International Journal of Life Science Research Archive

ISSN: 0799-6640 (Online)

Journal homepage: https://sciresjournals.com/ijlsra/

(REVIEW ARTICLE)

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# Study of *Datura stramonium* metallic nanoparticles showing anti-cancer and anti-microbial properties: A review

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International Journal of Life Science Research Archive, 2025, 08(01), 001-009

Publication history: Received on 08 November 2024; revised on 18 December 2024; accepted on 21 December 2024

Article DOI: https://doi.org/10.53771/ijlsra.2025.8.1.0077

## Abstract

Datura stramonium metallic nanoparticles show anti-cancer and anti-microbial propensities: in vitro precedes in vivo rationale. Gold, silver, copper nanoparticles and zinc oxide nanoparticles were prepared using *D. stramonium* extracts by green synthesis methods owing to its vast phytochemical profile with major tropane alkaloids content.

The nanoparticles showed greater stability and biopotency as revealed by their higher cytotoxic potential against a number of cancer cell lines as well as antimicrobial activity against Gram-positive and Gram-negative bacteria.

This research shed more light on the potential of using *D. stramonium*-mediated nanoparticles as effective cancer therapeutic and antibacterial agents, paving ways for further therapeutic applications.

**Keywords:** *Datura stramonium*; tropane alkaloids; metallic nanoparticles; anti-microbial properties; cancer therapy; anti-bacterial agents

## 1. Introduction

A common plant of Persian thorn apple *Datura stramonium Linn* (Solanaceae) commonly known as Jimsonweed is celebrated medicinal herb. This dish probably comes from the territories that surround the Caspian Sea and was disseminated to Europe by the Romans in the 1st century. It now occurs throughout many waste places of Europe, America, Asia and South Africa. Dry henbane — *D. stramonium* is also grown and kept significant location Germany, France, Hungary, South America and throughout the world.

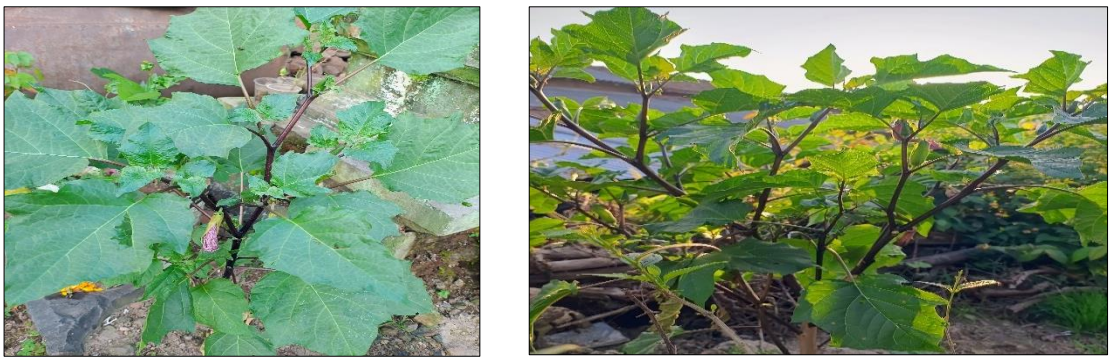

**Figure 1** *Datura stramonium* plant

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It has been studied for its rich phytochemical profile, which includes tropane alkaloids, amino acids, tannins, phytic acids, and carbohydrates. This plant is utilized all over the world in various traditional and folk medicine systems, whereby some medicinal value is tapped into for the treatment of manifold diseases.

**Table 1** Scientific classification of *D. stramonium*

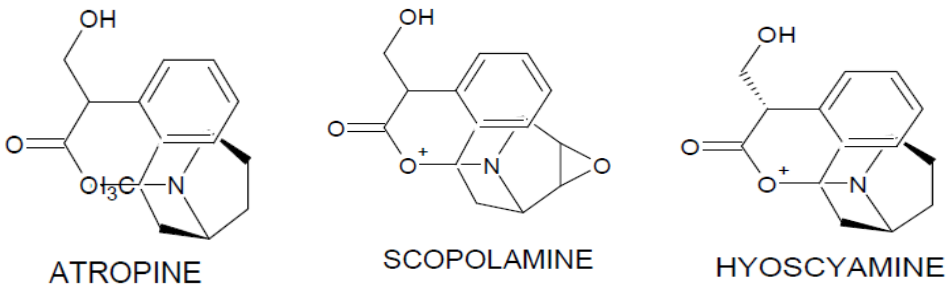
| **Rank** | **Classification** |
|---|---|
| Kingdom | Plantae |
| Division | Magnoliophyta |
| Class | Magnoliopsida |
| Order | Solanales |
| Family | Solanaceae |
| Genus | *Datura* |
| Species | *Datura stramonium* |

*Datura stramonium* is a rich variety of tropane alkaloids, with main ones including atropine, hyoscyamine, and scopolamine. Distribution of the two major alkaloids, hyoscyamine and scopolamine, is irregular throughout the different plant parts. It has been reported that young plants have the highest concentrations of these alkaloids within their stems and leaves.

In all, 64 tropane alkaloids have been reported in *D. stramonium*; new reports include 3-phenylacetoxy-6, 7-epoxynortropane and 7-hydroxyapoatropine.

The main alkaloids involved are atropine, hyoscyamine, and scopolamine, which are anticholinergic and official in many pharmacopoeias. The plant also contains secondary metabolites like saponins, tannins, and glycosides, contributing to its antimicrobial activity. These compounds define the importance of *D. stramonium* in traditional medicine and pharmacological aspects because of its variety in bioactive principles.

### 1.1. Chemical structures of the tropane alkaloids:




*Datura stramonium* is applied in the green synthesis of metallic nanoparticles, involving silver and gold. The bioactive compounds present in this plant turn it into a natural reducing and stabilizing agent for the development of nanoparticles within the 10-100 nm range. These nanoparticles are highly potential for their antimicrobial, antioxidant, and anticancer activities. The green synthesis methodology offers an environmentally friendly and cost-effective technique with stable nanoparticles, thus representing a perhaps promising alternative to conventional chemical methods.

Meanwhile, nanotechnology has emerged as a very promising approach so far for the elaboration of new cancer and antimicrobial therapies. Metal-based nanoparticles have gained widely increasing attention owing to their specific physicochemical properties and prospect of proper drug delivery and release regulation.

## 2. Mechanism of cytotoxicity and antimicrobial action

These properties of the cytotoxic and antimicrobial mechanisms are attributed to the bioactive compounds present in *Datura stramonium*, especially in their nanoparticle format: the tropane alkaloids atropine and scopolamine, flavonoids, and with anolides.

### 2.1. Cytotoxicity

Various pathways through which *Datura stramonium* exerts its cytotoxic effects include induction of ROS generation, disruption of cellular integrity, and interference with cellular metabolic function. Because of this induction of programmed cell death, also called apoptosis, in cancer cells, their alkaloid compounds are potent candidates for anticancer treatments. Some compounds disrupt the proliferation of certain cancer cells, inducing caspase enzyme activity, ultimately leading to cell death.

### 2.2. Antimicrobial Action

One of the antimicrobial actions of *Datura stramonium* arises from interference with bacterial cell walls and microbial growth. This effect is further enhanced by the nanoparticles of this plant due to increased surface area interacting with microbial cells. Nanoparticles may also pass through bacterial membranes, causing leakage of essential ions and molecules, leading to cell death. Antimicrobial activity has been notably observed against both Gram-positive and Gram-negative bacteria.

## 3. Synthesis, characterization, and anticancer applications of metallic nanoparticles from datura stramonium:

### 3.1. Gold nanoparticles

*3.1.1. Process of Synthesis*

The Green Synthesis method, also known as phytosynthesis, makes use of *Datura stramonium* seed extract

Actions made

- A suspension of seed powder in distilled water
- Filtration and centrifugation
- HAuCl3 Reaction at 1 mM

Monitoring synthesis using color change and UV-vis spectrophotometry

*3.1.2. Actions made*

1. A suspension of seed powder in distilled water
2. Filtration and centrifugation
3. HAuCl3 Reaction at 1 mM
4. Monitoring synthesis using color change and UV-vis spectrophotometry

### 3.2. Applications

*3.2.1. Antimicrobial Properties*

- Fungi, Aspergillus fumigatus, Aspergillus niger, Aspergillus flavus, and Candida albicans are all susceptible to antifungal action.
- Inhibition of fungal growth (60.7-80.6%)
- A potential replacement for dangerous fumigants in agriculture

*3.2.2. Antioxidant and Anticoagulant Properties*

- Antioxidant activity against DPPH and nitric oxide
- Anticoagulant activity inhibition (54-59%)

- Dissolution rate of thrombolytic action (33-52%)

### 3.3. Copper nanoparticles

*3.3.1. Process of Synthesis*

Process: Green synthesis, or phytosynthesis, employing ethanolic leaf extract from Datura stramonium is the synthesis technique employed.

Actions taken

- Making an ethanolic leaf extract using the Soxhlet and maceration techniques.
- Extract is added to a solution of 1 mM copper sulfate.
- The creation of reaction mixtures that result in the synthesis of copper nanoparticles.

*3.3.2. Characterization Techniques*

- Nanoparticle production was validated by UV-Visible Spectroscopy (UV-Vis), which showed a peak at 654.9 nm.
- X-Ray Diffraction (XRD): examined the crystallinity of nanoparticles.
- Functional groups were found using Fourier Transform Infrared Spectroscopy (FTIR).
- Nanoparticle size (42 nm) and shape (spherical) were ascertained using Transmission Electron Microscopy (TEM).

*3.3.3. Applications*

Antimicrobial Properties

- Antimicrobial activity (possible usage) against viruses, fungi, and bacteria.
- Dressing and wound healing.
- Purification of water.

Anticancer Properties

- Antimicrobial activity (possible usage) against viruses, fungi, and bacteria.
- Dressing and wound healing.
- Purification of water.

*3.3.4. Other applications*

- Implants used in biomedicine.
- Biosensors.
- Cleanup of the environment.
- The process of catalysis.

### 3.4. Zinc oxide nanoparticles

*3.4.1. Synthesis Process*

- Extraction: Maceration or Soxhlet techniques are used to obtain ethanolic leaf extract from Datura stramonium leaves.
- Preparing the reaction mixture: A 1 mM copper sulfate solution is mixed with the extract.
- Reduction: Copper ions (Cu2+) are converted to copper atoms (Cu0) by the extract's bioactive substances (such as flavonoids and alkaloids).
- Nucleation: Nuclei are created when copper atoms group together and develop into nanoparticles.
- Stabilization: By stabilizing the CuNPs, the bioactive substances stop them from aggregating.

*3.4.2. Mode of Action (Antimicrobial and Anticancer)*

Antimicrobial Mode of Action

- Disruption of cell membrane: CuNPs interact with microbial cell membranes, resulting in leakage and disruption.
- Oxidative stress: CuNPs produce reactive oxygen species (ROS), which harm the proteins and DNA of microorganisms.
- Release of metal ions: CuNPs release copper ions, which interfere with metabolic processes and inhibit microbial enzymes.

*3.4.3. Anticancer Mode of Action*

- Induction of apoptosis: By producing ROS, CuNPs cause cancer cells to undergo apoptosis, or programmed cell death.
- DNA damage: By interacting with the DNA of cancer cells, CuNPs harm them and prevent them from proliferating.
- Inhibition of angiogenesis: CuNPs prevent the creation of blood vessels, depriving cancer cells of nourishment.

*3.4.4. Characterization Techniques*

- Nanoparticle size and shape were examined using Field Emission Scanning Electron Microscopy (FESEM).
- Zeta Potential Measurement: assessed surface charge and stability of nanoparticles.

*3.4.5. Applications*

Antimicrobial Properties

- Antimicrobial action against a range of infections (possible application).
- Protection of plants against bacterial and fungal diseases.

Anticancer Properties

Induction of apoptosis in cancer cells (possible use) is one of the anticancer properties.

- ✓ Preventing the growth and multiplication of cancer cells.

*3.4.6. Other Applications*

- Heavy metal phytoremediation.
- Nutrition and growth stimulation for plants.
- Improving defence mechanisms and stress tolerance.
- In therapeutic plants, secondary metabolism is stimulated.
- Bioactive chemical biosynthesis.

### 3.5. Silver nanoparticles

*3.5.1. Synthesis Process*

Green Synthesis is the synthesis method employed in this investigation, particularly:

- Plant Extract Preparation: Datura stramonium leaves were used to make an aqueous (AQ) extract and a non-alkaloidal (NA) fraction.
- Biogenic Reduction: A silver nitrate (AgNO3) solution was combined with the AQ extract and NA fraction,and the mixture was agitated for 30 minutes at 60°C.
- Formation of Nanoparticles: Ag+ ions were reduced to Ag0 nanoparticles by leaving the mixture in the dark for a whole day.
- Plant phytochemicals are used as capping and reducing agents in this green synthesis process to create silver nanoparticles.

*3.5.2. Characterization Techniques*

The synthesized silver nanoparticles were characterized using:

- UV-vis, or ultraviolet-visible spectroscopy
- Infrared Fourier Transform Spectroscopy (FTIR)
- DLS, or dynamic light scattering
- SEM, or scanning electron microscopy
- Electron Microscopy Transmission (TEM)

*3.5.3. Applications*

AgNPs made from D. stramonium seeds and leaves were shown to have antibacterial properties in the paper. The produced AgNPs exhibited cytotoxicity against a number of cancer cell lines, including A549, HCT-116, PANC-1, SH-SY5Y, and U87. When compared to AQ NPs, NA NPs showed more anticancer potential. IC50 values demonstrated the great potency of NA NPs against A549 cells.

According to the study, the green-synthesized AgNPs from D. stramonium leaves may find use in antibacterial and cancer therapies.

### 3.6. Magnesium oxide nanoparticles

*3.6.1. The synthesis method used is*

- Green Synthesis (Biosynthesis): Making use of leaf extract from Datura stramonium.
- Chemosynthesis: employing sodium hydroxide (NaOH) and magnesium nitrate (Mg (NO3)3H2O).

*3.6.2. Steps involved in Biosynthesis:*

- Making a leaf extract from Datura stramonium.
- 2. Combining the extract with a solution of magnesium nitrate.
- Sodium hydroxide is added.
- Heating and stirring.

*3.6.3. Characterization Techniques*

- Diffraction of X-rays (XRD)
- SEM, or scanning electron microscopy
- Spectrophotometry using UV-Visible (UV-Vis)
- Analysis of Photoluminescence (PL)

*3.6.4. Applications*

Antimicrobial Properties

- Antibacterial activity against both Gram-positive (Bacillus and S. aureus) and Gram-negative (E. coli) bacteria.
- 2. Formation of an inhibition zone.
- Possible uses in medical implants, water purification, and wound healing.

Anticancer Properties

- It causes cancer cells to undergo apoptosis.
- Preventing the growth of cancer cells.
- Drug delivery that is targeted.

*3.6.5. Other Applications*

- Implants for medical purposes
- Biosensors.
- Cleanup of the environment.
- The process of catalysis

## 4. Conclusion

Datura stramonium is an important choice for the biosynthesis of metal nano-particles with excellent anti-cancer and antimicrobial effects. The green synthesis of gold, silver, copper and zinc oxide NPs using leaf and seed extracts of D. stramonium testifies its phytochemical potentialities and eco-friendly approach. Being rich in various bio-active metabolites particularly tropane alkaloids like atropine and scopolamine not only plays a direct/indirect role in enhancing cytotoxic activity against numerous cancerous cells but escalate antimicrobial efficacy against different pathogens also.

Research has shown that the synthesized nanoparticles have "nano" mechanisms of action (MOAs) which lead to microbial cell disintegration, ROS generation and induction of apoptosis in cancer cells indicating their dual therapeutic role. These nanoparticles can be utilised in different technologies like wound healing, water treatment and nanomedicine etc. other than anti-cancer as well as antimicrobial therapies.

Overall, the present overview of Datura stramonium and its metallic nanoparticles has given scope for new challenging therapeutic approaches and emphasized that it is an urgent need to search more natural sources to develop potential drug candidates against such diseases. In future, more studies are required to be carried out in search of mechanism(s) of actions to further standardize and characterize these nanoparticles as this may provide superiority and invaluable support for modern chemotherapeutics.

## Compliance with ethical standards

*Disclosure of conflict of interest*

No conflict of interest to be disclsoed.

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