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GREEN SYNTHESIS OF SILICA NANOPARTICLES USING RICE HULL AND ITS IMPACT ON GROWTH AND SEED GERMINATION OF RICE (*Oryza sativa*)

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Recent advances in nanotechnology have enabled the development of nanofertilizers that offer controlled nutrient release, improved plant uptake, and reduced environmental impact. Among these, silica nanoparticles (SiNPs) show great promise due to their unique nanoscale properties. Rice (*Oryza sativa*) is one of the major crops in Sri Lanka. Rice plants actively accumulate silicon (Si), which provides significant agronomic benefits. Within the plant, Si is deposited beneath the cuticle as a cuticle–Si double layer, primarily in the form of monosilicic acid absorbed from the soil. Rice hulls (RHs), an agricultural waste byproduct rich in amorphous silica, serve as a sustainable raw material for SiNP synthesis. However, existing methods for synthesizing SiNPs still require further optimization and characterization. Additionally, the precise effect of these SiNPs on rice cultivation as a nanofertilizer has not yet been discovered. Investigating cost-effective synthesis approaches and evaluating the effects of SiNPs on rice plant growth could contribute to more sustainable agriculture and enhanced rice production. The present study utilized RHs from three rice varieties (BG 359, BG 94, and BG 374/1) collected from paddy fields in the Ukuwela region of the Matale District. Among these, BG 359 exhibited the highest silica content. The SiNPs synthesized from the BG 359 RH variety were characterized using several analytical techniques. UV–Vis spectroscopy revealed absorption peaks in the 190–220 nm range, confirming the presence of pure silica through Si–O electronic transitions. Fourier-transform infrared (FTIR) spectroscopy identified key vibrational modes corresponding to Si–O–Si and O–Si–O bonds (~1100, ~650, and ~470 cm^{-1}), indicating the presence of an amorphous silica network. Scanning electron microscopy (SEM) revealed a porous, quasi-rod-shaped morphology with particle sizes ranging from 25 to 70 nm, further confirming the nanoscale structure of the synthesized SiNPs. The resulting SiNPs were then applied to rice seeds and plants to assess their effects on seed germination and growth. The findings demonstrated that SiNPs had a positive impact on both germination and the growth performance of *Oryza sativa*.

Keywords: silica nanoparticles, rice hull, nanofertilizer, *Oryza sativa*

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INTRODUCTION

Silicon (Si), the second most abundant element in the Earth's crust, is primarily found in nature as silica (SiO_2). It plays a crucial role in enhancing plant structural integrity, disease resistance, stress tolerance, and nutrient uptake, particularly in Si-accumulating crops such as rice (Oryza sativa) (Weerahewa *et al*., 2016). The effectiveness of silicon is closely linked to its transport within plants, which can be enhanced by using nanoscale silicon particles. (Nguyen *et al*., 2025) Recent advances in nanotechnology have enabled the development of nanofertilizers that offer controlled nutrient release, improved plant uptake, and reduced environmental impact (Yan *et al*., 2024). Among these, silica nanoparticles (SiNPs) show great promise due to their unique nanoscale properties. Rice hulls (RHs), a byproduct of agricultural waste rich in amorphous silica, serve as a sustainable raw material for SiNP synthesis (Mitani *et al*., 2005). However, existing methods for synthesizing SiNPs still require further optimization and characterization. Investigating cost-effective synthesis approaches and evaluating the effects of SiNPs on rice plant growth could contribute to more sustainable agriculture and enhanced rice production (Parmar *et al*., 2019).

METHODOLOGY

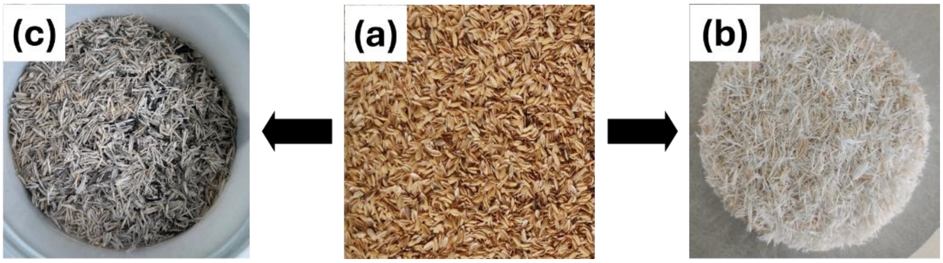
The SiNPs were synthesized from three varieties of RH (BG 359, BG 94, and BG 374/1) collected from paddy fields in the Ukuwela region of the Matale District, Sri Lanka. The cleaned RHs underwent acid pre-treatment followed by thermal combustion to produce rice hull ash (RHA) (Snehal *et al*., 2018). The RHA was then chemically treated with NaOH, neutralized with H_2SO_4 to form silica xerogel, and subsequently washed, centrifuged, and dried to obtain SiNPs (Anuththara *et al*., 2021; Todkar *et al*., 2016).

The SiNPs derived from the BG 359 rice hull variety were characterized using UV–Vis spectroscopy, Fourier-transform infrared spectroscopy (FTIR), and scanning electron microscopy (SEM). To assess their biological effects, BG 359 rice seeds were treated with 100 ppm SiNPs and monitored for germination compared to a control group. For growth evaluation, two sets of seedlings were cultivated; one treated with SiNPs and the other with distilled water. After 21 days, shoot and root lengths were measured to determine growth differences.

RESULTS AND DISCUSSION

Thermal combustion of RH produced two distinct types of RHA, as shown in Figure 1. White rice hull ash (WRHA), shown in Figure 1(b), was obtained at elevated temperatures and is essential for synthesizing high-purity SiNPs. In contrast, incomplete combustion resulted in black rice hull ash (BRHA), as shown in Figure 1(c).

Figure 1. Images of the BG 359 rice variety (a) RH, (b) WRHA, and (c) BRHA.



The yields of RHA and SiNPs were determined for three RH varieties (BG 359, BG 94, and BG 374/1) based on weight differences before and after pyrolysis. BG 94 produced the lowest extractable RHA content at 17.52%, while BG 374/1 showed the highest, at 18.57%. The SiNP yields were calculated by comparing the dry weights of WRHA and the resulting SiNPs, with yield percentages varying by rice variety. The lowest SiNP yield was recorded for BG 94 at 72.86%, whereas BG 359 yielded the highest at 82.22%.

The SiNPs synthesized from the BG 359 RH variety were characterized using several analytical techniques. UV–Vis spectroscopy revealed absorption peaks in the 190–220 nm range, confirming the presence of pure silica through Si–O electronic transitions (Alhadhrami *et al*., 2022). The FTIR spectroscopy identified key vibrational modes corresponding to Si–O–Si and O–Si–O bonds (~1100, ~650, and ~470 cm^{-1}), as well as O–H stretching vibrations (~3400 cm^{-1}), indicating the presence of an amorphous silica network with surface silanol groups or adsorbed moisture (Saravanan *et al*., 2020). Scanning electron microscopy revealed a porous, quasi-rod-shaped morphology with particle sizes ranging from 25 to 70 nm, as shown in Figure 2, further confirming the nanoscale structure of the synthesized SiNPs (Dorairaj *et al*., 2022).

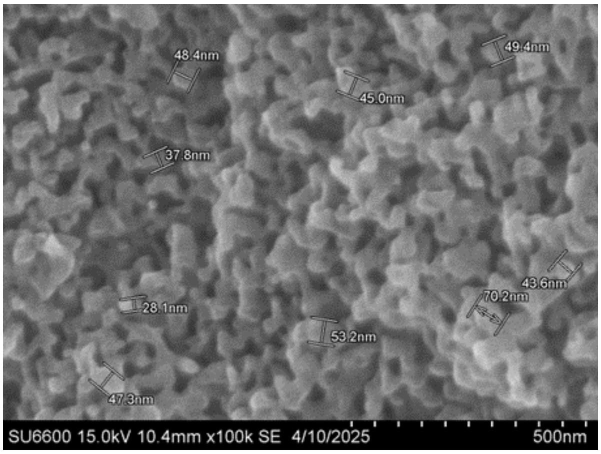


Figure 2. A SEM image of SiNPs derived from the BG 359 RH variety.

Seed germination trials using BG 359 rice seeds were conducted to compare the effects of germination in distilled water (control) versus a 100 ppm SiNP solution. Seeds treated with SiNPs began germinating earlier, starting on the second day, while those in the control group began germination on the fourth day. By the fifth day, SiNP-treated seeds exhibited enhanced growth, with an average root length of 2.2 cm and a shoot height of 1.8 cm, whereas the control group showed an average root length of 1.3 cm and a shoot height of 0.7 cm. These results suggest that SiNP treatment positively influenced and accelerated the germination process in rice seeds.

A 21-day growth evaluation of BG 359 rice plants revealed that those treated with 100 ppm SiNPs exhibited significantly enhanced growth compared to the control group treated with distilled water. SiNP-treated plants showed a greater average shoot height of (17.2 ± 1.9) cm and root length of (7.4 ± 0.7) cm, whereas the control group showed an average shoot length of (14.4 ± 1.6) cm and shoot height of (6.2 ± 1.7) cm.

In addition, these plants displayed more erect shoots, darker green coloration, and a higher number of leaves compared to the control group, as illustrated in Figure 3. These observations confirm that SiNPs contribute to improved plant vigor and overall growth performance in rice cultivation.

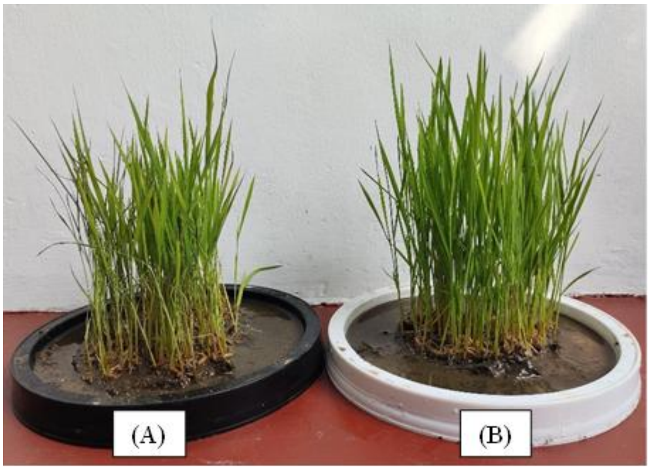


Figure 3. Images of cultivated rice plants A) Treated with only water (control) and B) Treated with 100 ppm SiNPs.

CONCLUSION

Rice husk, often regarded as agricultural waste, serves as a valuable source of silica for the production of eco-friendly silica nanoparticles. Among the varieties studied, BG 359 yielded the highest silica content (82.22%), while BG 94 yielded the lowest (72.86%). The synthesized silica nanoparticles significantly enhanced seed germination, plant growth, and overall vigor in *Oryza sativa*, highlighting their potential as a low-cost nanofertilizer. This approach not only supports sustainable agriculture but also promotes the effective utilization of agricultural waste.

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