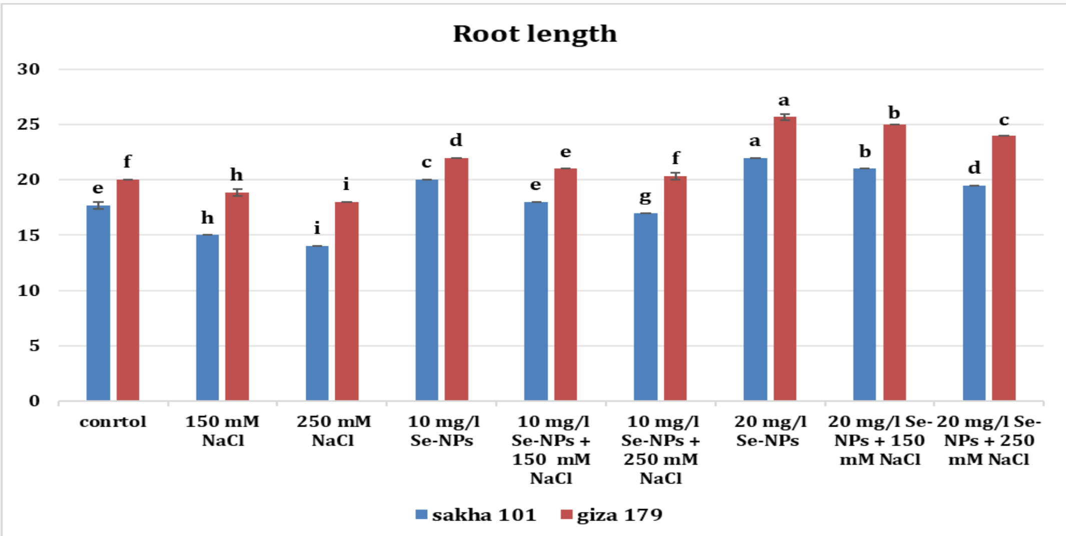

Fig. (5): Influence of application of Se-NPs on root length of rice plants (Sakha 101 and Giza 179) exposed to different salinity levels. Different letters above bars refer to significant differences.

In concordance with our findings, **Çelik et al. (2019)** reported that salinity reduced the lengths of shoot and root of rice plants. Moreover, **Alkahtani and Dwiningsih (2023)** revealed that salinity stress reduced the root length, shoot length, and biomass of rice plants. In addition, **Elsheery et al. (2025)** reported that the foliar application of SeNPs reduced the salinity-induced adverse effects and enhanced faba bean plant height. Our results were supported by those reported by **Hussein et al. (2019)** who demonstrated that Se-NPs improved the growth criteria of some groundnut cultivars.

In conclusion, the findings of the current study demonstrated the key role of Se-NPs in improving the resistance of rice plants to salinity stress conditions through improving the growth characteristics, including shoot fresh weight, root and shoot lengths, and root and shoot dry weights.

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تأثير جسيمات السيلينيوم النانوية على نمو نباتات الأرز تحت الإجهاد الملحي

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يُعد الإجهاد الملحي من أكثر الضغوطات اللاحيوية شيوعًا والتي تؤثر على نمو النبات وإنتاجيته. تطبيق الجسيمات النانوية يعزز نمو النباتات ومقاومتها للملوحة. كان الهدف من هذا العمل هو التخفيف من التأثير السلبي للملوحة على نمو نمطين وراثيين من الأرز باستخدام جسيمات السيلينيوم النانوية.
تعرض نمطان وراثيان من الأرز (سخا ١٠١ وجيزة ١٧٩) لإجهاد ملحي (١٥٠ و٢٥٠ ملي مولار كلوريد الصوديوم) وعولجا بجسيمات السيلينيوم النانوية (١٠ و٢٠ ملجم / لتر).
أظهرت النتائج أن معالجة النمطين الجينيين للأرز بتركيزات ١٥٠ و٢٥٠ ملي مولار كلوريد الصوديوم قد ثبطت صفات النمو بما في ذلك طول البراعم وطول الجذور والأوزان الجافة للجذور والبراعم والوزن الطازج للبراعم والجذور لكلا النمطين الجينيين للأرز، مقارنةً بالمجموعة الضابطة. ومع ذلك، عززت معالجة جسيمات السيلينيوم النانوية (١٠ و٢٠ ملجم/لتر) معايير نمو كلا النمطين الجينيين للأرز في ظل ظروف الملوحة. وبشكل عام، حسّن استخدام جسيمات السيلينيوم النانوية خصائص النمو وقلل من التأثير الضار لإجهاد الملوحة على نباتات الأرز.