

GREEN SYNTHESIS OF SILVER AND GOLD NANOPARTICLES USING TRADESCANTIA PALLIDA EXTRACT: THEIR CHARACTERIZATION AND ANTIMICROBIAL ACTIVITY

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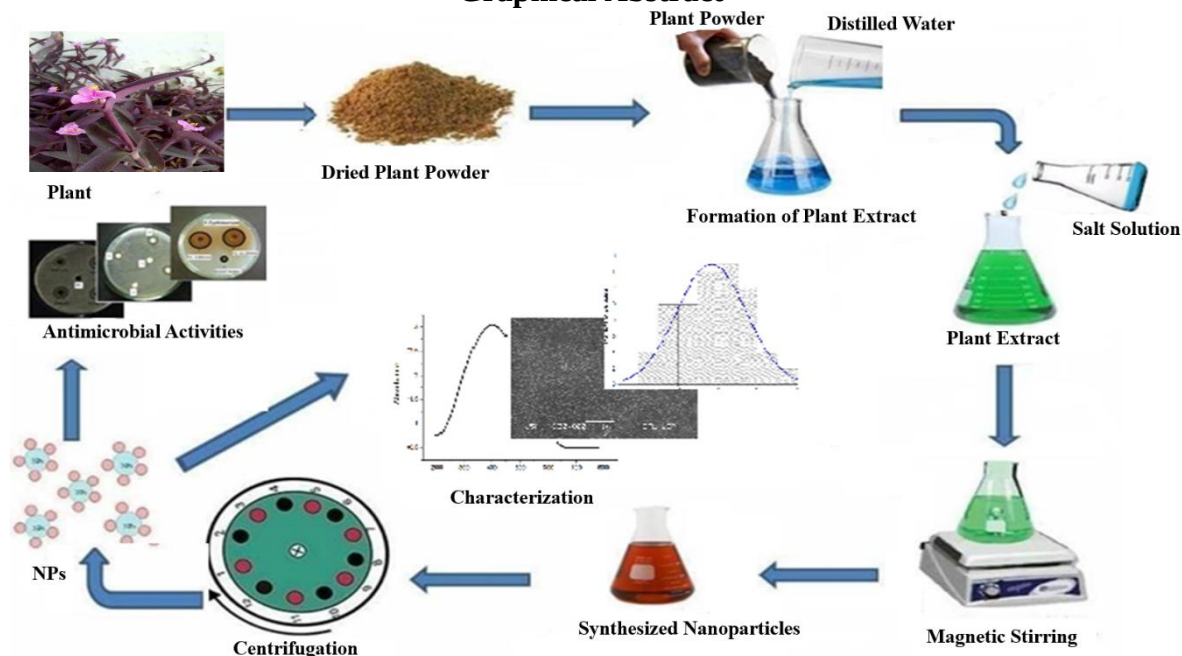
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Abstract

The purpose of this research was to find eco-friendly nanoparticles synthesized from the leaf extract of *Tradescantia pallida* and to find their antimicrobial activities. Phytochemical investigation of these plants reveals the occurrence of flavonoids, alkaloids, sterols, terpenoids, tannins, saponins, proteins, carbohydrates phenols, etc. Nanoparticle confirmation was done by UV/Visible spectroscopy which gives a peak at 429 nm for Ag-NPs and 532 nm for Au-NPs. The morphology of the nanoparticle was checked by spectroscopic techniques. The average size of the nanoparticles was established by using SEM analysis. The antibacterial activity of synthesized nanoparticles was checked against gram-positive and gram-negative bacterial strains like *Escherichia coli*, *Staphylococcus aureus*, *Salmonella typhimurium*, and *Pseudomonas aeruginosa* and for antifungal activity two fungal strain *Candida albicans* and *Aspergillus niger* were used. The results demonstrate that the synthesized nanoparticles have promising activity against all used strains and can be used as antimicrobial agents.

Graphical Abstract



Keyword: Green Synthesis, Silver Nanoparticles, Antibacterial Activities, *Tradescantia Pallida*

Introduction

Nanotechnology is an evolving interdisciplinary field of research interposing material science, nano-science and technology. Nanotechnology is science, engineering, and technology conducted at the nano-scale, which is about 1 to 100 nanometres. Nano-science and nanotechnology are the study and application of extremely small things and can be used across all the other science fields, such as chemistry, biology, physics, materials science, and engineering. Nanotechnology deals with matter at the scale of 1 billionth of a meter (i.e., 10^{-9} m = 1 nm), and is also the study of manipulating matter at the atomic and molecular scale.

Today, many novel materials with high strength, light weight, and greater chemical resistance have come into existence and are grouped under nano-materials (A. Ahmad et al., 2003) nanotubes (carbon nanotubes CNTs), nanowires (light emitting diodes LEDs), nano-crystals and nano-catalysts. The synthesis of metal and semiconductor nanoparticles is a vast area of research due to its potential applications which was implemented in the development of novel technologies. Metal nanoparticles have a high specific surface area and a high fraction of surface atoms (Goncearenco et al., 2022). Because of the unique physicochemical characteristics of nanoparticles, including catalytic activity, optical properties, electronic properties, antibacterial properties, and magnetic properties. they are gaining the interest of scientist for their novel methods of synthesis. Over the past few years, the synthesis of metal nanoparticles is an important topic of research in modern material science. Nano-crystalline silver particles have been found tremendous applications in the fields of high sensitivity bio-molecular detection, diagnostics, antimicrobials, therapeutics, catalysis and micro-electronics. However, there is still need for economic commercially viable as well as environmentally clean synthesis route to synthesize the silver nanoparticles. Silver is well known for possessing an inhibitory effect toward many bacterial strains and microorganisms commonly present in medical and industrial processes (Qi et al., 2004).

In medicines, silver and silver nanoparticles have an ample application including skin ointments and creams containing silver to prevent infection of burns and open wounds (Durán et al., 2005) medical devices and implants prepared with silver-impregnated polymers (Ribeiro et al., 2014). In textile industry, silver-embedded fabrics are now used in sporting equipment (Langer et al., 2023).

Nanoparticles can be synthesized using various approaches including chemical, physical and biological. Although chemical method of synthesis requires short period of time for synthesis of

large quantity of nanoparticles, this method requires capping agents for size stabilization of the nanoparticles. Chemicals used for nanoparticles synthesis and stabilization are toxic and lead to non-eco-friendly by products (A. U. Khan et al., 2023). The need for environmental non-toxic synthetic protocols for nanoparticles synthesis leads to the developing interest in biological approaches which are free from the use of toxic chemicals as by products. Thus, there is an increasing demand for “green nanotechnology”(Ganaie et al., 2023). Many biological approaches for both extracellular and intracellular nanoparticles synthesis have been reported till date using microorganisms including bacteria, fungi and plants (Carrapiço et al., 2023). Plants provide a better platform for nanoparticles synthesis as they are free from toxic chemicals as well as provide natural capping agents. Moreover, use of plant extracts also reduces the cost of micro-organisms isolation and culture media enhancing the cost competitive feasibility over nanoparticles synthesis by microorganisms(Carrapiço et al., 2023). Utilization of nontoxic chemicals, environmentally benign solvents, and renewable materials are some of the key issues that merit important consideration in a green synthetic strategy (Gul et al., 2023). Plant mediated biological synthesis of nanoparticles is gaining importance due to its simplicity, cost effective and eco-friendliness. Plant mediated synthesis of nanoparticles is a green chemistry approach that interconnects nanotechnology and plant biotechnology (K. Ahmad et al., 2023).

Jose-Yacaman and co-workers first reported the formation gold and silver nanoparticles by living plants. Plants provide a better platform for nanoparticles synthesis as they are free from toxic chemicals as well as provide natural capping agents (Restrepo et al., 2021). Plant crude extract contains secondary metabolites such as phenolic acid, flavonoids, alkaloids and terpenoids in which these compounds are mainly responsible for the reduction of ionic into bulk metallic nanoparticles formation (Roopashree et al., 2019). Moreover, use of plant extracts also reduces the cost of microorganism isolation and culture media enhancing the cost competitive feasibility over nanoparticles synthesis by microorganisms. Use of plant extract for the synthesis of nanoparticles could be advantageous over other environmentally benign biological processes by eliminating the elaborate process of maintaining cell cultures (Adeyemi et al., 2022).

Tradescantia pallida:

The genus *Tradescantia* is innate to the New World tropics and comprises about 70 species dispersed from Canada to northern-Argentina (*Plants Database | US Forest Service*, n.d.).

Tradescantia pallida is a much common garden plant which is generally used as a bioindicator (Rhoden et al., 2008).



Fig. 1 Tradescantia pallida

It is persistent herb with shoots climbing with stretch decumbent and flowering sub-erect branches. This specie contains numerous compounds as a secondary metabolite which are not involve directly in growth and development. Although not necessary for survival but plays their role in defence rivalry and species communications.

Existence of alkaloids, mainly significant in the treatment of pain and inflammation, tannins, notable antimicrobial and antitumor agent, saponins, therapeutically significant species having the ability of antihepatotoxic, antiulcerogenic, anticoagulant, anticarcinogenic agent, notable inhibitor of dental caries and platelet aggregation, (Huq, 2015) flavonoids, the vital group of polyphenols having significant anticancer characteristics, anti-inflammatory and antibacterial action (Ahmed et al., 2022), hepatoprotective ability and more significantly the set of natural antioxidants that show important part in free radical scavenging, metal ion chelation and prevention of lipid peroxidation (Saxena et al., 2013). All such compounds are identified as secondary plant metabolites.

Research Methods

1.1 Materials

Silver nitrate AgNO_3 , auric chloride AuCl_3 and ethanol of analytical grade, taken from Sigma-Aldrich®, Germany. Plant was collected from local area of Haripur, KPK, Pakistan. Doubly distilled water was used throughout the procedure.

2.2 Preparation of *Tradescantia pallida* extract

The leaves and stems of plants were profusely wash away with tap water and then by distilled water to remove any dust particles or unwanted materials. They were shredded and shade dried for minimum two weeks. The dried material was crushed to a fine powder. 5g of the plants powder were added to 100 ml of demineralized water to form 5% w/v stock solution. The mixture was boiled for 2hrs. The solutions were decanted after cooling and filtered. The filtrate was centrifuged for 20min at 10,000 rpm to remove any suspended biomass. The centrifuged solutions were refrigerated for further experimental usage.

2.3 Synthesis of Silver Nanoparticles by using *Tradescantia pallida*

Solution of 1Mm AgNO_3 was prepared in demineralized water. AgNO_3 solution and *Tradescantia pallida* extract were mixed and stirred for one hour. After 1 hour, the mixtures changed their colour to golden brown. To get the optimized ratio a number of reactions with different ratio of metal and plant i.e. (1:1, 1:2, 1:5, 1:10, 1:15, 1:20, 1:40, 1:50, 1:80) were carried out keeping the concentration of one constant and varying the other. By using spectrophotometer absorption spectra of the synthesized nanoparticles were taken and absorption band was recorded in UV-Vis region. The ratio 1:40 was optimized as evident through prominent change of colour and best absorption spectrum peak value 3.25 at 429 nm.

2.4 Synthesis of gold Nanoparticles by using *Tradescantia pallida*:

1mM solution of AuCl_3 was prepared in demineralized water. The plant extract and freshly prepared metal salt solution were mixed together in different ratios i.e. (1:1, 1:2, 1:5, 1:10, 1:15, 1:20, 1:40, 1:50). The solution was stirred for an hour, until change in colour was observed. The colour changes to ruby red. The ratio 1:10 was optimized as evident through prominent change of colour and best absorption spectrum peak as shown below. The optimum ratio was chosen because of intense colour change and showing absorption intensity value 3.3 at 532 nm.

2.5 Antibacterial activity

Agar well diffusion method is used to determine the antibacterial properties of silver and gold nanoparticles against *E. coli*, *P. aeruginosa*, *S. typhimurium* and *S. aureus*. Bacterial cultures were spread on agar nutrient petri dishes with swab and well duged with sterile borer. Suspension of silver and gold nanoparticles were prepared by ultrasonic dispersion of 1mg in 2 ml deionized water. The prepared suspensions were loaded in each well and were incubated at 37°C. The inhibition zones were measured in millimeter after 24 hours of incubation.

2.6 Antifungal activities

Antifungal activities of silver and gold NPs were checked against two fungal strain *Candida albicans* and *Aspergillus niger*.

2.7 Characterization of NPs

UV/Visible spectra were recorded on UV-1800, Shimadzu, Kyoto, Japan at a resolution of 1 nm. Philips XL-30 SEM at 12-16 kV were used for SEM analysis

Discussion

3.1 UV/Visible spectroscopy

The change in colour of aqueous solution of plants and metal salts indicate the synthesis of Ag-NPs and Au-NPs (Karthika et al., 2017) which were confirm by using spectrophotometer absorption spectra of the synthesized nanoparticles of silver and gold were taken and absorption band was recorded in UV-Vis region at 429 and 532 respectively. UV/Vis Spectra of silver and gold nanoparticles is given in Fig: 1 and 2 respectively.

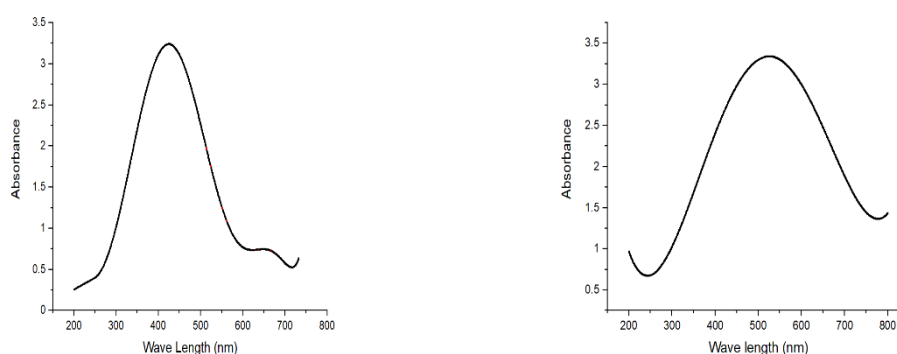


Fig.2 UV/Visible spectra of Ag-NPs and Au-NPs

3.2 SEM analysis:

SEM analysis were done to find size, structure and form of nanoparticles. It was observed through SEM images that green synthesized nanoparticles of silver and gold were spherical in shape (M. Khan et al., 2011). The size silver nanoparticles were 11.4nm and that of gold nanoparticles was 11.8nm respectively as shown in Fig. 3 and 4. Uniform distribution and small size of synthesized nanoparticles shows that plant extract reasonable amount of reducing and stabilizing agents (Tausif Ahmad et al., 2018).

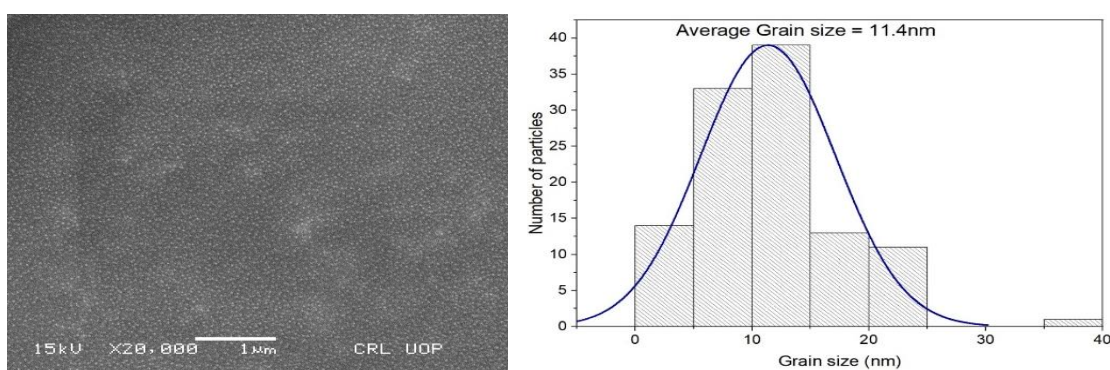


Fig. 3 SEM image of Ag-NPs

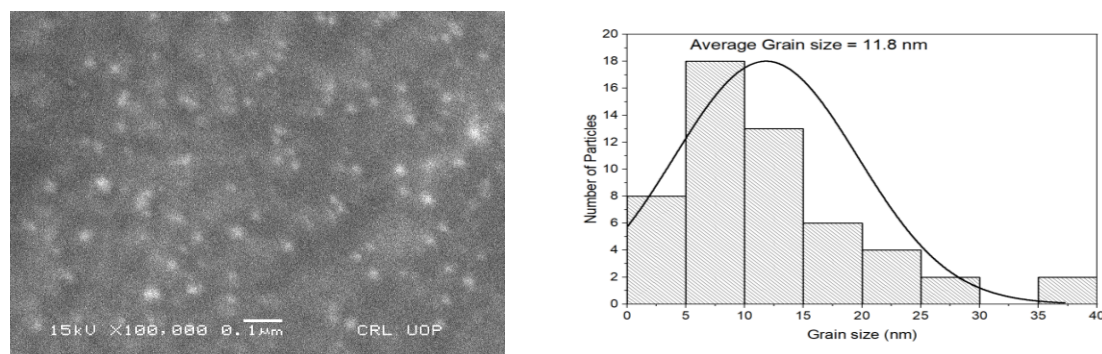


Fig.4 SEM image of Au-NPs

4 Stability assessment Ag-NPs and Au-NPs

4.1 Effect of temperature:

Green synthesized nanoparticles of silver and gold show quite stability when subjected to temperature of 25C°, 50C°, 75C° and 100C° each for one hour as no noticeable change in UV-Vis spectra. This very high stability is may be due to protective effect of plant materials on nanoparticles surfaces (Sadeghi et al., 2015). Temperature is one of the important factors that affect the stability and physio-chemical properties of materials (Liu et al., 2011).

Nanoparticles are used as a coating agent for reactive substances to protect reactive therapeutic agent from environmental effect and increased shelf-life.

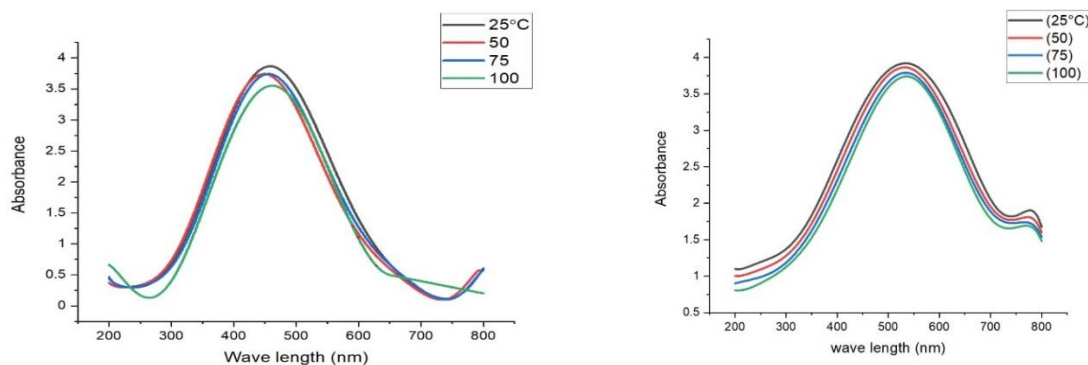


Fig-5. Effect of temperature on green synthesized nanoparticles of silver and gold

4.2 Effect of pH:

It was observed that the silver and gold nanoparticles were stable under acidic condition as negligible change was recorded in UV-Vis absorption spectra but in basic environment peak broadening was noted which is due to aggregation of nanoparticles. Thus, in basic medium gold nanoparticles show aggregation due to which particles increases and peak broadening was observed. In the formation of stable nanoparticles as well as in stabilization of re- dispersed nanoparticles pH plays vital role (Cao et al., 2019). Interfacial free energy of nanoparticles, protonation of the ionic species unconfined by the dissolution of nanoparticles and the dissociation equilibrium of a complexing agent (Zhang et al., 2010).

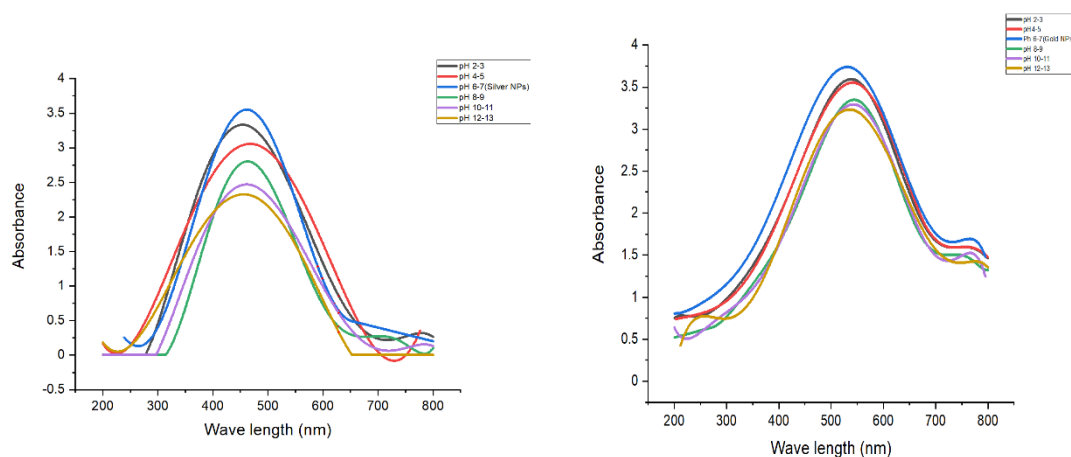


Fig-6. Effect of pH on green synthesized nanoparticles of silver and gold

4.3 Effect of storage:

Silver and gold nanoparticles were found to be stable on storage for six months at room temperature (Costa et al., 2020). As no change in colour and UV-Vis spectra was observed during storage period. It confirms the stability of green synthesized nanoparticles for long duration of time and this long-term stability is useful in biomedicine (Thanh et al., 2010).

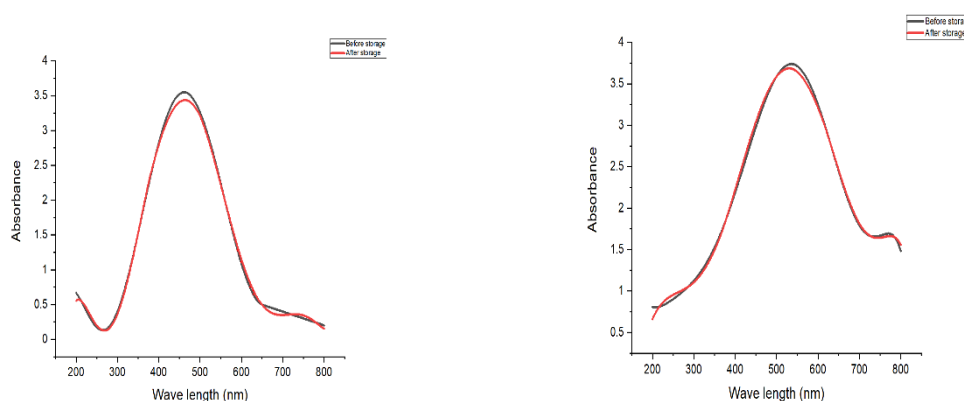


Fig-7. Effect of storage on green synthesized nanoparticles of silver and gold

4.4 Effect of sodium chloride:

Stability of plants synthesized nanoparticles were checked against 1M NaCl solution. 5 ml solution of silver nanoparticles were taken in separate test tubes and UV-Vis absorption spectra were taken by adding 20, 40 and 60 μ l of NaCl solution. No change was observed by adding various concentration of salt solution. The minor decrease in intensity of peaks were actually due to dilution of water in salt solution which was confirmed by adding distilled water. As the stability of nanoparticles mainly depends upon the nature of ligands and surface charge. Stability of nanoparticles extensively enhanced by raise in stearic hindrance and electrostatic repulsion. A minor decrease in the surface charge of particles was monitored by enhancing electrolyte concentration (NaCl), which causes aggregation and decreases the electrostatic repulsion of particles. The biological activities of nanoparticles based on stability and decrease in stability causes accretion and results in cost of nanoscale (Iqbal et al., 2019).

properties.

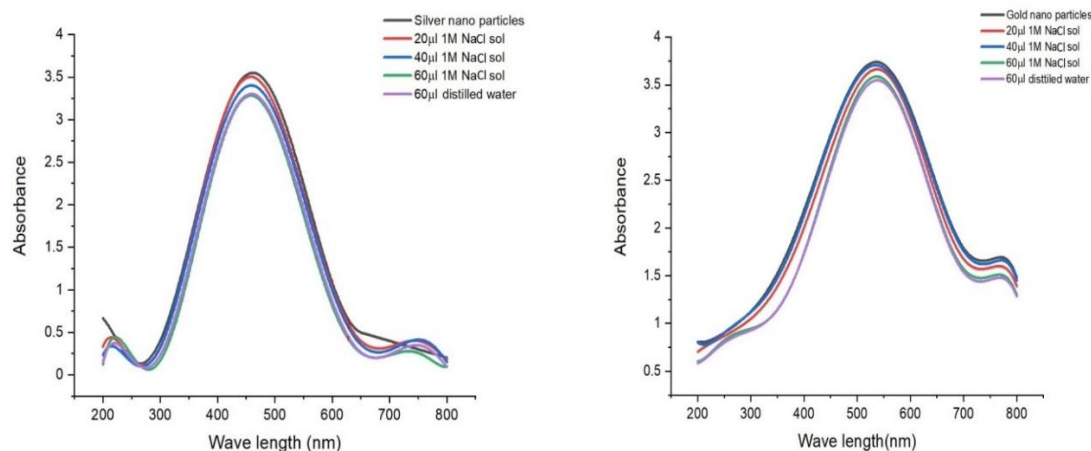


Fig-8. Effect of NaCl on green synthesized nanoparticles of silver and gold

5. Antimicrobial activities:

5.1 Antibacterial activities:

Silver nanoparticles synthesized from the aqueous extract of *Tradescantia pallida* (Shahzadi et al., 2022) were checked against *Staphylococcus aureus*, *Salmonella typhimurium*, *Pseudomonas aeruginosa*, *Escherichia coli*. Agar well diffusion method was applied to find the antibacterial activity of silver and gold nanoparticles. As it is clear from the literature that silver possess antimicrobial activities but due larger size their use was limited. In the recent past researcher were interested to prepare nanoparticles of silver to use them as antimicrobial agents. It was observed that the use of silver as nanoparticles was more effective but later on toxic effect of chemical-based nanoparticles was proved (K. Ahmad et al., 2023). Therefore researcher focused to synthesize nanoparticles through plants extract which is eco-friendly, cost effective as well as non-toxic. Keeping this in mind, in present study nanoparticles of silver and gold were prepared from the extract of *Tradescantia pallida*. From the result it is clear that nanoparticles are more effective against gram positive bacteria as compared to gram negative bacteria (Abbaszadegan et al., 2015). This may be due to electrostatic interaction of silver nanoparticles with the bacterial cell membrane and causes death.

Table 1. Antibacterial activities of silver and gold nanoparticles
(Zone of inhibition in millimetre)

Sample	<i>Staphylococcus aureus</i>	<i>Salmonella typhimurium</i>	<i>Pseudomonas aeruginosa</i>	<i>Escherichia coli</i>
Ag-NPs	11.2 ± 0.3	17.1 ± 0.5	13.5 ± 0.6	16.1 ± 0.9
Au-NPs	16.52 ± 0.3	18.1 ± 0.8	15.3 ± 0.7	19 ± 0.9
Streptomycin	22.5 ± 0.5	21.6 ± 0.5	15 ± 0.3	20.2 ± 0.3

5.2 Antifungal activities:

Antifungal assay was checked against two fungal strain *Candida albicans* *Aspergillus niger* and excellent results were shown by NPs synthesized by *Tradescantia pallida* having smallest size and highest surface area among all, however good result were shown by all the Ag-NPs and Au-NPs similar with (Tokeer Ahmad et al., 2013).

Table 2. Antifungal assay of plant synthesized Ag-NPs and Au-NPs

S. No	Sample	<i>Candida albicans</i>	<i>Aspergillus niger</i>	Miconazole
1	Ag-NPs	60.3 ± 0.3	67.3 ± 0.2	108.2
2	Au-NPs	80.4 ± 0.4	85.3 ± 0.9	108.2

Conclusion

The green synthesis of silver and gold nanoparticles from *Tradescantia pallida*. The reported method is easy, economical and eco-friendly. The phytochemicals of the plant play their role as reducing and capping agent. The size of synthesized nanoparticles was 11.4nm and 11.8nm for silver and gold nanoparticle respectively. Antibacterial and antifungal assay shows their effectiveness against all tested strain of bacteria and fungi. Further research can be done for the production of nanoparticles on commercial scale to overcome the toxic effect of chemical which are used as antimicrobial agent.

Bibliography

- Abbaszadegan, A., Ghahramani, Y., Gholami, A., Hemmateenejad, B., Dorostkar, S., Nabavizadeh, M., & Sharghi, H. (2015). The effect of charge at the surface of silver nanoparticles on antimicrobial activity against gram-positive and gram-negative bacteria: A preliminary study. *Journal of Nanomaterials*, 2015. <https://doi.org/10.1155/2015/720654>
- Adeyemi, J. O., Oriola, A. O., Onwudiwe, D. C., & Oyedeji, A. O. (2022). Plant Extracts Mediated

- Metal-Based Nanoparticles: Synthesis and Biological Applications. *Biomolecules* 2022, Vol. 12, Page 627, 12(5), 627. <https://doi.org/10.3390/BIOM12050627>
- Ahmad, A., Mukherjee, P., Senapati, S., Mandal, D., Khan, M. I., Kumar, R., & Sastry, M. (2003). Extracellular biosynthesis of silver nanoparticles using the fungus *Fusarium oxysporum*. *Colloids and Surfaces B: Biointerfaces*, 28(4), 313–318. [https://doi.org/10.1016/S0927-7765\(02\)00174-1](https://doi.org/10.1016/S0927-7765(02)00174-1)
- Ahmad, K., Warsito, B., Hidayat, J. W., Khan, S., Ahmed, N., Calvin, E. J., & Ashraf, M. (2023). Green synthesis of silver nanoparticles and degradation of AZO-dyes using *Cestrum diurnum* plant extract, and antimicrobial activities of AgNP's. *Journal of Bioresources and Environmental Sciences*, 2(2), 78–88. <https://doi.org/10.14710/JBES.2023.19246>
- Ahmad, Tausif, Bustam, M. A., Irfan, M., Moniruzzaman, M., Anwaar Asghar, H. M., & Bhattacharjee, S. (2018). Green synthesis of stabilized spherical shaped gold nanoparticles using novel aqueous *Elaeis guineensis* (oil palm) leaves extract. *Journal of Molecular Structure*, 1159, 167–173. <https://doi.org/10.1016/J.MOLSTRUC.2017.11.095>
- Ahmad, Tokeer, Wani, I. A., Lone, I. H., Ganguly, A., Manzoor, N., Ahmad, A., Ahmed, J., & Al-Shihri, A. S. (2013). Antifungal activity of gold nanoparticles prepared by solvothermal method. *Materials Research Bulletin*, 48(1), 12–20. <https://doi.org/10.1016/J.MATERRESBULL.2012.09.069>
- Ahmed, N., Raharjo, S., Swasono, R. T., & Raharjo, T. J. (2022). The Antibacterial Peptides (AMPs) Originated from tryptic hydrolysis of *Naja sumatrana* venom fractionated using cation exchange Chromatography. *Rasayan Journal of Chemistry*, 15(4), 2642–2653. <https://doi.org/10.31788/RJC.2022.1548066>
- Cao, D., Gong, S., Shu, X., Zhu, D., & Liang, S. (2019). Preparation of ZnO Nanoparticles with High Dispersibility Based on Oriented Attachment (OA) Process. *Nanoscale Research Letters*, 14(1), 1–11. <https://doi.org/10.1186/S11671-019-3038-3/SCHEMES/2>
- Carrapiço, A., Martins, M. R., Caldeira, A. T., Mirão, J., & Dias, L. (2023). Biosynthesis of Metal and Metal Oxide Nanoparticles Using Microbial Cultures: Mechanisms, Antimicrobial Activity and Applications to Cultural Heritage. *Microorganisms* 2023, Vol. 11, Page 378, 11(2), 378. <https://doi.org/10.3390/MICROORGANISMS11020378>
- Costa, L. H., Hemmer, J. V., Wanderlind, E. H., Gerlach, O. M. S., Santos, A. L. H., Tamanaha, M. S., Bella-Cruz, A., Corrêa, R., Bazani, H. A. G., Radetski, C. M., & Almerindo, G. I. (2020). Green Synthesis of Gold Nanoparticles Obtained from Algae *Sargassum cymosum*: Optimization, Characterization and Stability. *BioNanoScience*, 10(4), 1049–1062. <https://doi.org/10.1007/S12668-020-00776-4/METRICS>
- Durán, N., Marcato, P. D., Alves, O. L., De Souza, G. I. H., & Esposito, E. (2005). Mechanistic aspects of biosynthesis of silver nanoparticles by several *Fusarium oxysporum* strains. *Journal of Nanobiotechnology*, 3(1), 1–7. <https://doi.org/10.1186/1477-3155-3-8/FIGURES/9>
- Ganaie, S. A., Zahoor, I., & Singh, R. (2023). *Prunella vulgaris* leaf extract assisted green synthesis of silver nanoparticles: Antimicrobial activity. *Materials Today: Proceedings*, 79, 107–112. <https://doi.org/10.1016/J.MATPR.2022.09.520>
- Goncearenco, E., Morjan, I. P., Dutu, E., Scarisoreanu, M., Fleaca, C., Gavrila-Florescu, L., Dumitrache, F., Banici, A. M., Teodorescu, V. S., Anastasescu, C., Sandulescu, A., & Balint, I. (2022). The effect of noble metal addition on the properties of oxide semiconductors nanoparticles. *Journal of Solid State Chemistry*, 307, 122817. <https://doi.org/10.1016/J.JSSC.2021.122817>

- Gul, M. Z., Mukherjee, T., Rupula, K., & Rao, B. S. (2023). Strategies involved in bio-inspired synthesis of metallic nanomaterials and their applications—A comprehensive account. *Synthesis of Bionanomaterials for Biomedical Applications*, 1–36. <https://doi.org/10.1016/B978-0-323-91195-5.00007-6>
- Huq, S. (2015). *Comparative phytochemical evaluation and biological activity screening of Murdannia nudiflora and Tradescantia pallida*. <http://dspace.bracu.ac.bd/xmlui/handle/10361/4324>
- Iqbal, M., Bot, J. B.-P. J., & 2019, undefined. (2019). Phytosynthesis of silver nanoparticles FROM arisaema jacquemontii extract, their characterization and antimicrobial potential. *Pakbs.Org*, 51(5), 1853–1857. [https://doi.org/10.30848/PJB2019-5\(37\)](https://doi.org/10.30848/PJB2019-5(37))
- Karthika, V., Arumugam, A., Gopinath, K., Kaleeswarran, P., Govindarajan, M., Alharbi, N. S., Kadaikunnan, S., Khaled, J. M., & Benelli, G. (2017). Guazuma ulmifolia bark-synthesized Ag, Au and Ag/Au alloy nanoparticles: Photocatalytic potential, DNA/protein interactions, anticancer activity and toxicity against 14 species of microbial pathogens. *Journal of Photochemistry and Photobiology B: Biology*, 167, 189–199. <https://doi.org/10.1016/J.JPHOTOBIOL.2017.01.008>
- Khan, A. U., Hussain, T., Abdullah, Khan, M. A., Almostafa, M. M., Younis, N. S., & Yahya, G. (2023). Antibacterial and Antibiofilm Activity of Ficus carica-Mediated Calcium Oxide (CaONPs) Phyto-Nanoparticles. *Molecules* 2023, Vol. 28, Page 5553, 28(14), 5553. <https://doi.org/10.3390/MOLECULES28145553>
- Khan, M., & TYounus. (2011). Prevention of CCl4-induced oxidative damage in adrenal gland by Digera muricata extract in rat. *Pak J Pharm Sci*, 24(2), 469–473. https://www.researchgate.net/profile/Muhammad-Khan-469/publication/51682010_Prevention_of_CCL4-induced_oxidative_damage_in_adrenal_gland_by_Digera_muricata_extract_in_rat/links/0046351ff40f3ac883000000/Prevention-of-CCL4-induced-oxidative-damage-in-adrena
- Langer, J., Jimenez de Aberasturi, D., Aizpurua, J., Alvarez-Puebla, R. A., Auguie, B., Baumberg, J. J., Bazan, G. C., J Bell, S. E., Boisen, A., Brolo, A. G., Kneipp, J., Kotov, N. A., Kuang, H., Le Ru, E. C., Kwee Lee, H., Li, J.-F., Yi Ling, X., Maier, S. A., Mayerho, T., ... Liz-Marza, L. M. (2023). Silver-Based Surface Plasmon Sensors: Fabrication and Applications. *International Journal of Molecular Sciences* 2023, Vol. 24, Page 4142, 24(4), 4142. <https://doi.org/10.3390/IJMS24044142>
- Liu, W., Zhou, Q. F., Liu, J. Y., Fu, J. J., Liu, S. J., & Jiang, G. Bin. (2011). Environmental and biological influences on the stability of silver nanoparticles. *Chinese Science Bulletin*, 56(19), 2009–2015. <https://doi.org/10.1007/S11434-010-4332-8/METRICS>
- plants database | US Forest Service*. (n.d.). Retrieved December 12, 2023, from <https://www.fs.usda.gov/fs-tags/plants-database>
- Qi, L., Xu, Z., Jiang, X., Hu, C., & Zou, X. (2004). Preparation and antibacterial activity of chitosan nanoparticles. *Carbohydrate Research*, 339(16), 2693–2700. <https://doi.org/10.1016/J.CARRES.2004.09.007>
- Restrepo, C. V., & Villa, C. C. (2021). Synthesis of silver nanoparticles, influence of capping agents, and dependence on size and shape: A review. *Environmental Nanotechnology, Monitoring & Management*, 15, 100428. <https://doi.org/10.1016/J.ENMM.2021.100428>
- Rhoden, C. R., Carneiro, M. F. H., Petry, M. R., Oliveira, R. C., & Saldiva, P. H. N. (2008). Lipid peroxidation in Tradescantia pallida: a new bioindicator response of air pollutants. *The FASEB Journal*, 22(S1), 1137.2–1137.2.

https://doi.org/10.1096/FASEBJ.22.1_SUPPLEMENT.1137.2

- Ribeiro, T. G., Chávez-Fumagall, M. A., Valadares, D. G., França, J. R., Rodrigues, L. B., Duarte, M. C., Lage, P. S., Andrade, P. H. R., Lage, D. P., Arruda, L. V., Refidaff, C., Costa, L. E., Martins, V. T., Tavares, C. A. P., Castilho, R. O., Coelho, E. A. F., & Faraco, A. A. G. (2014). Novel targeting using nanoparticles: An approach to the development of an effective anti-leishmanial drug-delivery system. *International Journal of Nanomedicine*, 9(1), 877–890. <https://doi.org/10.2147/IJN.S55678>
- Roopashree, K. M., & Naik, D. (2019). Advanced method of secondary metabolite extraction and quality analysis. *Journal of Pharmacognosy and Phytochemistry*, 8(3), 1829–1842. <https://www.phytojournal.com/archives/2019.v8.i3.8275/advanced-method-of-secondary-metabolite-extraction-and-quality-analysis>
- Sadeghi, B., & Gholamhoseinpoor, F. (2015). A study on the stability and green synthesis of silver nanoparticles using Ziziphora tenuior (Zt) extract at room temperature. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, 134, 310–315. <https://doi.org/10.1016/J.SAA.2014.06.046>
- Saxena, M., Saxena, J., Nema, R., Singh, D., & Gupta, A. (2013). Phytochemistry of Medicinal Plants. *Journal of Pharmacognosy and Phytochemistry*, 1(6), 168–182. <https://www.phytojournal.com/archives/2013.v1.i6.83/phytochemistry-of-medicinal-plants>
- Shahzadi, I., Aziz Shah, S. M., Shah, M. M., Ismail, T., Fatima, N., Siddique, M., Waheed, U., Baig, A., & Ayaz, A. (2022). Antioxidant, Cytotoxic, and Antimicrobial Potential of Silver Nanoparticles Synthesized using Tradescantia pallida Extract. *Frontiers in Bioengineering and Biotechnology*, 10, 907551. <https://doi.org/10.3389/FBIOE.2022.907551/BIBTEX>
- Thanh, N. T. K., & Green, L. A. W. (2010). Functionalisation of nanoparticles for biomedical applications. *Nano Today*, 5(3), 213–230. <https://doi.org/10.1016/J.NANTOD.2010.05.003>
- Zhang, H., Chen, B., & Banfield, J. F. (2010). Particle size and pH effects on nanoparticle dissolution. *Journal of Physical Chemistry C*, 114(35), 14876–14884. https://doi.org/10.1021/JP1060842/SUPPL_FILE/JP1060842_SI_001.PDF