SUSTAINABLE NANOPARTICLE PRODUCTION FROM *SYZYGIUM TRAVANCORICUM* GAMBLE (WESTERN GHATS ENDEMIC): CHARACTERIZATION AND EVALUATION IN SEED PRIMING APPLICATIONS

Divina Mary P J and Shimi K S*

Department of Botany, St. Joseph's College (Autonomous) Irinjalakuda, Thrissur, Kerala, India
*Corresponding author: *shimiks@stjosephs.edu.in*

ABSTRACT

Plant-mediated synthesis of nanomaterials has gained increasing attention in recent years due to its eco-friendly, sustainable, and cost-effective nature. Among various biological routes, the use of plant extracts for the green synthesis of nanoparticles (NPs) offers a safer alternative to conventional chemical and physical methods that often involve toxic reagents. In the present study, silver nanoparticles (AgNPs) were synthesized using aqueous leaf extracts of *Syzygium travancoricum* Gamble, an endangered medicinal plant native to the Western Ghats. The plant extract acted as a natural reducing and stabilizing agent in the conversion of silver ions (Ag) to AgNPs. The formation of nanoparticles was visually confirmed by a color change from dark brown to light golden brown and spectroscopically validated using ultraviolet-visible (UV–Vis) spectrophotometry, which showed a distinct absorption peak at 432 nm, characteristic of AgNPs. The synthesized nanoparticles were further characterized by Energy-Dispersive X-ray Analysis (EDAX), Scanning Electron Microscopy (SEM), and Transmission Electron Microscopy (TEM). Furthermore, the synthesized AgNPs were evaluated for their application in seed priming. The results demonstrated that AgNP-treated seeds exhibited a significantly higher germination rate compared to untreated controls. This enhancement is attributed to the nanoparticles' ability to penetrate the seed coat, facilitating improved water absorption and activation of enzymatic processes essential for seed metabolism and growth. Overall, this study highlights an eco-sustainable approach for nanoparticle synthesis from an endangered plant species and its promising role in enhancing seed germination and early seedling vigor through nanoparticle-based seed priming.

Keywords: *Green synthesis, UV- Visible spectroscopy, TEM, EDAX, Ag2NPs, Seed priming*

INTRODUCTION

Plants have played an integral role in human civilization, providing food, medicine, shelter, and raw materials for centuries. In recent decades, their importance has extended into advanced scientific fields, particularly biotechnology and nanoscience. One emerging area is the green synthesis of nanoparticles, which utilizes plant-derived biomolecules to manufacture nanoparticles in an environmentally safe manner. Unlike conventional chemical and physical methods, which often require toxic reagents, high temperature, or expensive instrumentation, green synthesis is simple, sustainable, cost-effective, and eco-friendly. Plant extracts are rich in phytochemicals such as flavonoids, terpenoids, phenolics, alkaloids, and proteins, which naturally act as reducing, capping, and stabilizing agents during nanoparticle formation (Ahmed et al., 2016).

The present study focuses on the synthesis of silver nanoparticles (AgNPs) using the leaf extract of *Syzygium travancoricum*, locally known as *Kullavetty*. This species, belonging to the family Myrtaceae, is endemic to Kerala and listed as endangered due to habitat loss and limited

distribution (Sasidharan, 2007; Sreekumar et al., 2020). Utilizing its bioactive compounds for nanoparticle production not only demonstrates scientific value but also highlights the plant's hidden biochemical potential.

The green-synthesized AgNPs were further evaluated for agricultural application through seed priming of Brassica nigra (black mustard). Seed priming with nanoparticles has gained attention for enhancing germination, vigor, chlorophyll content, and early growth. In this study, the AgNP-treated seeds showed improved germination percentage and healthier seedling development compared to untreated seeds. The method is affordable, scalable, and does not require harmful chemicals, making it suitable for sustainable farming practices.

Overall, the synthesis of AgNPs using *Syzygium travancoricum* establishes a promising link between plant biotechnology, nanotechnology, and eco-friendly agriculture. It demonstrates how endangered medicinal flora can be scientifically explored while promoting greener innovations for future food security.

MATERIALS AND METHODS

Fresh *Syzygium travancoricum* leaves were collected from S.N.M College, Maliankara. The leaves were thoroughly washed with deionized water, air-dried, and finely crushed using a mortar and pestle. For extract preparation, 100 g of crushed leaves were mixed with 250 ml of deionized water in a 500 ml Erlenmeyer flask and agitated on a rotary shaker. The mixture was then filtered through Whatman No. 1 filter paper to obtain the leaf extract (Ravichandran, 2016; Song and Kim, 2009; Tripathi et al., 2019). For silver nanoparticle synthesis, a 0.1 M aqueous solution of silver nitrate ($AgNO_3$) was prepared, and 50 ml of the leaf extract was added to 10 ml of the silver nitrate solution. The mixture was exposed to sunlight for three hours, resulting in a color change from dark brown to golden brown, confirming the formation of silver nanoparticles (Dipankar and Murugan, 2012). The synthesized nanoparticles were collected by centrifugation at 5000 rpm for 20 minutes.

Characterization of the synthesized nanoparticles was carried out using both visual and instrumental methods. UV–Visible spectroscopy (Shimadzu UV–Visible spectrophotometer) was used to monitor the reduction of Ag^+ ions and confirm nanoparticle formation. Morphological and structural analyses were performed using Scanning Electron Microscopy (SEM,Jeol6390LA OXFORD XMXN) and Transmission Electron Microscopy (TEM, Jeol JEM 2100) at the Sophisticated Test and Instrument Centre (STIC), CUSAT, to determine nanoparticle distribution and size (Tripathi et al., 2019; Zhang et al., 2016).

For the nanopriming study, Brassica nigra seeds were surface-sterilized with 0.1 M mercuric chloride for 30 seconds, rinsed with deionized water, and soaked in five different priming solutions with aeration for two hours. Twenty-five seeds per treatment were germinated on tissue-lined Petri plates. Controls were soaked in distilled water, and unprimed seeds were also sown. Germination rates were recorded after seven days (Anand et al., 2020; Dipankar and Murugan, 2012; Rahimi et al., 2021).

$$\text{Germination Percentage} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds}} \times 100$$

RESULTS AND DISCUSSION

The synthesis of silver nanoparticles (AgNPs) using *Syzygium travancoricum* leaf extract was confirmed through a distinct color change in the reaction mixture. The transformation from dark brown to light golden brown indicated the successful reduction of silver ions (Ag^+) to elemental silver (Ag). This visual observation served as primary evidence of nanoparticle formation, suggesting that the phytochemicals present in the *Syzygium travancoricum* extract acted as natural reducing and stabilizing agents. The color transition demonstrated the efficiency of the plant extract in facilitating the biosynthesis process without the need for hazardous chemicals, confirming the environmentally friendly nature of this green synthesis method.

UV–Visible Spectral Analysis

The formation and stability of the synthesized AgNPs were further verified using UV–Visible spectrophotometric analysis. The reduction of silver ions upon exposure to the plant extract was supported by a characteristic absorption peak observed at 432 nm, which corresponds to the surface plasmon resonance (SPR) of silver nanoparticles. This SPR band results from the collective oscillation of conduction electrons on the nanoparticle surface when excited by light. The colloidal AgNP solution showed a strong absorption range between 300 and 480 nm, indicating well-dispersed and stable nanoparticles. The sharp spectral peak confirmed the presence of monodispersed nanoparticles and validated the successful green synthesis of AgNPs using S. travancoricum as a natural reducing agent (Fig. 1 & Fig. 2).

SEM and TEM Analysis

The morphological and elemental characteristics of the biosynthesized silver nanoparticles (AgNPs) were analyzed using Scanning Electron Microscopy (SEM) coupled with Energy Dispersive X-ray Analysis (EDAX) and Transmission Electron Microscopy (TEM). SEM–EDAX provided both qualitative and quantitative information on nanoparticle structure and composition. SEM images revealed a uniform surface topology with nanoparticles showing minimal aggregation, while the EDAX spectrum confirmed silver as the dominant elemental component, validating successful nanoparticle synthesis. The even distribution and reduced clustering observed in SEM suggested effective capping and stabilization of nanoparticles by the bioactive compounds present in *Syzygium travancoricum* leaf extract (Fig. 3).

TEM analysis was employed to determine the precise size, shape, and morphology of the nanoparticles. A drop of the nanoparticle-containing extract was placed on a carbon-coated copper grid and dried under vacuum before imaging. TEM micrographs showed that the silver nanoparticles were well-dispersed, predominantly spherical, and smooth in texture. The particles exhibited uniform morphology, with sizes ranging between 2 and 100 nm, confirming their nanoscale dimensions. These findings collectively demonstrate that S. travancoricum leaf extract is effective in producing stable, uniformly shaped silver nanoparticles suitable for biological and agricultural applications (Fig. 4).

Nanopriming and Its Effects on Seed Germination

Nanotechnology has emerged as a valuable tool in agriculture, particularly for improving seed germination, stress tolerance, and crop productivity. In this study, silver nanoparticles (AgNPs)

synthesized from *Syzygium travancoricum* were applied for nanopriming of *Brassica nigra* seeds. The AgNPs, along with controls including pure plant extract, tap water, and distilled water, were used for seed treatment. During synthesis, silver ions (Ag^{+}) were reduced to silver oxide (AgO), forming a bioactive nanoparticle suspension suitable for seed soaking.

The results demonstrated notable differences in germination responses. Seeds treated with AgNPs showed enhanced germination rates and improved seedling vigor compared to unprimed control seeds, whereas seeds soaked only in distilled water exhibited minimal germination. After seven days, AgNP-treated seeds displayed faster germination and healthier growth, suggesting that nanoparticles may enhance water uptake, enzyme activation, and metabolic activity during early seed development.

The mechanism of nanopriming is likely influenced by nanoparticle size, surface area, and chemical reactivity, with smaller nanoparticles interacting more efficiently with seed surfaces and cellular structures, promoting metabolic efficiency and early growth. Additionally, no significant inhibition of germination was observed in seeds treated with pure plant extract or AgO nanoparticle solutions. These findings indicate that AgNPs synthesized from *S. travancoricum* are effective in enhancing seed germination and hold potential for sustainable agricultural applications (Fig. 5).

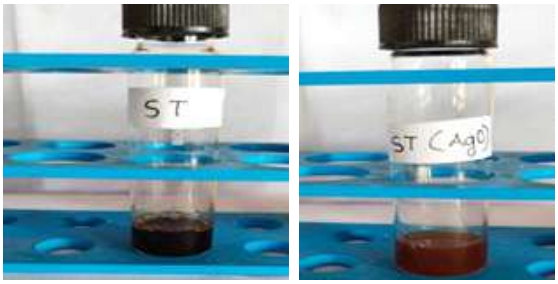

Fig. 1: Plant Extract before and after adding silver nitrate

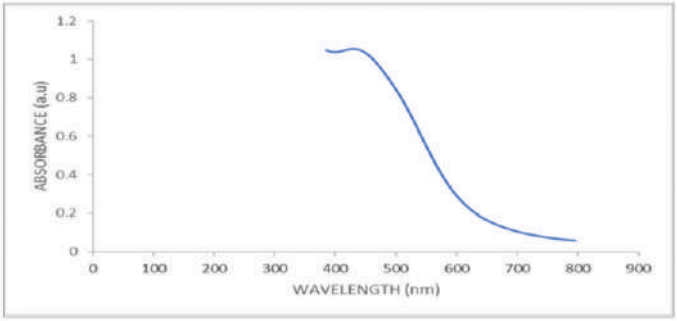

Fig. 2: UV Visible Spectral Analysis of Silver Nanoparticles from plant Extract

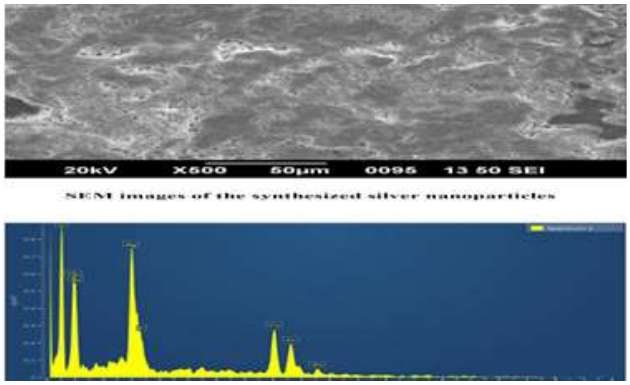

Fig. 3: SEM EDAX result of Syzygium travancoricum- AgNPs

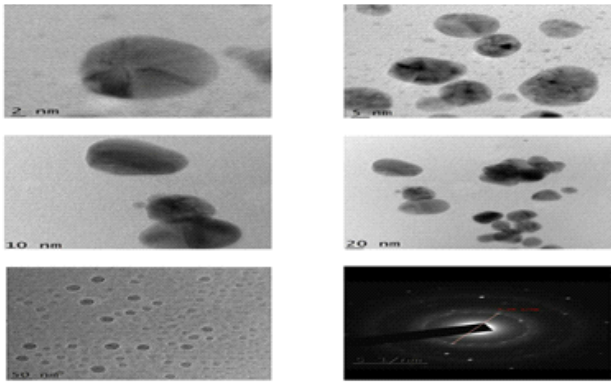

Fig. 4: TEM Images of Syzygium travancoricum -AgNPs

Fig. 5: Nano priming of Brassica nigra seeds

CONCLUSION

Silver nanoparticles synthesized from *Syzygium travancoricum* leaf extract were successfully produced, characterized, and shown to be stable and uniformly shaped. Nanopriming with these AgNPs significantly enhanced *Brassica nigra* seed germination and seedling vigor, demonstrating their potential as an eco-friendly tool to improve early plant growth and sustainable agriculture.

Table 1: Germination Percentage of Brassica nigra seeds

DAY	DISTILLED WATER	UNPRIMED	EXTRACT +Ag	AgNO
DAY1	4%	16%	36%	8%
DAY2	8%	20%	40%	12%
DAY3	12%	20%	40%	16%
DAY4	16%	24%	44%	20%
DAY5	20%	24%	48%	24%
DAY6	20%	28%	52%	24%
DAY 7	24%	32%	60%	28%

ACKNOWLEDGMENTS

The authors sincerely thank Dr. M.G. Sanilkumar, HOD (Assistant Professor) of the Department of Botany, S.N.M. College, Maliankara, for providing the plant material, and the Sophisticated Test and Instrument Centre (STIC), CUSAT, for assistance with SEM and TEM analyses. The authors also acknowledge DST-FIST (SR/FST/COLLEGE/2023/1321) and KSCST-SARD (KSCSTE/623/2019-SARD) for supporting the research facilities of the host Institution.

REFERENCES

- **Ahmed, S., Ahmad, M., Swami, B. L., & Ikram, S.** (2016). Green synthesis of silver nanoparticles using Azadirachta indica aqueous leaf extract. *Journal of Radiation Research and Applied Sciences, 9*(1), 1–7.
- **Anand, K. V., Anugraga, A. R., Kannan, M., Singaravelu, G., & Govindaraju, K.** (2020). Bio-engineered magnesium oxide nanoparticles as nano-priming agent for enhancing seed germination and seedling vigour of green gram (*Vigna radiata* L.). *Materials Letters, 271,* 127792.
- **Dipankar, C., & Murugan, S.** (2012). The green synthesis, characterization and evaluation of the biological activities of silver nanoparticles synthesized from *Iresine herbstii* leaf aqueous extracts. *Colloids and Surfaces B: Biointerfaces, 98,* 112–119.
- **Kuriakose, G., Sinu, P. A., & Shivanna, K. R.** (2018). Floral traits predict pollination syndrome in Syzygium species: A study on four endemic species of the Western Ghats, India. *Australian Journal of Botany, 66*(7), 575–582.
- **Rahimi, S., Hatami, M., & Ghorbanpour, M.** (2021). Silicon-nanoparticle mediated changes in seed germination and vigor index of marigold (*Calendula officinalis* L.) compared to silicate under PEG-induced drought stress. *Gesunde Pflanzen, 73*(4), 575–589.
- **Ravichandran, S., Paluri, V., Kumar, G., Loganathan, K., & Kokati Venkata, B. R.** (2016). A novel approach for the biosynthesis of silver oxide nanoparticles using aqueous leaf extract of *Callistemon lanceolatus* (Myrtaceae) and their therapeutic potential. *Journal of Experimental Nanoscience, 11*(6), 445–458.
- **Sasidharan, N.** (2007). *Flowering plants of Kerala* [CD]. Kerala Forest Research Institute.
- **Song, J. Y., & Kim, B. S.** (2009). Rapid biological synthesis of silver nanoparticles using plant leaf

extracts. *Bioprocess and Biosystems Engineering, 32*(1), 79–84.

- **Sreekumar, V. B., Sreejith, K. A., Sanil, M. S., Harinarayanan, M. K., Prejith, M. P., & Varma, R. V.** (2020). Distribution of *Syzygium travancoricum* Gamble (Myrtaceae), a critically endangered tree species from Kerala part of Western Ghats, India. *Journal of Threatened Taxa, 12*(17), 17340–17346.
- **Tripathi, D., Modi, A., Narayan, G., & Rai, S. P.** (2019). Green and cost-effective synthesis of silver nanoparticles from endangered medicinal plant *Withania coagulans* and their potential biomedical properties. *Materials Science and Engineering: C, 100,* 152–164.
- **Zhang, X. F., Liu, Z. G., Shen, W., & Gurunathan, S.** (2016). Silver nanoparticles: Synthesis, characterization, properties, applications, and therapeutic approaches. *International Journal of Molecular Sciences, 17*(9), 1534.