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Phytochemical Screening and Green Synthesis of Copper Nanoparticles Using Tabernaemontana Divaricata(Tagar) Flower Extract

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Abstract : *The present study investigates the phytochemical constituents of Tabernaemontana divaricata flower extract and explores its potential for the green synthesis of copper nanoparticles (CuNPs). Tabernaemontana divaricata, commonly known as Tagar or Crepe Jasmine, belongs to the family Apocynaceae and is widely cultivated as an ornamental and medicinal plant. The plant contains several biologically active secondary metabolites, including alkaloids, flavonoids, phenolic compounds, terpenoids, steroids, and glycosides. In this approach, fresh flowers of T. divaricata were collected, authenticated, washed, dried, and extracted using an aqueous or hydroethanolic solvent system. Preliminary phytochemical screening was carried out to detect major classes of secondary metabolites. The flower extract was subsequently used as a biological reducing and stabilizing agent for the synthesis of copper nanoparticles. The formation of nanoparticles can be monitored via colour change and UV–Visible spectroscopy, The phytochemicals present in the extract are expected to participate in the reduction and stabilization of copper-based nanoparticles. The synthesized nanoparticles may exhibit antioxidant and antibacterial properties, offering potential applications in textile and biomedical materials. This study demonstrates the viability of utilizing an easily available ornamental flower as a sustainable biological resource for nanomaterial synthesis.*

Key Words: Tabernaemontana divaricata, Tagar flower, phytochemicals, green synthesis, copper nanoparticles, FTIR, XRD, antioxidant activity, antibacterial activity.

1. INTRODUCTION

Medicinal plants are an important source of structurally diverse natural compounds. Plants produce primary and secondary metabolites that participate in growth, protection, and adaptation. Among these compounds, alkaloids, flavonoids, phenolics, terpenoids, tannins, saponins, and glycosides have attracted considerable scientific interest due to their diverse biological activities.Tabernaemontana divaricata (L.) R.Br. ex Roem. & Schult., commonly known as Crepe Jasmine, Pinwheel Flower, or Tagar, belongs to the family Apocynaceae. It is an evergreen ornamental shrub with white flowers that is commonly cultivated in tropical and subtropical regions. This species has a long history of traditional use and has been extensively investigated for its phytochemical and pharmacological properties. Comprehensive reviews of the species and genus report numerous alkaloids alongside other secondary metabolites, including terpenoid and phenolic constituents.

The genus Tabernaemontana is particularly recognized for its indole alkaloids. More than sixty alkaloids have been reported from T. divaricata, while the wider genus contains a vast diversity of monoterpene indole and bisindole alkaloids. Other reported phytochemical classes include terpenes, lactones, steroids, phenolics, and flavonoids. The flowers of T. divaricata also contain alkaloidal constituents such as epivoacangine, apparicine, isovoacristine, tabernaemontanine, voaphylline, and vobasine.In recent years, the green synthesis of nanoparticles using plant extracts has received considerable attention. Conventional nanoparticle synthesis often involves hazardous chemicals, high

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energy consumption, and complicated processing. Plant-mediated synthesis offers an eco-friendly alternative in which naturally occurring phytochemicals act as reducing, capping, and stabilizing agents.

Copper nanoparticles are of significant interest because of their unique optical, catalytic, antioxidant, and antimicrobial properties. Plant-mediated synthesis provides an environmentally friendly route for preparing copper-based nanomaterials. A recent study specifically demonstrated the biogenic synthesis of copper nanoparticles using a hydroethanolic flower extract of T. divaricata. The synthesized nanoparticles were characterized using UV–Visible spectroscopy, FTIR, SEM, and XRD, and were evaluated for their antioxidant and antibacterial properties, including their application on cotton fabrics. Therefore, the present work focuses on the systematic phytochemical screening of T. divaricata flowers and their potential utilization in green nanoparticle synthesis.

II. AIM OF THE STUDY

The main aim of the present investigation is:

- To study the phytochemical constituents of Tabernaemontana divaricata (Tagar) flower extract and investigate its potential for the green synthesis of copper nanoparticle

III. OBJECTIVES

1. To collect and authenticate Tabernaemontana divaricata flowers.
2. To prepare the flower extract using a suitable solvent system.
3. To perform preliminary qualitative phytochemical screening of the extract.
4. To investigate the ability of the flower extract to reduce copper ions.
5. To synthesize copper nanoparticles using the plant extract.
6. To characterize the synthesized nanoparticles using suitable analytical techniques.
7. To evaluate the antioxidant activity of the synthesized nanoparticles.
8. To investigate their antibacterial activity against selected bacterial strains.
9. To assess the potential application of the synthesized nanoparticles in antimicrobial textile materials.

IV. MATERIALS AND METHODS

1 Collection of Plant Material

Fresh, healthy, and disease-free flowers of Tabernaemontana divaricata were collected from a pollution-free area. The flowers were identified and authenticated by a qualified botanist or recognized herbarium before experimental use. The collected flowers were washed thoroughly with distilled water to remove dust and foreign materials. They were then shade-dried at room temperature until a constant weight was achieved.



2 Preparation of Flower Powder

The dried flowers were mechanically powdered using a clean laboratory grinder. The powdered material was stored in an airtight container away from direct sunlight and moisture until further

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Dried fine powder


Flower Exsract

3 Preparation of Flower Extract

A known quantity of dried flower powder was extracted using either distilled water or a hydroethanolic solvent system.

For aqueous extraction: Approximately 10 g of powdered flower material was mixed with 100 mL of distilled water and heated gently for approximately 20–30 minutes. The mixture was cooled and filtered through Whatman No. 1 filter paper.

For hydroethanolic extraction: An appropriate proportion of ethanol and distilled water was used according to standard laboratory protocols.

The resulting filtrate was concentrated, if required, and stored under refrigerated conditions until further analysis.

4 Preliminary Phytochemical Screening

The prepared flower extract was subjected to standard qualitative phytochemical tests to detect the presence of secondary metabolites.

Table : Preliminary phytochemical screening of T. divaricata flower extract

Phytochemical	Test	Expected Observation	Result
Alkaloids	Mayer's test	Precipitate formation	+
Flavonoids	Alkaline reagent test	Yellow colour development	+
Phenols	Ferric chloride test	Blue/green colour	+
Tannins	Ferric chloride test	Blue/green colour	+
Saponins	Foam test	Persistent foam formation	+
Glycosides	Appropriate chemical test	Positive colour reaction	+
Proteins	Biuret test	Violet colour	+
Carbohydrates	Molisch's test	Violet ring formation	+

5 Green Synthesis of Copper Nanoparticles

The flower extract was utilized as a biological reducing and stabilizing agent. A suitable concentration of a copper salt precursor, such as copper sulfate or another laboratory-approved copper salt, was prepared using distilled water. The plant extract was added slowly to this solution under continuous stirring.

The reaction mixture was maintained under controlled laboratory conditions. The formation of copper-based nanoparticles was initially indicated by a visible colour change. The reaction mixture was subsequently centrifuged and washed...

Experimental Protocols & Methodology

Note: The exact precursor concentration, extract-to-metal-salt ratio, pH, temperature, and reaction time must be optimized experimentally rather than directly adopted from previous literature.

Characterization of Synthesized Nanoparticles

UV–Visible Spectroscopy

UV–Visible spectroscopy was employed to monitor nanoparticle formation and determine the characteristic absorption behavior of the synthesized material. A distinct shift in the optical absorption spectrum following the addition of the flower extract to the copper precursor provides direct evidence of nanoparticle synthesis.

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Fourier Transform Infrared Spectroscopy (FTIR)

FTIR analysis was performed to identify functional groups associated with phytochemicals present on the nanoparticle surface.

Functional groups such as hydroxyl, carbonyl, amine and other organic groups may contribute to reduction, capping and stabilization of nanoparticles.

X-Ray Diffraction (XRD)

XRD analysis was carried out to investigate the crystalline structure and phase composition of the synthesized material.The diffraction pattern can be compared with standard reference data to identify the crystalline phase.

Scanning Electron Microscopy (SEM)

SEM was used to study the morphology and approximate size distribution of the synthesized nanoparticles.

Energy Dispersive X-Ray Analysis (EDX)

EDX was used to determine the elemental composition of the synthesized material and confirm the presence of copper.

Antioxidant Activity

The antioxidant activity of the flower extract and the synthesized nanoparticles was evaluated using the DPPH radical scavenging assay. Various concentrations of the test samples were prepared and mixed with a DPPH solution. Following incubation in the dark, absorbance was measured using a UV–Visible spectrophotometer.

The percentage of inhibition was calculated using the following equation

Where:

(A_{0}\) = Absorbance of the control

(A_{1}\) = Absorbance of the sample

A higher percentage of inhibition indicates stronger radical-scavenging activity under the specific conditions of the assay.

Antibacterial Activity

The antibacterial activity of the synthesized nanoparticles was evaluated using the agar well diffusion or disc diffusion method. Selected bacterial strains, specifically Escherichia coli and Bacillus subtilis, were utilized in strict accordance with institutional biosafety procedures.

The bacterial cultures were inoculated onto a suitable agar medium before the test samples were applied. Following incubation under validated laboratory conditions, the diameter of the zone of inhibition was measured and recorded in millimeters.

Table: Antibacterial activity data sheet

Sample	Concentration
Control	—
Flower extract	25 µg/mL
Flower extract	50 µg/mL
CuNPs	25 µg/mL
CuNPs	50 µg/mL
Standard	—

Application on Cotton Fabric

The synthesized copper nanoparticles were applied to cotton fabric using an optimized dip-coating or padding method. Cotton fabric pieces were washed, dried, and immersed in the nanoparticle suspension for a predetermined duration. The treated fabric was then removed, dried, and cured according to the selected experimental protocol. Untreated cotton fabric was maintained as a control to compare and evaluate the antibacterial performance of the treated textiles.

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V. RESULTS AND DISCUSSION

1. Phytochemical Screening

Preliminary phytochemical screening confirmed the presence of several classes of secondary metabolites in the Tabernaemontana divaricata flower extract. Established literature indicates that T. divaricata contains rich alkaloidal and non-alkaloidal constituents, including terpenoids and phenolic compounds.

The presence of phenolic and flavonoid compounds is highly significant because these hydroxyl-containing phytochemicals actively participate in redox reactions. Consequently, these compounds contribute effectively to the reduction and stabilization of the nanoparticles.

2. Green Synthesis

A visible color change in the reaction mixture immediately following the addition of the flower extract to the copper precursor indicated the chemical transformation associated with nanoparticle formation. Plant metabolites serve as both reducing and capping agents. The biological molecules adsorbed onto the nanoparticle surfaces contribute to their stabilization and prevent excessive aggregation.

A recent study utilizing T. divaricata hydroethanolic flower extract documented the successful biogenic synthesis of copper nanoparticles, The synthesized nanoparticles were characterized using UV–Visible spectroscopy, FTIR, SEM and XRD and were evaluated for antioxidant and antibacterial properties, including application on cotton fabric. identifying key phytochemicals including alkaloids, flavonoids, tannins, terpenoids, glycosides, proteins, carbohydrates, and saponins.

3. Antioxidant Activity

The antioxidant activity of the extract and the synthesized nanoparticles was determined via DPPH radical-scavenging experiments. A concentration-dependent increase in percentage inhibition indicates robust radical-scavenging activity. However, the definitive strength of this antioxidant capacity must be interpreted strictly from the empirical data obtained.

4. Antibacterial Activity

The synthesized nanoparticles demonstrated notable antibacterial activity against the selected microorganisms. The underlying mechanism likely involves the interaction of the nanoparticles with the bacterial cell envelope, leading to membrane damage, oxidative stress, and the disruption of vital cellular processes. Previous studies on T. divaricata flower-mediated copper nanoparticles have confirmed their antibacterial efficacy against both E. coli and B. subtilis.

Proposed Mechanism of Green Nanoparticle Synthesis

The green synthesis pathway can be conceptualized through the following sequential stages:

text{Plant/phytochemicals/rightarrow \text,Reduction\ of\ copper\ ions\rightarrow \text{Formation\ of\ copper/copper-oxide\ nuclei}\rightarrow \text{Growth\ of\ nanoparticles \rightarrow \text{Phytochemical-mediated\ capping\ and\ stabilization}\)

Phenolic compounds, flavonoids, terpenoids, and other reducing molecules facilitate the conversion of metal ions into nanoscale structures. A simplified chemical representation is outlined below:

The exact chemical mechanism remains highly dependent on the choice of precursor, pH, oxygen availability, temperature, and specific reaction conditions.

Strategic Overview & Conclusions

Environmental Significance

Utilizing plant extracts for nanoparticle synthesis offers several distinct advantages over conventional methods:

- Facilitates the use of renewable biological materials.
- Reduces dependency on hazardous synthetic reducing agents.
- Allows reactions to occur under mild, energy-efficient conditions.
- Enables plant-derived compounds to act simultaneously as reducing and stabilizing agents.
- Converts agricultural and botanical biomass into value-added resources.
- Aligns directly with the core principles of green chemistry and sustainable nanotechnology.

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Potential Applications

The synthesized nanoparticles hold significant potential for development in the following fields:

1. Antibacterial textile finishing
2. Medical textile research
3. Surface antimicrobial coatings
4. Water-treatment and purification research
5. Advanced antioxidant materials
6. Protective packaging and surface defense
7. Nanotechnology-based environmental remediation

Note: These potential applications require comprehensive toxicity, stability, durability, and safety evaluations prior to any practical or biomedical implementation.

VI. LIMITATIONS OF THE STUDY

Despite promising results, the present study faces several key limitations:

1. Qualitative phytochemical assays provide preliminary screening but cannot conclusively identify individual chemical compounds.
2. Nanoparticle size and morphology remain highly sensitive to fluctuating reaction conditions.
3. Copper-based nanoparticles are highly prone to oxidation; therefore, rigorous phase identification is essential.
4. Positive in vitro antibacterial activity does not automatically guarantee clinical efficacy or biomedical applicability.
5. Inherent toxicity and long-term environmental impacts require separate, dedicated investigations.
6. Experimental reproducibility must be further validated through independent replicates.

VII. CONCLUSION

This study highlights the rich phytochemical profile of Tabernaemontana divaricata (Tagar) flowers and validates their potential as a viable biological resource for green nanotechnology. Preliminary screenings successfully demonstrated the presence of critical secondary

metabolites, including alkaloids, flavonoids, phenolics, tannins, terpenoids, glycosides, and saponins. These naturally occurring compounds drive the reduction, capping, and stabilization of copper-based nanoparticles.

This approach offers an eco-friendly and sustainable pathway for repurposing an ornamental medicinal plant for nanomaterial fabrication. Previous research supports the feasibility of T. divaricata flower-mediated copper nanoparticle synthesis, validating its antioxidant, antibacterial, and antimicrobial textile application potential.

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